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Cold water fisheries in the trans-Himalayan countries

FAO FISHERIES TECHNICAL PAPER

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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. Recognising 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:

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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).

CONTENTS

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).

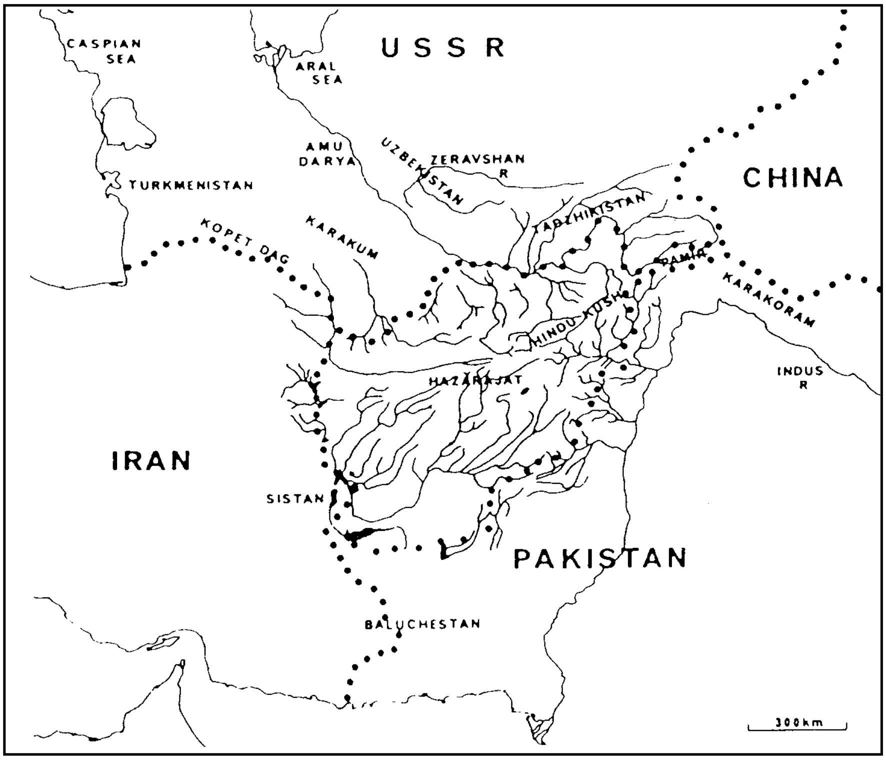

Fig. 1 - Major mountain ranges of Afghanistan (from Coad, 1981)

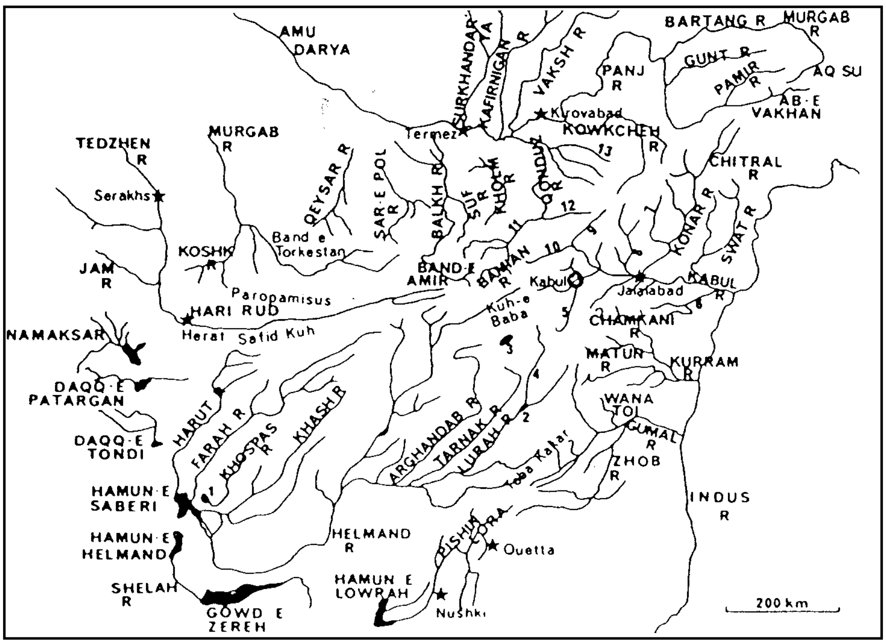

Fig. 2 - Major drainages of Afghanistan (from Coad, 1981)

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).

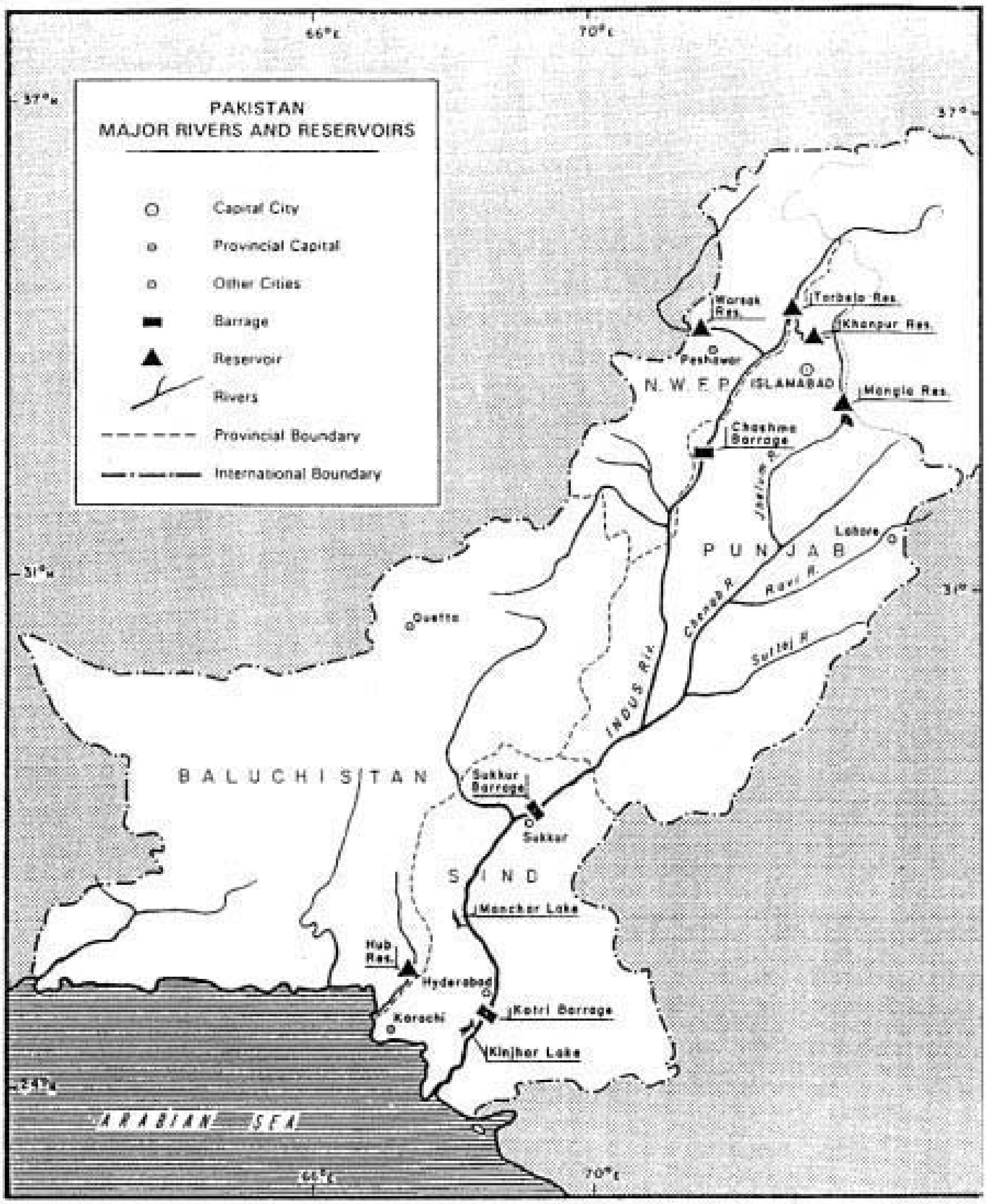

Fig. 3 - Map of Pakistan and location of major reservoirs (from Petr, 1999b)

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

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.

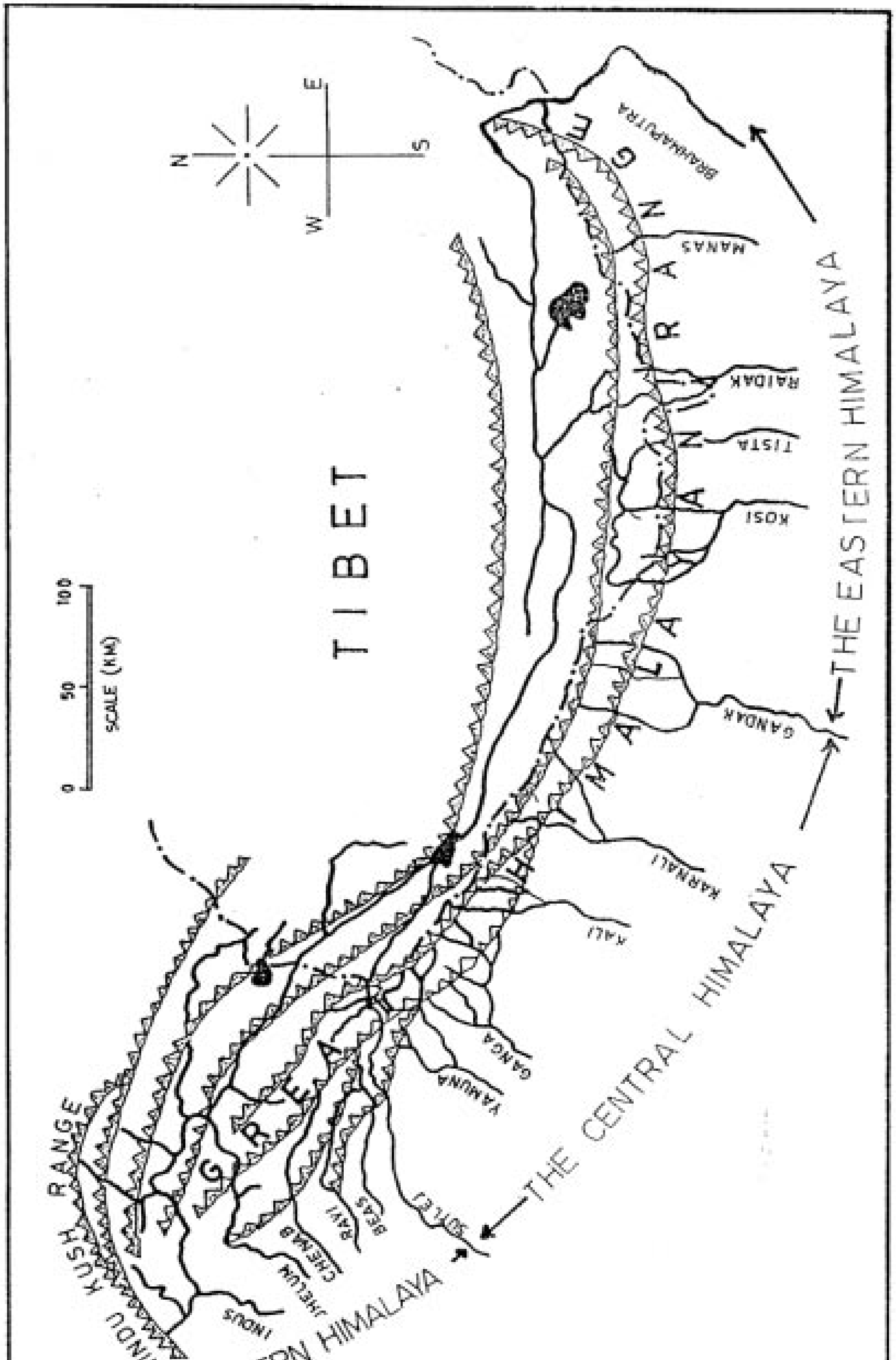

Fig.4 - The Himalayas and its principal rivers (from Sehgal, 1999)

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)	4 000-2 000	2 000-1 000
Below 100		
Substratum	Rocks and boulders	Boulders/stones with
Pebbles,sand		
	with sandy patches	gravel, etc.
Water temp. (°C)	13.4	18.7
22.9		
pH	7.4	7.9
8.0		
Diss. O_2 (mg/L)	9.3	8.7
7.9		

Major fish species

Schizothoraichthys esocinus	+	-	-
Schizothorax richardsonii	+	+	+
Diptychus maculatus	+	-	-
Glyptosternum reticulatum	+	+	-
Tor putitora	+	+ (monsoon)	+
Labeo dero	-	+	+
Salmo trutta	+	+	-

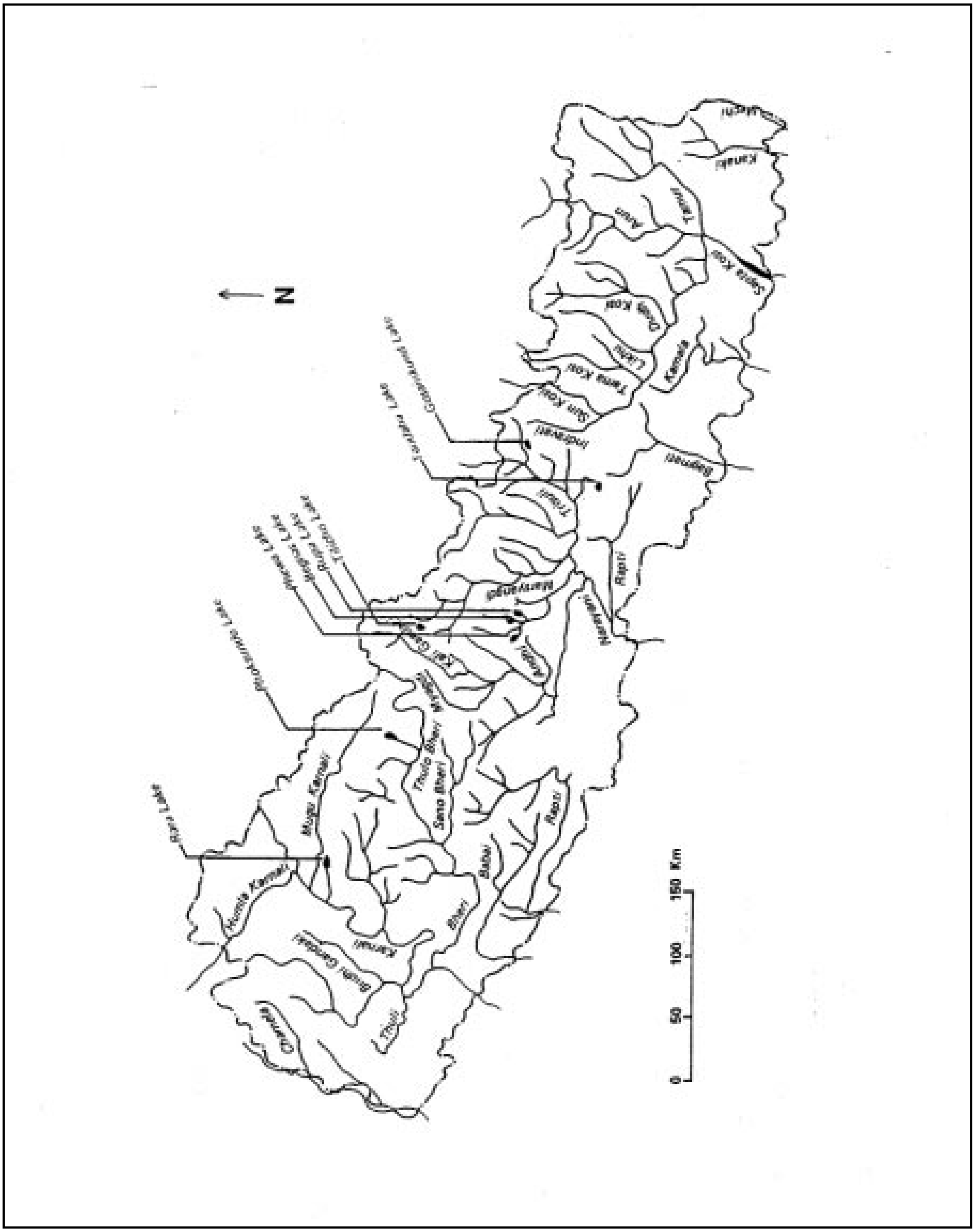

Fig. 5 - Major rivers of Nepal (from Shrestha, 1999)

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.

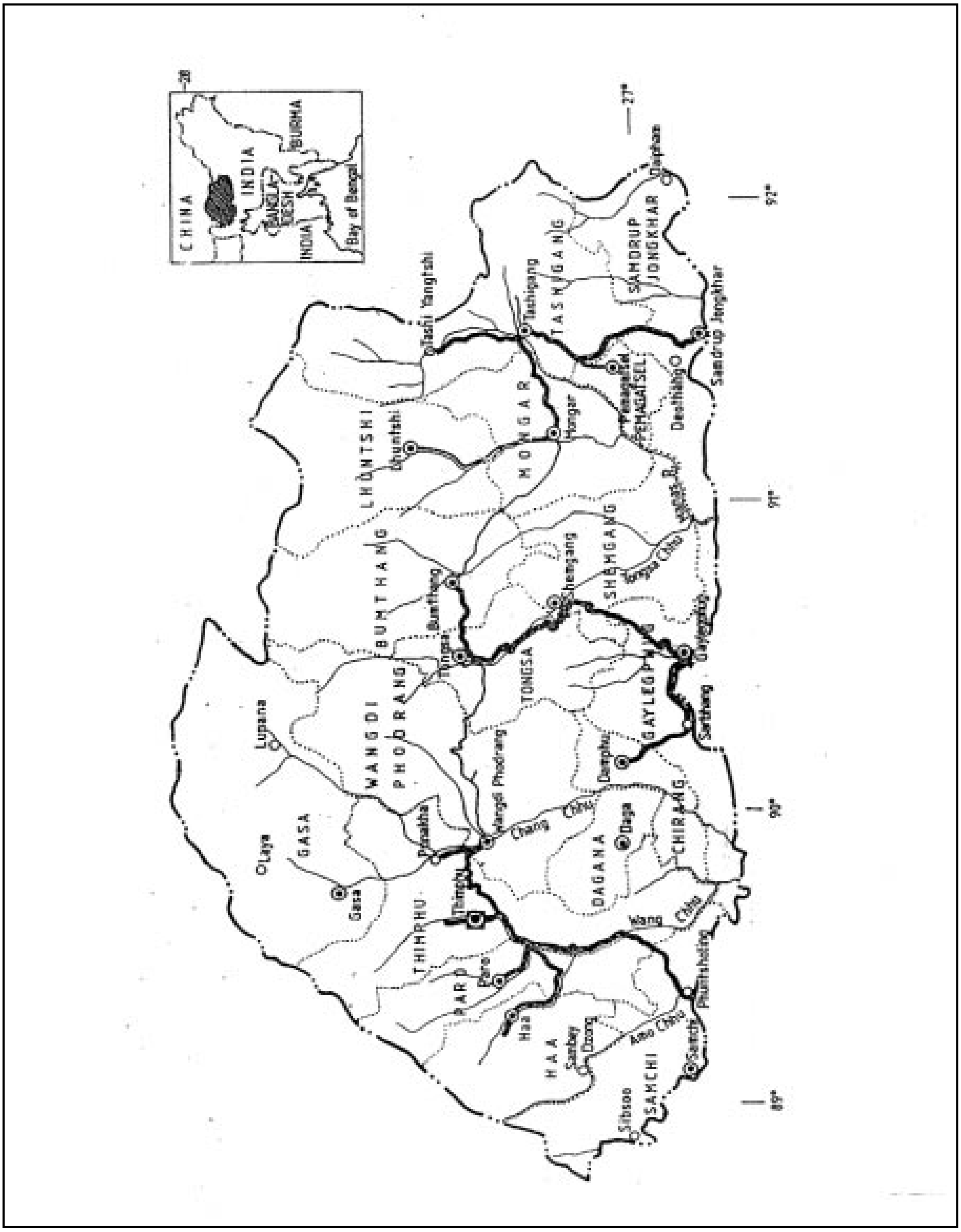

Fig. 6 - Map of Bhutan with the major rivers (from Petr, 1999a)

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.

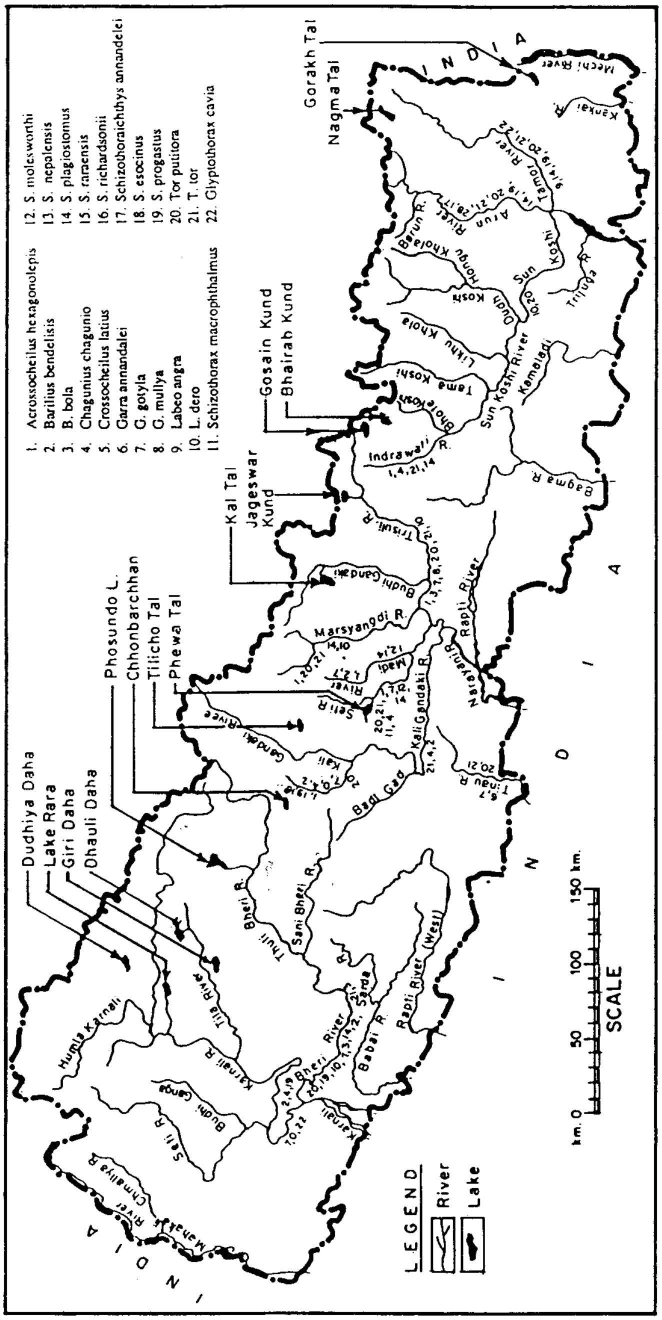

Fig. 7 - Distribution of the major fish species in Nepal (from Shrestha, 1999)

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*.

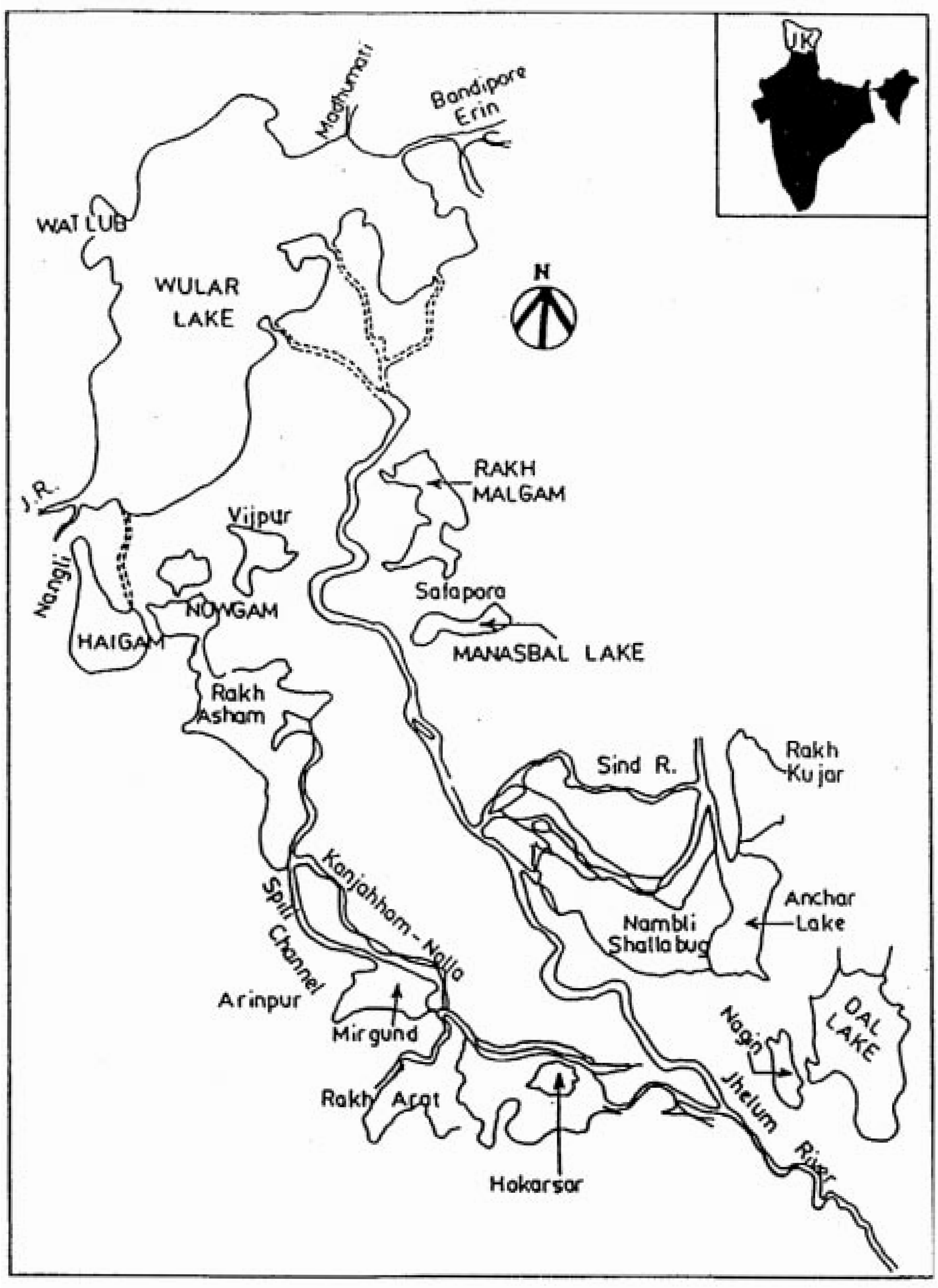

Fig. 8 - Floodplain lakes and major wetlands in Kashmir Valley
(from Raina and Petr, 1999)

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).

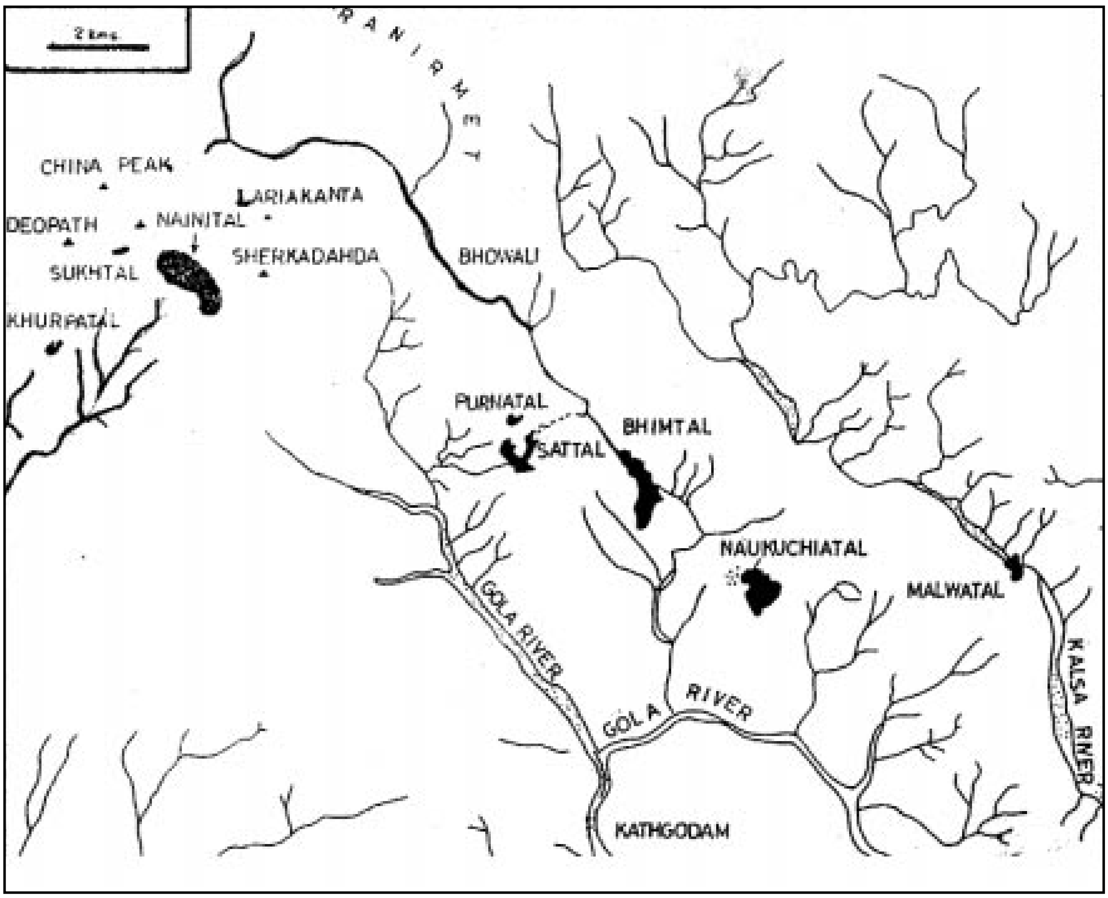

Fig. 9 - Lakes in the Kumaon Himalaya (from Raina and Petr, 1999)

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.

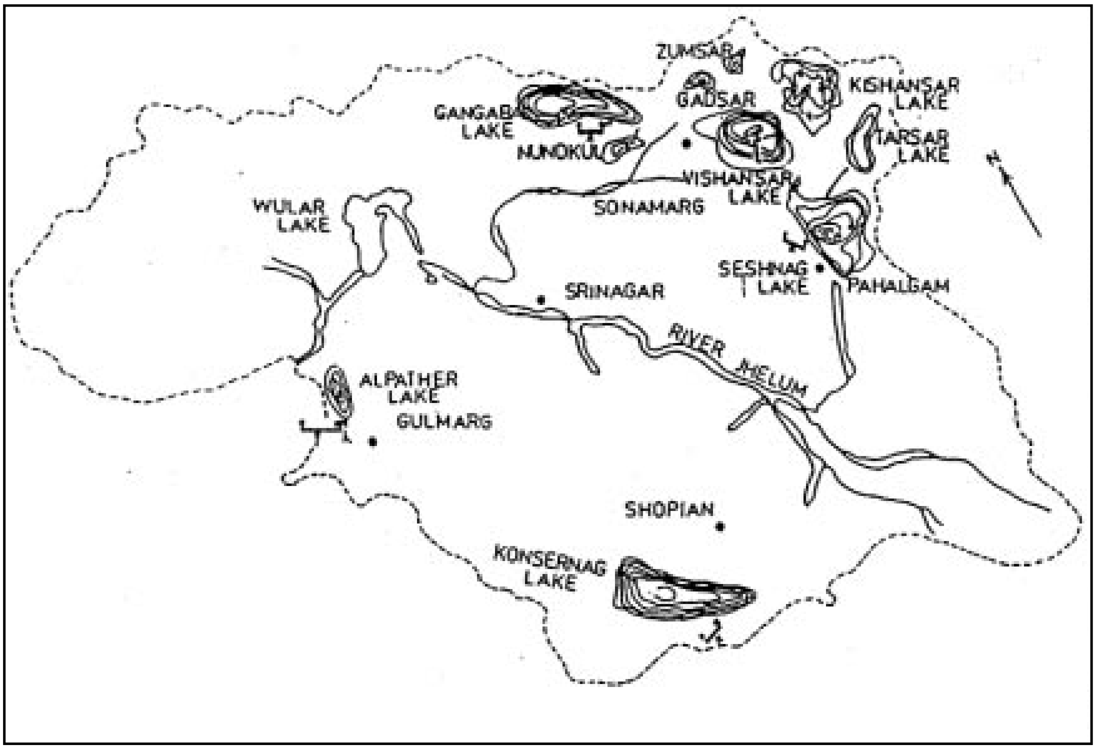

Fig. 10 - High mountain lakes in Kashmir (from Raina and Petr, 1999)

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).

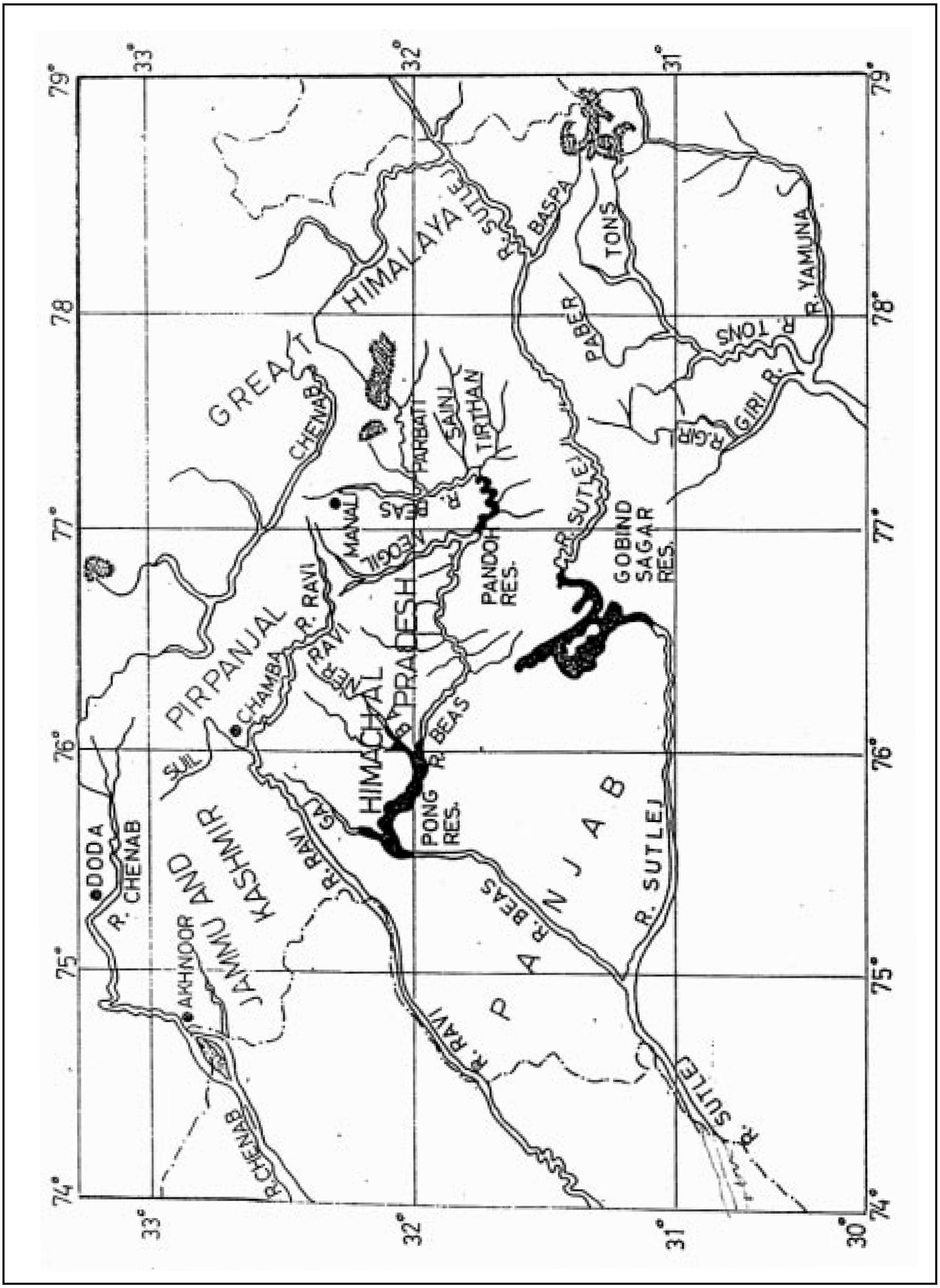

Fig. 11 - Gobindsagar, Pong and Pandoh reservoirs in Himachal Pradesh, India
(from Raina and Petr, 1999)

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.

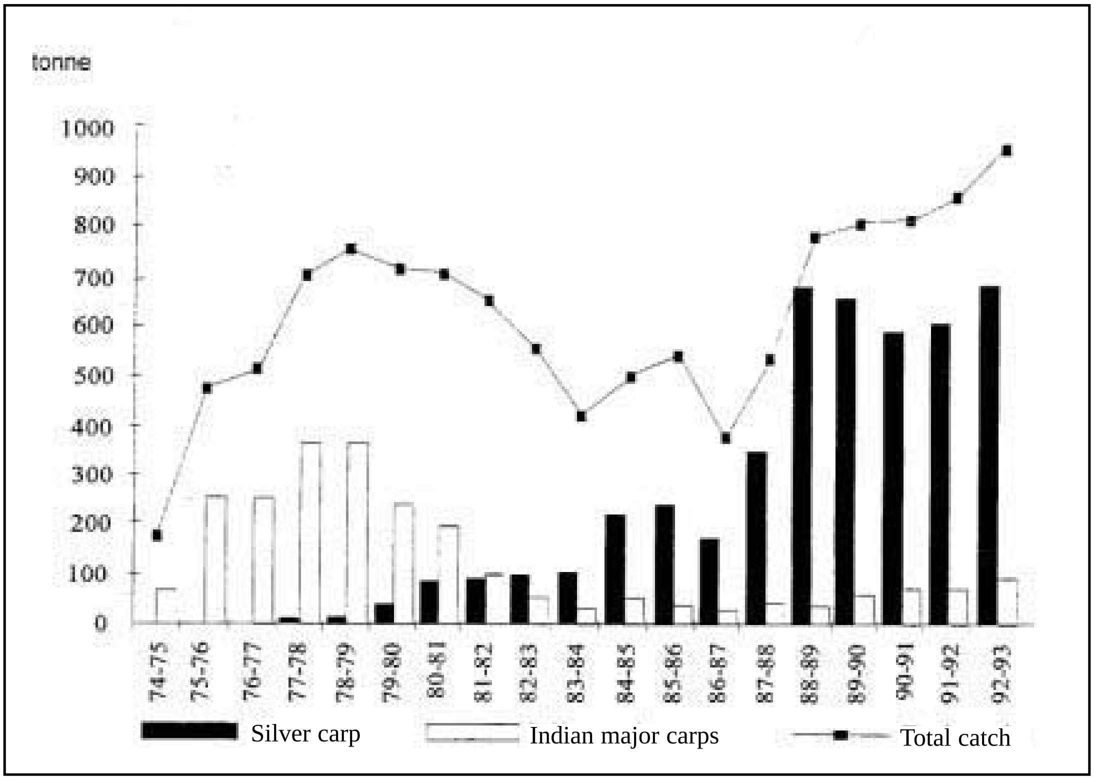

Fig. 12 - Gobindsagar reservoir, India: development of silver carp fishery
(from Sugunan, 1997)

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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ENVIRONMENT, LIVELIHOODS AND INDIGENOUS COLD WATER FISHES

by

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ABSTRACT

The paper considers some environmental and socio-economic aspects to be considered in the development of aquaculture and cold water fisheries in the Hindu Kush - Himalayan region. Indigenous fish species living within the Hindu Kush - Himalayan region represent an important aquatic resource for the sub-Himalayan region. Unfortunately, this resource is generally unrecognized and undervalued and has so far been given limited consideration in rural development. Experiences available within highland areas in Asia suggest there is potential for aquaculture and fisheries development to contribute to rural development and poverty alleviation. What is needed is not a "sector driven approach" but to emphasize and recognize aquatic resources as a part of an integrated approach driven by concerns for poverty, peoples livelihoods and rural development. The paper discusses some of these issues, and identifies a number of follow up actions, including some initiatives to raise the profile of aquatic resources as part of the celebrations of the "International Year of the Mountain" in 2002.

1. INTRODUCTION

The presentation covers cold water species (or ecosystems) in the Hindu Kush - Himalayan region and relevant experiences from other nearby highland areas in the Asia-Pacific region, particularly in Vietnam and Laos. The emphasis is given on highland ecosystems and the people living in these areas, rather than cold water fish species *per se*.

2. AQUATIC RESOURCES IN THE HINDU KUSH - HIMALAYAN REGION

The water resources in this large region include rivers and streams of various sizes, lakes, man-made reservoirs, floodplains and swamps, rice fields and man-made ponds and irrigation canals. These water resources have a diverse fish fauna that support the livelihoods of rural communities within the region. They also provide various opportunities for development of fisheries and aquaculture.

The aquatic resources are part of the larger ecological/agricultural, social, economic and institutional systems. Therefore management of these resources necessarily have to consider these related systems.

3. ENVIRONMENTAL IMPACTS AND COLD WATER FISHERIES

The environment in the Hindu Kush - Himalayan region influences the fish populations and opportunities for fisheries and aquaculture development. The natural barriers to fish movement and temperature in particular play a significant role in the distribution of species.

Man-made environmental changes arising from outside of the fisheries sector have had direct and indirect impacts on fisheries and the livelihoods of people dependant on these resources. The environmental impacts include water pollution leading to eutrophication, localized chemical pollution, siltation caused by erosion and road building, sand mining impacting on spawning beds, water development projects creating barriers to migration and hydrological changes and loss of wetland habitat. The impacts of barriers caused by dams or diversion of water to irrigation schemes in particular impacts on migratory species. Less is known about the downstream effects of such changes on the aquatic resources in floodplains and wetlands and the people living in these areas.

Within the sector, overfishing and destructive fishing practices are reported to have contributed to reduction in stocks. Transboundary movement of fish also impacted on indigenous fish stocks; these include impacts from introductions of exotic species, such as brown trout (*Salmo trutta*), common carp (*Cyprinus carpio*) and silver carp (*Hypophthalmichthys molitrix*).

A number of important diseases are relevant to the region. These include:

- IPN – Infectious pancreatic necrosis; a viral disease affecting all salmonid producing regions including Asia (reported in 1999/2000 from Japan and Korea); brown trout is a susceptible species; vaccine available against disease.
- SVC – Spring Viremia of carp: a viral disease, several carp and cyprinid species are susceptible, currently only in Europe.
- VHS – Viral haemorrhagic septicaemia – reported in brown trout; European based disease, but reported in Japan during 2nd quarter of 2000, no treatment known
- EUS – Epizootic ulcerative syndrome; a fungal disease affecting freshwater and estuarine warm water fish; epizootic spread in Asian region since 1985 and now prevalent in the Asian region; latest occurrence is in the Punjab waters of Pakistan.

There are also environmentally positive aspects of cold water fisheries and aquaculture development. These include the possible opportunities for conservation of indigenous biodiversity through "genetically sensitive" breeding programmes of indigenous species, small-scale aquaculture that can contribute to water storage and diversification on small-scale agricultural farms and the potential "value" that fish can add to water resources and provide a justification conservation. Unfortunately, there is little information on this value.

4. APPROACHES TO MANAGEMENT

The approaches to management of fisheries and aquaculture are described in the various country and resource papers presented during this Symposium. These approaches appear so far to have been largely driven by technical interests and sector management strategies, rather than consideration of aquatic resources management within the framework of the Himalayan ecosystem or rural development. The current approaches and status may be summarized as follows:

Management of small-scale aquaculture:
- Technologies are becoming available (although technical constraints appear to exist for several indigenous Himalayan species).

Support to implementation and participation of poor people in aquaculture have, however, been limited.

Management of capture fisheries:
- There appears to have been limited success in management, indeed many fish stocks and catches from natural waters are reported to be declining.
- Some “mitigation” measures are being tried for water resources development, but the success of these measures is poorly understood and questionable.
- Some management practices are becoming available elsewhere in the region (e.g. co-management) but there are few examples of these local management measures being tried within the Hindu Kush - Himalayan region.

So far, it appears that there has been limited consideration of the livelihoods of people in development efforts involving fisheries and aquaculture in the Himalayan region, and fisheries and aquaculture are rarely considered in rural development. It is time to give more emphasis on the role of aquatic resources in poverty alleviation and sustainable livelihoods of people in the region.

5. PEOPLE IN HINDU KUSH – HIMALAYAN REGION

The people of the region are characterized by very low levels of human development and their livelihoods have been summarized by the International Center for Integrated Mountain Development (ISIMOD) as follows:

- The lowest per capita incomes in the world - probably the lowest even within each country.
- Mountain economies are mostly subsistence-oriented and meet food requirements for only a part of the year, compelling household members to move out in search of income-earning opportunities, mostly to urban centres and agricultural areas in the plains.
- Women and children have to bear increasing burdens of agricultural and subsistence activities in the rural mountains because of the absence of male members from mountain households.
- Many parts of the mountains are not easily accessible, limiting the scope for development of various opportunities provided by a diverse, scenic but fragile environment and hampering the provision of health, education, and extension services.
- Many parts of the mountains are experiencing rapid loss and damage of natural resources, resulting in further difficulties to households in meeting their subsistence needs.

These conditions represent a challenge for all concerned with poverty alleviation and development in region.

6. AQUATIC RESOURCES IN HINDU KUSH – HIMALAYAN REGION LIVELIHOODS

The livelihoods of people in the region are characterized by poverty. How do fisheries contribute to livelihoods – what do we know about cold water fisheries?

At the present time, it appears that fish are an important ‘natural asset’ in the livelihoods of people in some parts of the region. This includes the role of aquatic resources food and subsistence fishing, eco-tourism and income from sport fishing and some small-scale aquaculture. It also appears to be a neglected and diminishing ‘natural asset’.

The country papers provide some examples of human utilization of aquatic resources. For example:

In Nepal, fish provide sport fishing, food and income for rural communities. There are reported to be 204 000 active fisher families (the number of households involved in foraging of aquatic resources for food on a part time basis is unknown). In the Koshi River, evidence shows that the poorest of the poor are dependant on aquatic resources - “the socio-economic status of the fishing communities is the lowest in society”.

In Pakistan, the government appears to be giving emphasis to aquaculture and fisheries development for poverty alleviation. However, little information is provided. Sport fisheries are reported to be important within ecotourism in the mountain areas.

In India, fish provide food and income for rural communities, and are also important for sport fishing in some mountain areas.

In Bhutan, rivers in mountain areas are important for sport fishing.

Generally, though, information on the role of fish in the livelihoods of poor people living in rural areas is far from complete. It is known from other parts of the Asian region, such as the upper reaches of the Mekong River, that part time foraging of poor people are usually “hidden” from fisheries statistics. *Are fisheries a ‘hidden and undervalued asset’ in the Hindu Kush - Himalayan region?*

Women, as caretakers of livestock, crops, and forest lands, are in a key position to contribute to the building and maintenance of the sustainability of these lands and farm resources. Continual neglect of their important role in the mountain agro-ecosystem means missing out on a great source of under-utilized potential in the struggle to rehabilitate and enhance the environmental conditions of rural villages. *What is known about women in fisheries in the Hindu Kush - Himalayan region? Has fisheries development considered this important role of women in rural households?*

Experiences gained from highland areas in northern parts of Vietnam (see MOFI, 2001) and Lao PDR clearly demonstrate the benefits of small-scale aquaculture which can include:

- improving farm productivity and water storage,
- contribution to food supply in fish deficit upland areas and in seasons when wild fish are not available,
- opportunity for additional source of flexible income,
- means to diversify out of the wild fishery and rice farming,

- providing a stabilizing source of aquatic animal protein and substituting a source of income.

Recognizing the generally understated and unrecognized role of aquatic resources in rural development and poverty alleviation in the region, the member governments of the Network of Aquaculture Centres in Asia Pacific (NACA) have requested development of a regional initiative to support better aquatic resources management for poverty alleviation. This Asian regional initiative is called "STREAM" which stands for Support to Regional Aquatic Resources Management.

7. THE STREAM INITIATIVE

The STREAM initiative has been developed at the request of NACA member governments in Asia. The STREAM "founding partners" include NACA, the Food and Agriculture Organization of the United Nations (FAO), the Department for International Development of the United Kingdom (DFID) and Voluntary Service Organization (VSO). The implementation has been mandated by NACA member governments and is a key strategic priority for NACA's Third Year Work Programme (2001-2005).

The rationale for STREAM includes:
- importance of aquatic resources to the poor,
- the need to share existing human and social capital across the region,
- the need to address broader livelihoods and governance issues,
- the key challenge now to establish support agencies and institutions that:
  - utilise existing and emerging information more effectively,
  - better-understand poor people's livelihoods,
  - enable poor people to exert greater influence over policies and processes that impact on their lives.

To meet these challenges, there is a need to develop the policies and processes of mediating institutions, and their capacities to:
- identify aquatic resource management issues impacting on the livelihoods of the poor,
- monitor and evaluate management approaches,
- extend information,
- network within and between sectors and countries.

The STREAM aims to build capacity to:
- understand and secure the livelihoods of poor aquatic resource users,
- accelerate communication and learning between stakeholders,
- facilitate policy-making that supports the interests of the poor in the Asia Pacific region.

The guiding principles are:
- policy change,
- securing effective participation and sustainable livelihoods,
- centrality of communications,
- open process and partnerships.

The approach, regional in nature, is justified as planning and management of aquatic resources is necessarily local, national and regional. A substantial aquatic resource management knowledge base already exists in the region. There is a degree of commonality in the problems and solutions across the region. Support and positive examples from other countries strengthens the effectiveness of advocacy.

The key components of STREAM are:

- **Capacity building**. STREAM will support capacity building among local government institutions, NGOs, and community groups, via training and long-term practical support which will focus on:
    - o livelihoods analyses and participatory approaches.
    - o innovative communication approaches,
    - o monitoring and evaluating management approaches.

- **Learning initiatives**. STREAM will support new community-based learning initiatives, the practical experiences of which will combine with lessons learned from existing case studies and feed into STREAM's communication strategy to influence policy and practice in the region.

- **Communication**. STREAM will develop a communications and learning strategy to increase the participation of poor aquatic resource users in decision-making processes and ensure policy-making is informed by lesson learning. Approaches will include case studies, workshops, field visits, translation of materials into local languages, use of the public media and the internet, discussion groups, pictorial communication, etc.

- **Policy changes.** STREAM will support on-going policy and institutional changes, by:
    - o facilitating policy development at the national level,
    - o increasing exposure to lessons and experiences at the community level,
    - o maximising utilisation of the existing regional knowledge base,
    - o providing capacity-building support to the change process.

What is the relevance of STREAM to the Hindu Kush - Himalayan region?

- The Himalayan region is regionally and globally a serious poverty 'hotspot' – urgent action is required.
- The role of aquatic resources within the rural livelihoods of people in the sub-Himalayan region – is it important?
    - o Water resources and some demonstrated successes with aquaculture in some highland areas are available;
    - o Poor people are involved in fisheries and new approaches to management are needed.

The STREAM initiative and processes can support better understanding, capacity building and sharing of experiences in the region. Further information is provided in NACA/DFID/VSO/FAO (2001).

8. SOME ENVIRONMENTAL ISSUES RELATED TO AQUACULTURE

There are some environmental issues within the sector that should be addressed. These include:

- The need to promote aquaculture systems that integrate within - farms and ecosystems.
- The need for aquaculture systems that add value – rice-fish, integrated in irrigation.

- The need for aquaculture species that make efficient use of resources. In particular, whether to promote carnivorous species that rely on expensive fishmeal based feeds, or fish feeding lower in the food chain. The role of larger and small species in aquaculture also needs to be considered.
- Breeding and restocking programmes – need to consider genetics of wild and cultured populations. There is a need to understand and maintain this diversity where possible through well managed breeding programmes.
- Aquatic animal health and transboundary movements. Health management has to be considered, as diseases have already impacted (socio-economic and environmental, and possibly biodiversity impacts) on the aquaculture sector in the region. An urgent need exists to address health aspects with transboundary movement[1]. There are also existing international/regional agreements/treaties that need to be adopted in a practical way to the region.

9. CONCLUSIONS AND FOLLOW UP

The cold water indigenous fish species living within the Hindu Kush - Himalayan region represent an important aquatic resource for the sub-Himalayan region. This resource is characterized by:
- being generally unrecognized and undervalued,
- being given limited consideration in rural development.

However, experiences available within highland areas in Asia suggest there is potential for aquaculture and fisheries development to contribute to rural development and poverty alleviation (Haylor, 2000; DFID, 2000). What is needed is not a “sector driven approach” but to emphasize and recognize aquatic resources as a part of an integrated approach driven by concerns for poverty, peoples livelihoods and rural development.

Where to from here?

The following are suggestions for follow up from the Symposium:

- bring together existing information on poverty and aquatic resources,
- better understand livelihoods through analyses and social and economic valuation of resources,
- promote sharing and testing of approaches to aquaculture and fisheries management,
- communicate findings and exchange experiences,
- seek policy and institutional changes based on this understanding,
- use the good opportunities for sharing of experiences through national and regional cooperation.

It will be important to ensure that sufficient information and justification on the role of aquatic resources in the livelihoods of poor people and the potential for small-scale aquaculture and

[1] FAO/NACA. 2000. Asia Regional Technical Guidelines on Health Management for the Responsible Movement of Live Aquatic Animals and the Beijing Consensus and Implementation Strategy. *FAO Fisheries Technical Paper*. No. 402. Rome, FAO. 53 p. The ‘Technical Guidelines’ were adopted in principle by 21 participating countries/territories in the Asia-Pacific region, including Nepal, in Beijing in June 2000. The guidelines provide the basis for Aquatic Animal Health Management Strategies.

fisheries to contribute to sustainable livelihoods is generated within 2001 to incorporate and be considered in the programmes and activities to be initiated during the celebration of the "International Year of the Mountain" in 2002. Don't forget the fish!

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COLD WATER FISHERIES DEVELOPMENT IN NEPAL

by

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ABSTRACT

Nepal has a dense net of rivers and streams, as well as numerous lakes of cold water character. Fish stocks in these waters have been undergoing changes as a result of overfishing, poor land management resulting in siltation, damming, pollution and some other adverse impacts. The potential of cold water fisheries is not fully utilized and its is believed that with a proper management, introducing innovative methods, especially in the direction of a better protection of fish stocks, their enhancement through controlled and protected spawning, habitat improvements and some other management measures, the cold water fishery resources can be brought to a level which will allow their sustainable harvesting without further harming the fish stocks. The author puts forward twenty ideas as how to improve the current situation.

1. INTRODUCTION

Nepal covers an area of 147 181 km^2 and extends for 800 km along the southern slopes of the Himalayas, separating the arid Tibetan Plateau to the north from the fertile Gangetic Plain to the south. More than 80 percent of the land area is covered by rugged hills and mountains, which include Sagarmatha (Mount Everest) and seven more of the world's ten highest peaks. There are four main ecological zones: trans-Himalaya (a small, semi-arid mountain zone north of the main Himalayan axis), highlands, subtropical/temperate midlands and tropical lowlands or Terai. Nepal has 22 million people with 2.08 percent population growth per year (2001).

Nepal is a landlocked country, where snow-clad Himalayas, eternal glaciers, ice-cold torrents, clear-water and lakes contribute to much of its hydrosphere. These vast stretches of inland water support many and varied forms of freshwater life including fish. The need and opportunities for the study of the freshwater bioresource and its management are enormous.

The "high water" of highland Nepal forms the base of Trans-Himalayan hydrobiology. Up to this time our knowledge about the physical, chemical and biological features of these waters is only meagre. All forms of freshwater life are influenced by their complex hydrometeorological cycle. From the human standpoint its main influence is seen on climate, water supplies, forests, fisheries and navigation. Many wild and scenic rivers and lakes of Nepal provide opportunities for recreational fishing, wetland bird watching, fowl raising and aquaculture. More progressive, dynamic and imaginative management techniques have to be developed for sustaining harvest of fish from these waters and integration of aquaculture.

Nepal has considerable fishery resources, but these have not yet been properly assessed. At present (1999-2000) about 34 500 metric tons of fish are produced from water bodies of Nepal. The potential sources of inland fisheries lie in rivers, lakes, hill streams, ponds, tanks, reservoirs and paddies (Table 1). In these vast stretches of inland waters, fish stocks have been gradually declining owing to the lack of sound conservation measures and harmful fishing practices.

Table 1
Estimated water surface of Nepal available for fishery development (1986)

Water bodies	Estimated Area (ha)	Percentage
Rivers	395 000	5.4
Lakes	5 000	0.7
Reservoirs	1 500	0.2
Village Ponds	5 000	0.7
Paddies	325 000	44.4
Total	731 500	100.0

Fishes and aquatic life in the hill streams were studied by a number of ichthyologists, including Hora (1937, 1952), Taft (1995), DeWitt (1960), Menon (1974, 1999), Shrestha, J. (1981), Shrestha (1981, 1990, 1992, 1997) and Talwar and Jhingran, (1991). Shrestha,T.K. (1990a) and Shrestha J. (1999) gave an account and habitats of fishes of the Himalayan waters. Hill streams of Nepal are exploited for a diverse array of reasons including power generation, water abstraction for domestic, industrial and agricultural effluent disposal, fisheries and aquaculture. These fish habitats have also been altered by many human activities such as land drainage, flood protection and urbanisation. Many of these activities have interrupted, degraded or destroyed the functioning of hill streams, leading to loss of amenity and resource value for other users.

Aquatic resources of Nepal remain virtually uncontrolled. The major river systems supporting fish and other aquatic life are the Koshi in the east, the Gandaki in the central and the Karnali in the western part of the country. Each river system has numerous tributaries that run from north to south. These running waters abound with a great variety of fish and other living aquatic resources such as fresh water shrimps, crabs, prawns, edible frogs, molluscs and algae. A correct assessment of the composition and extent of aquatic resources is highly desirable for future aquaculture development (Shrestha, 1990).

The snow-fed hill streams of Nepal are still very little exploited for cold water sport fishery. Recreational fishing in hill streams can become a major tourist attraction and in the long run become an important source of foreign exchange (Table 2).

In remote places like upper Karnali valley, Kaligandaki, Sunkoshi, Khimti, Chatra and Chisapani there is some fishing for local consumption, but curing and refrigeration facilities remain to be developed. Some commercial fishery has been developed in Pokhara, Hetauda, Janakpur, Biratnagar and Rajbiraj but the limited supply cannot meet the growing demand.

2. PROBLEMS

Nowhere else in the Himalayan region could one find hundreds of kilometres of fine and cool crystal clear fishing waters, teeming with mahseer, snow trout, fresh water eel, and catfishes as in the upper reaches of the rivers Gandaki, Koshi and Karnali of Nepal. Angling in such beautiful waters amidst glorious scenery is a diverse, subtle and beguiling sport. Earlier, when fishermen set their little boats they could actually see the fish jumping about in abundance – some of them even leaping into the boat. Now the dancing, frolicking fish are a rare sight and the Himalayan rivers are no longer an angler's dream.

Cold water aquaculture development in Nepal has lagged behind due to lack of scientific and technological innovations and partly due to the lack of transport and communication facilities.

Table 2
Rare cold water fish of Nepal, showing the preferred habitat and distribution in the major rivers of Nepal

The status* of each species is given as: in danger of extinction (ED), threatened (TH), restricted (R), widespread (WS). Economic and social values are indicated in parentheses after the common names of species: C, preserved in temple ponds due to cultural taboos, worshipped as Fish Goddess; F. used in folk medicine: G, game fish for angling; O, ornamental fish used by Buddhists.

Family and Species	Common name	Status	Preferred habitat	Distribution in rivers
Cyprinidae : *Tor putitora* (Hamilton)	Mahseer (C,G)	ED	Pool/run areas swift gorges	Mainstream of Gandaki, Koshi, Karnali and Mahakali
T. tor (Hamilton)	Mahseer (C.G)	ED	Eddy/run interfaces	Mainstream of Gandaki, Koshi, Karnali and Mahakali
Acrossocheilus hexagonolepsis (Mc Clelland)	Copper Mahseer (C.G)	R	Small streams and creeks	Sunkoshi, Arun, Tamur and Trisuli
Schizothorax richadsonii (Gray)	Spotted snow trout (C.G)	TH	Rhithron streams	Upper reaches and feeder streams Gandaki, Koshi and Mahakali
Schizopyge (Schizothoraichthys) esocinus (Heckel)	Mountain trout (C.G)	TH	Sandy and gravel -bottom river	Headwater streams of Koshi, Karnali and Mahakali: Himalayan lakes
S. progastus (Mc Clelland)	Point-snouted snow trout (C.G)	TH	Deep run backwater	Mainstream and tributaries of Gandaki, Koshi, Karnali, Mahakali
Diptychus maculatus (Steindachner)	River trout (C.G)	ED	Rhithron streams	Mainstream of Bagmati, Sunkoshi, Kulekhani; Himalayan lakes
Garra gotyla (Gray)	Sucker head (F.O)	R	Rhithron streams	Sunkoshi, Arun, Tamur and Trisuli
G. annandali (Hora)	Stone roller (F.O)	WS	Pool/run areas of swift streams	Mainstream of Gandaki, Koshi Karnali and Mahakali
Cobitidae: *Nemacheilus botia* (Hamilton)	Sand loach (F.O)	WS	Rocky pools of rhithron streams	Tributaries of Gandaki, Koshi, and Karnali
N. rupicola (Mc Clelland)	Stone loach (O)	R	Shallow water riffles and spring pools	Hills, streams and creeks

* Status of fishes based on Nepal Country Report on Biological Diversity, IUCN Nepal, Shrestha (1999)

Family and Species	Common name	Status	Preferred habitat	Distribution in rivers
N. beavani Gunther	Creek loach (O)	WS	Pools/riffle areas of creek	Tributaties of Gandaki, Koshi and Karnali
Botia lohachata (Chaudhuri)	Painted loach (O)	R	Rocky and gravel bed creeks	Trisuli, Bagmati and Rapti
B. almorhae (Day)	Tiger laoch (O)	R	Rocky gravel bed, pools of streams	Mountain rivers and creeks
Amblycipitidae : *Amblyceps mangois* (Hamilton)	Catfish (C.F.O)	ED	Rhithron stream	Mainstream and tributaries of Gandaki, Koshi and Karnali
Psilorhynchidae : *Psilorhynchus pseudecheneis* (Menon & Datta)	Stone carp (O)		Pool/run areas of rhithron stream	Duch Koshi and feeder stream
P. homaloptera (Hora & Mukerjee)	Torrent stone carp (O)	R	Small headwater stream cienagas	Tributaries of Gandaki, Koshi, Karnali and Mahakali
P. sucatio (Mc Clelland)	River stone carp (O)	WS	Pool/ run areas of mountain streams	Narayani, Rapti, Kaligandaki, Arun and Tamur
Homalopteridae : *Balitora brucei* Gray	Rock carp (O)	F	Backwater and quiet eddies	Mainstream and tributaries of Gandaki, Koshi and Karnali
Sissoridae : *Pseudecheneis sulcatus* (Mc Clelland)	Sucker throat catfish (O)	R	Deep riffles and runs over gravel, cobble substrata	Mountain rivers and creeks
Echiloglanis hodgarii (Hora & Silas)	Torrent catfish (O)	TH	Rhithron stream gravel riffles in creek and spring	Snow-fed mountain rivers and creeks
Myersglanis blythi (Day)	Stone cat (O)	R	Pool/run areas of rhithron streams	Bagmati and tributaries
Corglanis kishinoui (Kimura)	Catfish (O)	ED	Rocky and gravel bed pools, rhithron streams	Mountain rivers and creeks draining Kulekhani area
Laguvia ribeiroi (Hora)	Painted catfish (O)	TH	Pool/ run areas of swift streams	Tributaries of Gandaki, Koshi and Karnali
Glyptosternum pectinopterum (Mc Clelland)	River cat (O)	R	Pool/run areas of rhithron streams	Tributaries of Gandaki, Koshi and Karnali
Glyptothorax trilineatus (Blyth)	Three-lined catfish (O)	R	Pool and riffle areas of streams	Tributaries of Gandaki, Koshi and Karnali
G. cavia (Hamilton)	Catfish (G.O)		Sandy or rock bottomed springs	Mainstream and tributaries of Gandaki, Koshi and Karnali

Family and Species	Common name	Status	Preferred habitat	Distribution in rivers
G. horia (Shaw & Shebbeare)	Catfish	TH	Back water of quiet eddies	Mainstream and tributaries of Gandaki, Koshi, and Karnali
G. gracilis (Hora)	Catfish	R	Pool/ run areas of mountain streams	Tributaries of Gandaki, Koshi Karnali and Mahakali
Bagaridae : *Rita rita* (Hamilton)	Striped catfish (O)	TH	Back water of quiet eddies	Tributaries of Gandaki, Koshi, Karnali and Mahakali
Anguillidae:*Anguilla bengalensis* Gray	Freshwater eel (C.G)	TH	Sandy or rock bottomed crevices of rivers	Mechi, Seti, Arun and Tamur

persistent problem combined with perishability of aquatic products and geographical isolation between the fishermen and the consumers prevents good use of the catch (Table 3). Lack of modern fish-processing plants means substantial losses between the time of fish capture and consumption. Seasonal glut of fish landed in rural areas is generally salted, sundried and smoked by using crude traditional methods of fish preservation. These processed products, due to rough packing methods, are liable to undergo quick microbial infestation and thus have short shelf life. Such processed fish fail to fetch good market prices. Due to the lack of expertise and knowledge of life history, breeding, migration and behaviour, the development of cold water fishery has remained underdeveloped in Nepal.

3. PRIORITIES

Realising the necessity of giving utmost attention to aquaculture development, the present author would like to draw attention to the following points: (i) Lake and reservoir fisheries need to be given serious concern. Fisheries in lakes and reservoirs may be developed by the introduction of fishing vessels of modern types. Introduction of power-driven fishing boats will enhance the fishermen’s ability to take their catch to a landing place with an access road and therefore an access

Table 3
Fishermen community and their major catch

Fishermen community	Geographical area	Major catch	Fishing gears
Bote/Majhi	Midland hills and plains	Mahseer (*Tor tor*) Katle (*Acrossocheilus hexagonolepis*)	Cast net
Tharu	Terai	Eel (*Anguilla bengalensis*)	Hook line, spear
Muser	Terai	Jalkapoor (*Pseudeutropius*)	Gill net, drift net
Kumale	Hills and Terai	Snow trout (*Schizothorax*)	Nets and traps
Dharahi	Terai and hills	Tenger (*Mystus tengara*)	Nets and traps, hookline
Chepang/Tamang	Hills and plains	*Puntius, Garra, Xenentodon*	Bow and arrow, spear, cat net
Chetri/Gharti	Midland hills	Stone carp (*Garra*), Stone eel (*Mastacembelus*)	Gradient fish trap, cast net
Pode	Midland hills	Minor carps (*Puntius*), Carp minnow (*Barilius*)	Cast net, lift net
Sunaha	Hills and Terai of Western Nepal	Mahseer, river carps and catfishes	Cast net, gill net, traps, fish poison
Badi	Western Nepal	Mahseer, eels, catfishes	Hookline, spear, lines
Magar/Gurung	Midland hills	Snow trout (*Schizothorax*), Katle (*Acrossocheilus hexagonolepis)*	Fish snaring, trapping, lift nets, cover pots

to good market. The better prices they would receive at such a landing point would be a stimulus to increase production. This would also increase the proportion of fresh fish reaching markets. (ii) At certain hydroelectric dams the cold tail waters could be used in fish hatcheries, fish pens, cages and fish spawning channels for the production of cold water fish. In such cold water fish hatcheries fed with running water of the river, controlled breeding or hormone-induced breeding of game fish such as golden mahseer (*Tor putitora*), deep-bodied mahseer (*Tor tor*), spotted snow trout (*Schizothorax plagiostomus*) and point nosed river snow trout *S. progastus* can be conducted with great ease. (iii). Confluence sites of river and creek are congregation points or staging areas of migratory and resident fish. Such areas should be converted into fish spawning channels by applying habitat simulation techniques.

4. REMEDIES

The potential for increasing fisheries production can come from three areas: utilization of untapped species (aquatic plants), harvesting of hitherto unattractive aquatic resources (frogs, shrimps, crabs, mollusc and ducks), and development of novel methods of aquaculture and harvesting. In Nepal, the traditional fishing crafts used by native fishermen are outmoded. For better harvests, better fishing vessels, in particular the replacement of traditional crafts by powered boats, together with good storage and freezing facilities and extension of biotechnology, are highly desirable.

Many hydroelectric reservoirs and irrigation projects have been put into effect in Nepal during the last two decades. These projects have given scant attention to the possibilities of running water fish hatchery development; future projects should give due consideration to evolving management in such a way that no deleterious effect is produced on the fish fauna due to impact of dams. To facilitate seasonal migration of fish and other aquatic animals, fish passage (fish ladders and fish lifts) should be constructed along hydroelectric dams.

Conservation of rare fish of Nepal needs to be given proper attention and should be observed in context of international perspectives of a developing country. There ought to be a symbiosis between biologists and engineers in formulating the multiple policy of water use. Harmful fishing practices such as poisoning, electrofishing, dynamiting and rock striking must be stopped. Sections of rivers and reservoirs where fish congregate for spawning must be closed to fishing or declared fish sanctuaries or fish parks.

It is essential to determine whether the native cold water fish are superior to the introduced trout and other cold water fish. The impacts of introduced species such as carp, rainbow trout, tilapia, etc., upon the native ones should be thoroughly studied.

For the development of aquaculture, attention needs to be given to increased production through introduction of integrated aquaculture, techniques of induced breeding of fish and their faster propagation, and to ranching of migratory fish stocks. An international centre of cold water aquaculture and fishery development should be established for the mountain countries of Asia.

Fishermen in Nepal are mostly poor and landless people. They usually take to this profession on a part-time basis. If fishing could become more lucrative, more people would be engaged in fishing and marketing would commensurately develop further (Table 4). For this purpose fishing co-operatives should be developed.

5. INTERNATIONAL PERSPECTIVE FOR THE DEVELOPMENT OF AQUACULTURE

Aquaculture research in Nepal is still in its infancy. A long-term programme of both basic and applied aquatic ecology, genetics and biotechnology will resolve this problem. In all developing countries much constraint has been put on fish habitat and natural water courses by damming, silting, agricultural insecticides, industrial and domestic effluents. In order to protect aquatic life from adverse effects, a concerted effort of hydrobiologists, ecologists, fishery biologists and engineers is needed.

Bhutan, Nepal, India and Bangladesh share common water resources of the Himalayas. Besides these countries the mountain countries of the Hindu Kush – Karakoram – Himalayan region, i.e. Myanmar, Pakistan, Afghanistan and Iran also have considerable cold waters. Fish, turtles, dolphins, crocodiles are much threatened by dams, misuse and pollution. Therefore, effort should be made to draw up a dynamic fish and aquatic resource management policy to implement in international cold waters of these countries.

Table 4
Maximum weight of commercially important fish of Nepal used for food, game and recreation

Local name	Scientific name	Maximum weight recorded (kg)
Chuche Asla	*Schizothorax progastus*	5.0
Sahar (Kalo Sahar)	*Tor tor*	60.0
Sahar (Pahelo Sahar), Ratar	*Tor putitora*	48.0
Gardi or Thed	*Labeo angra*	3.0
Karsa	*Labeo gonius*	3.0
Banga or Thed	*Labeo dero*	3.9
Bata	*Labeo bata*	3.0
Karnoch or Bishari	*Labeo calbasu*	3.0
Mrigal, Naini	*Cirrhinus mrigala*	5.0
Catla	*Catla catla*	6.0
Saur or Saul or Bhoura	*Channa maurilus*	15.0
Buhari	*Wallago attu*	5.0
Gaichi	*Macrognathus aculeatus*	1.0
Banai	*Mastacembelus armatus*	1.0
Tenger	*Mystus tengara*	3.0
Jalkapoor or Pottasi	*Clupisoma garua*	3.0
Jalicapoor	*Pseudeutropius goonawaree*	5.0
Moi	*Notopterus chitala*	20.0
Chunche Bam or Kauwa	*Xenentodon cancila*	0.5
Mugri	*Clarias batrachus*	2.0
Singhi	*Heteropneustes fossilis*	1.0
Bachawa	*Eutropiichthys vacha*	2.0
Pabata	*Pangasius pangasius*	2.0
Tenger, Kanti	*Mystus seenghala*	10
Voktari	*Ompok bimaculatus*	0.5
Rewa	*Chagunius chagunio*	0.5
Raj Bam	*Anguilla bengalensis*	10
Gounch or Thed	*Bagarius bagarius*	80

The governments, in addition to fulfilling their responsibilities for the administration of laws pertaining to national, territorial and international fisheries, should collect and disseminate information on fisheries and should serve in an advisory capacity on regional fishery problems.

Many nations from the developed world like United Kingdom, United States, Canada, who share a rational fishery management have made conservation policies by means of multilateral approach and international agreements. In promulgating these treaties the signatory nations take into account the research and conservation measures undertaken by the component states and provinces.

Fisheries should be administrated on a nonpolitical basis and by specialists. Biological facts should receive primary consideration in the utilisation of fish stocks. The agency charged with the administration of the fisheries should be responsible for formulation of needed regulations. Public access to sport fisheries is important. Present public ownership of water frontage should be jealously guarded. Conflicts between sport, commercial and subsistence fisheries should be settled on basis of the pertinent facts in each case. In many instances waters will support all types of fisheries with mutual benefit. Where competition exists to the proved detriment of one fishery, an objective socio-economic appraisal should form the basis for the determination of proper regulations.

The success of any fisheries management policy, in private or in public waters, is in proportion to its basis on factual information. This is a clear demonstration of the prior requirement for research in all phases of fish stock management. Research must include detailed physiological studies on individual fish species as well as broad studies of relationships between fish populations and environment. Constructive programmes of research should be developed by universities and by administrative units to make the most advantageous use of available facilities and personnel. The comprehensive programmes made possible through such coordination of resources should encompass the necessary fundamental research in all related fields and the practical problems arising from the application of research findings.

Regulatory laws, stocking, hatchery development and habitat improvement are the recently recognised tools for management of most subsistence, commercial and recreational/sport fisheries. Laws for regulation of the catch should be based upon proved need, limited to those necessary for orderly management of fish stocks, and should be stated as simply as possible. The harvestable surplus of fish should be removed at the most desirable size and in the best condition.

Food, game and forage fish reared at public expense should be stocked only for public benefit; private fish culture should be encouraged to supply privately owned waters. Only fish free of diseases and parasites should be used for stocking. Periodic restocking is desirable in lakes and tail waters of dams that are washed by monsoon infrequently or in waters which are occasionally depleted by pollution, otherwise the stocking of the young of any species in waters having adequate spawning conditions is considered of doubtful value. The introduction of exotic species (tilapia, gourami, amago, mosquito fish) is proper where adequate biological investigation has demonstrated the benefits and the suitability of the environment including the possible effects on continuous waters.

Propagation and stocking of fish in waters where reproduction is lacking and where environmental deficiencies cannot be remedied, is recommended if those who benefit pay the cost of such stocking, or where such stocking contributes to the livelihood of the poor fisher communities. Elsewhere public agencies limit the harvest to maintain sustainable fish stocks. In heavily used waters, fishing for game species must be regarded as a source of recreation, not meat. Private fish culture should be encouraged to provide fish for the table and for those who must have and will pay for a full creel.

Habitat improvement includes creation of spawning channels, development of ranching centres, control of pollution (including soil erosion), and provision of additional shelter, food and spawning facilities for fish. Such work should be preceded by a physical and biological survey to determine the factors limiting fish production and the remedies to be applied. The watershed approach is recognized as logical and most efficient. Predators of fish such as dolphins, crocodiles, turtles should also come into the general picture of fisheries management although they are not a component of tangible fisheries. For this dual international fish parks or sanctuaries should be created along borders.

Fishery resource development should receive top priority in high dam and irrigation projects. Any plan to use water for power, irrigation, navigation or mining or to carry waste products should include maintenance of the fisheries as a co-equal objective and this shouldbecome part of the high dam project cost. Environmental Impact Assessment (EIA) studies are now being conducted for all new dams planned or being constructed in Nepal.

Wherever an agency plans any development that will impair either the quantity or the quality of water available for fish life, mitigation of fish losses should be the financial responsibility of the sponsoring agency. Local projects are government responsibilities. Inter-governmental and interstate problems should be solved by inter-governmental compacts.

The central agencies concerned with fisheries and public health should be responsible for conducting research in cooperation with the Government states or provinces on the effects of pollution and other water uses and on methods for preventing loss of fisheries.

6. RECOMMENDATIONS

For cold water aquaculture in the rivers and lakes long-term research and planning are necessary. The following measures are suggested;

1. The natural environment of major watersheds of the rivers has been greatly changed by deforestation, erosion and silting of river beds. To restore the ecological balance of watersheds monitoring and management must be practiced.

2. Regular ecological surveys should be made to monitor fish population changes in pristine rivers as well as river courses altered under the influence of man.

3. Habitat improvement is an essential factor for the fishery improvement. To avoid seasonal changes of water level, suitable pools should be created by constructing rock or boulder dams. Such a habitat restoration practice will improve the fish habitat quality and avoid the winter desiccation.

4. Water requirements for fish and river wildlife in the rivers of Nepal should be determined by constant monitoring. The water quality and volume should be well regulated to improve the habitat quality.

5. Areas downstream of dams are dewatered at many hydropower projects. Therefore consideration should be given for water release from the dam.

6. Biological considerations should be given to change traditional pond design by incorporating spawning and incubation channels at suitable places.

7. Fish ladders, fish lifts and fish guiding systems should be developed along the dams to allow fish, river dolphins, crocodiles and turtles to pass upstream and downstream.

8. Protective and catch-restrictive fishing regulations should be based on periodic assessments of fish stocks and the critical stages in fish life histories should be studied. Fishing law and bag limits, restricting the use of nets below 2 cm mesh size, should be enforced.

9. In the upland section of the rivers practice of electrofishing and tossing of dynamite into water is in vogue. Such destructive activities should be stopped.

10. In rivers the spawning and migration of fish usually take place in June-September. These two months should be declared as closed seasons by law.

11. To reduce the incidence of pollution in the rivers an adequate provision should be made through legislation to check the pollution caused by waste disposals from paper, beer and other factories.

12. Snow trout populations are declining owing to high fishing pressure in alpine waters. Therefore, it is highly desirable to establish “snow trout sanctuary” at suitable places. The breeding of snow trouts in a hatchery and releasing spawn or fry in rivers and streams will help to stabilize the snow trout populations.

13. The deep-water pools of rivers and their feeder streams should be declared mahseer sanctuaries. Such an establishment will help to protect spawners.

14. Collection of fish fry from rivers, reservoirs and tail waters of dams and spillage should be stopped. Such a commercial exploitation will deplete the fish stock.

15. To preserve fish stocks of mahseer and the snow trout gene bank a conservation programme should be developed.

16. Proper consideration should be given to develop environmentally friendly aquaculture and uplift socio-economic conditions of fishermen as well as fishermen education.

17. A nation-wide fish marketing network should be developed.

18. Introduction of exotics and transgenic species in native water should be conducted only after pilot studies and so that they do not disturb the ecosystem.

19. Enforcement of fishing laws and regulations should be implemented.

20. A national aquarium should be constructed to popularize the knowledge of fish and fisheries.

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Section 2: Country reviews

COLD WATER FISHES OF THE TRANS-HIMALAYAN REGION: BHUTAN

by

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ABSTRACT

While Bhutan is rich in cold water streams, rivers and lakes, the fish distribution in them is poorly known, fish exploitation minimal, and aquaculture of cold water fish species does not exist yet. Apart from indigenous fish with fisheries potential, such as asla and mahseer, the exotic brown trout is also present in some rivers where it has established self-reproducing populations. Only controlled and limited sport fishery for mahseer (*Tor* sp.) is allowed. It is proposed to establish a cold water fish hatchery, both for the production of stocking material for releases in rivers and lakes, as well as for production of table-sized fish.

1. BACKGROUND

Unlike other Trans-Himalayan countries, the Kingdom of Bhutan is a small landlocked country of 46 500 km^2 which lies in between China in the north and India in the east, west and south. Almost 90 percent of the land is mountains, the rest consists of foothills in the south, with some plains stretching from east to west.

Numerous rivers, most of them fed with snow- and ice-melt from Himalayan glaciers, flow from north to south and drain into the Indian plains of Assam and West Bengal. Among them, three major rivers, the Amo chu (Torsa), Pho chu Mo chu (Sunkosh) and Dangme chu (Manas), form the main river system of Bhutan. These rivers are rich in fish. The main indigenous fish are Himalayan trout (*Barilius* spp) and Mahasheer (*Tor* spp). Exotic brown trout (*Salmo trutta*) was introduced and is a common fish in some rivers and streams of Bhutan. Bhutan has also a number of large and small lakes scattered throughout the country. Most of these lakes are situated at altitudes above 2 000 m and are covered by ice during the winter months. With a view to propagating cold water fish especially trout, the Royal Government has initiated stocking trout yearlings in lakes. The yearlings required for stocking in the lakes have been obtained from rivers of Bhutan by capturing them in nets.

The fish stocks in the rivers of Bhutan have not been properly assessed but among cold water fish species brown trout predominates. As the government does not permit catching of fish on commercial scale fish catch statistics are not available. During the non-breeding seasons the Royal Government issues sport fishing permits for certain areas.

Previous assessment of cold water fish and fisheries potential of Bhutan was presented in two FAO reports (Dubey, 1978; FAO, 1987), and the situation was also reviewed by Petr (1999).

2. THE ROLE OF COLD WATER FISH IN SUPPORTING LIVELIHOOD OF RURAL PEOPLE

The aquaculture industry in Bhutan is still in its infancy and only few farmers are involved in fish culture of warm water fish species. The breeding and culture of cold water fish species has so far not been initiated. As mentioned above, very few people obtain fishing permits, which is mandatory for everyone catching fish. The fishing equipment employed are hooks or spoons, as nets are not permitted. This is to avoid catching fish on a large scale, which would negatively affect fish stocks within a very short period of time.

2.1 Human impact on native cold water fish

The impact of human intervention on aquatic ecosystems and eventually on the native cold water fish community is viewed as a serious problem. Problems arising from siltation and pollution are not common in Bhutan since almost all the river systems have their origin in the snow fed mountains and pass through thick forests where there is less erosion. Siltation due to flash floods during the monsoon season or melting of snow has only a negligible impact on fish. Several hydro-power projects, some of them with a capacity of 1 000 MW, are under construction, but it is anticipated that they will have only a minute impact on fish fauna, due to the location of these projects. Overfishing and introduction of exotic fish species may have direct impact on indigenous fish, and this needs to be studied.

2.2 Conservation and mitigating measures

The Royal Government has initiated very few conservation and mitigation measures so far. However, as precautionary measures the government does not encourage import of fish species or fish seed for stocking in ponds, rivers and lakes. The only cold water fish species imported and introduced in the rivers of Bhutan was brown trout, which was brought in 1958. Lakes and rivers are not yet fished or used for fish culture. The government regulations help to conserve the fish species, as indiscriminate fishing is not permitted, and other types of fishing are limited.

2.3 Domestication of economically important fish

A small fish-breeding farm in the western part of the country was established in the early 1970s. The farm was established with the objective of breeding brown trout to be released in rivers and lakes to enhance production of fish fauna in natural water bodies. The farm remained functional for about 15 years and was closed by the government due to unforeseen reasons. An FAO Mission visited Bhutan in 1987, reviewed the situation, and put forward a proposal for a model hatchery for the cold water indigenous fish asla and for the exotic trout (FAO, 1987), but there has been no follow-up.

3. FUTURE POTENTIAL OF COLD WATER FISHERIES DEVELOPMENT IN THE COUNTRY AND PROSPECTS FOR REGIONAL COOPERATION

Based on the availability of natural water bodies comprising rivers and lakes and reservoirs created as a result of hydropower development there is good potential for the development of cold water fishery in Bhutan. Cold water trout and mahseer capture could be expanded on a trial basis, and the Royal government in collaboration with other countries could initiate a water trout aquaculture pilot study for which perhaps some lakes could be used. Other cold water fish species, such as mahseer, could be also tried for farming. This could be supplemented by establishing a trout farm for trout seed production.

As farming in Bhutan is done mostly in valleys where rivers exist, there is potential for cold water fish culture involving the farmers, which would in turn increase income at the rural household level. Starting cold water fish culture could also have complementary benefits, such as contributing to eco-tourism and export earning.

Regional cooperation with SAARC countries in the field of fishery development to exchange technical know-how needs to be established.

4. SUMMARY AND RECOMMENDATIONS

Cold water fishery in Bhutan does not exist and no work has been done as far as culture is concerned. Trout breeding and breeding of indigenous fish species on a small scale specifically for stocking rivers and lakes can be carried out for conservation of biodiversity. The country has good potential for development of cold water fishery in rivers, lakes and reservoirs. Current plans and proposal include the establishment of a trout hatchery and its culture by starting a pilot project in northern Bhutan.

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COLD WATER AQUACULTURE IN IRAN

by

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ABSTRACT

Iran has been making a rapid progress in cold water aquaculture, which is concentrating mainly on the production of rainbow trout. The past limited supply of fry has been overcome by the private sector taking over this important step in aquaculture production. With the production of 9 000 t of market size trout achieved in year 2000, as compared to 7 000 t in 1999, and 1 500 t in 1995, further expansion is envisaged in the current Third Development Plan (2000-2004).

1. INTRODUCTION

The first documented report on inland fish farming in Iran dates back to 1922. The farming was carried out in a small ichthyology center near the Bandar Anzali fisheries office in the north of Iran, on the coast of the Caspian Sea. The objective was to breed sturgeon artificially for stocking the Caspian Sea. Following the establishment of a research ichthyological station affiliated with the North Fisheries Company and the nationalization of the fisheries industry and also the termination of Irano-Russia cooperative activities, production of kutum (*Rutilus frisii*) fingerlings in hatcheries for their release into northern rivers started. Millions of kutum fingerlings were produced and released over a number of years. These activities were the beginning of fish farming in Iran. As before, hatcheries produce fish fry and fingerlings for release to rehabilitate fish stocks and to give support to fisheries.

2. COLD WATER FISH FARMING

Until 1961 there was no cold water fish farming of the native red spot trout, rainbow trout and the Caspian salmon (*Salmo trutta caspius*). The Karaj Mahisara Company was the first which engaged in salmon culture in Iranian inland waters. It was established in 1962 and following the approval of stocking plans for the inland rivers the company purchased 15 million rainbow trout eyed eggs from Denmark during 1965-1967. Consequently, 3 million fingerlings were released into the rivers and reservoirs. During the same period, female breeders of red spot trout (native of Karaj jajrood and especially in the Karaj River) were captured and following the application of the artificial breeding method fish fry were released into the rivers.

Subject to the decision made by the Ichthyological Centre a small centre was set up in 1965 on the coasts of Ghazian district for artificial breeding of several species. The centre was mainly concerned with aquaculture, nutrition and fish diseases including native warm water species and aquarium species, and salmon and trout.

Jajrood Trout Company (a private entity) was set up in 1966 to produce rainbow trout for markets. Like the former company the latter one also imported eyed eggs from Denmark and supplied the market with the product following the completion of the hatching process. Gradually, these companies produced enough broodstock to achieve self sufficiency in eyed eggs and to sell the surplus fish fry to both private and public firms and organisations, such as the Environment Protection Organization, which were involved in releasing them in a variety of inland water bodies.

In autumn 1967, 300 Caspian salmon were captured from the rivers flowing into the Caspian Sea (i.e. from the Killeh Tonokabon spring) by a gamekeeper organization and were transferred to the Karaj Mahisara Company. In December of the same year hatching operations started and using artificial fertilisation resulted in production of about 400 000 eyed eggs. This was the first step in the breeding of the Caspian Sea salmon.

During 1968-1969 the Caspian Sea Salmon Breeding Center was established by the Iranian Fisheries (Shilat) for rehabilitation of salmon stocks. It started operating in Age Oskaled village on the Killeh River. The Yeghandasht trout farm in Fars Province was set up in 1977 and started operating two years later.

The Karaj Mahisara Company has been the turning and starting point in the cold water fish farming industry in Iran. This was later on supplemented by the establishment of the Gazian Breeding Station of the Jajrood Trout Company and the Yeghandasht trout farm.

The first eyed eggs of rainbow trout were imported during 1965-67 and naturalized in the Iranian farming system. They were grown to a mature stock and started reproducing.

2.1 History of cold water fishery in inland waters of Iran

Catch and exploitation of cold water species from Iranian inland waters, mostly from rivers, has been very common for many years. Cold water fish is considered to be of high quality and it has been targeted by recreational fishermen, and sometimes also by commercial fishermen. More recently the capture became regulated by the same regulations and licencing as warm water fisheries.

The studies conducted by an Iranian fisheries expert and an English ichthyologist on the trout in the Karaj River have indicated that overfishing using hook and line and explosives during the years preceding the ban on capture reached such an extent that it will take many years before the fish stocks recover.

2.2 History of cold water fish fry releases in inland waters

Following the import of a sample of rainbow trout and its breeding, the stocking started in 1964. By 1966 eighteen rivers and four reservoirs were stocked. The major objective was to develop sport fishery through enhancing the stocks of these species, with some side benefits for the locals.

Referring to the high mortality rate of fish fry during the transportation the Gatekeeper and Catch- monitoring Organization provided a tank with the capacity of one and half ton, which was equipped with the latest technology, in particular with an aeration system. The first fish used the tank in 1965 under the supervision of the same organization. In this way a large number of fish fry were introduced to the Jajrood River. This initiative was the first step in releasing trout fry and in transporting live fish within Iran. The continuous production of seed material made it possible to stock a large number of inland waters. This was executed by the Karaj Mahisara Company and the Jajrood trout farm. The rivers stocked were: Jajrood, Lar, Haras chaloos, Karaj, Zayndeh rood, Sardab rood, Lighvan chai, Nomrood, Sefeed rood, Shafa rood, Shahsavar, Taleghan Shahrood, Lamber, Khotbeh sara, Pood rood and Karoon, and reservoirs Sefeed rood, Amikabeer ckarga and Layan. In 1970 and the following years rainbow trout were released by an Israeli company in Doroodzan reservoir, in 1972 to 1974 in Arablis meor lake by an agriculture shareholding company, and in 1973 in Gohar and Valesht lakes.

2.3 Developmental trend of cold water fish farming until 1978

Untill 1978 only two aquaculture centers, the Karaj Mahisara Company and Jajrood trout farm, were active in this field. Only informal information is available on fish fry production and on marketed fish (Table 1).

Table 1
Production of fish fry and market size trout (1965-1978)

Year	65	66	67	68	69	70	71	72	73	74	75	76	77	78
Fish fry (thousands)	1 000	1 000	1 000	1 100	1 200	1 400	3 500	3 500	3 800	4 000	4 000	45		
Marketed (tons)	20	20	30	50	70	80	120	120	120	160	160	200	200	180

2.4 Development of cold water (trout) aquaculture centres – 1979-1988

2.4.1 Development of cold water fish stocks

Provision of fry of cold water fish and their stocking in inland water bodies have been the major objectives of the development of cold water fisheries. A number of aquaculture centres were set up, with some never reaching the operational stage due to a number of constraints.

2.4.2 Aquaculture centres affiliated with Shilat

From the beginning of this period the establishment of cold water fish breeding centres for rainbow trout was included in the agenda of the inland water planners of the Iranian Fisheries (Shilat). The following centres were established and active.

Kelardasht salmon culture centre (Shaheed Bahonar)

This centre was designed in collaboration with experts from the former USSR. Following the site selection in Radbarsk village in the Kelardasht zone the construction started in 1979 and the centre started operating in 1983. During the first year the 800 imported eyed eggs from Denmark failed. However, in the following years not only salmon fry was produced, but also grown to broodstock size and seed was produced for stocking purposes.

Yasooj trout culture center (Shaheed Motahari)

The center was set up by Shilat in Yasooj dasht region of Khohkiloeh and Bayer Ahmad provinces. The objective was to produce 2 million rainbow fry annually to meet the needs of cold water fish farms and for stocking inland water bodies. Construction started in 1984 and production started in 1989.

Dimeh trout culture centre

This was supposed to become one of the largest trout breeding centres in Iran. The centre was to take advantage of spring water supply in Dimeh and to produce up to 7 million fry. Due to the opposition of the local authorities, even though considerable construction work had been accomplished, the centre was never finished.

2.4.3 Private sector aquaculture centres

Karaj Mahisara Company

The company was one of the centres involved in importing eyed eggs for the purpose of fish fry production during 1979-1988 and it was very active in producing fish for consumption.

Jajrood trout culture company

It was involved in fish fry production during 1979-1988 mainly using its own broodstock and occasionally also importing eyed eggs. It was also producing a quantity of fish for market.

Yeghandasht trout farming company

The construction of the necessary facilities started in 1977 and by 1979 the fish farm was fully functioning. It is the largest trout farm operating in Iran, with a capacity of 240 tons in two different phases. The incubation facilities were completed in 1981 with the objective of fish fry production, and in 1982 about one million eyed eggs were imported. Consultant experts managed to produce fish fry for the first time in Iran.

2.5 Development of cold water fish farms (1979-1988) (Table 2)

During this period a number of cold water fish farms were constructed and started functioning in the following provinces: Tehran, West Azerbaijan, Chahar Mahal and Bakhtiari, Khorasan, Farse, Kohkiloyeh and Bayer Ahmad, Lorestan and Mazandaran. The number of trout farms reached 26 of which the largest number were constructed in 1985, most of them in Chahar Mahal and Bakhtiari, Khorasan and Mazandaran. Eight cold water fish farms were active in 1985 and the fish production, according to one report, was 227 tons. Another report reported 400 tons, which could be realistic given the capacity of the farms in 1988. But the rate of development of cold water fish farming in that period was still slow. The major reasons for this could be summarized as follows:

- Lack of government policy and support concerning trout culture development (it was considered a luxury commodity);
- Shortage of experts both in the public and private fisheries sectors;
- Dependence on foreign countries for eyed eggs as well as fish meal;
- High finished product price and lack of comprehensive and general consumption market;
- Heavy investment costs.

In short, trout farms were not fully developed until 1988 when the first training course in inland water fisheries was held. The year 1989 was a turning point.

During the period 1979-1988 the annual rainbow trout fry production increased by 33%, from 3 million to 4 million, while in the government sector during the period 1984-1988 the initially steep rise in fry production was followed by an equally steep decline as a result of the private sector taking over.

Table 2
Cold water fish farms development (1979 – 1988)

Year Province	79	80	81	82	83	84	85	86	87	88	Total
Tehran							1	1			2
West Azerbaijan			1			1				1	3
Chahar Mahal & Bakhtiari							2		1	1	4
Khorasan			1				1	1		1	4
Fars				2			1				3
Kohkiloyeh & Bayer Ahmad				2			1				3
Loristan							1		1		2
Mazandaran							1	1	1	1	4
Total	-	-	2	4	-	1	8	3	3	4	25

Information provided by the Aquaculture Department (1973-1991). Estimates only for the private sector for the period 1979-1988.

2.6 Trout production during 1988-1997

In 1978 the total annual cold water farm production was 140 t. By 1998 farm trout production reached 500 t.

During 1989-1999 the first and second five year development plan for inland waters were implemented. Fish culture entered a new policy period of comprehensive national planning and due attention was paid to the economic, social, environment and land rehabilitation aspects. Parallel to this there was a great structural change in management and due attention was paid to aquaculture research in inland waters and to promotional and training services required for the new initiatives. While the growth of fish production was not fast during this period the fundamental changed which were implemented prepared the ground for future improvements.

Average annual growth rate in inland, warm and cold water fish farms was 18.2%, 6.6%, and 58.7%, respectively. Trout culture had the highest annual growth rate, and in the future it can play a major role in inland fish farming business if the trend continues.

A study of fish fry farming in the period before 1987 showed fish fry production in 1978 of 8.7 million, out of which trout production was 4.5 million. This was followed by a rapid growth which was mainly the result of the public (except Shilat) and private sectors, while the Iranian Fisheries (Shilat) had the least important role in this respect.

During 1979-1988 fish fry production was 65.5 million, of which 61 million were warm water species fish fry (93.1 percent) and 4.5 million trout fry (6.9 percent). Most of the trout farming was carried out by the private sector as public sector involvement was negligible. The reduction in trout fry numbers compared to those before 1979 indicates that the impact of the

Iranian Fisheries policies with respect to trout culture was not effective. During this period cold water fish farming including fish fry and market size fish was growing slowly.

During 1989-1997 trout fry production grew faster, from 4.5 million in 1988 to 38 million in 1997, this corresponding to an annual growth rate of 83%. This was due to a number of factors. Unlike in other years, Iranian Fisheries policies focuses on the development of trout culture, with big steps taken especially in the Second five year development plan. Fish fry shortage due to the limited number of government owned hatcheries led to many private farms setting up breeding and fish fry production facilities. This resulted in a significant increase in trout farming. Proper environmental conditions in many farms for breeding and fry production, as well as technology transfer to the private sector, improved the production conditions and raised the output in a number of farming centres throughout the country.

Abundance of water bodies for trout rearing and economical feasibility, together with the demand for fresh fish of good quality and taste, assisted with the development of fish culture, and this went in parallel with fish fry production which was developed by the private sector supported by the Iranian Fisheries (Shilat).

Although 80% has been considered as a good survival rate from 1 g to market size stage (250–300 g), the actual rate is less, in some farms only 50 percent. It may be even less than 50% due to poor quality fish meal, and low technical level of the personnel. In other words, the production requires a large number of fish fry. The Iranian Fisheries should pay due attention to these issues.

Reorganization of trout production policy, professionalism in the aquaculture industry, building of hatcheries with sufficient capacities are among the tasks which should receive due attention in the current supervisory policy of the Iranian Fisheries. One should avoid leading the affiliated aquaculture centres towards further production or following product–oriented approach only. Converting some cold water hatcheries to applied research on cold water fish should be among the considerations for upgrading aquaculture research. Cold water trout production in 1998 was about 500 t from 5 ha, which is 10 kg/m^2.

The annual total trout production during 1989-1993 was 440, 577, 478, 775 and 840 t, respectively which indicates 410, 523 889 and 1 160 tons less than planned. The plan did not have much impact on trout culture development. One can conclude that even without a plan the same production would be achieved.

The major drawbacks of fish farming during the implementation of the First plan were:

- Lack of a comprehensive fish fry production plan to secure adequate numbers required by the present and future capacities especially in terms of appropriate and adequate site selection.
- Lack of continuation of the plan and lack of coordination of the new ones with the old ones.
- Lack of coordination and planning for long and short term training in order to provide required technical personnel.
- Intervention with fisheries (Shilat) of institutions such as the environment protection organization and veterinarian organization.
- Lack of adequate follow-up activities concerning suitable land and adequate water provision for the fish farming plans, and lack of discussions with other organizations with demand on the resource use.

- One of the principle causes of failure to achieve the objectives of the First plan was the difficulty of obtaining licenses for water and land.

In the Second five year development period three areas of fisheries development have been identified: inland fish farming development; fish and shrimp farming infrastructure; and fish fry capacity building to produce 300 million fry each year for stock rehabilitation purposes.

There exist a number of mechanisms for trout farming, such as fish farming in closed areas and irrigation canals; close–circuit systems; trout farming in multipurpose and agriculture ponds; trout farming in rice fields following the harvest period. The policies for their development have been elaborated in the Second plan by the Iranian Fisheries..

The notion of “promotion“ received due attention mainly because of upgrading of the general information level concerning aquaculture technology transfer and as a result of farmers being introduced to new aquaculture methods such as fish farming in closed areas and integration of fish farming with agriculture. A sound foundation was set up for future plans.

The Iranian Fisheries (Shilat) concluded that the people during the First plan were not familiar with aquaculture. Therefore introduction of new methods, technology transfer and upgrading the public knowledge became of prime importance. This gave parity to promotion, and many projects would become promotion oriented.

As none of these promotional projects set for the Second plan were backed by required research findings the Second plan referred to the deficiencies in inland aquaculture research including lack of specialized research.

Upgrading quality and increasing yields was another aspect of the Second plan, which was included in the agenda. Projects were quantity oriented and were to pay full attention to the utilization of aeration systems and standard formulated feed, take advantage of well trained experts, and apply best water quality and quantity control.

Research on water resources and their production capacity, and applying methods supporting the principle of sustainable development taking account of environmental considerations, were focal points of the Second plan in the area of inland fishery development.

As the research was mainly short-term and not well focussed, the Second plan called for development of proper methodologies and for studies of those water bodies suitable for fisheries development. Furthermore, as a result of an agreement between the Iranian Fisheries (Shilat) and the environment protection organization, the former became responsible for conducting studies on inland water resources before carrying out any fishery management measures such as stocking, and any further action would be subject to the approval of a joint committee. The following priorities of the Second plan are highlighted.

a. Repair and improvement of small earthen ponds so as to economise water use.

b. Fish health of farmed fish. While the veterinary organization deals with diseases, health and hygienic issues are the responsibility of the Iranian Fisheries. Monitoring of fish health and hygienic conditions on fish farms and in hatcheries was to be given proper attention.

c. Increasing production on fish farms of market size fish and improvements in their processing were considered as crucial, as shortage of supply limited fish consumption in the country.

d. Improvement of aquaculture infrastructure. Good infrastructure would speed up the development of both warm and cold water fish farming.

e. Fisheries insurance. Subject to the sub-paragraph 3 of the article 77 of the Second plan at least 50% of agriculture livestock and fisheries products were to go under the insurance by the end of the Second plan. Creation and development of insurance culture and appropriate legislation for inland water fish farming business were among the most important issues in the Second plan.

f. Construction of fishmeal plants as being essential for rapid aquaculture development.

g. Increase in production of carp and trout fry in breeding centres affiliated with Shilat, i.e. the Kalerdasht hatchery and the Yasooj hatchery (Shaheed Motahari).

h. Inland fish fry production was to be increased through developing private sector hatcheries.

Table 3 gives an overview of planning for fisheries development and of the results achieved during the first three five year development plans, with the third plan being the current plan.

Table 3
Plan and performance of cold water fisheries

First 5-year plan (1989-1993)

Year	Plan (t)	Production (t)	Realisation (%)
1989	850	599	70
1990	1 080	557	52
1991	1 376	578	42
1992	1 655	775	47
1993	2 000	835	42

Second 5-year plan (1995-1999)

Year	Plan (t)	Production (t)	Realisation (%)
1995	1 666	1 500	90
1996	2 525	1 900	75.2
1997	3 272	2 514	76.8
1998	5 118	4 994	97.6
1999	7 238	7 000	96.7

Third 5-year plan (2000-2004)

Year	Plan (t)	Production (t)	Realisation (%)
2000	10 647	9 000	84.5
2001	16 074		
2002	24 264		
2003	33 537		
2004	40 238		

By the end of the Second plan (1995-1999) trout production was fulfilled by 87.26 percent. In the first year of the Third plan 84.5 percent of the planned production was achieved.

INLAND FISHERIES OF THE UNION OF MYANMAR

by

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ABSTRACT

Marine fisheries in Myanmar accounts for about 75 percent of the total fish production, with the rest coming from fresh waters. Cold water fisheries is limited to four states, i.e. Kachin, Kayah, Chin and Shan, which are situated in the hilly and remote region of the country. In the fiscal year 2000-2001 cold water capture fisheries production was 7 711 t, aquaculture 2848 t, as compared to the total inland capture fisheries production of 235 373 t, aquaculture 109 188 t, plus 6 603 t of prawn production from aquaculture. Cold water fishery resources are poorly known as there have been virtually no surveys and research done in recent years. Cold water fish are an important source of protein for the hill people, and there is an urgent need for cold water fisheries development with the assistance of international organisations. Fish consumption in Myanmar is 21 kg *per caput* per year.

1. INTRODUCTION

The fisheries sector plays a vital role in the culture and socio-economic life of Myanmar. Traditionally Myanmar people prefer freshwater fish to marine fish. With the population of Myanmar 50 million in the year 2000 the *per caput* fish consumption was 21 kg/year.

Of the fourteen states of Myanmar four are situated in the temperate region. Myanmar has extensive water resources, both inland and marine. Its river system consists of 2 000 km of Ayeyarwady (Irrawaddy), Sittaung and Thanlwin (Salween) rivers and 2 600 km of tributaries and smaller rivers combined. Myanmar has many natural lakes and there are 260 reservoirs. Inland fisheries production comes mostly from floodplains, the water surface of which covers some 6 million hectares during 4-5 months of the year. Myanmar also has 2 800 km of coastline with vast stretches of mangroves. The list of freshwater fish in Kachin, Chin and Shan states of Myanmar is presented as Annex 1.

2. AQUACULTURE

Myanmar has vast potential for the development of aquaculture. While aquaculture development started in the 1960s most fishermen still practice traditional methods of fishing. Prior to the 1960s there was no agency to develop aquaculture mainly because of easy access to and regular supply of fish from inland fisheries resources. In 1975 the Department of Fisheries succeeded in mass production of carp fry using hypophysation technology. Induced breeding and hatchery technique for freshwater fish is now a well developed aquaculture technology. Aquaculture in Myanmar is presently limited to twelve freshwater finfish, one freshwater prawn and one marine shrimp. Three new species have been added last year. Aquaculture is practiced largely in fresh water and brackish water along the coastal area, and on a limited scale in sea water.

In 1999, the Government laid down a very special plan to increase and develop shrimp and fish culture on 48 583 ha and 26 291 ha, respectively, by 2003. There had been a significant increase in production from about 3 000 tons in 1981-1982 to over 85 000 tons in 1998-1999. In 1992, the Department of Fisheries released 1.8 million fish seed into reservoirs and other water bodies, and in the year 2000 it stocked 188.72 million fry and fingerlings.

Due to the continuing deterioration of fish habitat and inland fish stocks the Government has encouraged the industry to increase fish production through aquaculture and aquaculture-based fishery. In response to the new policy aquaculture production started to increase rapidly in the early 1990s. It is clear that with the limitation of capture fisheries resources the expansion of aquaculture is a must and essential for closing the gap between supply and demand for aquatic food products. A key factor in the rapid development of aquaculture in Myanmar is the increasing availability of hatchery produced fish seed and intensification of R&D activities. There is a huge potential for the development of aquaculture, especially of mariculture that is yet to be initiated in Myanmar. It has been envisaged that with combined efforts by the government, cooperatives and private sector the aquaculture industry will expand very rapidly.

The national development goals and aspirations include food security, higher farm income, employment generation to absorb excess rural labor, and increase in export earnings. The emphasis is on the development of a national technological base through research on breeding and seed production, diversification of aquaculture practices, nutrition and feed development, strengthening training and extension, product development and quality assurance.

Integrated management of coastal and marine areas is recognized as an essential tool for development and environmental protection. The fishery, including aquaculture, is a significant major source of protein. For this reason the Department of Fisheries has encouraged the expansion of aquaculture through proper management so as not to cause environmental degradation. Intensive culture, improper use of chemicals, destruction of mangroves and other habitats, discharge of untreated wastes, etc., are considered grave offences, and are dealt with accordingly.

The State, having been empowered by the Forest law 1992, declared all mangrove forests as protected areas. Fishing within three hundred yards around mangrove areas is strictly prohibited. In order to ensure the sustainable development of aquaculture techniques and to promote mangrove-friendly aquaculture practices strict guidelines were laid down by the Department of Fisheries.

In Myanmar, the quality of marine and freshwater resources is still good and the Government is exerting uttermost care to protect and conserve the resources.

The newly established department and offices for environmental issues within the National Commission for Environmental Affairs (NCEA) are formulating and implementing sustainable environmental policies and enforcing existing legislation in order to reduce pollution. At state or division level there is a need for environmental scientists and an organization to be responsible for environmental management. Since local fisheries officers have limited experience in environmental management and there is inadequate cooperation among or assistance from government agencies, the enforcement is inadequate and poorly implemented. In addition, the public is not sufficiently informed. There is a need to formulate programmes of public awareness. To establish sound environment policies for uses of water, land, forests, minerals, marine resources and other natural resources in order to conserve the environment and prevent its degradation, the Department of Fisheries has adopted the National Environment Policy of Myanmar.

The policy is as follows:
"The wealth of a nation is its people, its culture heritage, its environment and its natural resources. The objectives of Myanmar's environment policy are aimed at achieving harmony and balance between these through the integration of environmental considerations into the development forces to enhance the quality of all its citizens. Every national has the sovereign right to utilize its natural resources in accordance with its environmental policies, but great care must be taken not to exceed its jurisdiction or infringe upon the interests of other nations. It is the responsibility of the Government and every citizen to preserve its natural resources in the interest of present and future generations. Environmental protection should always be the primary objective in seeking development."

The Department of Fisheries has also issued notifications regarding wastewater management for processing plants and aquaculture farms.

Myanmar is mainly an agricultural country. There are many by-products from agriculture activities which represent potential substitute materials for fishmeal. Raw materials such as soybean, groundnut cake, sesame cake, sunflower seed cake, cotton seed cake, broken rice, rice bran are used in aquaculture traditionally. Fish farmers use the material as traditional aqua-feed. Ten years ago, prawn and shrimp culture farms started to use pellets. Myanmar has plenty of marine fish for fishmeal preparation. The Department of Fisheries is setting up a nutritional laboratory. However, nutrition specialists are as yet very few in number.

In 1985, an outbreak of epizootic ulcerative syndrome (EUS) occurred in Myanmar. It occurred only for a short period and was brought under control before it became widespread and had a major socio-economic impact. On fish and shrimp farms diseases are not common and this concerns also parasitic infections. An aquatic animal health management unit is already established in the Department of Fisheries but the technologies and equipment need to be upgraded. Introductions of new species must receive permission from the Department of Fisheries prior to being brought into the country.

Experience, chemicals and equipment are the key components in establishing biotechnology. Myanmar would welcome if regional organizations such as SEAFDEC would offer more training and technical assistance in genetic engineering technology.

The Government has programmed and taken responsibility for rural development. This involves enhancing agriculture, poultry farming and aquaculture to generate income for rural communities and border areas. The Department of Fisheries is distributing the technologies to those areas. The Government encourages the rural communities by providing quality seed, bank loans and assistance in obtaining land. Freshwater aquaculture is being practiced by grass roots in rural and border areas, and some is integrated with paddy and livestock.

3. INLAND CAPTURE FISHERIES

Poor management of capture fisheries is threatening the fish supply in the near future. This means that more effective management is urgently required. But the management must be fitted to the prevailing fisheries status of the country. The approach to fisheries management must also change from the conventional system to a more appropriate management system. The Government has to take responsibility to ensure that effective measures are implemented. The fisheries sector is very important in Myanmar’s economy, as fish constitute a major source of animal protein in the diet of the people. Sustainability of fisheries is urgently required and must be based on an appropriate policy. Fisheries (species, areas, use of fishing gear and boats) must be approved by appropriate authorities.

Decentralization of management is essential for promoting broader management of the fisheries because fisheries problems are being encountered in rural areas. Local government authority and communities should take responsibility for determining the management policy, taking full consideration of the local knowledge, as the nature of fisheries is not uniform throughout the country. Although management is decentralized, the central government maintains its full authority, especially over high seas and distant water fisheries and for coordination of decentralisation of management. It is therefore suggested that the selected functions and responsibilities are delegated and shared with the local government authority and community.

Stock enhancement coupled with well disciplined fishing rights may be the proper management approach to capture fisheries. In some inland waters recruitment from the wild stocks is insufficient and enhancement, particularly through releases of hatchery produced juveniles, may be needed. For this reason the Government of Myanmar has been implementing seed stocking project, for the last two decades. Stocking of quality fish seed in open waters including lakes, reservoirs, canals, rivers, etc., has been regularly undertaken to generate more fish.

Fish and rice form the basis for the food security for Myanmar people, with an average fish consumption of 21 kg *per caput* per year. In the fiscal year 2000-2001 inland capture fisheries contributed 235 373 t, culture fisheries 109 188 t, plus 6 603 t from prawn farming. During the same year marine fisheries harvested 848 442 t plus 83 042 t of shrimp. Inland fisheries thus contributed approximately 25 percent of the total fisheries output. Since the majority of people live along the four big rivers and in delta regions the freshwater fish from the inland capture fisheries is a mainstay not only in the daily diet but also in trade. It is believed that inland fisheries production could be increased. There is an effort both from the government and the private sector to better utilize all resources to meet the increasing demand. With such a high importance of the inland fisheries sector in the food security it seems certain that action must be taken in order to include the sector in the national and regional process and to preserve the sector from negative impacts of any unregulated and undisciplined industry, in order not to endanger the food security. It is important that countries with huge natural inland water resources such as Myanmar determine the size of the resources related to their role in the food security and take appropriate action to manage and preserve them for their sustainability.

4. COLD WATER FISH AND FISHERIES

Kachin, Kayah, Chin and Shan states are situated in hilly regions of the country and have a cooler climate than the rest of the country. The list of fish species (see below) is based largely on older literature as there has been no recent work done on fish and fisheries of these remote areas.

Some cold water streams in Putao in Kachin State, Lake Indawgyi (length 25 km, width 10 km), Lake Inle in Shan State (length 23 km, width 12 km), and Lake Reeve in Chin State (length 5 km, width 5 km) were surveyed and fish species identified. Cold waters have no exotic species and are not overfished. Fish are captured traditionally by using home-made equipment. The captured fish is enough for family consumption only. There is also some fish culture in these states. In the year 2000-2001 the total production from freshwater capture fisheries in the four states was 7711 tons, most of it coming from the Kachin State (6 599 t). The total aquaculture production was 2 848 t, most of it produced in Shan State (2048 t).

The region does not have major environmental problems as yet. To prevent environmental degradation some measures are being taken in preserving good quality water in Indawgyi and Inlay lakes. Reeve Lake has at present no environmental degradation problem.

Fish fingerlings are stocked in these lakes under the supervision of the state sector which is also in charge of any further fishery development measures. No exotic cold water species are at present in cold waters of Myanmar. The mountain regions have an insufficient supply of fish from their own resources and therefore fish are brought in from other areas.

Due to the remoteness of the mountain areas and difficult access, there have been only few studies on fish and on fishery activities in the cold regions of Myanmar. Basic studies are needed, such as on fish species distribution and biodiversity, behaviour and the current fishing pressure. Research should be carried out on cold water lakes Reeve, Indawgyi and Inlay.

Due to the shortage of fish as food in the remote regions of Myanmar there is a need to assess the potential for further cold water aquaculture development. Once it has been decided to go ahead there will be need for breeding technology. Myanmar cordially invites interested individuals or groups to visit the mountain region, to conduct research and carry out pilot studies on cold water aquaculture appropriate for hilly regions of Myanmar.

Annex 1

List of freshwater fish species of Kachin, Chin and Shan states, Myanmar

Aborichthys kempi	Chela laubuca
Acanthopthalmus pangia	Chela sardinella
Akysis prashadi	Chela sladeni
Akysis variegatus	Chopraia rupicola
Ambassis baculis	Cirrhinus latia
Ambassis ranga	Cirrhinus mrigala
Amblyceps horae	Clarias batrachus
Amblyceps mangois	Colisa fasciata
Amblyceps murray stuarti	Crossocheilus latius
Amblypharyngodon atkinsonii	Cyprinion semiplotum
Amphipnous cuchia	Cyprinus carpio
Anabas testudineus	Cyprinus intha
Aoria (macroponoides) dayi	Danio aequipinnatus
Aoria aor	Danio daniconius
Aoria bleekeri	Doryichthys dunckeri
Aoria carassius	Epalzeorhynchus siamensis
Aoria gudio	Erethistes asperus
Aoria leucophasis	Erethistes conta
Aoria pulchar	Esomus altus
Aspidoparia morar	Euchiloglanis feae
Badis badis	Euglyptosternum lineatum
Badis dario	Eutropiichthys vacha
Bagarius bagarius	Exostoma stuarti
Balitora brucei	Exostoma vinciguerrae
Balitora maculata	Exotoma labiatum
Barbodes hexagonolepis	Gagata cenia
Barilius bendelisis	Garra gotyla
Barilius barna	Garra gravelyi
Barilius guttatus	Garra kempi
Batasio tengana	Garra lamta
Belone concica	Garra nasuta
Botia berdmorei	Glyptosternum lineatum
Botia grandis	Glyptosternum madraspatanum
Brachydanio choprai	Glyptosternum malaisei
Brachydanio rerio	Glyptosternum pectinopterum
Callichrous pabo	Glyptothorax burmanicus
Callichrous pabta	Glyptothorax cavia
Catla catla	Glyptothorax dorsalis
Chanda ranga	Glyptothorax platypogonoides
Channa burmanica	Glyptothorax tuberculatus
Channa gachua	Gudusia variegate
Channa harcourtbutleni	Hara filamentosa
Channa marulius	Heteropneustes fossilis
Channa punctatus	Indostomus paradoxus
Channa striatus	Inlecypris auropurpureus
Chaudhuria caudata	Labeo angra

Labeo boga Labeo calbasu Labeo dero Labeo gonius Labeo pangusia Laubuca laubuca Lepidocephalichthys berdmorei Lepidocephalichthys guntea Macrognathus caudiocellatus Mastacembelus armatus Mastacembelus dayi Mastacembelus oatesii Microphis duenkeri Microrasbora erythromicron Miscrorasbora rubescens Monopterus albus Monopterus cuchia Mystus bleekeri Mystus gulio Mystus seengala Nemacheilus botia aureus Nemacheilus brevis Nemacheilus brunneanus Nemacheilus multifasciatus Neolissocheilus hexastichus Notopterus chitala Notopterus notopterus Olyra horai Ompok bimaculatus Ompok pabda Ompok pabo Oreinus plagiostomus Osteobrama belangeri Osteobrama cunma Osteobrama feae Parasphaerichthys ocellitus Physochistura brunneana Proeutropiichthys macrophthalmus Propuntius myitkinae Pseudambassis roberti Pseudecheneis sulcatus Pseudeutropius takree Pseudolaguria tuberculatus	Psilorhynchus balitora Pterocryptis burmanensis Pterocryptis cochinensis Pteroglanopsis horai Puntius ticto Puntius blythii Puntius burmanicus Puntius charunio Puntius chola Puntius chrysopterus Puntius compressiformes Puntius conchonius Puntius dukai Puntius hexagonolepis Puntius hexastichus Puntius myitkyinae Puntius orphoides Puntius phutunio Puntius sarana Puntius sophore Puntius sphanicus Puntius stedmanansis Puntius stoliczkanus Rasbora daniconius Rasbora rasbora Rohtee alferendiana Rohtee balengeri Rohtee feae Sawbwa resplendens Schistura malaisa Schistura sikmaiensis Semiplotus cirrhosus Semiplotus modestus Silurus burmanensis Silurus cochinchinensis Silurus torrentis Tetraodon cutcutia Tor mosal Tor tor Trichogaster fasciatus Walago attu Xenentodon cancila Yunanilus brevis

THE STATUS OF COLD WATER FISH AND FISHERIES IN NEPAL AND PROSPECTS OF THEIR UTILIZATION FOR POVERTY REDUCTION

by

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ABSTRACT

The aquatic ecosystems of Nepal offer excellent habitats to at least 186 indigenous and 11 exotic fish species of high economic, environmental and academic value. Among the total of 186 fish species, 59 have been considered as cold water fish. The most important indigenous cold water fish species are sahar (*Tor* spp), katle (*Neolissocheilus hexagonolepis*) and snow trout (*Schizothoraichthys* spp and *Schizothorax* spp). They are excellent from the economic and sport fishery point of view, but many other species are fished for subsistence. Cold water fisheries offers a great opportunity for self employment and income generation among poor people living along rivers, lakes and other natural waters. Normally they are widely scattered and not organized. About 400 000 beneficiaries are engaged in this subsector. As the watersheds inhabited by the important species are shared by a number of nations, a regional cooperative effort is a necessity to share experiences and initiate collective actions to conserve and manage these shared aquatic resources.

1. BACKGROUND

Nepal (26°20'-30°10'N and 80°15'-88°19'E) has common frontiers with the Xizang Zizhiqu (Tibet) Autonomous Region of China in the north and with India in the west, east and south. It has an area of 147 181 km^2 and is divided into three physiographic regions, from south to north: the Terai plain, the mid hills and the Himalayas (CBS, 1992). The Terai lies between 130 m and 500 m elevation, the lower hills up to 2 700 m, the upper hills up to 4 000 m, and the greater Himalayas are located above the tree line (>4 600 m). Mountains and hills make up 83 percent of the area of Nepal while the Terai occupies only 17 percent. The Himalayas in the north strongly influence the climate of Nepal. The country may be divided into three climatic zones according to altitude: subtropical in the Terai, temperate in the hills, and alpine in the mountains. The climate varies little from east to west.

1.1 Water resources

Nepal is endowed with many forms of water resources scattered throughout the country (Table 1). These water bodies are in the form of rivers and streams, lakes, reservoirs, ponds, swamps and paddy fields. On the basis of the resource availability, the rivers are of major importance representing about 49 percent of the total water area. Lakes and reservoirs cover 0.8 percent, and swamps and irrigated paddy fields share the rest of 50.2 percent. Open waters cover approximately 5.5 percent of the total area of Nepal.

Table 1
Estimated water surface area in Nepal (FDD, 1996)

Resource	**Estimated area (ha)**	**Coverage percent**	**Potential for fisheries (area in ha)**	**Remarks**
Natural waters	401 500	49.00	-	
Rivers	395 000	48.20	-	
Lakes	5 000	0.60	-	
Reservoirs	1 500	0.20	78 000	
Village ponds	6 500	0.80	14 000	
Marginal swamps around irrigated fields	12 500	1.50	-	
Irrigated paddy fields	398 000	48.70	-	
Total	**818 000**	**100.00**		

1.2 Fishery resources

The aquatic ecosystems of Nepal offer excellent habitats to at least 186 indigenous and 11 exotic fish species of high economic, environmental and academic value (Shrestha, 1995; Subba and Ghosh, 1996; Shrestha, 1999). They are distributed from Terai, through the hills to the Himalayan mountains up to the altitude of ca. 4 000 m a.s.l. They inhabit rivers and lakes of mid hills and mountains, with water temperature of 10°-20°C. The large-scaled cyprinids (sahar – *Tor* spp, and katle – *Neolissocheilus hexagonolepis*) may tolerate a wider range of temperature. Among the total of 186 fish species, 59 native and 2 exotic are considered as cold water fish (Table 2). The most important indigenous cold water fish species are katle - snow trout (*Schizothoraichthys* spp and *Schizothorax* spp), and sahar. They are excellent from the economic and sport fishery point of view, but many other species are fished for subsistence.

Table 2
Cold water fish in Nepal

Fish	Koshi	Kali Gandaki	Karnali	Pokhara lakes	Rara lakes	Indrasaro bar
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	+	+	+			
G. lamta	+	+	+			
G. mullya						
Labea angra	+		+			
L. dero	+	+	+			
Neolissocheilus hexagonolepis	+	+		+		+
Puntius chilinoides						+
P. sophore	+	+	+	+		
P. ticto		+	+	+		
P. titus				+		
Schizothorax macrophthalmus					+	
S. molesworthii						
S. ne palensis					+	
S. plagiostomus	+		+	+		
S. raraensis					+	
S. richardsonii		+	+			+
Schizothoraichthys annandalei	+					

Fish	Koshi	Kali Gandaki	Karnali	Pokhara lakes	Rara lakes	Indrasaroba
S. esocinus		+				
S. progastus	+	+	+			
Semiplotus semiplotus		+				
Tor putitora	+	+		+		
Tor tor	+	+		+		+
Homalopteridae						
Balitora brucei	+					
Cobitidae						
Lepidocephalichthys guntea		+		+		
Nemacheilus beavani	+	+				
N. botia		+				
N. corica		+				
N. rupi ***cola***		+				
N. rupicola var. inglishi	+					
N. savona			+			
N. scaturigina	+	+				
N. shebbearei		+				
Schilbeidae						
Clupisoma garua	+	+				
Amblycepitidae						
Amblyceps managois		+				
Sisoridae						
Bagarius bagarius	+					
Euchilogl anis hodgarti		+				
Glyptosternum blythi						
Glyptothorax cavia	+					
G. horai	+					
G. kasmirensis		+				
G. pectinopterus		+		+		
G. telchita	+	+				
G. trilineatus	+	+				
Pseudecheneis sulcatus	+		+	+		
EXOTIC						
Salmonidae						
Oncorhynchus mykiss						
Salmo trutta						

Two exotic fish species of food and sport value are rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*). Rainbow trout was introduced in 1968 and 1971 from India, and in 1988 from Japan, while brown trout was introduced in 1971 from England and Japan.

1.2.1 Capture fishery

Capture fishery is widely scattered throughout the kingdom of Nepal and is not well organized. The fishers are dispersed along rivers where they use their traditional gears for fishing. Subsistence and sport fishery are practiced at different levels of intensity on different rivers. Most of the captured fish are consumed around the catch sites. In order to increase the fish resources in large inland water bodies (lakes and reservoirs), selected fish species are often stocked. Fish selected for stocking are those that do not reproduce naturally in the particular water body, such as silver carp, bighead carp and grass carp, but also those that reproduce naturally, such as common carp, sahar and katle. The enhancement is being carried out in the lakes of Pokhara Valley and in Indrasarobar reservoir by fisheries officers in collaboration with the local fishermen communities.

2. ROLE OF COLD WATER FISH IN SUPPORTING THE LIVELIHOOD OF RURAL POPULATION

Fish captured from rivers, lakes, reservoirs, marginal swamps and paddy fields have an important role as a source of animal protein, as well as source of income, providing employment opportunities to local fisher folk communities.

Aquaculture: Cold water aquaculture in Nepal is still in its beginnings. Only a few indigenous species have been domesticated. Their culture has yet to be adopted by the private sector. Among the exotic species rainbow trout is cultured in the public sector Fisheries Research Centres. Recently several fish farmers have started its culture on a pilot basis. While at present cold water aquaculture in Nepal has only a small role in supporting the livelihood in mountainous regions it is becoming popular among the farmers.

Open water fishery: Capture fishery is often the only source of livelihood for the fisher’s communities near water bodies. Capture fisheries from natural and man-made water bodies are traditional. The estimated fish yields from capture fisheries for the last three years are presented in Table 3.

Table 3
Estimated fish production from capture fishery in Nepal

Water body	Area (ha)	Production in metric tons			
		1996/97	1997/98	1998/99	1999/2000
River	395 000	3 950	3950	3 950	4 937.5
Lakes	5 000	500	750	750	775.0
Reservoirs	1 500	300	300	315	337.5
Irrigated paddy fields	398 000	3 980	4 378	4 975	5 970
Swamps/ditches	11 700	2 500	2 622	2 762	4 680.0
Total	811 200	11 230	12 000	12 752	16 700.0

Note: total area of swamps – 12 500 ha. Fish cultured in 600 ha. Unused area of swamps is 11 900 ha.

Most of the studies were carried out during the feasibility study of hydroelectric projects. Patchy studies on dam sites are mostly for environmental impact assessment (EIA). Data on fish catches and production were estimated for a certain stretch of two rivers, and total production estimates for the rivers are presented in Tables 4 and 5.

Table 4
Annual fish catch and yield estimates for rivers

Details	Tamur [1]	Kali Gandaki [4]	West Seti river [5]	Sunkoshi [2]	Trishuli [3]	
Year	1998	1996	1999	1988	1993	1996
Site	Guheli-Baridhap	Kali-Gandaki	Seti valley	Dolalghat Barabhise	Rijalghat	Rijalghat
Area	190 km	300 km	33 km	32 km	5.7 ha	5.7 ha
Annual catch	14 062 kg	150 -170 t	712 kg	20 371 kg	663.6 kg	301.1 kg
Annual yield	74 kg/km	500-567 kg/km	22 kg/km	637 kg/km	117 kg/ha 46 kg/ha 1151	53 kg/ha 93 kg/ha 407

1.Swar and Shrestha (1998); 2. Bisgaard *et al*. (1999); 3. FRC Trisuli (1993,1996); 4. Kali Gandaki 'A' (Associates *et al*., 1996); 5. Neupane and Poudel (1999)

Table 5
Capture fisheries in the Seti Valley (from Neupane and Poudel, 1999)

Resource	Yield (mt)	Area (ha)	% of total catch	Yield (kg/ha)
Rivers Lakes Reservoirs	4 345 500 300	395 000 5 000 1 500	36.2 4.2 2.5	11 100 200
Swamps/ghols	2 476	12 500	20.6	198
Paddy fields	4 378	398 000	36.5	11
Total capture fishery production	11 999		100	
Total aquaculture production	12 866			

The capture fisheries is widely scattered throughout mid hill valleys, high hills and mountains of the country. There is no concentrated effort, and fishing is not organized, hence the fish production has been assessed as small-scale. Fishers are mostly scattered and use traditional gears with nominal economic benefits. The fished areas and production are presented in Table 6. A large number of perhaps 400 000 beneficiaries are engaged in this activity.

Table 6
Annual catch and percentage contribution from different types of water bodies
(adapted from Swar and Bisgaard, 1999)

Fishing frequency	Households	Percentage	Catch/week (kg)	Catch/year (kg)
Part-time (3months)	418	60%	7.6	91.2
Occasional (1 month)	243	35%	7.6	30.4
Full-time (9 months)	38	6%	16.4	590.4
Total	**699**	**100%**		**712.0**

Community involvement in open water fish captures: Capture fisheries play a significant role in providing income generating employment opportunity to local fisher folk communities. Capture fisheries in Nepal are widely scattered and not organized. The fishers living along rivers and lakes use traditional fishing gear mainly for subsistence production, generating only a marginal economic benefit. The fisheries can be developed through proper fisheries management, including enhancement and aquaculture. Rivers, which are spread throughout the country, provide fresh fish to the rural people. From an increase in river fish catches most rural people would benefit from the nutritional point of view, and the benefits would also go to the people living further away from the rivers. Investment in capture fisheries is much lower than inputs required for aquaculture and other income generating activities. It benefits poor rural people, as little investment is needed in fishing gear. The fishers use different kinds of traditional fishing gear like nets, baskets, rod and line, spearing, fish traps and indigenous fish poison, as well as some destructive fishing methods such as insecticides, pesticides, dynamiting and electric fishing (Swar and Shrestha, 1998; Swar and Bisgaard, 1999).

Fishing technology and fisher communities: Fishers and their communities living along or around open waters are widely scattered and not organized. In most cases, fishing supplements their agriculture activities. Only few fishermen in some river valleys (Seti valley) use fishing as the sole employment. The main part of fish catch is consumed locally. Involvement of fisher's community in open water fishery as an employment is presented in Table 7.

3. HUMAN IMPACT ON NATIVE COLD WATER FISH

Human activities cause the following problems:

Siltation: Conversion of forested lands on steep slopes into agricultural land, and road construction in the mountain regions have resulted in heavy soil erosion during the monsoon season. Soil erosion affects the river ecology, resulting in the loss of breeding and nursing grounds of the riverine fish species. Fish are affected indirectly when their food organisms are destroyed. Mechanical injury or blocking of gills from silt or other suspended material has also affected the river fish fauna.

Table 7
Estimated number of fishermen in capture fisheries

Waters	Area/ length	Families involved	Fishers engaged	No. of fishers per ha or km
Phewa, Begnas and Rupa lakes[1]	986 ha	-	292	0.3/ha
Sun-koshi river[2]	32 km	-	200-250	7.0/km
Koshi river[3]	26 km	-	300	11.5/km
Marshyandi river[4]	15 km	-	30	2.0/km
Tamur river[5]	190 km	-	203	1.1/km
Kali Gandaki[6]	300 km	-	1100	3.7/km
West Seti river[7]	33 km	-	204	6.2/km
Total		**51 000**	**204 000**	**0.3/ha**

1. FRC Pokhara, (1998); 2. Bisgaard *et al.* (1999); 3. FDD (personal communication) 4. FDD (personal communication), 5. Swar and Shrestha (1998); 6. Kali Gandaki 'A' Associates *et al.* (1996); 7. Neupane and Poudel (1999); 8. Swar and Bisgaard (1999)

Chemical pollution: Several rivers including the Bagmati and Bishnumati in Kathmandu Valley, Sirsia in Parwanipur and Birganj, Mushari Paini in Biratnagar, and Sunsari near Inurawa receive a heavy load of domestic and industrial sewage consisting of a combination of organic, inorganic and living matter, especially bacteria and protozoans. The pollution kills fish along with many other aquatic organisms. Nutrient-rich fertilizer runoff increases the rate of eutrophication. Excessive quantities of non-biodegradable debris (such as plastic materials) are becoming a serious hazard to fish, which ingest the material or are entrapped by it. There is also a growing concern over the unrestricted discharge of effluents into the Narayani River from a paper mill, brewery, grease, textile and several other industries.

Introduction of exotic species: There are several instances where an exotic species, especially a piscivore, has had adverse effects on local fish (Frey, 1969). The presence of high numbers of common carp resulted in an adverse effect on the native fish of the upper Mississippi River (Lubinski *et al.*, 1986). However, there are also instances where an exotic species has had positive effect on the indigenous fish community, e.g. in Lake Parakrama, Sri Lanka (Fernando, 1984), where tilapia *Oreochromis mossambicus* was introduced. Nepal is still far from having such experience and information on the effect of exotic fish on the native fauna is not available. However, a 42% reduction of the native fish *Mystus* spp and *Puntius* spp after introduction of bighead carp (*Aristichthys nobilis*), silver carp (*Hypophthalmichthys molitrix*), and grass carp (*Ctenopharyngodon idella*) has been observed in Lake Begnas in Pokhara Valley (Swar and Gurung, 1988).

Overfishing, illegal fishing: The ever-increasing human population has become the main cause of high, illegal and irrational fishing pressure on the aquatic ecosystems of the country. Fishing effort has been intensified without considering the size and species of fish. Such activities not only degrade the target fish population by changing the population size and structure, but also affect other species linked to it in the food chain. Non-target species may also be injured or killed by the use of unsuitable fishing gear and practices.

*Use of small mesh gill nets***:** Several types of fishing gears, e.g. cast nets, small mesh size seine nets (chatty jal), gill net trammel nets, are used in different rivers of Nepal. Gill nets, especially those with small mesh size, tend to be nonselective in their catch. Thus large quantity of fish fry, fingerlings smaller than the legal size limit and non-targeted species such as juvenile Gangetic dolphin, crocodiles and turtles are captured and killed as by-catch by fishers. Mortalities of these non-target organisms may have an unwanted impact on the riverine ecosystem and the aquatic biodiversity (Swar and Shrestha, 1998).

*Use of explosives***:** A number of small and large road construction projects are underway in Nepal. Such projects are provided with explosives to facilitate their construction work, but unfortunately the explosives are often misused in killing fish in large numbers. They are killed together with other aquatic animals, and this is accompanied by a damage to the habitat, which recovers only slowly.

*Electrofishing***:** Use of electricity to catch fish in small shallow rivers and streams is yet another way of destructive fishing. It is usually not selective, killing fish of all stages.

*Poison***:** Traditionally, different plants have been used for killing fish (Karki and Rai, 1982). In recent years the practice has been further intensified by the use of chemical pesticides (Aldrin, Thiodine, BHC, Malathion, DDT, etc). Free access to hazardous chemicals, insecticides and pesticides and their rampant use is, consequently, another threat to our inland fish fauna.

Hydraulic engineering: In addition to the above-mentioned human interventions, water resource development activities and infrastructure projects are responsible for altering the ecological conditions of aquatic ecosystems. Three main types of structures are used either in combination or separately: dams and impoundment, levees and canals. These structures affect riverine and associated ecosystems, both upstream and downstream of the structures (Ward and Stanford, 1979; Petts, 1984; Swar, 1992).

4. CONSERVATION AND MITIGATION MEASURES

In response to the growing global awareness about the importance of maintaining a balance between economic development and environmental conservation, the Nepal Environmental Policy and Action Plan (NEPAP) has been prepared and launched. NEPAP is a part of HMG's continuing effort to incorporate environmental concern into the country development process. Efficient and sustainable management of natural and physical resources and mitigating the adverse environmental impacts of development projects and human action are the main theme of NEPAP. Conservation of fishery resources is part and parcel of the broad NEPAP. The following measures have been carried out to conserve fisheries resource in Nepalese water systems:

Legislative arrangement: Conservation of aquatic life is addressed by the Aquatic Animal Protection Act 2017 (1961) (AAPA), which prohibits the use of explosive or poisonous substances in any body of water where the intention is to catch or kill aquatic life. This act has been revised by the parliament and consolidated in 1999. HMG/N has formulated aquatic life protection regulation and the procedure of its implementation. It regulates fishing gears, size of the fish and season. Study on the effects of development projects on fishery resources and implementation of mitigative measures has been made mandatory under this regulation.

Environmental Impact Assessment: After the implementation of the NEPAP, Nepal has introduced legal or institutional mechanisms for the use of EIA. Impact of development projects on aquatic life is thoroughly assessed and several measures are taken to mitigate the adverse impact of a project. The establishment of a fish hatchery and fish trapping and handling activities under Kali Gandaki 'A' Hydropower Project are examples of such measures.

Establishment of fish sanctuaries: The majority of fish inhabiting rivers are extremely sensitive to modifications and to the environmental changes that occur in modified rivers. An extensive network of protected areas has now been established in Nepal. Nepal has six national parks, four wildlife reserves and one hunting reserve, encompassing an area of over 11 000 km^2 or 7.4 percent of the country, with fishing being strictly prohibited in water bodies situated on their territory.

Fish species in Nepal: According to Shrestha, J. (this volume) there are 182 fish species in Nepal, belonging to 92 genera under 31 families and 11 orders. Of these cold waters are inahbited by 59 indigenous and two exotic species. The present status of fish species (based on an older account listing 185 species) is given in Table 8. Native fish species recommended for legal protection are listed in Table 9. One species (*Tor tor*) is listed as endangered, 9 species as vulnerable.

Table 8
Status of fish species in Nepal (adapted from Shrestha, 1995)

STATUS	NUMBER OF SPECIES
Common/occasional	90
Insufficiently known	61*
Vulnerable	9
Endangered	1
Rare	24
TOTAL	185

Promulgation of Aquatic Animal Protection regulations: Aquatic Animal Protection Act (AAPA) was passed in 1961, in 1999 the Government promulgated AAPA regulations. The guidance, policies, and experience related to the development of fisheries have now been defined. In the past fisheries in inland water bodies have often been subject to ecological damage from poisoning, bombing, poaching and stealing of fish. In order to protect national interests and the legal rights of fishermen the law defines concrete administrative penalties, civil liabilities and responsibilities.

Fish trapping and hauling:

Fish trapping and hauling is an alternate for assisting natural fish migration. Trapping can be used for a variety of fish species and sizes. Migratory species can be captured and hauled. It is applied in the Kali Gandaki 'A' Hydropower Project.

Table 9
List of species recommended for legal protection

Scientific name	Common name	NRDB code	Distribution
Acrossocheilus hexagonolepis	Katle	V	Koshi, Gandaki, Karnali, Mahakali
Chagunius chagunio	Rewa	V	Koshi, Gandaki, Karnali, Mahakali
Tor putitora	Mahseer	V	Koshi, Gandaki, Karnali,
Tor tor	Sahar	E	Gandaki, Mahakali
Danio rerio	Zebra macha	V	Gandaki, Karnali,
Schizothorax plagiostomus	Buchhe asla	V	Koshi, Bheri, Gandaki, Karnali, Mahakali, Phewa, Lake, Gandaki
Schizothorax richardsonii	Asala soal	V	Koshi, Gandaki, Karnali,
Schizothoraichthys progastus	Chuche asala	V	Koshi, Gandaki, Karnali,
Psilorhynchus pseudecheneis	Tite macha	V	Koshi
Anguilla bengalensis	Rajabam	V	Koshi, Gandaki, Karnali,

Fish ladder:

One of the remedies commonly proposed for blockages to migration caused by dams is the construction of fish passage or fish ladder. Most of the existing and proposed water development projects in Nepal do not have fish ladders. There are only few examples of fish ladders (e.g., Koshi barrage, Chandra Nahar in Trijuga, Andhi Khola and Gandak barrage). But very little is known about their performance.

Fish hatchery:

Establishment of a fish hatchery is another measure for mitigating the impact of a dam formation on the native fish fauna. Hatcheries play an important role in fish conservation and management in developing countries. In recent years, their efficiency has increased with better knowledge of the biological and reproductive requirements of fish. A fish hatchery is being established at Kali Gandaki 'A' Hydropower Project.

5. DOMESTICATION OF ECONOMICALLY IMPORTANT FISH SPECIES

5.1 Indigenous species

Among the 59 indigenous cold water fish species of Nepal, *Neolissocheilus hexagonolepis* (katle), *Tor Tor, Tor putitora* (sahar, mahseer or mahaseer), and *Schizothorax richardsonii, Schizothoraichthys progastus* (snow trout or asala) have been identified as important for sport fishery as well as being excellent food fish. Their domestication started in the 1970s at the Trishuli Fishery Research Center (then FDC Trishuli) by catching their juveniles from the Trishuli and Tadi rivers and culturing them in earthen ponds. Brood stock was collected from the river and fed with artificial feed. In August, brood fish ready to spawn were stripped without using hormone injection (Rai, 1978; Rai and Swar, 1989). Since then katle has been bred in the Trishuli Fisheries Research Center every year. Besides its propagation and domestication, feeding, behavior, growth and reproductive aspects of these fish have been thoroughly studied by Swar (1994). Domestication of mahseer started at the same time. The juveniles were captured from the river and cultured in an earthen pond of the Trishuli FRC. They were also domesticated in the nylon-submerged cages in Lake Phewa in Pokhara Valley. Mahseer has been bred in Trishuli and Pokhara FRC since then. Now its growth is being observed with different diets in captivity. Fish fry is being produced on a mass scale. Snow trouts are also bred in the FRC Trishuli every year and observations on growth with different diets are in progress. The seed of these species was introduced to improve the inland fisheries in the rural hills of Papua New Guinea.

At present there are three Fisheries Research Centres (Trishuli, Godawary and Pokhara) where these cold water fish are being propagated and trials are going on to culture them in captivity. In addition to these research centres one cold water fish hatchery is being established in Shyanja District for propagating these species to mitigate the adverse effect of the Kali Gandaki 'A' Hydropower Project on these important fish species. There are ten qualified experts and thirty experienced technicians working on these economically important fish. Besides their work in the public sector, several researchers have also studied these fish (mahseer, katle, snow trout) in the natural habitat and in controlled conditions (Shrestha, T.K., 1976, 1979, 1979a, 1986, 1989, 1990, 1992). Expertise has been provided to Pakistan and Papua New Guinea.

5.2 Exotic species

Eleven exotic fish species of food and sport value have been introduced in Nepal. These include the cold water rainbow trout introduced in 1968 and 1971 from India, and in 1988 from

Japan. Brown trout was introduced in 1971 from England and Japan. Prior to that the first rainbow trout fingerlings from Kashmir, India, and fertilized eggs (eye stage) from the United Kingdom, were reared in the Godawary Fishery Development Centre, Lalitpur. The first trout hatchery was established in Nuwakot on the bank of the river Trishuli. Its objective was to propagate, rear and release the trout in suitable hill streams to establish sport fishery for tourist development. These trout were later transferred to the Trishuli trout hatchery but the trout did not survive. Realising the importance of trout for cold waters of Nepal, 50 000 eyed stage eggs of *Oncorhynchus mykiss* were again imported from Japan in November/December 1988 and incubated in the Godawary Fisheries Development Centre where about 80 percent of eggs hatched. The hatchlings were reared to the fingerling stage and half of the fingerlings were sent to the Trishuli Fishery Development Centre. This Centre has developed pellet feed for trout. The Centre also succeeded in breeding the trout without hypophysation. A similar success has been achieved in the Godawary Fishery Development Centre.

Research on the growth rate of trout, local feed effectiveness and spawning behavior of trout in Nepalese waters and on interactions between native fish and exotic species is being implemented by the FRCs Trishuli and Godawary. Rainbow trout is being produced to the marketing size (Joshi and Westland, 1996). Research and development trials are also being conducted in farmer's ponds and the results are encouraging. In addition to aquaculture rainbow trout fingerlings have also been recently introduced in one of the isolated rivers in high hills (Modi River). Studies are carried out to assess the survival rate of rainbow trout and its impact on native fish fauna. Besides these activities in Nepal rainbow trout seed has also been exported to Thailand. Nepalese experts under a TCDC programme sponsored by JICA provide technical assistance. Trout farming is gaining popularity among the farmers of high hill region due to its excellent taste and high value.

6. FUTURE POTENTIAL OF COLD WATER FISHERIES DEVELOPMENT IN THE COUNTRY AND PROSPECTS FOR REGIONAL COOPERATION

6.1 Food, employment, recreational fisheries, ornamental values

Nepalese rivers originating from the Himalayan Range are inhabited by a number of indigenous fish species, including the snow trout (*Schizothorax macrophthalmus*, *S. molesworthii*, *S. nepalensis*, *S. plagiostomus*, *S. raraensis*, *S. richardsonii*, *Schizothoraichthys annandalei*, *S. esocinus*, *S. progastus*). The rivers are spawning and nursery grounds for katle (*Neolissocheilus hexagonolepis*) and mahseer (*Tor putitora*, *Tor tor*). Besides these species, there are many other cold water species including *Puntius chilinoides*, *Labeo angra*, *L. dero*, *Barilius* spp, *Chagunius chagunio*, *Clupisoma garua* and *Bagarius bagarius*, which have promising potential from the fisheries point of view. Most of these fish are valued for their size, food and sporty nature. The local people also appreciate other hill stream fish as subsistence food. And as already mentioned above, in addition to the native species, rainbow trout and brown trout have been introduced in Nepal for cold water high value fish production.

Improvement of fisheries in rivers and lakes offers a great opportunity for self-employment and income generation among poor – mostly landless - people living close to such waters. An increase in capture fisheries in natural waters would benefit poor rural people by raising their economic status, and could thereby enable these people to invest in other income generating activities such as aquaculture.

Cold water fish are not only a protein source in the diet, but they also offer a great potential for sport fishing, especially for the game fish sahar, katle and asala. Sport fishing as an activity within the tourist industry should be developed much further. It offers a great potential for generating income for the country as a whole, and employment and income for rural people. A number of river fish species have ornamental value and this potential needs to be assessed and exploited.

6.2 Further development of river fisheries

To increase fish production from rivers and streams of Nepal requires proper fisheries management, including regular stocking. As the river systems form a well developed net throughout the country this makes fish available to many rural people. In areas with easy access to roads, an increase in fisheries, from a nutritional point of view, will also benefit people living further away from the rivers.

It is reasonable to expect fish yields from the plains in Nepal to be as high as the yields in India and Bangladesh, and through wise management a significant increase could be achieved. The yield/ha/year in rivers of Nepal has been estimated as 22 to 637 kg/km/year, and 46 to 117 kg/ha/year (Table 4). The yield decreases with increasing altitude.

6.3 Prospect for fisheries enhancement in lakes and reservoirs

From a national point of view, the potential of lake and reservoir fisheries is of less importance because of the limited area, but at the local level the potential is of great importance. From a management point of view it is relatively easy to manage fisheries activities in such water bodies because of their local nature. With proper enhancement measures, including cage and pen culture, the yield potential from lakes and reservoirs is higher than that for rivers and this is an important factor in local nutrition, income generation and employment. If there is good access to roads, part of the yield can be sold in distant markets, increasing the well-being of local communities.

Within the next 20 years fish production in Nepal is estimated to increase from 800 t to 2800 t mainly as a result of the increase in the total reservoir area. This increase comes from the construction of dams for hydropower generation in Dudh Koshi, West Seti, Andhi Khola and others. A potential increase from 100 kg/ha to 180 kg/ha is expected for lakes and 200 kg/ha to 280 kg/ha for reservoirs.

The increasing number of hydroelectric power stations and irrigation projects is likely to add more water bodies in the years to come. A feasibility study on various river basins and systems indicates an addition of about 78 000 ha of reservoirs upon their completion (Pradhan and Shrestha, 1997). This increases the production potential for reservoirs dramatically although there may be a decline in the yield from rivers if no action is taken to counteract the negative impact of dams on riverine fisheries. When constructing dams in the future several measures have to be taken to mitigate these projects’ impact on riverine fisheries.

6.4 Prospects of cold water aquaculture

Studies carried out in research centres in Nepal on the introduced rainbow trout led to the preparation of a technology package on their breeding and culture. By now three private fish farms, two north-west (Ranipauwa) from Kathmandu Valley and one in the Western

Development Region (Birethanti) produce trout for markets. More farmers are interested and expansion of rainbow trout aquaculture is gaining momentum. Abundance of unpolluted cold water flowing down the Himalayas is an important factor for the development of cold water fish culture.

7. SUMMARY AND RECOMMENDATIONS

To further develop capture fisheries and aquaculture in Nepal the following recommendations are put forward.

- Conduct a socio-economic baseline survey of fisheries communities. The fishery in natural waters is directly dependent on the socio-economic conditions of the fishermen. A survey is very important and relevant for the economic up-liftment of fishing communities as well as for the development of natural water fisheries in the country.

- Develop tools for systematic and comprehensive collection of fisheries statistics. This is urgently needed for a sound fisheries management.

- Initiate investigations in fish population dynamics in Nepalese rivers. First priority should be given to accessible and important water bodies, to be followed up by the other water bodies.

- Initiate investigations in stocking of fish in rivers for enhancement of fish production.

- Deepen investigations in limnology of natural waters. Knowledge of limnology is the basis for understanding the fish production in natural waters.

- Initiate investigations into the possibilities of aquaculture in rivers and streams utilizing indigenous species.

- Establish a Natural Waters/Wetlands Development and Conservation Committee at the national level to adopt a clear cut policy for natural waters/wetlands conservation and utilization.

- Aquatic resources should be included in the planning process. Being appended to agriculture development programmes, fisheries have not received due priority. Policies should be adopted to ensure that the fisheries resources are adequately protected.

- At present, the rivers of Nepal are utilized either for generating hydroelectric power or for irrigation purposes only, with little consideration being given to their fisheries value. For the conservation of the freshwater fishery resources it is important to involve fisheries scientists and local communities in the planning and feasibility study phases of water resources development projects.

- Increase popular awareness of the need for fish protection and development of sustainable fisheries. This activity plays an important role in poverty alleviation as well as in providing source of needed food.

- Initiate activities for further development of manpower in the field of open water fisheries management. Nepal continues to be short of well qualified technical and managerial man-power.

- As the countries of the Trans-Himalayan region share many important fish species, a regional cooperative effort is needed to share experiences and to initiate collective activities to protect and manage such valuable fisheries resources.

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COLD WATER FISH CULTURE IN CHINA

by

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ABSTRACT

The paper gives a history of trout farming which in China started in 1959, but has developed fully since the 1970s. By 1998 more than 500 rainbow trout farms were established in 22 provinces, and by 2000 they reached annual production of 10 000 t. At present up to 28 million eyed eggs are produced annually. Most of the market size trout comes from Shandong, Gansu, Beijing, Liaoning, Heilongjiang, Yunnan and Zhejiang provinces. There are now 127 rainbow trout farms which serve tourism and recreational fishing which is becoming an important economic activity especially in the Beijing area. Regarding cold waters in remote areas, the potential for cold water fishery of some water resources in the south and west of China still needs to be assessed. There is also considerable potential in northwestern China.

1. INTRODUCTION

In China cold water fish farming is sometimes called salmon and trout farming because the major fish species cultured in China is rainbow trout. Cold water aquaculture in China is of a relatively late date being practiced for only some 40 years. In spite of that fishery researchers and managers in China have been making good progress in popularizing the knowledge and techniques of cold water fish farming.

2. THE ORIGINS AND DEVELOPMENT OF COLD WATER FISH CULTURE IN CHINA

China began cold water fish culture in 1959 when it received 50 000 eyed eggs and 6 000 fry of rainbow trout from the Democratic People's Republic of Korea (DPRK). While in Europe and Japan cold water fish culture had existed for already more than 80 years China started to culture the trout from scratch. The Fishery Department of China allocated the Heilongjiang River Fishery Research Institute (HRFRI) the responsibility for testing the rainbow trout culture. In 1959 the first experimental cold water fish farm was built in the town Hendaohezi of the city of Hailin. It produced the first generation parent fish of rainbow trout in 1963, and at the same time rainbow trout was successfully reproduced in hatchery conditions. The experimental farm was then moved to Bohai town of Ningan city in 1965. It produced two million eyed eggs that were distributed to several provinces of the Huang River region and the culture technique of rainbow trout were popularized. In 1964, 24 broodstock fish and 200 rainbow trout fry were received from the DPRK. At that time the rainbow trout culture was tested at Taiyuan city in Shanxi province and Yingyou county of Liaoning province. About ten years later, the technology of rainbow trout aquaculture was fully established, but it took more than ten years before rainbow trout farming in China took off.

In 1978 the Bohai experimental fish farm became the key center for further rainbow trout culture studies. The HRFRI has been researching and disseminating the culture techniques of cold water fish in collaboration with foreign experts from Europe and Japan. The Department of Agriculture and some provinces/cities sent their fishery specialists to other countries to study cold water aquaculture, and experts from Japan and Denmark came to China to give lectures and demonstrate trout culture techniques. The former National Fishery General Bureau organised the first training in cold water aquaculture in 1981 at the Beijing Fishery Research Institute, the first training course in Heilongjiang was organised in 1984. We invited Japanese experts to give lectures at the HRFRI on research progress of rainbow trout aquaculture in 1984 and 1988. The Fishery Society of China organized and held an international symposium on cold water fish farming and promoted further development of rainbow trout culture.

The cold water fish culture then started rapidly expanding. By 1998 more than 500 rainbow trout farms were established in 22 provinces, producing more than 4 000 tons of rainbow trout per year and using 18 cubic meters of running water per second. By year 2000 the production reached 10 000 t. By volume of used water and culture installations the HRFRI and the Zuanxin Lake Rainbow Trout Farm of the Ningan city have the biggest trout production capacity in China. 150 tons of market size rainbow trout and 6 million eyed eggs have been produced in the two farms annually. The other farms are relatively small, such as the Benxi rainbow trout farm in Liaoning province, the Huairou rainbow trout farm of Beijing city, the Sishui rainbow trout farm in Shandong province, the Jinchuan gorge rainbow trout farm in Yongchang county of Gansu province, the Shentou rainbow trout experimental station in Shanxi province, the Zhanghe reservoir rainbow trout farm in Hubei province, and some others.

At present 25-28 million eyed eggs of rainbow trout are annually produced, 90% of which come from Heilongjiang, Liaoning, Beijing, Hebei and Shanxi. Most market size rainbow trout come from Shandong, Gansu, Beijing, Liaoning, Heilongjiang, Yunnan and Zhejiang.

The rainbow trout fishery business for tourism and recreational fishing has developed in some areas with good economic conditions. 127 rainbow trout farms covering 8 800 m^2 have been constructed for tourism and recreational fishing in six areas of Beijing suburbs, such as Huairou and Yanqing. One million kg of rainbow trout have been produced, with a gross output value of 40 million and profit of 8 million Yuan per year. Rainbow trout culture and fishing promoting the development of the tourist business have become an important economic activity in these areas.

3. COLD WATER FISH CULTURE RESEARCH

3.1 The first period (1959-1966)

Fertilized eggs were hatched in improved Atkins incubators that were once used to hatch chum salmon. The fry of rainbow trout was fed with paste feed from 1959 to 1966. Because of the unbalanced nutrition, only about 30% of fry survived. The first generation parent rainbow trout weren’t successfully produced until 1963. The artificial fertilization technique broadcasting the sperm directly onto eggs and the hatching technique in running water were mastered.

3.2 The second period (1978-1984)

Rainbow trout culture became established between 1978 and 1984. The Bohai experimental station of HRFRI converted the earthen ponds into cement tank raceways which resulted in a more efficient use of water. A closed hatching room with running water and shaded from direct light was constructed. Rainbow trout farming developed in some provinces, supported by research stations and this laid foundations for the rapid development of research on rainbow trout culture.

3.3 The third period (1984-present)

From 1984 on China has been exchanging information on culture techniques with experts from Japan, France, Denmark and some other countries. This has assisted further the development of rainbow trout culture in China. Today there are more than ten organizations and more than sixty experts involved in this research in China. The research includes reproduction physiology, nutrition, complete formulated feed, breeding techniques, research into some native cold water fish, and potential for introducing other exotic cold water fish species. The role of reproductive organs in growth and sex differentiation and the physiological function of sexual hormones have been studied. The technique of isolating IPN and IHN in trout as well as diagnostic methods of trout virus diseases have been mastered. We also isolated from rainbow trout *Vibrio anquillarum* and some pathogens causing streptococcicosis. The pathogen and the cause of diplostomiasis in rainbow trout were researched and the prevention and cure for some parasitic diseases, such as gyrodactylosis, were applied in rainbow trout. The technique of polyploid cultivation and gynogenesis were applied and the transgenic technique was tried in rainbow trout breeding. We systematically analysed the research history of trout culture in Japan and the techniques of rainbow trout culture in France. Starting in 1987 we began researching the biology of *Brachymystax lenok* and *Hucho bleekeri* for their potential for aquaculture. We also successfully introduced brown trout, landlocked *Oncorhynchus masou,* yellow rainbow trout (S*alvelinus leucomaenis*) and some other species. The landlocked form of S*almo salar* was introduced in 1998. Some problems that retard the development of cold water fish have been solved. Among our achievements is the doubling of the survival rate of rainbow trout fry.

4. CURRENT STATUS OF COLD WATER FISH CULTURE IN CHINA

Cold water aquaculture has rapidly developed in China during the last 20 years and is catching up with especially trout culture in other countries of the world. However, some problems still need to be solved and some practices improved.

The pail-like incubator for fertilized eggs and the troughs placed side by side for hatching of fry were introduced from France in the 1980s, but most farms still use self-made incubators. The egg-eyed rate and incubated rate of fertilized eggs of rainbow trout range from 50% to 80% and from 60% to 80%, respectively. Fingerlings and adults are fed with complete formulated diet but the feed conversion ratio is between 2 and 3. Because the technique of controlling maturity of gonads of rainbow trout by the means of a photo-control has not been yet popularized, eyed eggs are available only in winter and autumn. The technology of the preparation of complete formulated feed for rainbow trout has been mastered since the mid 1980s, but not yet widely applied. Most farms still produce semi-dried or wet feed. Some problems exist in producing pellet feed, such as non-standardised processing programme, not homogeneous enough raw materials, low fat content, shortage or poor quality of some ingredients, etc. We can prevent and cure some common bacterial and parasitic diseases of rainbow trout, but prevention of viral epidemic diseases is still to be mastered. Most trout farms treat the infected rainbow trout, but cannot prevent the diseases. The research work on breeding began so late that the question of genetic degeneration of rainbow trout was not highly thought of. The technique of gynogenic diploid cultivation has been achieved but it is not fully applied. Except for simple machines for preparing fish feed, most of the work done on rainbow trout farms is done by hand. Intensive fish culture in cement raceways is still at the very beginning. Mechanisation of rainbow trout culture in China is expected to substantially increase the fish production.

5. THE PROSPECTS FOR EXPANSION OF COLD WATER CAPTURE FISHERIES AND AQUACULTURE IN CHINA

While cold water aquaculture in China is still largely at a low level, the foundations have been laid and much progress has been made. Several proposals are put forward for improving the production of cold water fish, both through capture and culture fisheries.

Tapping the native cold water fisheries resources
China's territory is 9.6 million km^2, and 50% of it is located north of the latitude 30^oN. There are also many mountains and plateaus in the south and west of China, rich in cold water and cold water fisheries resources.

Some of these resources have not yet been fully investigated. It is believed that there is a considerable potential, for example in northeastern China, in provinces in the Huang He region, etc. There are 56 species of native cold water fish that belong to 12 families and 30 genera in China. Some of them could be assessed for their potential for cold water culture, or where necessary, for enhancement of the diminishing fish stocks.

Studies on cold water fish introductions
After the introduction of rainbow trout, other salmonids such as brown trout, landlocked *Oncorhynchus masou,* yellow rainbow trout (*Salvelinus leucomaenis),* landlocked S*almo salar* were also introduced and they adapted to the conditions in China. There may be a potential for bringing some of these species into culture.

Research on breeding salmon and trout
Rainbow trout is a major cold water fish farmed in China. It is important to prevent the genetic degeneration of this species.

Research on large-scale production of cold water fish
Rainbow trout culture is still using a simple aquaculture technology, which makes for an inefficient use of cold water resources. It is important that China adopts large-scale technologies, including mechanisation, developed in western countries, and also rationalise the administration of the fish culture process.

Salmon and trout ranching using sea water
We have tested the possibility of salmon and trout ranching in sea water but the high temperature of sea water made salmon and trout farming unsuccessful in July and August. This is an important problem.

Need for rules to prevent virus epidemics and other diseases of cold water fish
At present there are no rules for prevention of epidemics of virus diseases of cold water fish.

Research on high fat content in feed for cold water fish
We intend to investigate the potential for replacing high concentration of proteins by fat in fish feed, following the trend in Denmark and some other countries of northern Europe.

COLD WATER FISHERIES OF PAKISTAN

by

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ABSTRACT

There are two exotic and 26 indigenous cold water fish species in Pakistan, mainly restricted to the north of the country's North West Frontier Province and Northern Areas. The stocks of indigenous fish have been threatened by overfishing and deterioration of the environment. Exotic brown trout has established self-reproducing stocks in a number of rivers, and the rainbow trout is cultured. Indigenous fish protection and domestication are major priorities. Raising awareness among the local population of the need to protect fishery resources and social uplift of fishers are two major areas for future action. Other needs are the establishment of a database management system, and encouraging regional cooperation and networking to resolve issues of common interest.

1. INTRODUCTION

Pakistan is a country of great variety of landscapes and environmental conditions. This variety of habitats is especially remarkable in the North West Frontier Province (NWFP). In addition, there is a critical constrast between winter and summer seasons. The rivers and streams are deep or shallow, clear or muddy, cold or warm, fast or slow and may have stony, sandy or muddy bottom and rich or scanty vegetation along the banks.

2. BACKGROUND AND STATUS

Pakistan's freshwater resources are dominated by the Indus River system, which serves as a drainage basin for the Himalayas. The Indus originates in western Tibet and enters Pakistan through Baltistan. As the river flows through the Northern Areas, the Shyok, Astor and Gilgit rivers join the Indus. In the NWFP it is joined by the Kabul River, where the Jhelum, Chenab, Ravi, Beas and Sutlej join it and then it flows into Sindh before draining into the Arabian Sea. Inland waters, which extend over about 8 million hectares area include a network of canals, dams, lakes and water-logged areas. At least 180 species of fish are reported to exist in Pakistan freshwaters, including representatives from important groups such as loaches, carps and catfish. A total production of 185 000 tons of fish was recorded from inland waters of Pakistan during 2000-2001 (Government of Pakistan, 2001).

There are 28 fish species listed as inhabiting cold waters of Pakistan. Most of the snow trout are restricted to the Trans-Himalayan Region of the Indus system where the temperature of the river remains below 20°C and only a few come down from the mountains, mainly due to low water temperature.

CHECK LIST OF COLD WATER FISH IN PAKISTAN

(Lone, 1983; Rafique and Qureshi, 1997; LEAD-Pakistan, 1999)

Scientific name		Distribution in Pakistan
1.	*Salmo trutta fario***	N.A©, NWFP©, Balochistan®, A. K
2.	*Oncorhynchus mykiss***	NWFP®,
3.	*Schizothorax plagiostomus*	NA©, NWFP ©, Punjab ®, Balochistan ®, AK
4.	*S. intermedius*	NA®
5.	*S. skarduensis**	NA®
6.	*Racoma labiatus*	NA©, NWFP ©, Punjab ®, Balochistan ®, AK
7.	*Schizopyge esocinus*	NA®, NWFP®, AK
8.	*S. micropodon*	NA®, AK
9.	*Schizothoraichthys longipinnis*	NA®, AK
10.	*Diptychus maculatus*	N.A®, AK
11.	*Ptychobarbus conirostris*	N.A®, AK
12.	*Botia lohachata*	Punjab©, Sindh©, Balochistan®, AK
13.	*B. birdi*	NWFP®, AK
14.	*Schistura nalbanti*	AK
15.	*S. parashari*	AK
16.	*Glyptothorax kashmirensis**	AK
17.	*Clupisoma naziri*	AK
18.	*Nemacheilus corica*	NWFR®, Punjab ©
19.	*Triplophysa stoliczkai*	NA®, NWFP ®
20.	*T. tenuicauda*	N.A®
21.	*T. gracilis*	N.A®
22.	*T. yasinensis**	N.A®
23.	*T. naziri**	NWFP®
24.	*T. hazaraensis**	NWFP®
25.	*T. stenurus choprai*	NWFP®
26.	*T. kashmirensis**	A.K
27.	*T. microps**	A.K
28.	*Glyptosternum reticulatum*	N.A©, NWFP®

R: Rare
C: Common
* Endemic
** Exotic
NA: Northern Areas
NWFP: North West Frontier Province
AK: Azad Kashmir

Akhtar (1991) also listed for Northern Areas the exotic species *Cyprinus carpio* and *Carassius auratus*, and the indigenous species *Schizopyge longipinnis*, *Schizopygopsis stoliczkai, Schizocypris brucei* and *Nemacheilus semiarmatus* as cold water species of Pakistan. He also provided a list of species for Azad Jammu and Kashmir (Akhtar, 1991a). A comprehensive list with 36 fish species of the Indus River and its tributaries around Tarbela was prepared by Ali *et al*. (1980), with most of these species of a cold water character. All these lists are available in Petr (1999), with more details on species distribution and development potential for cold water fish in Pakistan.

3. ROLE OF COLD WATER FISH TO SUPPORT THE LIVELIHOOD OF RURAL PEOPLE

Not enough land is available in the northern areas of Pakistan. Rapid population growth has placed increasing pressure on the rural resources. Land, forest, water and wildlife resources have been degraded or destroyed. Agricultural production is not keeping pace with population growth. Poor health, nutrition and education contribute to low labour productivity. Poor links to markets limit farmer's ability to acquire sufficient capital to invest in draft animals, better implements and technologies that conserve the productivity of the land.

In order to overcome these hurdles in agriculture cold water fish farming in the area can be very useful in focusing local people needs. Farming of cold water fish can identify the path along which the people and communities themselves can manage the resources in an efficient and sustainable way for the improvement of their well-being. While practicing this effort local people's experience, social organization and capabilities should be given preference. Fish input in the form of good quality fish feed to produce good stocking material is necessary. This and other inputs should be offered free rather than imposed and the people of the area should be given free hand for the selection of the inputs according to their needs because development of the area for any commodity is a dynamic process rather than a stagnant process.

4. INTRODUCTION AND DOMESTICATION OF EXOTIC SPECIES

Cold water fisheries prevails in NWFP and Northern Areas, where two species of exotic trout have established themselves in rivers. They are brown trout, *Salmo trutta*, and rainbow trout, *Oncorhynchus mykiss*. Trout culture began in NWFP in 1928, when brown trout was first brought from Kashmir and kept in a nursery tank in the Shinu hatchery, Kaghan Valley. In 1930, it was introduced in Swat and Chitral, but without success. In 1945, about 120 adult brown trout were stocked directly in the Lutkoh River, Chitral, where they reproduced and established a good population. In 1961, trout was stocked in Swat from Kaghan and later in Baluchistan, Azad Jammu Kashmir and Punjab. The first breeding was conducted in 1962 and the resultant fry were stocked in the upper reaches of the Swat River, where they successfully became established.

An artificial trout feed was formulated based on locally available feed ingredients to replace conventional feed, i.e. 50% flour and 50% minced meat. This artificial feed not only reduced fish production cost by 50% but also provided a base for establishing trout culture on a commercial scale (Rab *et al*., 1990). In another experiment (Rab, personal communication) conducted on a private fish farm at Madyan, fish meal and other costly feed ingredients were replaced with soybean meal, and other plant origin ingredients, resulting in further reduction of cost of fish production by improving the conversion to 1:1.45.

Director, Federally-Administered Northern Areas, Director, Directorate of Fisheries, NWFP, and Deputy Director, Fisheries Department of Azad Jammu Kashmir with their supporting officers look after the propagation and culture of cold water fish, particularly trout.

5. HUMAN IMPACT ON NATIVE COLD WATER FISH

The widespread destruction of habitats as a result of the burgeoning human population, pervasive poverty and people's consumption habits have quickened the pace of species loss. Fish and fishery products have made significant contributions to food and employment in Pakistan, yet little effort has been made for their preservation.

Domestic waste is probably one of the main sources of organic waste that mostly enters the riverine system untreated resulting in high loads of waste reaching the rivers. Refuse also contributes substantial pollution loads to rivers. There are also large inputs of organic waste from agriculture-based industries. High concentrations of suspended solids in rivers are commonly present as a result of land erosion following deforestation and mining operations. A number of dams and barrages regulate river water flow in NWFP, Punjab and Sindh. This interferes with free movement of fish. Indiscriminate fishing and overfishing are also a major threat to native fish species of Pakistan. Many northern cold water hill stream loaches of the genus *Nemacheilus* and *Triplophysa* are threatened (LEAD-Pakistan, 1999).

6. CONSERVATION AND MITIGATION MEASURES

Sustainable capture fishery production is only achieved when stock is not over-exploited. To protect the stocks against this, the following measures should be implemented:

- Implement Fisheries Ordinance 1961 and Fisheries Rules, 1976, to prevent illegal fishing and to control mesh size of nets, poisoning, use of explosives, etc.
- Enforce closed season for fishing (from the 1 October to 9 March) allowing protection of broodstock, undisturbed migration and spawning.
- Regularly stock the waters to replenish the fish stock. The seed necessary for that is to be produced in hatcheries.
- Form fish protection committees to promote awareness among the people.

7. FUTURE POTENTIAL OF COLD WATER FISHERIES DEVELOPMENT IN THE COUNTRY AND PROSPECTS OF REGIONAL COOPERATION

The waters of the entire Deosai Plateau (above 4 000 meters) from the Astor River to Sheosar Lake are excellent for trout. Sheosar Lake and all the major rivers of the Deosai should be stocked with trout. A major trout fishing programme could be developed on the Deosai with very little overall cost, and with little environment impact. Limited fishing licenses could be sold as part of the management programme, and the proceeds from these fees could be used to further enhance the fishing programme. Brown trout and rainbow trout are carnivores, and will not be in direct competition with the local fish fauna. The local snow trout of the Deosai, which reach enormous size, are also very good to eat, and could be developed as a game fish on the Deosai (Woods *et al*., 1997). The indigenous snow trout *Schizothorax plagiostomus* seems to be the most suitable species for aquaculture in NWFP (Butt, 1994).

Based upon the observations made at the Madyan Trout Hatchery, Swat, the Kamloop strain of rainbow trout is better suited than the brown trout. It is faster growing, well tolerant of crowding and water temperature fluctuations.

The snow trout *Schizothorax plagiostomus* also has a good potential for aquaculture in NWFP. Its culture would generate income and provide employment to the rural population. Regional cooperation in form of exchange visits of experts for research and development and other matters of common interests is necessary.

8. SUMMARY AND RECOMMENDATIONS

- Human resources development and participatory research among scientists, extension workers and fishermen should be established.
- Broodstock of indigenous species and undersized fish must be protected from capture.
- Regional cooperation and networking to encourage cooperation in the region to resolve issues of common interests should be developed.
- Efforts should be made to strengthen policies for the social uplift of fishers by providing basic amenities of life, education, health and security.
- A database management system should be established.
- Research and development institutions should focus on conducting studies aimed at improving native stocks through genetic selection and genetic engineering.
- Effort should be made to breed non-commercial threatened fish.

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Section 3: Experience papers

NUTRITION, FEED AND FEEDING OF GOLD MAHSEER (*Tor putitora*) FOR DOMESTICATION AND PRODUCTION IN NEPAL

by

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ABSTRACT
One of the major impediments in development of the production system of mahseer (*Tor putitora*) is an inadequate knowledge and dietary formulation of their feed. To fill such a gap of knowledge on nutrition, feed and feeding of mahseer we performed series of experiments with different life stages of golden mahseer. In our study with hatchlings and fry stage the most effective food was natural zooplankton. However, for the growth of growers effective diets were feed dominated with matter of animal rather than plant origin. Mahseer growth rate is slower than that of cultured carps, i.e. common carp (*Cyprinus carpio*), rohu (*Labeo rohita*) and mrigal (*Cirrhinus mrigala*). All studies were done in cages or tanks, but not in ponds as there was not enough of mahseer hatchlings, fry and growers. Since mahseer hatchlings and fry also showed increased growth with natural planktonic food, it can be suggested that mahseer larval and fry growth rate could be similar to that of cultured carps. Adult mahseer grew well with feed containing a high percentage of animal and low percentage of plant components. This might be due to their preference for animal food. Gut content analysis of mahseer ranging from 250 to 3 000 g confirmed their preference for food of animal origin. However, the fish can be sustained by offering both types of food.

1. INTRODUCTION

Understanding feed, feeding and nutrition of fish species suitable for fishery and aquaculture development is one of essential preconditions for successful aquaculture production. Mahseer (also called *sahar* or *mahasheer - Tor putitora*) is a well acknowledged, highly valued indigenous fish of the Himalayan belt. The species is distributed in many rivers, streams and lakes of mid hills of the Himalayan belt from Afghanistan in the west to Myanmar in the east (Skene-dhu, 1923; McDonald, 1948; Day, 1958; Chaturvedi, 1974; Shrestha, 1981; Nautiyal, 1994). In Nepal, mahseer mainly inhabits cool waters of rivers and lakes of mid-hills and inner Terai. Mahseer is one of the potential fish species of Trans-Himalayan countries for fishery development, including aquaculture. In natural systems the fish is known to reach 45 kg of body weight in large rivers.

Mahseer is known to be an omnivore fish in its adult stage. In earlier days considering the mouth opening and massive size, the fish was supposed to be a carnivore (Malhotra, 1982). However, we have collected many samples from rivers of Pokhara Valley, where gut contained rice grain, small insects and plants. Mahseer therefore appears to be an opportunistic feeder which feeds on a wide variety of food of plant and animal origin. Mahseer have been found to also feed on green filamentous algae, insect larvae, small molluscs, and algal coatings on rocks (Shrestha, 1997; Negi, 1994; Dubey, 1985). Nautiyal and Lal (1984) reported that in natural habitat food of mahseer fingerlings consisted of insect matter (81.4 percent), plant matter (15.9 percent) and other items including fish (1.6 percent). Knowledge of natural feeding habits of mahseer would provide a basis for formulated feed development for this species. Studies on nutrition and feed management for different developmental stages of mahseer are a prerequisite for farming possibilities of this high value native species.

Growth of mahseer in captivity is slower than of fish reared in the wild (Shrestha, 1997). Very little is known about artificial food and growth responses of mahseer. Preliminary studies conducted at ARS (Fish), Pokhara (1998) on diet development for mahseer showed promising results when fed on a feed containing mixture of animal and plant protein sources (Bista and Yamada, 1998). Similar results with different cultivable fish have been described in several other studies (Tacon, 1981; Viola et al., 1982; Wee and Wang, 1987; Juyal, 1994).

Mahseer populations have been declining in most of their natural habitats due to impacts caused by industrialization, urbanization, and agricultural development causing ecological alterations and physical changes in natural environment in lakes and rivers of mid hills (Das and Joshi, 1994; Shrestha, 1994). In Lake Phewa of Pokhara Valley, mahseer decline is attributed to pollution and overfishing (Shrestha, 1997). To replenish the declining populations of mahseer in its natural habitats attempts are being made to breed and develop culture techniques of the *Tor* species.

For promotion of mahseer one alternative could be the development of suitable breeding and rearing technology *ex-situ*, which requires knowledge of their nutritional requirement from hatchlings to adult stage. At present there is only limited knowledge on feed, feeding and nutritional requirement of mahseer. Preliminary studies conducted at the Pokhara Fisheries Research Centre showed promising results when mahseer was fed with pellets containing proteins of animal and plant origin (Bista and Yamada, 1998). Studies on nutrition and feed requirement of different stages of mahseer are a prerequisite for assessment of the possibilities for farming this high value native fish. The present study has aimed to generate baseline data on nutrient requirements so as to develop appropriate feeds to enhance growth of mahseer in captivity, i.e. under aquaculture conditions.

The present work describes studies on feed, feeding and nutritional requirements of the species and offers suggestions for the development of fisheries and aquaculture of mahseer.

2. METHODS AND MATERIALS

We performed several short term to long term experiments to identify suitable feed for mahseer ranging from early larvae to adult fish.

Methodology for response studies of different types of feed on hatchlings (first)

To examine the growth response of hatchlings in captive conditions, experiments with 10-day-old hatchlings were performed from May 6 to July 15, 2000 for a total 35 days. The hatchlings were obtained as breeding by-product of the Pokhara Fisheries Research Centre.

Usually, yolk sac is absorbed within 4 days after hatching at water temperature more than 20˚C. Larvae start feeding on natural and artificial feed afterwards. In this experiment four treatments with 3 replicate each were examined. In controls zooplankton were fed while in other treatments Japanese crumble No-1, (Treatment 1), microfeed prepared at the Fisheries Research Centre (Treatment 2), and silk worm based microdiet (Treatment 3) were examined for hatchling growth response.

Zooplankton for feeding in controls was collected by plankton net of 80µ-mesh size from highly fertilized ponds adjacent to experimental sites. The microdiet was prepared at the Fisheries Research Centre, Pokhara using different ingredients such as shrimp meal, milk powder, soy puff, which was sieves through 300µ mesh. Later on these ingredients were mixed in proper ratio, mixed with 5% of gelatin and 56% of water to prepare paste. The paste was spread over tray and dried in oven at 50˚C for one night. Then ground and sieved with 150µ mesh. In each treatment 40 larvae in 50 L of water were stocked. In each tank water supply was maintained through inlet and outlet and water flow was maintained at about 1.0 L per minute. In each treatment water quality parameters such as temperature, DO, pH were measured. The larvae were fed *ad libitum* from 6 AM to 7 PM 6 times a day. At the beginning all larvae were weighed in water using microbalance to determine their initial weight. The change in body weight was determined once a week in the same way. At the time of growth check 100% population was weighed for accuracy. In this feeding trial mortality loss of hatchlings was zero. No disease was noticed during the study period.

Methodology for response studies of different types of feed on hatchlings (second)

This experiment was carried out inside the hatchery. The fry were obtained from the brood collected from Lake Begnas. In 9 treatments the effect of feed on growth of fry of 0.0185 g body weight was examined. This experiment was run for 30 days with 80 hatchlings in 50 L plastic tank where a continued water supply was maintained. Air was supplied through blower at the rate of 0.4-0.5 liter /minute. Feeding started at 8 AM, 10 AM, 12 PM, 2 PM, 4 PM up to the level of satiation. Water temperature and pH were checked at 10 AM and 12 PM, DO at 12 PM daily. Tank bottom cleaning and water change was done in 2 days interval and mortality was checked at the same time.

The experimental diets were made from soybean cake, dried shrimp, chicken egg, corn- starch, dry fish, cod liver oil, vitamin and mineral premix. Gelatin was used as a binder for microdiet. The diet-1 was based on 55 percent fishmeal, in diets 2, 3, 4, 5 and 6 the proportion of fishmeal was gradually decreased to 5 percent of diet 1. Similarly soybean cake was used for diets 4 to 6 in gradually increasing order from 12 to 40 percent. Diet 7 was based on fermented soybean while diet 8 consisted of only live zooplankton, and diet 9 was a frozen zooplankton. The microfeed was prepared as described in earlier section. The composition of zooplankton is shown in Table 1.

Survival of hatchlings at the end of the trial was 33.3 to 92.1 percent. The highest survival occurred in hatchlings fed with zooplankton while the lowest was in the group fed with the lowest percentage of fishmeal, i.e. diet No.1.

Table 1
Composition of zooplankton in micro-feed

Species	Ratio
Daphinia longispina	12.8
Eudiaptomus	19.2
Thermocyclops	11.2
Keratella	3.1
Nauplius	0.6
Diaphnanosoma	7.5
Brachionus	10.6
Chydorus	0.6
Asplanchna	3.2
Filinia	0.6
Shells, eggs etc	10.4

Methodology for response studies of different types of feed on fingerlings

Fingerlings of approximately 6g body weight were stocked at a density of 650 individuals in 8 m^3 net cages at Phewa Lake, Pokhara, Nepal. In this experiment two treatments were taken where diets containing crude protein 30 percent (Treatment 1) and 40 percent (Treatment 2) were tested on experimental fish (Table 1).

To prepare 30 percent and 40 percent feed different ingredients were ground and mixed in appropriate ratios. Powdered ingredients were mixed with 8 percent moisture for pelleting. Californian pellet mill was used to prepare the pellets for experiment. The pellets were crushed by crumble mill to adjust the feed size according to the mouth opening of hatchlings.

The experiment was replicated in floating cage of similar dimension (2x2x2 m^3). The feed was fed 6 days a week at 3 percent of total body weight of fish in each cage. The daily requirement of diet was split into 3 equal amounts and fed 3 times a day. The experiment lasted for 210 days from December 1998 to June 1999. The quantity of daily ration was adjusted on the basis of growth which was checked at 30 day intervals. The growth of fingerlings was estimated by using electronic balance.

During the experimental period basic water quality parameters (dissolved oxygen concentration, , temperature and pH of the location) were recorded.

Methodology for response studies of different types of feed on fingerlings

This experiment was performed in floating cages of 2 m x 2m x 2m dimensions from January to late May 2001 in Lake Phewa. We took 4 treatments for this experiment. The following diets were fed as pellets: in treatment 1, fish meal (75 percent) mixed with other ingredients, in treatment 2, fish meal with 18 percent soy meal, in treatment 3, 50 percent soy with 12 percent fish meal, and in treatment 4, 50 percent soy and 23 percent fish meal. As binder wheat meal was used in all the diets. At the beginning average stocking size was 20.0±2.0 g (TL 13±2 cm). In each cage 150 fish were stocked. This experiment was conducted for 140 days. Fish in each cage were fed with different feed at the rate of 5 percent of total body weight 4 times a day. The growth check was performed near the Phewa Lake shoreline using electronic balance. During the study period the mortality in cages was less than 5 percent.

Experimental trials for response studies on grower mahseer by three types of pellet diets

This experiment was carried out as indoor trial in 500 liter round bottom circulation tank. The yearlings of mahseer with an average weight of 57-61 g were stocked at a density of 25 fish in each treatment. Each was replicated. The experimental diets were made by using locally purchased fish meal, shrimp meal, wheat flour, corn starch, soybean puff, fish oil, vitamin and mineral mixtures. Diet 1 was imported commercial Japanese feed for trout. All diets were in pellet form. The diets were isonitric. The crude protein level of diet 1, 2 and 3 was 43 percent, 38 percent and 43 percent respectively. The experiment was carried out for 70 days from April to June. Water circulation and aeration was continuous. Daily feeding was carried at 7 AM, 11 AM and 3 PM, three times a day. Water temperature and pH were checked at 10 AM and 12 PM, and DO at 12 PM every day.

3. RESULTS OF RESPONSE TO DIFFERENT TYPES OF FEED

3.1 Results of response studies of different types of feed on hatchlings (Fig. 1)

Growth pattern of hatchlings fed with different variety of feed generally increased during most of the study period. The group fed with zooplankton showed highest growth response, while group fed with silkworm pupae showed lowest growth response. Other hatchlings fed with micro-feed prepared at Fisheries Farm Pokhara and Japanese crumble showed moderate growth response. The group fed with Japanese crumble showed better growth than locally made micro-feed.

During the study period variation in DO was from 6 to 9 mg/L, change in water temperature was 24 to 28°C and pH varied from 7-9 during the study period.

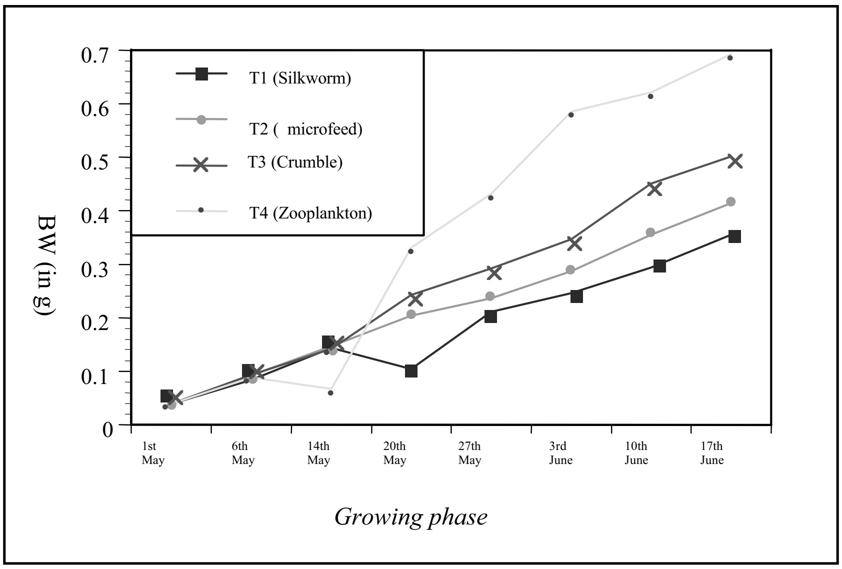

Fig. 1 - Growth response of mahseer hatchlings fed with different diets

3.2 Result of response studies of different types of feed on fry (Fig.2)

During the experiment period water temperature ranged from 22-30°C. The difference in pH was 0.6, while DO ranged 1.2 mg/L during 30 days of study period. At the end of highest growth occurred in treatment fed with D-8 (live zooplankton). Other treatment did not show substantial changes in body weight during the study period. The survival rate of fry ranged from 33.3- 92.1%. The highest survival occurred in the group fed with live zooplankton and lowest was in the group fed with diet 1.

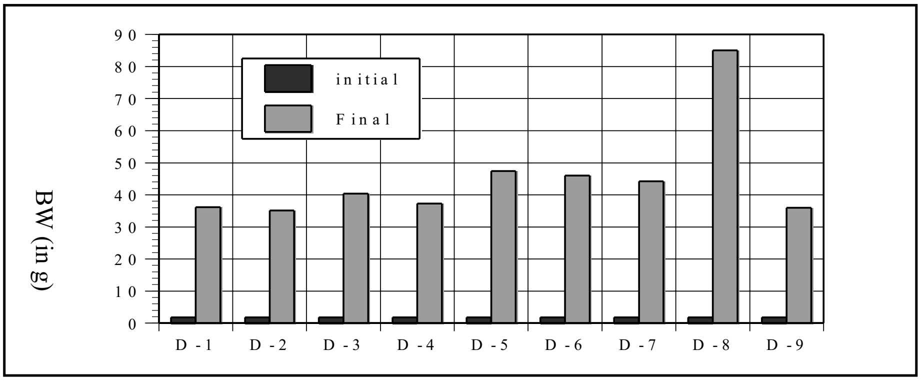

Fig. 2 - Initial and final growth response of mahseer hatchlings fed with different diets (D-1 to D-9)

3.3 Response studies of different types of feed on fingerlings

The growth responses of mahseer under different dietary treatments are illustrated in Figure 1. The fingerlings of mahseer well accepted both 30% and 40% crude protein containing diet and fish fed actively. Body weight gain in each growth period until 90 days was significantly different (P<0.05) within the treatment 1.

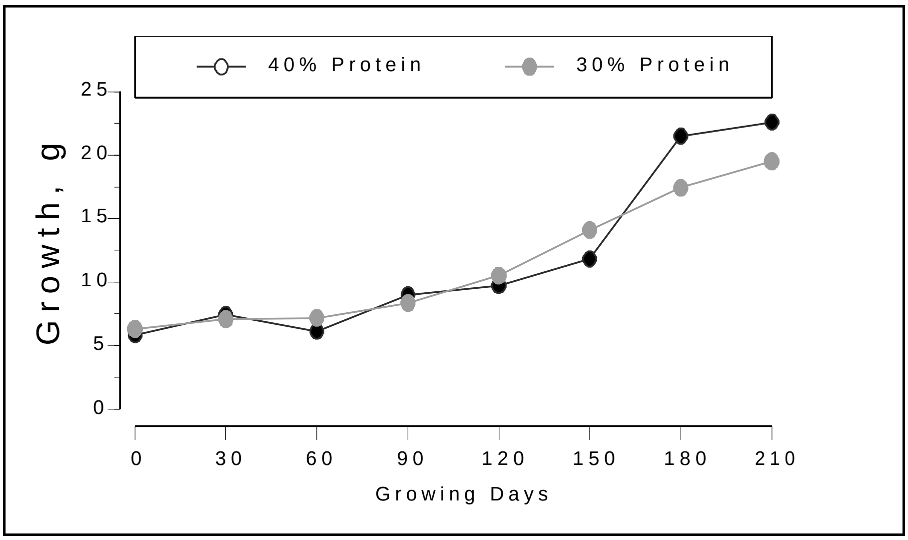

Fig. 3 - Growth of mahseer fingerlings fed on 30 and 40% protein content diets

Body weight gain of fish fed on 40 percent protein diet did not showed any significant difference during same growing period (until 90 days) in the treatment but after 90 days till harvest fish grew significantly. There was no significant difference between treatment in weight gain till 150 days but after 150 days there was a significant difference ($P<0.05$) between 30 percent and 40 percent diet. The mean value of body weight of mahseer obtained at harvest were 19.5 g and 22.5 g from 30 percent and 40 percent protein diet fed group, respectively. During the study water temperature was low during the first month but later on water temperature increased till the end of the study period.

3.4 Response studies of different types of feed on advanced fingerlings

The results showed that growth of advanced fingerlings was positively consistent in all the treatments. The highest body weight was achieved in the treatment with combination of fish meal and soy meal. At first two months fingerlings did not grow despite of feeding at the same rate. After March growth increased gradually till the end of the study period. In winter months fish were usually inactive and consumed the supplied feed inactively. But while feed ingredients and their composition were different the growth response was almost similar except in the treatment 2 fed with combination of fish meal and soy meal (75% and 18%).

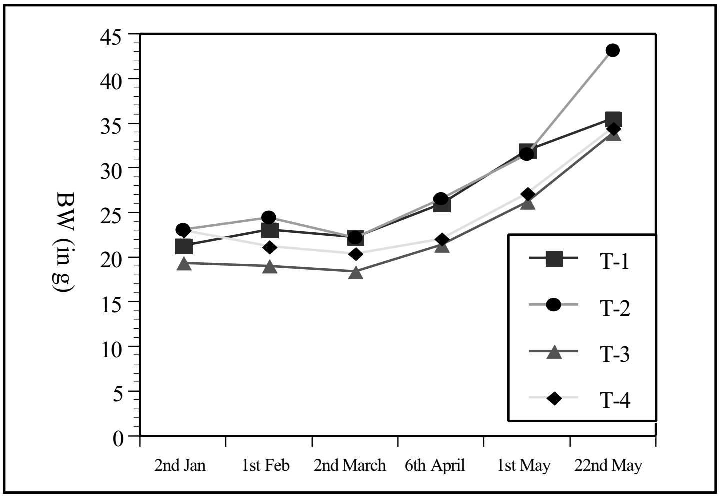

Fig. 4 - Growth response by mahseer advanced fingerlings fed with 4-different types of animal and plant origin diets

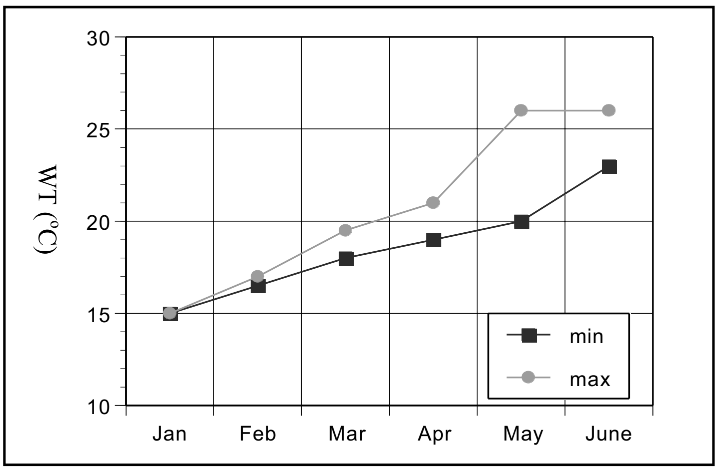

Fig. 5 - Seasonal change in minimum and maximum water temperature in Lake Phewa

3.5 Result of the feeding trial with three different diets on grow out mahseer

In this trial the highest effect was shown in the treatment fed with Japanese commercial feed on growers, while the lowest growth and net gain occurred in the treatment fed with diet comprising of 30% soybean and 27% fish meal during a 70 day culture period. During the study water temperature ranged from 24.3 to 29.9 °C. The pH varied from 6.8 to 9.4, and DO from 3.5 to 8.0 mg/L. In this experiment the survival was 100%.

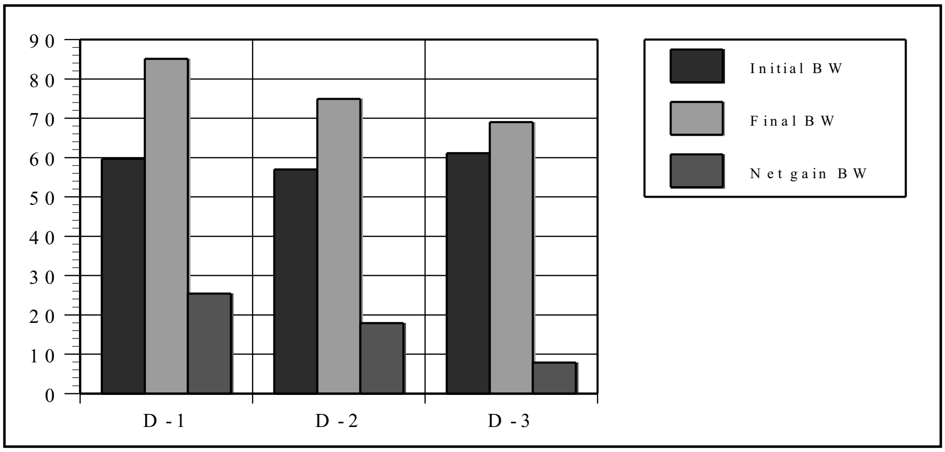

Fig. 6 - Net gain in body weight of grow-out fingerlings fed with three different types of feed

4. DISCUSSION

Our present study showed that hatchlings, fry, fingerlings and growers mahseer could be successfully reared on artificial diets, but natural zooplankton was the best food for hatchlings of mahseer (Fig. 1 and 2). It is known that most fish species require plankton food during their earliest life stages of development (Huet, 1972). The best food to grow small hatchlings of the carps rohu (*Labeo rohita*), bhakur *(Catla catla*), and mrigala (*Cirrhinus mrigala*) during their earlier stages is plankton in highly enriched pond waters (Jhingaran and Pullin, 1987). Our studies showed that mahseer hatchlings could also be successfully reared with plankton food grown in ponds. However, hatchling growth studies have not yet been attempted in fertilized ponds due to the small number of hatchlings available for such studies. Since hatchlings could be rear successfully with highest growth and turnover in most of the experiments one may speculate that mahseer hatchlings could be raised successfully in fertilized ponds.

Hatchlings fed with Japanese commercial feed showed faster growth than with other supplementary feed. The least growth attained was with silk worm based feed. Silk worm is considered one of the important ingredients in fish diets. However, in our case it is possible that small hatchlings could not utilize them properly as an adult fish could.

In other experiments when hatchlings were fed with eight different types of feed, fastest body growth response occurred in the group fed with zooplankton (Fig. 2). Somatic growth response with other feeds only varied unsubstantially. The above two experiments confirmed that for mahseer hatchlings natural plankton are the best initial food.

Feeding experiment with fingerlings showed that pellet feed could be one of alternatives to raise the fish in captive condition. The feed supplied to experimental fish contained 30% and

40% protein. In this experiment initial body weight of fingerlings was about 6.0 g. In 210 days fingerlings fed with 30% protein feed gained about 19.6 g while another group fed with 40% feed attained about 22.4 g average weight. This experiment showed that though the growth rate was low mahseer could be raised on supplementary pellet feed.

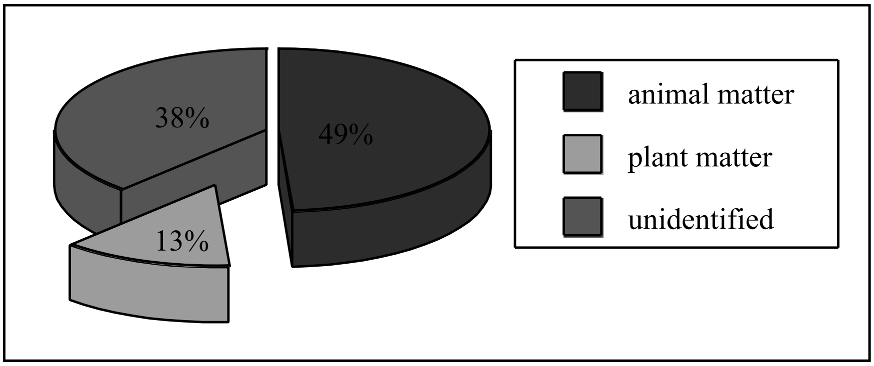

Fig 7 - Proportion of animal and plant food matter in gut content of mahseer ranging from 250 to 3 000 g

In another study conducted with advanced fiongerlings of approximately 19-23 g the weight attained was 44 g in 6 months. The results showed poor growth performance of fingerlings. This might be related to low water temperature from January to March when it was only 15-18°C. The growth was slightly faster with increasing water temperature after March. This indicates that mahseer growth response could be increased with increasing water temperature, and this is common with many other cyprinids. In the treatment where fingerlings were fed with a mixture of fishmeal and soy meal in equal proportion they grew fastest, while slow growth was observed with the diet with large proportion of soybean.

In another experiment highest gain in body weight occurred in treatment fed with Japanese crumble comprising a high proportion of animal origin ingredients. In another treatment where proportion of animal protein was low the net gain was relatively less (Fig 6).

The present study showed that feed choice changes with age and size of mahseer. Minute hatchlings showed higher inclination towards planktonic food, which is abundant in natural waters. Later on when fish grow up to fingerling and grower stages their choice is inclined more towards animal origin food. This is supported by analyses of gut contents of 101 adult mahseer (250 to 3000 g) collected from different rivers and lakes: about 50 percent comprised animal matter, 13% plant matter and the rest was unidentified matter.

This result shows that supplementary feed with large proportion of animal matter and relatively small part of plant matter would be the most appropriate feed for grower mahseer.

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FISH FAUNA OF THE NARAYANI RIVER SYSTEM AND THEIR IMPACT ON THE FISHERMEN COMMUNITY IN CHITWAN, NEPAL

by

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ABSTRACT

Sixty-nine species of fish belonging to 9 orders and 19 families were collected from the Narayani River system, Nepal. Of these, 13 species can be classified as cold water fish. The status of each fish species is described based on the observations from the Narayani and some of the tributaries. Forty-seven fishermen families are catching fish and all fishermen have reported decreasing fish catches. At Gaindakot (Nawalparasi) the catch per person per gear per day was 0.9 kg and at the Bharatpur municipality it was 1.3 kg. Because of low catches some river fishermen seek alternative work. The demand for fish remains high. It is recommended to set up a fish farm for producting *Tor putitora* (mahseer/sahar) and *Neolissocheilus hexagonolepis* (katle), protect the environment, minimise pollution, establish fish sanctuaries, ban destructive fishing methods and enforce fishery regulations.

1. INTRODUCTION

Chitwan District is located in the southwestern corner of the Central Development Region of Nepal, between latitudes 27°21' and 27°46' and longitudes 85°55' and 85°35'. It is a part of Nepalese midlands, a relatively flat area at an altitude of 244 m above mean sea level, with a sub-tropical climate. During heavy rains, a major portion of this area is flooded. The region is drained by the Narayani River catchment, and the river eventually discharges into the Ganga River in India.

The Narayani River is one of the largest rivers in Nepal. It is the final collector of seven extremely complex drainage systems of the Trans-Himalaya and consists of countless creeks, hill streams, rivers, forest lakes, wetlands, floodplains and oxbows. The Kaligandaki is the main feeder system of the Narayani. It originates on the Tibetan plateau and cuts through the Nepal Himalayas between Dhaulagiri and Annapurna, forming the world's deepest gorge. After joining the Trishuli (also called Trisuli) River in Deoghat it is called the Narayani, which runs for approximately 332 km through Nepal before it spills onto the Gangetic plains of India. The Kaligandaki/Narayani system cuts through all of Nepal's varied zones and thus presents an excellent opportunity to examine the fish distribution along an impressive altitudinal gradient.

Small scale fishery is an important sector for rural fishermen. It provides employment indirectly through fish marketing and distribution, net making and boat construction. Despite the contribution of the fishery to the national economy, until recently this sector has been receiving less support from the Government than other sectors.

The present study investigated the distribution of fish fauna, fish catch and fisheries in the Narayani River system in Chitwan.

2. MATERIAL AND METHODS

Randomly selected fishermen at Narayanghat and Shivghat under Bharatpur Municipality, and Gaindakot and Kharkhareghat under Gaindakot Village Development Committee, were interviewed.

The rivers and streams of Chitwan were regularly visited from January 2000 to December 2000 to collect fish. The study area (Figs 1-3) was divided into seven localities based on the abundance of fish stocks:

- I. North-eastern bank of the Narayani River at Sivaghat, Kharkhareghat and Koleghat
- II. Rapti-Narayani confluence at Khoriamohan
- III. Narayani River at Deoghat and Narayanghat
- IV. Panesa stream, Dhungre River (Padamur) and Rapti River at Kasara
- V. Khageri River at Tikauli (Tandi) and Budhi Rapti at Chitrasari
- VI. Trishuli River at Kuringhat and Trishuli/Marsyangdi confluence at Muglin, and
- VII. Irrigation canals of Chitwan and Lothar River.

Fish were collected with the help of locally prepared nets and traps. Special features of each habitat were recorded as well as the fresh colour of the captured fish. Fish were preserved in 5 to 10 percent formalin. To minimise colour fading, some specimens were also preserved in 70 percent alcohol. The fish were then identified in the laboratory. Their scales and fin rays were counted using the system of Srivastava (1988) and Shrestha (1981). Body depth and head length were measured. Fish were classified after Berg (1947). The identified specimens are kept in the Department of Fisheries and Aquaculture, IAAS, Rampur Campus, Chitwan, Nepal.

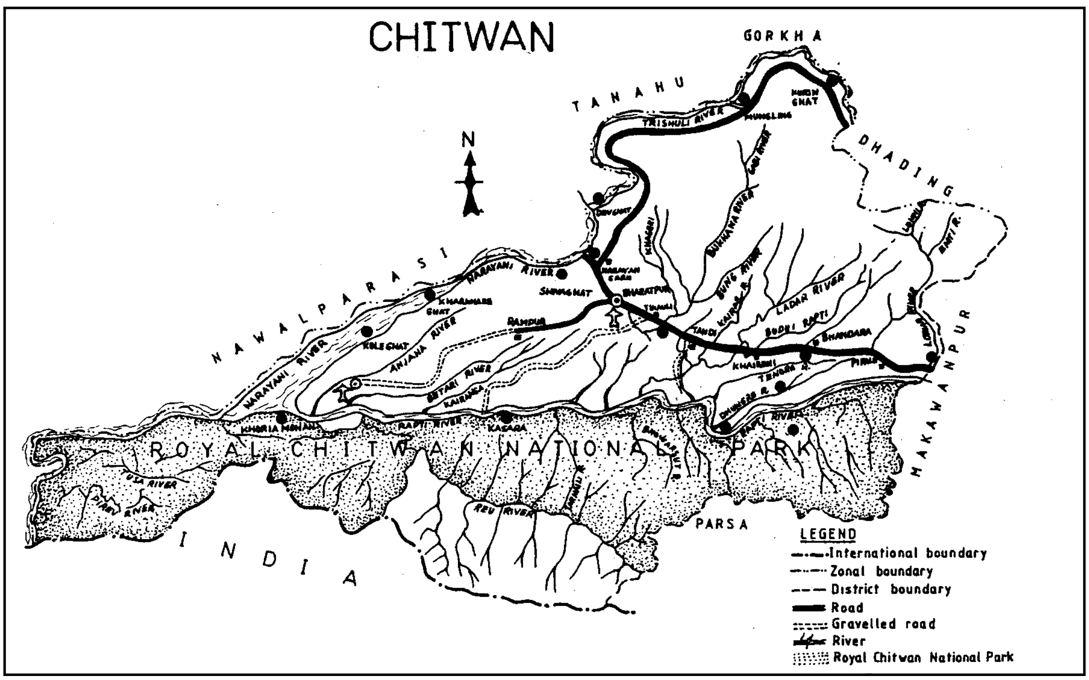

Fig. 1 - Map of the river systems of Chitwan. Black dots indicate the sampling points

Fig. 2 - The Narayani, Kaligandaki, Seti and Trishuli rivers

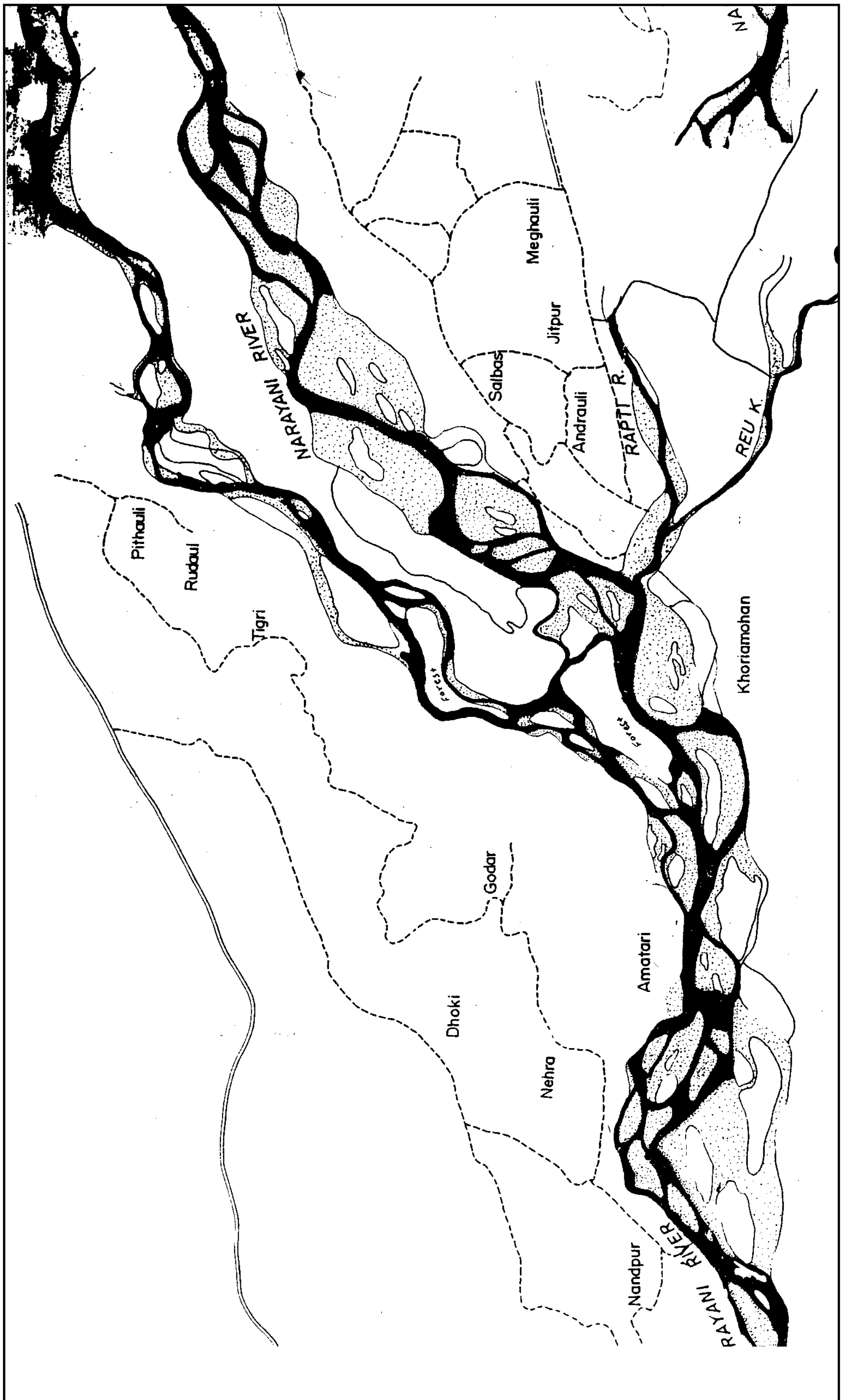

Fig. 3 - The downstream section of the Narayani River

3. RESULTS AND DISCUSSION

Sixty-nine species of fish were collected from the Narayani River system in Chitwan. Order, family, local names, abundance and status of the individual fish species are listed in Table 1.

Table 1
Status of fish species in the Narayani River system

FISH SPECIES / LOCAL NAME & LOCALITY	ABUNDANCE	STATUS
I. Order: Clupeiformes		
Family: Clupeidae		
1. *Gudusia chapra* (Ham.) / suiya III, V, VII	Common in III	Local Migrant, Rare in upper stretches of the river system.
Family: Notopteridae		
2. *Notopterus notopterus* (Pallas) / Bhuna, Patra II, IV, V	Common in IV	Rare in upper section. Found in lower section from July to November.
II. Order: Cypriniformes		
Family: Cyprinidae		
3. *Aspidoparia morar* (Ham.) / Chepua I, III	Common	Rare in other localities.
4. *Barilius barna* (Ham.) / Donrhi I, II, III	Common	Local Migrant.
5. *B. bendelisis var. chedra* (Ham.) / Faketa, Motia, I, II, III, IV, V, VII	Common	Abundant in all the sections. Used as bait.
6. *B. bola* (Ham.) / Chepua, I, II, VII	Resident	Mostly found in July to Sept.
7. *B. jalkapoorei* (Shrestha) / Galara, I.	Rare	Found in June to Oct.
8. *B. tileo* (Ham.) / Chepua, I, II	Resident	Rare in upper section Mostly found in May to June.
9. *B. vagra* (Ham.) / Chepua, I, II	Resident	Rare in upper section Mostly found in May to June.
10. *Chagunius chagunio* (Ham.) / Chaurahi, I, IV	Common	Local migrant. Common Food fish mostly found April to June.
11. *Cirrhinus reba* (Ham.) / Garahani, I, II, IV, VII	Common	Local migrant. Important food fish mostly found in June to Sept.
12. *Crossocheilus latius* (Ham.) / Budhuna I to VII	Common	Rare in upper section.
13. *Danio devario* (Ham.) / Chaiyapothi, I to IV	Common	Mostly found during low water phase from Oct to Jan.
14. *D. rerio* (Ham.) / Khida I to IV	Common	do
15. *Esomus danricus* (Ham.) / Denrhi I to IV	Common	Small fish having little commercial value.
16. *Garra annandalei* (Hora) / Budhuna I, V, VI, VII	Resident	Common in feeder streams.
17. *G. gotyla* (Gray) / Budhuna, I, V, VI, VII	Resident	Hill stream fish, mostly found in May to July.
18. *Labeo angra* (Ham.) / Basarhi, Rohu, I, II, IV, VII	Common	Local migrant, important food fish mostly found in May to August.
19. *L. dero* (Ham.) / Gardi, I, V, VI	Common	Important food fish. Migratory in nature, mostly found in July to Nov.
20. *Osteobrama cotio* (Ham.) / Chuna I, II, IV	Common	Rare in upper stretches.
21. *Neolissocheilus hexagonolepis* (McClelland) III, VI	Rare	Important food fish, migratory in nature mostly found in upper section only.
22. *Oxygaster bacaila* (Ham.) / Chalhawa I, II, III	Common	Oct to December.
23. *Puntius chola* (Ham.) / Sidhre, I, II, III, IV, VII	Very common	Small size fish common every where.
24. *P. conchonius* (Ham.) / Sidhre, I, II, III, IV, VII	Very common	Small size fish common every where.
25. *P. sarana* (ham.) / Darhi	Common	Small size fish common every where.
26. *P. sopore* (Ham.) / Gujarahta	Common	Small size fish common every where.
27. *P. ticto* (Ham.) / Tikulia sidre	Very common	Small size fish common every where.
28. *Rasbora daniconius* (Ham.) / Dedhwa I, II	Very common	Small size fish common every where.
29. *Semiplotus semiplotus* (McClelland) / Mahanga III	Rare	Migratory mostly found in April to June.
30. *Tor putitora* (Ham.) / Mahaser I, IV, V, VI, VII	Rare	Migratory mostly found in July to September.
31. *T. tor* (Ham.) / Shar I, IV, V, VI, VII	Rare	Migratory mostly found in July to Sept.

FISH SPECIES / LOCAL NAME & LOCALITY	ABUNDANCE	STATUS
Family: Cobitidae		
32. *Botia lohachata* (Chaudhari) / Baghe, I, II, III, VII	Rare	Mostly found in May to June.
33. *Lepidocephalichthys guntea* (Ham.) / Hile goira	Common	Mostly found in May to June.
34. *Somileptes gongota* (Ham.) / goira	Common	Mostly found in May to June.
35. *Nemacheilus beavani* (Gunther) / Goira, I, IV, VI, VII	Rare	Common in upper reaches, mostly found in May and June.
36. *N. botia* (Ham.) / Goira, I, II, IV, VI	Common	Mostly found in February to March.
Family: Siluridae		
37. *Ompok bimaculatus* (Bl.) / Nanaria, I, IV	Common	Medium size fish found in lower stretches of the river
38. *Wallago attu* (Bl. & schn.) / Barari; Padhni, I, IV	Common	Large sized migratory fish mostly found in July to December.
Family: Bagridae		
39. *Mystus (M) bleekeri* (Day) / Tengana, I, II, IV, VII	Resident	Small sized fish mostly found in June to November.
40. *M. (M) cavasius* (Ham.) / Sujaha, I, II, III, IV	Resident	Small sized fish mostly found in June to November.
41. *M. (M) tengra* (Ham.) / Tengra, I, II, IV	Resident	Small sized fish mostly found in June to November.
42. *M. (o.) aor* (Ham.) / Datari, I, II, III, IV, V, VI	Common	Medium sized fish mostly found in July to September.
43. *M. (o) seenghala* (Sykes) / Sujah, I, II, III, IV, V, VI, VII	Common	Large sized fish mostly found in September to Nov.
44. *Rita rita* (Ham.) / Tenger, I, II, III	Uncommon	Medium sized fish mostly found in July to September.
Family: Amblycipitidae		
45. *Amblyceps mangois* (Ham.) / Paidani, I, IV, V, VII	Common	Small hill stream fish common during June to Sept, and Feb to March.
Family: Sisoridae		
46. *Bagarius bagarius* (Ham.) / Gonch; Thenda, I, IV, VII	Uncommon	Largest catfish of Nepal mostly found in June to Sept.
47. *Gagata cenia* (Ham.) / Gogata, I, II, VII	Uncommon	Medium sized fish having.
48. *Glyptothorax horai* (Shaw & Shebbeare) Kursimlo, III, IV, VII	Uncommon	Medium sized fish, mostly found in June to September.
49. *G. trilineatus* (Blyth) / Capre, III, IV	Rare	Medium sized fish, mostly found in June to September.
50. *Pseudecheneis sulcatus* (McClell) Vedra, I, IV, VII	Common but rare	Local Migrant hill stream fish, mostly found in June to Sept.
Family: Schilbeidae		
51. *Clupisoma garua* (Ham.) / Jalkapoor, I, IV, VII	Common	Delicious fish found in June to Oct.
52. *Eutropiichthys vacha* (Ham.) / Suha, I, IV, VI	Uncommon	Mostly found in upper stretches of the river.
Family: Saccobranchidae		
53. *Heteropneustes fossilis* (Bl.) / Singhe, I, II, IV	Common	Common food fish, available through the year.
Family: Clariidae		
54. *Clarias batrachus* (Linn.) / Mangur, I, II, IV, V	Common	Common food fish, available through the year.
III. Order: Angujilliformes		
Family: Anguillidae		
55. *Anguilla benfalensis* (Gray & Hardw) Rajbam, I, VI, VIII	Rare	Migratory fish, mostly found in July to Oct.

FISH SPECIES / LOCAL NAME & LOCALITY	ABUNDANCE	STATUS
IV. Order: Beloniformes		
Family: Belonidae		
56. *Xenentodon cancila* (Ham.) / Kauwa machha, I, IV, VII	Common	Local migrant, mostly found in June to December.
V. Order: Ophiocephaliforms		
Family: Ophiocephalidae		
57. Channa gachua (Ham.) / Bhoti; Hile, I, II, III, IV, V, VI	Common	Small sized fish, found through out the year.
58. *C. marulius* (Ham.) / Saur, I, II, III, IV	Common	Large sized fish, rare in upper section of the river.
59. *C. punctatus* (Bl.) / Khasurhati, I, II, III, IV	Common	Small sized fish, found through out the year.
60. *C. striatus* (Bl.) / Gajhari, I, IV	Common	Medium size fish, throughout the year.
VI. Order: Symbranciformes		
Family: *Amphipnoidae*		
61. *Amphipnous cuchia* (Ham.) / Anhi; Andhabam, I, II, IV, VI	Common	It is an amphibious fish living in the muddy bottom. Found in June to Nov.
VII. Order: Perciformes		
Family: Centropomidae		
62. *Chanda nama* (Ham.) / Chuna, I, II, IV	Common	Small fish. Found in Oct. to Jan.
63. *C. ranga* (Ham.) / Chuna, I, II, IV	Resident	Mostly found in stagnant water pools in June to Nov.
Family: Nandidae		
64. *Nandus nandus* (Ham.) Dhendari, I, IV, VII	Common	Mostly found in stagnant water pools in June to Nov.
Family: Gobiidae		
65. *Glossogobius giuris* (Ham.) / Balkokra, I, II, IV	Common	Mostly found in the lower streams of the river.
VII. Order: Mastacembeliformes		
Family: Mastacembelidae		
66. *Macrognathus aculeatus* (Bl.) / Kusot, I, II, III, IV, V, VII	Resident	Medium Size food fish, mostly found in stagnant pool during Sep. to Dec.
67. *M. armatus* (Lacepede) / Bam I, II, III	Common	Medium Size food fish, mostly found in stagnant pool during Sep. to Dec.
68. *M. pancalus* (Ham.) / Setamhi, I, II, III, IV, V, VII	Resident	Medium Size food fish, mostly found in stagnant pool during Sep. to Dec.
IX. Order: Tetrodontiformes		
Family: Tetrodontidae		
69. *T. cutcutia* (Ham.) / Phuwa, I, IV, V, VII	Common	Small sized fish, mostly found in lower stretch of the river.

I, II, III: Narayani river at Sivaghat, Kharkhareghat, Koleghat; Khoriyamohan and Deoghat and Narayanghat, respectively.
IV: Panesa stream, Dhungre river (Padampur).
V: Khageri river at Tiklauli and Budhi Rapti river at Chitrasari.
VI: Trisuli river at Kuringhat and Trisuli Marsyngdi confluence at Muglin.
VII: Irrigation canal of eastern Chitwan.
Common: Frequently noted during sampling period.
Resident: Never migrate according to local fishermen.
Uncommon: Very few represent in the sample.
Rare: Very few, sometimes absent, only repeated sampling revel the presence of the species.

The family Cyprinidae dominated with 34 species, followed by Siluridae (18 species). The Order Cypriniformes represented 75.36% of the total fish species, while none of the other orders represented more than 4.34% of the total number of species found. Among the 69 species, 13 cold water species (18.84%) were collected from the main course of the Narayani River. Out of these 8.69% represented important food fish, which were restricted mostly to the upper stretch of the river. Many of these were collected during floods.

Among the Cyprinidae, *Labeo* sp., *Neolissocheilus hexagonolepis* and *Tor* sp. were the dominant food fish. Catfish *Wallago attu*, *Mystus seenghala* and *Mystus aor* were common. *Clupisoma garua* and *Eutropiichthys vacha* are relished as food by local people; these two species appeared only during early summer. *Amblyceps mangois* was collected from the rivers Khageri and Dhungre. *Glyptothorax* sp. were collected from the Marsyangdi-Trishuli confluence near Muglin. *Gudusia chapra* was found only once. *Anguilla bengalensis*, a migratory fish, was collected at Sivaghat and Narayanghat from the Narayani River. It was also collected during floods from the rivers Lothar and Rapti. Upper reaches of the Narayani River have an abudnance of hill stream fish. *Garra* and *Crossocheilus* were collected from the localities V,VI and VII. These fish were also collected from the lower reaches of the river during monsoon. *Tetraodon cutcutia* was collected from the Dhungre River. *Botia lohachata*, *Somileptes gongota* and *Pseudecheneis sulcatus* were rare.

Among the previous records of fish fauna of the Gandaki River Shrestha (1981) reported 23 species, and Edds (1986) listed 111 species species from a longitudinal survey of the Kali Gandaki/Narayani river system from 100 m to 3 000 m. Jha *et al*. (1989) reported 68 species from the Narayani and Rapti river systems in Chitwan. Shrestha (1990) reported 85 species from the main stem of the Narayani River. We collected 69 species from Kuringhat to Khoriamohan and from the Khageri, Lothar and the Narayani river systems. Some species were also collected from the Rapti River near Kasara.

There are 47 fishermen families catching fish from the Narayani River. Only 10 families own a boat which is used for fish catching. They use cast nets, gill nets, scoop nets and hook line. The Narayani River is leased every year by the Bharatpur Municipality and Gaindakot Village Development Committee. The contract details are shown in Table 2. A fisherman has to pay Rs. 50 for one net and Rs. 250 per boat per month to the contractor. At Gaindakot (Nawalparasi) the average catch per person per gear per day was 0.9 kg whereas at Bharatpur Municipality it was 1.3 kg. Because of low catch some fishermen of Gaindakot and Shivghat search for alternative jobs, while other fishermen continue fishing or collecting fish from fish farmers. All fishermen have reported severe decrease in fish catches but the contract amount is increasing every year.

Fish fauna in the Narayani River has been declining because of unregulated fishing and use of destructive methods such as dynamiting, poisoning and fishing for broodstock during the spawning season.

Table 2
Contracts for fishing in two areas of the Narayani River
Bharatpur Municipality

Contractor	Year	Amount (NRs)
Yam Lal Acharya	2000/2001	61 000
Gorakh Sah	1999/2000	17 000
Rosahn Baniya	1998/1999	16 501

Gaindakot Village Development Committee

Mr. Thapa	2000/2001	7 100
Rambilash Sahni	1999/2000	13 000
Sambhu Sahni	1998/1999	9 000

4. RECOMMENDATIONS

Fish catches in the Narayani River have been declining because of the use of illegal fishing methods such as poisoning and fishing for broodstock during the spawning season. To preserve the fish stocks, controls should be imposed on illegal fishing practices and a fish sanctuary established. The deep water pools of the Narayani and their feeder streams should be declared fish sanctuaries for the protection of spawners.

The Narayani catchment has been subject to deforestation, resulting in erosion and silting of streams and rivers. There is a need for land rehabilitation measures to be urgently implemented in the watershed. The incidence of water pollution is increasing in the lower reaches of the river due to the discharges of industrial waste, and the illegal use of insecticides, pesticides and piscicides. Control over such activities must be strictly enforced.

Habitat improvement is an essential factor for fishery improvement. To avoid seasonal changes of water level, suitable pools should be created under the management of the local development authority. Such a practice will improve the fish habitat quality and avoid the winter desiccation.

Protection of fish stocks and fishery regulation should be based on periodic assessments of fish stocks. It is high time to enforce the existing fishery law and to restrict the use of nets with less than 2 cm mesh size. In the lower stretches of the Narayani River fish fry is collected for commercial purposes. There is a need for restriction of this practice.

Tor putitora (sahar) and *Neolissocheilus hexagonolepis* (katle) are highly priced fish, but their stocks are declining. A sahar/katle fish farm should be established near the crocodile farm of the Royal Chitwan National Park, and artifical breeding should be applied to produce these valuable fish under controlled conditions.

All fishermen have reported severe decrease in fish catches from the river and because of low catches fishermen from Gaindakot V.D.C. are searching elsewhere for alternative jobs. To keep them in the area an aquaculture programme should be implemented. Some areas of the river should be leased to the fishermen’s community.

Acknowledgements

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IMPACT OF DAMMING ON THE AQUATIC FAUNA IN NEPALESE RIVERS

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ABSTRACT

Nepal has more than 6 000 rivers and streams, most of which originate in the high Himalayas and midhills and are fed by glaciers and springs forming perennial rivers. Those of lowlands are fed by rain and intermittent streams and dry up during the low flow period. The rivers support a large variety of aquatic flora, insects and 185 fish species. The fish are classified as long distance migrants, mid and short distance migrants, or resident fish. Rivers of Nepal are renowned for hydropower potential. The theoretical hydropower potential is estimated to be 83 200 MW, with 42 133 MW as economically feasible. Two methods, i.e. runoff river type and high dam reservoir type, have been adopted for hydropower development in Nepal. Weir type is adopted in the steep northern part of Nepal where low and average flow of water show less variation. High dams with a reservoir are built in the lower hills of Nepal where valleys are wide with small gradient. In the reservoir, some resident and game fish may decline, whereas *Neolissocheilus hexagonolepis,* resident non-game fish species and hardy fish such as murrels and catfish may find reservoir conditions favorable. Long distant migrants such as *Tor* sp, *Bagarius, Pseudeutropius, Clupisoma* etc. and mid-distance migrants as *N. hexagonolepis* and *Labeo* sp cannot pass through the physical barrier of a dam. Fish passes are an important mitigation measure at lower dams while fish lifts may be used at higher dams to assist fish in their upstream migration. Minimum downstream discharges recommended in EIA studies of small to large rivers of Nepal vary from 0.5 to15 m^3/s to maintain an aquatic environment suitable for riverine fish.

1. IMPACT OF DAMMING ON AQUATIC FAUNA IN RIVERS

1.1 Nepal rivers

Most of the rivers originating in the high Himalayas are nourished by snow and glaciers and flow to the south to provide water to millions. They also threaten the livelihood of people of the Trans-Himalayan region through floods, erosion, landslides, water-borne epidemics, etc. Nepal lies in the central part of the 2 400 km long Himalayan region, and has features of both the east and west Himalayas. This position offers a relative advantage in understanding the problems and prospects of Himalayan rivers. Physiographically, Nepal is divisible into three regions: Himalayan (highlands), Mahabharat (midlands or midhills), and Churia and Terai (lowlands). There are three basic types of rivers: i) perennial glacier- and snow-fed coldwater rivers carrying significant flows in dry season; ii) perennial ground water (e.g. springs) and rain-fed rivers carrying some flow in dry season; and iii) seasonal rain fed rivers with no flow in dry season. Monsoon rainfall is an important source of water for all the river systems of Nepal: 72 percent of rainfall flows as surface run-off from basins. Late monsoon, comprising 12 percent of the total rainfall, comes as snow. The remaining rainfall percolates as ground water to cause delayed run-off. Perennial rivers are supplemented with water from melting of snow during the dry season before monsoon, and by ground water from September to March.

In Nepal, 10.7 percent of river basin areas are located in permanent snow regions (5 000 m and higher), 17 percent in seasonal snow regions (between 3 000 m and 5 000 m), and the remaining 70 percent are in no-snow regions (Sharma, 1997).

Nepal has more than 6 000 rivers and streams belonging to four main drainage basins: Sapta Koshi, Gandaki, Karnali and Mahakali. The total area of all the rivers and streams is estimated to be about 395 000 hectares (FDD, 1998). Different rivers of Nepal support a variety of aquatic flora and fauna. Fishes of Nepal are unique depicting the characteristic of three major regions: i) very cold water fishes of the high mountain Himalayan region, ii) cold water fishes of the midland region, and iii) warm water fishes of lowlands. These fishes also show diverse biological and structural adaptations to fluctuating torrents of the rivers flowing through different topographies. So far 185 fish species have been identified for Nepal (Shrestha J., 1997), including a significant number of cold water species. There is a high demand for cold water fish as they fetch a good price for their excellent taste. Some of them have recreational/sport importance. Indigenous fish species of the Himalayan region make a significant contribution to the livelihood of the rural population and are also a valuable genetic resource.

Water resources of Nepal can be profitably utilized for power generation, irrigation, domestic uses, aquaculture and recreational fisheries. Of all the above, hydropower development has become the most attractive as a reliable, cheap and safe energy source. The theoretical hydropower potential of Nepal is 83 200 MW of which 44 552 MW is regarded technically feasible and 42 133 MW economically feasible. Snow-fed Himalayan streams and rivers are small and highly turbulent down to the base of the Himalayas where they get bigger and become less turbulent. In the midhills they are supplemented by springs. The larger perennial rivers are ideal for hydropower development. Run-off river schemes and high dam reservoirs are the major types adopted for power generation in Nepal. In the steep northern parts where average flows of water are lower, the former type is applied. This type generates a lifelong small benefit and one fourth of the Nepal's economically feasible hydropower potential is of this type. In the lower hills or lowlands of Nepal, where rivers flow through flat valleys and wide plains where precipitation and ground water are the major sources of water, river discharges decrease to low or no volume in the dry season. Hydropower development in such areas requires water to be stored in a reservoir established by blocking the river with a high dam to provide for year-round use. It is estimated that under Nepal conditions a high dam storage reservoir can generate electricity for about 50 years. Weak geology, frequent earthquakes, high sediment load and fragile environment are the challenges for a high dam reservoir together with the problems of submergence, stratification, fast sedimentation and erosion of downstream areas.

Cold water fish of Nepal are facing problems due to an increasing number of hydropower projects. Once abundant indigenous fish stocks have been declining due to overfishing, harmful fishing practices (electrofishing, dynamiting, use of chemicals), pollution and developmental works. Developmental works such as river damming have a major impact on river ecology, aquatic flora and fauna, including fish. Cold water fish of Nepal are affected by the increasing number of hydropower dams in the country. In view of this, His Majesty's Government (HMG) of Nepal has made Environment Impact Assessment (EIA) compulsory under the EIA National Guidelines (HMG 1993) for all the hydroelectric projects above 5 MW. In the eyes of HMG of Nepal and international agencies including IUCN, the conservation status of none of the fish species seems yet to be alarming in Nepal. However, an EIA study for the Ilam (1994) has reported *Neolissocheilus hexagonolepis* and *Tor tor* endangered and threatened, respectively. The EIA study for the River Gandaki (1996) had listed three fish species endangered, five species threatened and seven species restricted. In a study of fish status in Nepal, Shrestha J. (1997) has listed 34 species threatened and 61 species insufficiently known.

2. PRE-IMPOUNDMENT CONDITIONS

2.1 Water quality

Water of most of the rivers having hydropower structures is well oxygenated, unpolluted and suitable for cold water fish (Table 1).

2.2 Aquatic life

All the rivers mentioned above harbour rich phytoplankton, zooplankton and zoobenthos as the main source of food of fish (Table 2). The average densities of phytoplankton and zooplankton are 206 units/liter and 16.25 units/liter, respectively. In zoobenthos insects dominate (94.34 percent) in the Trishuli River (Shrestha T.K., 1997). The average densities of macroinvertebrates are 91.5 ind/m^2 and 178 ind/m^2 in the Trishuli and Karnali rivers, respectively. The reported wet weight of large invertebrates averages 1.9 kg/m^2 in the Karnali River. Among the large invertebrates, molluscs comprised 36 percent, followed by chironomids (34 percent), oligochaetes (16 percent) and crustaceans (14 percent) (EIA Upper Karnali, 1997). The ecological studies of the Trishuli River have shown a higher density of benthos downstream than upstream (Shrestha T.K., 1997). This may be an important factor supporting the presence of a large number of cold water fish species, with high abundance, in midhill rivers of Nepal.

Table 1
Water quality in selected rivers of Nepal

Parameter	**Tri-shuli**	**Tamur**	**Melamchi**	**Bheri**	**Babai**	**Upper Karnali**	**Budhi Ganga**	Seti
Electrical conductivity (σS)	84	42-75	-	-	-	140	143-164	-
Temperature (^{0}C)	-	10.0-12.5	19-21	18-19	23-25	18-20	14.5-15.0	10.9
Dissolved oxygen (mg/L)	-	11.0-13.0	9-10	8.4 –10.0	8.0-8.7	11.8	8.6-10.2	7.8
PH	7.6	6.5-7.0	7.0-7.9	8.4-8.6	7.8-8.8	7.6	7.7	8.1
Total hardness (mg/L)	48	-	17-34	13.3-17.0	17.6-20.0	-	28-36	-
Ca hardness (mg/L)	-	-	-	-	-	9.5	60-64	-
Total alkalinity (mg/L)	-	-	17-34	10.4-11.0	16.8-20.7	-	77-95	-
Chloride (mg/L)	8	-	-	-	-	-	2.8-5.7	-
Silicate (mg/L)	-	-	-	-	-	-	10-20	-
NH_3 (mg/L)	-	0.01-0.14	-	-	-	-	<0.02	-
Calcium (mg/L)	13	-	-	-	-	-	24-26	-
Magnesium (mg/L)	2	-	-	-	-	1.5	7.0-8.8	-
Nitrate(mg/L)	-	0.001-0.52	-	-	-	-	<0.02	-
Nitrite(mg/L)	-	-	-	-	-	-	<0.03	-
Suspended solids (mg/L)	-	-	-	-	-	58	10-32	-
Total dissolved solids (mg/L)	-	-	-	-	-	95	86-98	-
Transparency	-	Clear	Clear	74 – Clear	76 – Clear	Clear	Clear	-
Total nitrogen (mg/L)	-	0.042-0.571	-	-	-	-	-	0.38
Phosphate (mg/L)	-	0.01-0.06	-	-	-	-	-	0.00
CO_2	-	-	5.0	0.62-12.8	0.26-1.28	-	-	-
Biochemical Oxygen Demand (mg/L)	-	-	-	-	-	0.19	-	-
Potassium (mg/L)	-	-	-	-	-	1.4	-	-
Sodium (mg/L)	-	-	-	-	-	1.2	-	-
Iron (mg/L)	-	-	-	-	-	0.12	-	-

Table 2
Aquatic organisms (as listed in EIA reports)

Organisms	A	B	C	D	E	F	G	H
Aquatic flora								
Chlorophyceae	*	-	-	-	-	-	*	*
Bacillariophyceae	*	-	-	-	*	-	*	*
Cyanophyceae	*	-	-	-	-	-	*	-
Desmidiaceae	*	-	-	-	-	-	-	-
Submerged plants	*	-	-	-	-	-	-	-
Aquatic fauna								
Protozoa	-	-	-	-	-	*	-	-
Rotifera	*	*	*	*	*	*	*	*
Copepoda	*	*	*	*	*	*	*	*
Cladocera	*	*	*	*	*	*	*	-
Plecoptera	*	*	*	-	*	-	*	-
Ephemeroptera	*	*	*	*	*	*	*	-
Odonata	*	-	-	*	*	*	*	-
Diptera	*	*	-	*	*	*	*	-
Coleoptera	*	*	*	*	*	*	*	-
Hemiptera	*	*	*	*	-	*	*	-

Source: EIA reports

A - Melamchi
B - Bheri
C - Babai
D - Upper Karnali
E - Tamur
F - Kali Gandaki 'A'
G - Budhi Ganga
H - Seti River

2.3 Fish

Schizothorax and *Schizothoraichthys* spp are dominant among the cold water fish in all rivers in terms of catch and abundance in all seasons except during floods. They are caught by a series of loops made from a long nylon thread and set across the river in daytime and harvested in the morning. Other common fish species are *Barilius* sp, *Garra* sp, *Neolissocheilus hexagonolepis, Glyptothorax* sp*, Glyptosternum* spp and *Pseudecheneis* sp and arecaught by cast nets. The EIA reports for different hydropower projects reported a total of 84 fish species (Table 3). The fish are classified as: i) long distance migratory, ii) mid and short distance migratory, and iii) resident fish species (Tables 4, 5 and 6). The long distance migratory fish include *Tor* sp, *Bagarius bagarius, Anguilla bengalensis* and *Clupisoma garua.* They are captured mainly during the rainy season using long hooks. Mid and short distance migratory species are *Amphipnous cuchia, Chagunius chagunio, Labeo angra, L. dero, L. dyocheilus, Neolissocheilus hexagonolepis, Puntius chillinoides, Schizothorax* spp and some other. They are abundant througout the year. Some of the cold water species are important for fisheries and need to be protected.

Factors triggering the fish migration in Nepal are not well known. Migration is possibly done to find suitable spawning and feeding grounds. Plankton and benthos are washed away by the turbid monsoon water at lower altitude, but rapid growth of insects takes place in headwaters during the high water level phase (June-September). Abundant food and increased water volume may attract large long distance migratory fish to headwaters during the monsoon. A diminishing flow rate in headwaters and abundance of fish food organisms downstream induce these fish to migrate back. The short distance migratory fish *Schizothorax* and *Schizothoraichthys* move upstream in response to high turbidity, higher water temperature, and due to the scarcity of food during the rainy season in the lower reaches.

Table 3
Fish species recorded in EIA studies

Fish species	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Tor putitora	*	*	*	*	*	*	*	*	*	-	*	-	*	*	*
T. tor	*	*	*	*	*	-	*	*	*	*	*	*	*	-	-
Bagarius bagarius	*	*	*	*	*	*	*	*	*	-	*	-	-	*	-
Anguilla bengalensis	*	-	*	*	*	*	*	*	*	-	*	*	*	-	*
Clupisoma garua	*	*	*	-	*	-	*	-	*	-	*	-	-	*	*
Schizothorax plagiostomus	*	*	*	*	*	*	*	-	*	-	*	*	*	*	*
S. richardsonii	*	*	*	*	*	*	-	-	*	-	-	*	*	*	-
Schizothoraichthys progastus	*	-	*	*	-	*	*	-	*	*	*	*	-	*	*
S. annandalei	*	-	-	-	*	-	-	-	-	-	-	-	-	-	-
S. esocinus	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-
S. sinuatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*
Neolissocheilus hexagonolepis	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Barbus chillinoides	*	-	-	*	-	-	-	-	-	-	-	-	-	-	-
Barilius bendelisis	*	*	*	*	*	*	*	*	-	-	*	-	*	*	-
B. barna	*	-	-	*	-	*	*	*	-	*	-	-	-	-	-
B. barila	*	-	-	-	*	*	-	-	-	-	*	*	-	*	*
B. shacra	*	-	-	*	-	*	-	-	-	-	-	-	-	*	-
B. vagra	*	-	-	*	*	*	*	*	*	-	-	-	-	-	-
B. teleo	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-
B. jalkaporei	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-
Chagunius chagunio	*	-	-	*	*	-	-	-	-	-	*	-	-	-	-
Crossocheilus latius	*	-	-	*	*	-	-	-	-	-	*	-	-	-	-
Cyprinon semiplotum	*	-	-	*	-	-	-	-	-	-	-	-	*	-	-
Danio aequipinnatus	*	-	-	-	-	*	-	-	-	-	-	-	*	-	-
Garra annandalei	*	*	*	*	*	-	*	*	*	*	*	-	*	*	-
G. gotyla	*	*	*	*	*	*	*	*	*	-	*	*	-	*	-
G. muliya	*	-	-	*	-	-	-	-	-	-	-	-	-	-	-
Labeo angra	*	*	-	-	*	-	*	-	*	-	*	-	-	-	-
L. dero	*	*	-	*	*	-	*	*	*	-	*	*	-	*	-
L. pangusio	*	-	-	-	-	-	-	-	-	-	-	-	-	-	*
L. dyocheilus	-	-	-	-	-	-	-	*	-	-	*	-	-	-	-
L. gonius	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-
L. ticto	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*
Cirrhina latia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*
Puntius conchonius	*	-	-	-	*	-	-	-	-	-	*	-	-	-	-
P. sophore	*	*	-	-	-	-	-	-	*	-	-	-	-	-	-
P. ticto	*	*	*	*	*	-	-	-	*	-	-	-	-	-	-
P. chillinoides	-	*	-	-	*	-	-	-	*	-	*	-	-	*	-
P. sarana	*	-	-	*	-	-	-	-	-	-	-	-	-	-	-
Psilorhynchus pseudecheneis	*	-	*	-	*	*	*	-	*	-	*	-	-	*	-
Botia almorhae	*	-	-	-	-	-	*	*	*	-	*	-	-	*	-
B. dario	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-
B. lohachata	*	-	-	*	-	-	-	-	-	-	*	-	-	-	-

Fish species	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Pseudecheneis sulcatus	-	*	-	-	-	-	-	*	-	*	-	-	-	-	*
Heteropneustes fossilis	*	*	*	*	-	*	-	-	-	-	*	-	-	-	-
Euchiloglanis hodgarti	*	*	*	*	-	*	-	-	-	-	-	-	-	-	-
Amblyceps mangois	*	-	*	-	-	*	-	-	*	-	-	-	-	-	-
Channa gachua	*	*	*	-	-	*	-	*	-	-	-	-	-	-	-
C. punctatus	*	*	*	-	-	*	-	-	*	-	-	-	-	-	-
C. marulius	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-
C. striatus	-	-	*	*	-	-	-	-	-	-	-	-	-	-	-
C. stewartii	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-
Amphipnous cuchia	*	*	*	-	*	*	-	*	*	-	*	-	-	-	-
Mastacembelus armatus	*	-	-	-	-	-	*	-	*	-	*	-	-	-	-
M. puncalus	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Macrognathus aculeatus	*	*	-	-	-	-	-	-	*	-	-	-	-	-	-
Nemacheilus rupicola	*	*	*	*	*	*	*	*	*	-	*	-	*	*	-
N. beavani	*	*	*	*	*	*	-	-	*	-	*	-	-	*	-
N. botia	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-
N. corica	-	-	-	*	-	-	-	-	-	-	*	-	-	-	-
Glyptothorax pectinopterus	*	*	*	-	*	*	-	-	*	-	*	-	*	*	-
G. telchita	-	-	-	-	-	-	-	*	-	*	-	*	-	*	*
G. trilineatus	*	*	-	*	-	-	*	-	*	-	-	-	-	-	-
G. cavia	*	-	-	*	*	*	-	-	-	-	*	-	-	-	-
G. horai	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-
Pseudeutropius murius	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P. garua	*	-	-	-	-	-	-	-	*	-	-	-	-	-	-
P. atherinoides	*	-	-	-	-	-	-	-	*	-	-	-	-	-	-
Balitora brucei	*	-	-	-	-	*	-	-	-	-	-	-	-	-	-
Glyptosternum pectinopterus	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. blythi	*	-	-	-	*	-	*	-	-	-	*	-	-	-	-
Rita rita	*	*	-	-	-	-	-	-	-	-	-	-	-	-	-
Eutropiichthys vacha	*	*	-	-	-	-	-	-	-	-	-	-	-	-	-
Wallago attu	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-
Nandus nandus	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-
Notopterus chitala	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-
Esomus danricus	-	*	*	-	-	-	-	-	-	-	-	-	-	-	-
Xenentedon cancila	-	*	-	-	-	-	-	*	-	*	-	-	-	-	-
Catla catla	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-
Rasbora daniconius	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-
Lepidocephalichthys guntea	-	-	-	-	-	*	-	-	-	-	*	-	-	-	-
Ailia colia	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-
Chaca chaca	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-
Oxygaster bacalia	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-

Source: EIA reports

A - Kali Gandaki 'A'
B - Kankaimai
C - Marsyandi
D - Trishuli
E - Tamur
F - Melamchi
G - Bheri
H - Babai
I - Upper Karnali
J - Kulekhani
K - Dudh
L - Likhu
M - Puwa Khola
N - Budhi Ganga
***** present
- absent

Table 4
Biological data for the long distance migratory fish

Species	Migratory pattern (months)												Spawning season	Spawning substrate	Food	Age and size at maturity	Behavior Economic importance
	J	F	M	A	M	J	J	A	S	O	N	D					
Tor putitora						↑	↑	↑	↑	↓	↓	↓	Sept – Oct.	Gravel beds	Algae, rotifers, protozoa, insects, fish, debris	2-5 yr 45 cm	Rest in deep pools, jumping nature; Excellent food fish
Tor tor					↑	↑	↑	↑	↑	↓	↓	↓	Sept – Oct.	Gravel beds	Filamentous algae, insects,molluscs,fish fry & adults,sand and mud	2-5 yr 55 cm	Rest in deep pools, jumping nature; Excellent food fish
Anguilla bengalensis		↑	↑	↑	↑	↓	↓	↓					June - July	Mud and sand	Fry, insects, shrimps, molluscs	- -	Excellent game fish caught on bait; Food value and sport fish
Bagarius bagarius			↑	↑	↑	↑	↑	↑	↑	↓	↓	↓	July – Aug.	Mud and sand detritus	Fry, large insects, crabs, shrimps, frogs, molluscs	2.5-3.0 yr 75 cm	Dwell in crevices , avoid direct light , piling, snapping , wriggling and overland movement; Excellent food fish
Clupisoma garua			↑	↑	↑	↑	↑	↓	↓	↓			June - July	Fine sand and pebbles	Fry, fingerlings, tadpoles and frogs	2.0 yr 20 cm	Anadromous migrants, sport fish angling by rod; Excellent food fish

Table 5
Biological data for the short and mid distance migratory fish

Species	Migratory pattern (months)												Spawning season	Spawning substrate	Food	Age and size at spawning (maturity)	Behavior Economic importance
	J	F	M	A	M	J	J	A	S	O	N	D					
Amphipnous cuchia					↑	↑	↑	↓	↓				June - July	Mud & twigs	Algae, copepods, insects, debris	2 yr, 30 cm	Air breathing, moves in swarms from lower reaches to floodplain swamp; food fish
Chagunius chagunio			↑	↑	↑	↑	↑	↓	↓				May - June	Gravel & pebbles	Microscopic plants, detritus	2 yr, 22 cm	Schooling (6-8), jumping behaviour, mid-distant migrants; food fish
Labeo angra				↑	↑	↑	↑	↓	↓				June - July	Gravel	Filamentous algae, higher plants, debris	2 yr, 28 cm	Residing in deep pools,schooling(10-12), sport fish, mid-distant migrants; food fish
L. dero			↑	↑	↑	↑	↑	↓	↓				June - July	Gravel bed	Filamentous algae, higher plants, debris	2 yr, 28 cm	Take rest in deep pools, sport fish; tasty fish
L. dyocheilus					↑	↑	↑	↑	↓	↓			July – Aug	Gravel	Microscopic plants, detritus, mud	2 yr, 28 cm	Live with *N. hexagonolepis*; tasty fish
Neolissocheilus hexagonolepis			↑	↑	↑	↑	↓	↓	↓				May – July	Gravel	Plant,animal,debris	3 yr, 17 cm	Residing in deep pools; good game fish
Puntius chillinoides				↑	↑	↑	↑	↓	↓				June – July	Pebbles	Algae, diatoms, insects	2 yr, 18 cm	Lives in runs & riffles, jumping; food fish
Schizothorax annadalei	↑	↑	↑							↓	↓	↓	Aug – Sept	Gravel+pebble	Algae, insects, fish fry, mud	1.5 yr,20 cm	Schooling (15-20), females chased by males during breeding season; delicious fish
S. plagiostomus	↑	↑	↑								↓	↓	Sept – Oct	-	Algae, insects, mud, detritus	2 yr, 18 cm	Females chased by males during breeding season; delicious fish

Table 6
Biological data of some important resident fish species

Species	Spawning season	Spawning substrate	Food	Growth rate (in a year)	Age and size at spawning (maturity)	Behaviour Economic importance
Barbus chillinoides	Aug- Sept	Gravel, sand, pebbles	Algae, earthworms, mud , small fish	4-5 cm	2.0 yr, 15.0 cm	Local migration in monsoon and spawn in spring; oily fish, sun&smoke dried
Glyptothorax trilineatus	June	Gravel bed, pebbles, algal bloom	Aquatic insects (may flies and stoneflies)	3.5 cm	2.0 yr, 10.0 cm	School & mass migration during monsoon floods; used for fish oil, sun&smoke dried
G. telchita	May-June	Gravel bed, pebbles	Aquatic insects, earthworms	3-5 cm	2.0 yr, 9.0cm	School & mass migration to creeks for spawning; fat&oils used to cure gastric ailments
G. horai	June	Gravel, sand, mud	Insects, dragonfly larvae	3.0 cm	2.0 yr, 7.0 cm	School (50-80); oily fish with plump flesh
G. pectinopterus	June	Gravel, sand, rooted vegetation	Insects, mayfly larvae	3.5 cm	2.0 yr, 13.0 cm	School (15-200), local migration during monsoon; oil for healing wounds
G. blythi	May-June	Gravel, sand, pebbles	Aquatic insects, zooplankton	3.5 cm	2.0 yr, 8.0 cm	School under rocks, crevices and backwaters; sun&smoke dried; for flavouring condiments

3. IMPACTS OF DAMS ON RIVERS

Dams alter aquatic ecology and river hydrology upstream and downstream, affecting water quality, quantity and breeding grounds (Helland-Hansen *et al*., 1995). They create novel and artificial types of aquatic environment for the life span of the dam.

3.1 Water quality and physical changes

Upper reaches of the reservoir may not be affected very much as the original riverine conditions are still retained in most Nepali reservoirs. Downstream of the dam the flow rate in the river will depend on the amount of thecompensation flow. Water volume is considerably reduced during the dry season. As a result the downstream may change to pools alternating with dry stretches for about nine months from November to June. Due to decreased water discharges, water temperature will rise in daytime and decline sharply at night. Rooted plants will grow in the riverbed due to the decrease in water volume.

3.2 Impact on fish

Fish such as snow trout, catfish and loaches may be pulled into the intakes and get killed. Even riverine fish adapted to fast current may be lost. Fish food organisms will be highly affected by reduced flow rates and new species will invade areas with a slow current. Golden and copper mahaseer are known to be affected directly by the changes in their habitat, which leads to stunted growth, diseases and parasite infestation and increased mortality.

3.3 Effects of impoundment

Installation of a weir on the Tamur River and Mewa Khola has changed 200 m and 100 m long river stretches, respectively, into two small reservoirs. Dudh Koshi is now turned into a reservoir of 687.4 Mm^3 storage, of which 442.1 Mm^3 is live storage. The riverine habitat of 53.1 km will be converted into a 1989 ha reservoir by the West Seti hydropower dam. Similarly, the Karnali dam will create a 7.0 km long reservoir of an average width of 90 m. Another reservoir will be created upstream of a dam at Likhu Khola, flooding a 700 m long river stretch and having an 18 m daily water level fluctuation.

Water in the reservoirs may become thermally stratified. This will depend on a number of factors, especially on the water retention time and the depth of the reservoir. As the water uptake for turbines is usually in the hypolimnion, cold water will be discharged downstream during the operation of the power station. The hypolimnion may become deoxygenated, and discharge of such water downstream may negatively impact the aquatic fauna in the river below the dam. The reservoir itself may undergo eutrophication as happened for example in the Indrasarovar reservoir (Pradhan and Swar, 1988). Lacustrine conditions of the reservoir will differ from those of the river and this will also have an impact on the original fish fauna. Some fish species may disappear, other will adjust by changing from stenophagous to euryphagous. Omnivorous or planktivorous fish may adapt to the reservoir conditions. But *Garra lamta*, *Glyptosternum*, *Coraglanis*, *Puntius* sp, *Glyptothorax pectinopterus*, *G. cavia*, *Psilorhynchus* and *Pseudecheneis* do not like lacustrine conditions. *Anguilla bengalensis* and *Schizothorax richardsonii* have been also known to decline abruptly in reservoirs. Snow trout, once abundant in the Kulekhani River, became rare after the river was dammed. The same happened to mahaseer after the impoundment of Phewa and Begnas lakes in Pokhara Valley. *Neolissocheilus hexagonolepis,* on the other hand, is a common fish in reservoir conditions (Swar, 1992). Carp minnow (*Barilius bendelensis*), stone loach (*Nemacheilus beavani*) and stone roller (*Garra gotyla*) find reservoir conditions favorable, and reservoir conditions are ideal for rapid colonization by hardy fish such as murrels and catfish (*Heteropneustes fossilis*). Shoreline erosion and rapid and intensive drawdown are other problems faced by fish as they affect spawning and egg incubation.

3.4 Effect of dams on fish migration

A dam will fragment and isolate upstream resident fish such as stone carp and catfish from downstream. The resident species may congregate in the tailwater release site. Fish from upstream will occasionally sweep downstream during the monsoon, stay in the tailwater or swim further downstream. A dam will obstruct the route of the long and mid-distance migratory fish. Upstream migrants will arrive at the dam site during the flow phase. Long distant migrants such as *Tor* sp., *Bagarius, Pseudeutropius*, *Clupisoma* and *Anguilla*, and mid-distance migrants *N. hexagonolepis* and *Labeo* species are most affected by a dam. These species will abandon the original pool and colonize deep pool regions downstream or upstream. Populations of snow trouts are less affected, as they make a small-scale migration to tributaries to breed in clear and cool water during the monsoon and return to the main stream during the low flow period (Shrestha, 1995).

3.5 Socioeconomic impact of dams

A large number of fisher communities are dependent upon fishing for livelihood. These fisher communities are classified as full time, part time and occasional fishermen depending upon the intensity of fishing (Table 7). Full-time fishers devote 200-230 days/year to fishing, part-time 60-65 days/year and occasional about 25-30days/year (EIA-Tamur, 1998). They belong to different ethnic groups: Bote, Majhi, Sarki, Badi, Raji, Gurung, Magar, Chhetri, Kami, Damai, Tamang, Brahmin, Sahi, Gharti, Thapa, Malla, Danwar, Bhujel and some others. The fish catches have been reported to decline due to the high fishing pressure, use of chemicals, dynamiting, electro-fishing and the use of small-meshed nets.

Table 7
Fisher communities recorded in EIA studies

Type of fisher	Tamur *	Melamchi *	Upper Karnali*	Bheri*	Babai*	Sun Koshi**
Full-time	15	8	-	15	10	45
Part-time	86	175	-	43	8	211
Occasional	102	8	-	57	10	500
Total	203	191	45-65	115	28	756

* Source - EIA Reports, **Source - Yearly Progress Report (2055/56)

Reduction of riverine fisheries will influence the livelihood of many fishers. Professional full-time fishermen have to seek alternatives to fishing. Some may respond by migrating to new places. There will be intense competition for the permanent jobs created by the project. Social interactions between the local communities and power station employees will have both positive and negative impacts on the traditional culture and values of local communities. Public safety concern is a problem and it may include accidents from sudden peak releases downstream in the dry season. Flooding of land to create a new reservoir also leads to the need to relocate fisher families as well as a permanent loss of arable land and hence of agricultural production,. On the other hand, the relocated fisher families may be provided with electricity and perhaps receive some other benefits arising from the presence of the dam and the reservoir, such as development of local tourism, catering services, and the use of reservoir for fisheries.

4. RECOMMENDED MITIGATION MEASURES

Several measures have been suggested to mitigate the adverse impacts of a hydropower project.

4.1 Mitigations for weirs

4.1.1 Maintenance of flow level

There may be a dewatering effect downstream during the dry season due to the flow diversion and damming of the river. The effect is local and can be overcome to some extent by releasing compensation flow downstream. Compensation flow for the conservation of microflora, aquatic insects and fish in the dewatering zone should be within 10-20% of the regular flow. Regular releases of flushing flows will maintain quality of spawning gravel scouring fine sediments away. The compensation flow varies from river to river. Depending on the volume of water discharge, the recommended minimum compensation discharge ranges from 0.5-15 m^3/s in Nepal (Mewa: 0.5 m^3/s, Melamchi: 0.5-1.0 m^3/s, Likhu: 0.6 m^3/s, Budhiganga: 1.7 m^3/s, Tamur: 3.5 m^3/s, Dudhkoshi: 4.0 m^3/s, and Upper Karnali: 12-15 m^3/s). However, these are not standard figures that can be used everywhere and for all rivers globally. While compensation flow release is present in the plan, negligence in commitment was noted as in the Marsyangdi Hydropower Project.

4.1.2 Screens and fish exclusion devices

Entrapment of fish is a critical issue and some provision should be made to protect the fish against entrapment and impingement. Installation of appropriate screen devices at the intake will divert the fish from water intakes. Ideally, fish bypass facilities should be installed.

4.1.3 Fish passes

Fish passes are one of the most important remedies for assisting fish migration. They have been proved satisfactory for salmon in the northern temperate rivers, for cyprinids in the Tigris and Euphrates, and for *Tor* and Indian major carps in the Ganga. Hydropower projects of Nepal are generally established in areas of fish migration and fish passes are recommended to mitigate the barrier effect of the dam. A fish pass should meet the following criteria:

- it should be adapted to the requirements of the species concerned
- it should be of a pool type, rocky ramp type, or a vertical slot

- flow velocities must not exceed the swimming capacity of fish
- it should provide passage for all fish sizes - large and small,
- it should be provided with proper fencing, with total ban on fishing.

The more natural types of passes, e.g. rocky ramps or artifical rivers (bypass channels), can even enhance the beauty of the landscape.

In Nepal there are fish passes at the Koshi Barrage, also at Chandra Nahar, Andhi Khola, Gandak Barrage and Kankaimai. Some existing passes, for example at Andhi Khola, are poorly designed. This pass has inadequate through flow and attraction flow to pass large fish such as *Tor* and *Bagarius bagarius*, and the entrance is not well placed. To make it more efficient, this pass needs drastic improvement. Similarly the pass of the Kankaimai Project that is of pool and weir type needs to be improved. There are hundreds of good examples of well-designed and effective fish passes in the world. A fish pass needs to be tested for the known fish species migratory behaviour. The pass has to be monitored by fishery specialists. If the monitoring finds that fish do not use the fish pass, the pass has to be improved.

4.2 Mitigations for high dam reservoirs

4.2.1 Artificial destratification

Water quality may deteriorate with its storage. Releases of good quality water are required for maintaining well-functioning downstream aquatic habitats. Artificial destratification is one of the effective measures for maintaining a good quality of water in a reservoir which undergoes stratification. It requires a small amount of energy per unit volume to lift cooler bottom water to the surface of a stratified impoundment. This helps to mix water and to maintain uniform temperature and vertical distribution of dissolved oxygen.

4.2.2 Trapping and hauling

It involves trapping of fish below the dam and transporting them to the reservoir or further upstream to maintain fish diversity and gene pool. But it is labor intensive, prone to poaching by handlers and stressful to fish which increases their mortality. It also needs an appropriate location: facilities have to be designed at the earliest possible stage and well incorporated into the project – a later addition may be problematic or not possible at all.

4.2.3 Fish lift

In the Kali Gandaki dam a fish lift would have been technically feasible and would be more efficient than the planned fish stocking.

4.2.4 Development of fishery

Fish passes play an important role in the conservation of the native fish resource. The existing fish passes in Nepal are not satisfactory. At present preference is given to maintenance of spawning grounds and fish hatcheries as a means of enhancing the fish stocks affected by dams.

Maintenance of spawning grounds

Some resident fish such as stone roller (*G. gotyla*), stone loaches (*N. beavani*), catfish (*Glyptothorax pectinopterus*) and murrel (*C. punctatus*) utilise gravel bed areas for spawning. Considerable loss of spawning grounds of these species has taken place immediately below dams. Adequate attention must be given to the protection of the spawning and nursery gravel beds. Where needed, additional measures should be taken:

- depositing gravel to increase the spawning habitat
- manipulating angular and large boulders to create pools for spawning and as an escape cover for resident fish during low water levels
- using large boulders to alter the flow pattern downstream
- keeping gravel and boulders together to create spawning riffles to attract resident stock to rapids
- releasing flushing discharge to rewater exposed gravel beds to maintain spawning gravel quality
- enhancing the habitat by tree planting to increase shelter cover, shade and drift food.

Fish hatchery

A reservoir associated hatchery should produce seed of important native fish such as mahaseer, copper mahseer, snow trout, jalkapore and freshwater eel which are most affected by dam projects. Stocking the reservoir and tail water will replenish the losses resulting from the disappearance of the natural spawning grounds and from secession of migrations. The fishers should be provided seed from the government hatchery to grow fish in ponds to market size. This provides alternative means of subsistence and income, thus reducing the pressure of the capture fishery on native stocks.

Reservoir fishery

While regular fish stocking is one way of enhancing reservoir fish stocks, reservoir-based aquaculture is also a useful enhancement practice. Beveridge and Phillips (1988) reviewed the cage, pen and enclosure practices in reservoirs. In Nepal, a successful cage culture is being practiced in Trishuli and Kulekhani reservoirs where it provides income to the local fisher communities.

5. RECOMMENDATIONS

- Appropriate fish pass should be designed for a sustainable development of cold water fishery
- adequate attention should be given to the conservation of cold water fish to maintain their gene pool
- there should be a legal provision for discouraging illegal methods of fishing, such as the use of chemicals, dynamite, electrofishing and the use of small mesh-sized nets
- expansion of cold water aquaculture will help in reducing emigration of hill people and sustain livelihood of fisher communities
- development of sport fishery will enhance tourism and strengthen local and national income
- fish passage facilities should be incorporated in the hydroproject design at the earliest stage of planning

- provisions in the laws should be made to oblige power companies to pay for the most efficient mitigation measure and to prove its efficiency
- establishment of a regional cold water fish centre in Nepal would help in the conservation and development of cold water fishery in the Trans-Himalayan region.

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BREEDING OF POND REARED GOLDEN MAHSEER (*Tor putitora*) IN POKHARA, NEPAL

by

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ABSTRACT

Female golden mahseer (*T. putitora*) of 3-5 years old spawned without hormonal use when reared in ponds at the rate of 1 000 kg/ha with 30-40 percent crude protein supplementary feed. Males of more than 2+ years were maintained with similar feed. Ova from mature females were obtained by simple hand-stripping method. Out of 50 females only 4-6 percent released viable ova in April, August, September, October and November 2 000, while 12-16 percent of females responded in March and April 2001. Data on breeding of naturally mature brood collected from inlet streams of lakes revealed that golden mahseer could spawn in July, August, September and October. Breeding response studies of pond reared broodstock and data from the field (inlet streams of lakes) both showed that golden mahseer could breed most months of a year when water temperature ranged between 18.5 and 33°C. The present study indicates intermittent breeding characteristics of pond-reared golden mahseer. Females released 550 to 19 795 ova at single response. Most ova were successfully fertilized and hatched out. During bi-weekly breeder maturity examination in August-November 2000 and March-April 2001 much brood were found over-matured implying that breeders should be examined more frequently. We compared size of ova, larvae and fecundity (released ova/body weight of female) of golden mahseer with some cultivable carps. It seems that from the egg size and larval size point of view (energy investment in reproduction by the fish) fecundity is reasonable when compared to other species. This suggests that mass scale breeding of golden mahseer is possible by maintaining a reasonable number of broodstock for aquaculture development and restocking purposes.

1. INTRODUCTION

Golden mahseer (*Tor putitora*), one of the well-known large freshwater game fish of mountain rivers and lakes of most Trans-Himalayan countries, is reported to be declining in their natural habitats due to overfishing, and chemical and physical alterations of their habitats. Attempts to culture and conserve *Tor* spp have been initiated in most Trans-Himalayan countries (Joshi, 1994; Shrestha, 1997).

In general, knowledge and methodological development of breeding techniques are an essential part of commercial fish production in a closed system, however, milk fish (*Chanos chanos*) and mullet (*Mugil cephalus*) industries were solely dependent on natural spawning for maintaining their stocks (Bardach *et al*., 1972). Most fish in nature are specific to certain feeding and breeding grounds, which restricts their distribution to certain agro-ecological zones (Maitland and Morgan, 1997). Generally, fish breeding in hatcheries is done for commercial production, however, it seems that loss of particular fish habitat, threat to species due to multiple factors, and limited ability of fish to acclimatize in a specific environment or habitat could also offer impetus for scientific intervention to breed specific fish to maintain diversity. Golden mahseer (*T. putitora*) at present is one of such fish in most Trans-Himalayan waters due to their habitat loss and over fishing (Shrestha, 1997; Nautiyal, 1994).

Aquaculture production mostly depends on mass seed production, however, it seems that advantages of hatchery breeding could also be used to conserve fish in nature. Fish conservation is improvement and strengthening of population by safeguarding and restoring endangered species and habitat, while fish farming is a production process using established technical methodologies from breeding to rearing which may be specific for a particular species. If the above categorization is true, species that multiply under human control may not need much effort to conserve, as they can be transferred easily into suitable habitats. But developing a farming methodology for some desired species is not simple. If it were then conservation and commercial production of desirable species would be an easy task.

T. putitora is reported from most Trans-Himalayan countries ranging from Afghanistan to Myanmar (Skene-Dhu, 1923; MacDonald, 1948; Day, 1958; Desai, 1994; Khan *et al.*, 1994). Two species of mahseer, *T. putitora* and *T. tor* inhabit Nepalese torrential waters and lakes of mid hills (Shrestha, 1981; Shrestha, 1997). These can be differentiated by the longer head length in *T. putitora* than body depth (Shrestha, 1981). *T. putitora* is relatively abundant in lakes of Pokhara Valley. The body length of this species may reach more than 1.0 m and the weight about 45 kg (Shrestha, 1997), suggesting a high growth rate. Over the last two decades most Trans-Himalayan countries have reported declining populations of mahseer (*Tor* spp) due to overfishing, damming and degradation of the environment (Desai, 1994). This has led to efforts to conserve, manage and propagate the species (Pathani, 1981; Shrestha *et al.*, 1990; Azadi *et al.*, 1991; Shrestha, 1997), especially after the 1970s.

In the early 1960s *Tor* spp represented one of the major species in the commercial fishery in lakes of Pokhara Valley (Shrestha and Gurung, 1990). But at present they contribute negligibly to the total catch (Swar and Gurung, 1988; Wagle and Bista, 1999). It is possible that effects of overfishing, environmental degradation, sedimentation, destruction of spawning grounds, non-conventional fishing methods, or all of these factors have caused the low yields (Shrestha, 1997). In Nepal, since mahseer is present in cool waters of mid hills and the inner Terai region of the country (Gurung and Wagle, 2000), conservation, management, and propagation were carried in water bodies close to two research centers: Pokhara and Trishuli, located in mid-hills. Shrestha (1994, 1997) contributed substantially to the knowledge on *T. putitora* in Nepal.

To enhance fishery and aquaculture, over a number of years investigations for developing a propagation method for *T. putitora* have been carried out in most of the Trans-Himalayan countries. This has led to a better knowledge of spawning biology, ecological aspects and behavior of *T. putitora* in its natural habitats (Tripathi, 1978; Masuda and Bastola, 1987; Shrestha, 1994; Kulkarni, 1980; Joshi, 1994; Nautiyal, 1994). While the natural, semi-natural, and stimulatory spawning techniques of *T. putitora* are known, there is no standardised breeding method for mass seed production of the species in captivity. MacDonald (1948) was the first to mention that "…. Mahseer is said to spawn three times in a season". Similarly, Desai (1994) noted breeding of mahseer from July to March in the Narmada River, Madhya Pradesh, India. Pathani (1983) suggested at least four spawning events on the basis of four types of egg diameter and stages of development in mature ovary of mahseer. Most authors agreed that mahseer is a partial spawner due to the low number of released eggs during a single spawning event (Joshi, 1994; Shrestha, 1997; Shrestha *et al.*, 1990). The partial or intermittent spawning could be used to conserve and develop fishery of the species by restoring its natural habitat as fish sanctuaries, while successes in captive breeding could be useful for aquaculture production of the species.

This paper discusses the breeding of pond reared mahseer and its intermittent spawning, summarizing the results of many years experience with breeding of this species in Nepal.

2. MATERIAL AND METHODS

Preliminary work on breeding of the species has been carried out in Pokhara and elsewhere in Nepal since the early 1960s. Spawning of golden mahseer (*T. putitora*) collected as mature broodfish from lakes started around 1982 in Lake Phewa with the objective of maintaining pure strains. Later this work was followed by Nakamura (1987), Shrestha *et al.* (1990), Morimoto *et al.* (1995) and Baidya *et al.* (2000) using different methods of mahseer breeding.

At the beginning mature males (0.3-3.4 kg body weight) and females (3-6.1 kg body weight) were collected at night at inlet streams using gill nets (50-125mm mesh, knot-less monofilament and trammel nets) in Lake Phewa and Begnas during mahseer upward migration in the pre- to post-monsoon season (June-October). Mature females were stripped and fertilized with milt obtained from mature males. Fertilized eggs were transported to hatcheries for incubation.

2.1 Study area and habitats

Study area is the lakes of Pokhara Valley in Kaski, Nepal (Fig. 1). Most field experiments were conducted near inlet streams of Lake Phewa and Lake Begnas. Indoor experiments were conducted in the Fisheries Research Centre, Pokhara.

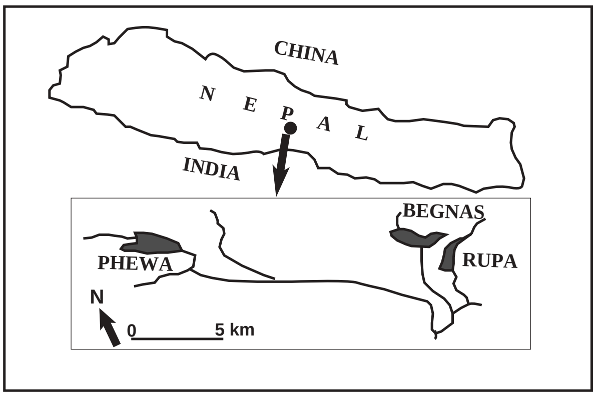

Fig. 1 - Map showing lakes in Pokhara Valley: natural spawning sites of mahseer (*Tor* spp)

<u>*Lake Phewa*</u>: Lake Phewa (742 m a.s.l.) is the largest (523 ha) and deepest (max. depth 24m) among all lakes in Pokhara Valley. Surface area, water volume, maximum and average depths of the lake are 5.23 km^2, 39.32 x 10^6 tons, 24 m and 7.5 m, respectively. However, the water surface area of the lake has shrunken and an island near the inlet stream has appeared due to silt deposition. Harpan Khola is the main perennial inlet stream feeding the lake. Harpan Khola is one of the best-known spawning spots of mahseer (*Tor* spp). Annual water temperature in this lake fluctuates between 14-29°C.

<u>*Lake Begnas*</u>: This is a medium-sized lake of approximately 323 ha situated at 700 m a.s.l. The main breeding ground of mahseer (*Tor* spp) is known to be in Syangkhudi Khola, which is perennial inlet stream of the lake. Water temperature in this lake ranges from 14.5 to 31.0°C.

2.2 Breeding of pond-reared broodstock

To examine breeding responses of golden mahseer in captivity we carried out experiments with artificial diet (Baidya *et al.*, 2000). For response studies *T. putitora* of F2 generation (F1 is considered those mature fish collected from Begnas Lake) were grown in controlled condition. For this, females of approximately 700-2 500g-body weight and 3-5 years age were stocked at the rate of 1 000 kg ha^{-1} in 2 ponds of 0.05 ha water surface area each. Broodstock fish were fed with 30-40% protein diets. The feeding rate was 4% of total body weight (Table 1). In broodstock ponds temperature and dissolved oxygen were measured every morning by YSI oxygen meter.

Table 1
Stocking density and feeding rate for broodstock of *T. putitora* in ponds

Description	Pond 1	Pond 2
Area (m^3)	500	500
Stocking density	1 000 kg/ha	1 000 kg/ha
Stocking No & BW	25,	25,
Feeding rate (of BW)	4%	4%
PH	7-9	7-9
DO (mg/L)	3-9	3-8.4
Depth (cm)	70-90	70-90
Transparency (cm)	30-50	30-50

From March to November 2000, female breeders were checked at biweekly intervals for maturity by applying gentle pressure by hand near the genital opening after partial anesthetization in 50 ppm Benzocain solution. Females releasing ova on slightest pressure were transported inside hatcheries, then anaesthetized and stripped gently to receive ova in a clean and dry bowl.

Milt from healthy males was gently mixed by feather with ova for dry fertilization. Eggs were weighed and counted, then washed with clean water as is commonly performed with other carps. This process of washing was repeated several times. Eggs were incubated for hatching in mesh trays in running water. The fertilized eggs in incubation trays were covered with black plastic screen. The rate of water flow in incubation trays was maintained at 4-5 L/minute. Dead eggs were counted and removed every day with a wooden fork to protect the eggs from fungal infection. After 3-5 days, hatching started and was completed within 48-72 hours. Early hatched larvae possessed large yolk sacs and settled down in corners of incubation trays. After attaining free-swimming stage the larvae were transferred into a tank of 2.5m x 0.40m x 0.30m dimension. Supplementary feed (microbinded feed) was fed to hatchlings after yolk sac absorption. Advanced fry were fed with zooplankton screened through a plankton net.

3. RESULTS

The techniques of *T. putitora* breeding gradually developed from stripping naturally mature brood collected in lakes to rearing of broods in pond conditions (Fig. 2). The use of sex hormone to induce spawning was also tested (Tripathi, 1978). The compilation of spawning data showed that golden mahseer could breed in most months of the year (Fig. 2). Since pond reared females were not examined in December and January, it is not yet clear whether they could breed in these months or not. Results showed that *T. putitora* could spawn from March to November at a water temperature ranging from 19.5 to 35°C (Fig. 3 and 4).

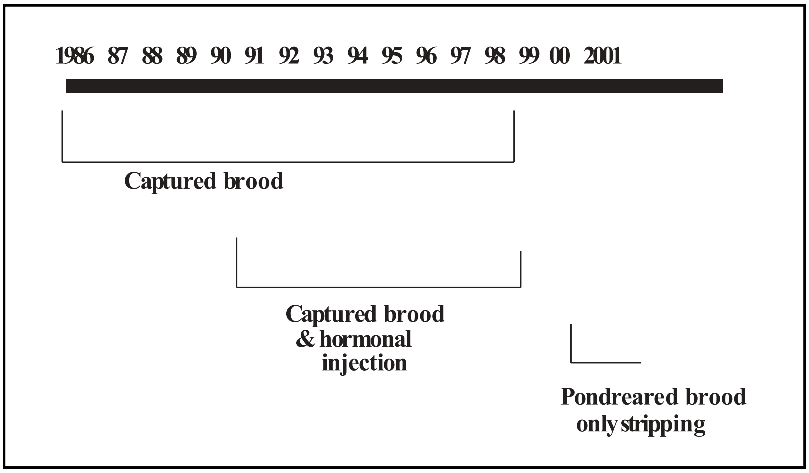

Fig. 2 - Methodological progression of obtaining mahseer broodstock from lakes and rivers and breeding it in ponds

Water temperature in ponds, where golden mahseer were reared, varied from 14.5 to 33°C at 6-7 am (Fig. 4). However, water temperature in summer reached up to 37°C, and pH values ranged 6.6 to 8.8 and dissolved oxygen from 4 to 8 mg/L (Table 1).

The spawning size of female mahseer ranged from 780 to 1985 g in body weight. These released 535-19 795 yellowish brown ova depending on size and maturity stages when hand-stripping method was used (Fig. 5). During maturity examination 90-95% population was seined from experimental ponds. Usually, most females were found over-matured and only a few were at the right stage for releasing viable ova. Over-mature females were identified as those releasing degenerated ova, which turned opaque soon after fertilization, or releasing orange fluid at slight pressure on abdomen. Orange fluid turned white when it came in contact with water.

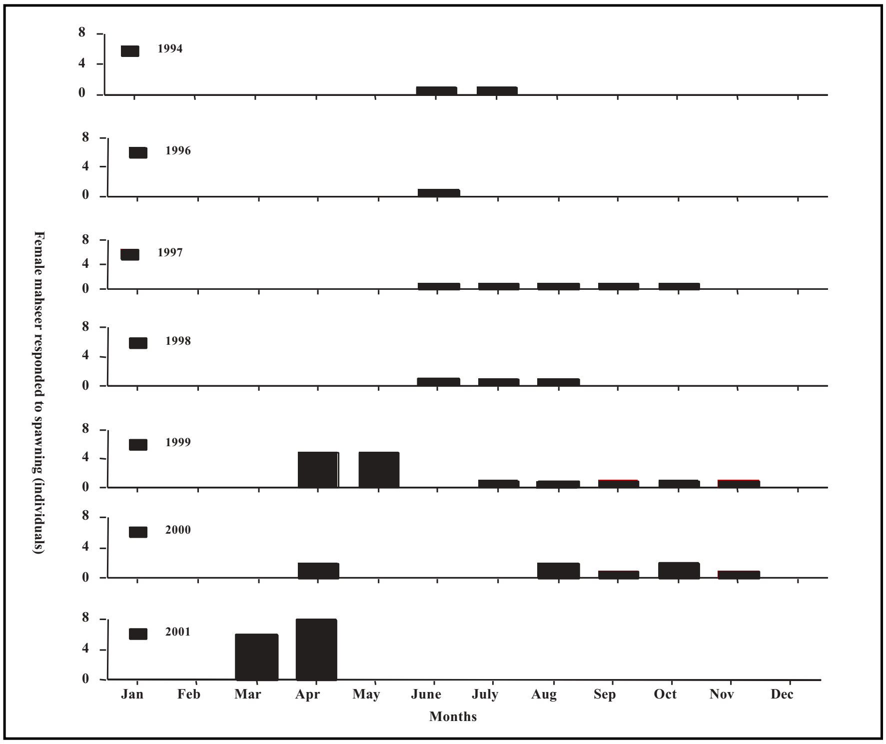

Fig. 3 - Response of mahseer (*Tor putitora*) in different months showing intermittent breeding

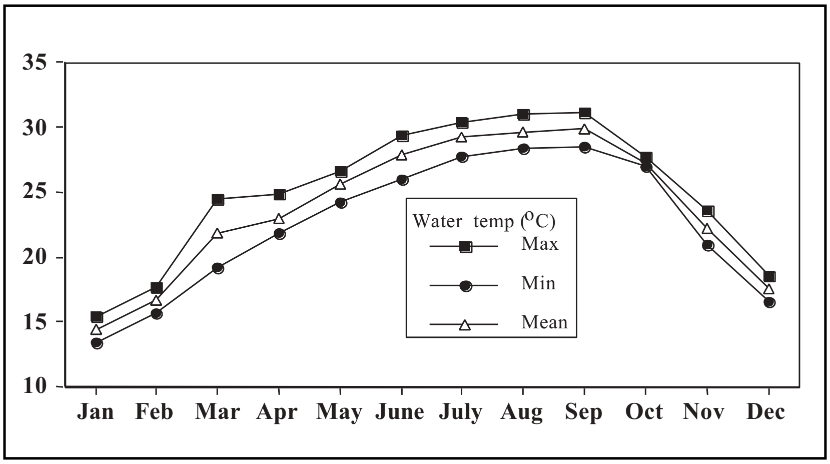

Fig. 4 - Seasonal changes in water temperature in golden mahseer rearing pond

Eggs were incubated in Atkin's incubators by allowing one layer of eggs on single mesh screen in flow through system. Water flow was maintained at a discharge rate of 6-8 L/min. Dead eggs were removed using forceps without touching other eggs. The dead eggs if not removed became infected with fungus (*Saprolegnia*) which could spread rapidly to the adjacent healthy eggs.

Hatchability of eggs ranged from 0 to 98% (Fig. 5). Fertilized eggs of mahseer also swelled slightly. The diameter of fertilized eggs ranged from 2.8 to 3.02 mm. Incubation period was 45-125 hours at water temperature between 19 and 28°C showing that hatching time is dependent on water temperature.

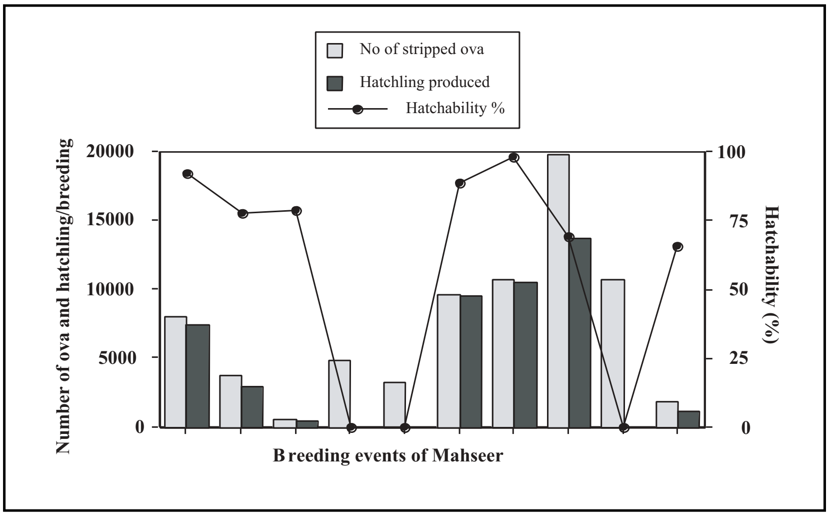

Fig. 5 - Number of ova, hatchlings produced and percentage hatchability in pond-reared golden mahseer (*T. putitora*) in different breeding events

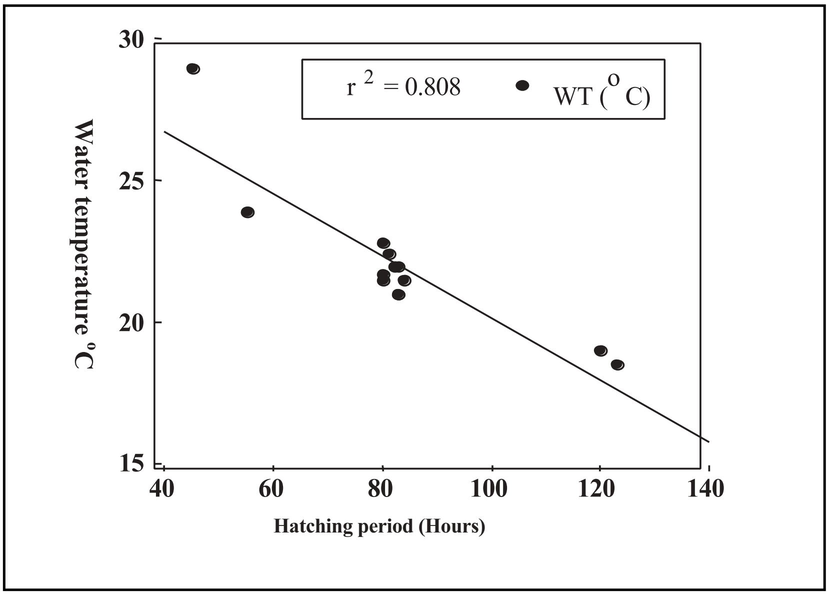

Fig. 6 - Relationship between hatching period and incubation water temperature

Even with the small set of the present data set the relationship between water temperature and hatching time (Fig. 6) showed substantial correlation (r^2=0.808).

The hatched larvae hatched on mesh net had a large yolk sac. Usually absorption of the yolk sac took 3-4 days depending on water temperature. Hatched larvae remain on the same mesh net until complete absorption of the yolk sac and attaining free swimming stage. At this stage mean larval length was 12.5 mm (Fig. 7).

4. DISCUSSION

The present study demonstrates that golden mahseer (*T. putitora*) do not breed only in pre- to post- monsoon period, but also in March and November when water temperature reaches 19°C. This implies that mahseer could breed in most months of the year. The present study suggests the possibility of mass seed production of *T. putitora*, though they might breed intermittently. The breeding responses between March-November imply that at least single brood might respond twice in a year. Giving support to this is the multiple spawning of the common carp (*Cyprinus carpio*) 3-5 times a year (Horvath 1978; Gurung *et al.*, 1993). Recent studies have also shown that grass carp (*Ctenopharyngodon idella*) can breed twice a year, and *Catla catla* four times a year (Rath *et al.*, 1999).

This study showed that pond reared golden mahseer could breed at 19.5-33°C from March to November by simple hand stripping without any hormone use and brood loss. This also demonstrated that golden mahseer brood could be reared like other carps such as *C. carpio,* Chinese and Indian major carps (Table 1). Interestingly, surface water temperature in experimental ponds exceeds 37°C in summer. Successful breeding in such waters without any apparent negative effects suggests their high acclimatization capabilities.

Spawning of mahseer mostly was dependent on collection of naturally mature broodstock from lakes (Morimoto *et al.*, 1995). However, attempts were also made to study the possibilities of reproduction in captivity by using sex hormones (Shrestha *et al.*, 1990; Baidya *et al.*, 2000) as it is practiced with the Chinese and Indian major carps (Chondar, 1994). Several studies reported successful breeding of mahaseer (*Tor* spp) by stimulating breeders by use of sex hormones (Tripathi, 1978; Shrestha, 1990; Joshi, 1994) showing possibilities of maturation of gonads by using sex hormones. However, the present study revealed that to breed mahseer the use of hormone is unnecessary, if breeders are managed using present methods.

At the beginning of our investigations mahseer broodstock collected from lakes (F1 generation) were wild, shy and hesitant to take supplementary feed. However, these problems were overcome by mahseer of F2 generation onwards. At present golden mahseer consume supplied feed as voraciously as *C. carpio* in captivity, suggesting that wild stock have been domesticated in captive conditions.

Most breeders showed over-mature ova during routine checks, which implied that broodstock should be examined more frequently. Over mature females were recognized as those releasing ova with 100% mortality soon after fertilization; or degenerating ova, which become thick orange watery fluid oozing through the vent when slightly pressed. Such over-matured females were obtained even when fish were examined biweekly during the peak season in March-April. Usually such over matured breeders releases more ova. Breeding of golden mahseer was examined in December and January when water temperature in ponds ranged from 16 to 18°C.

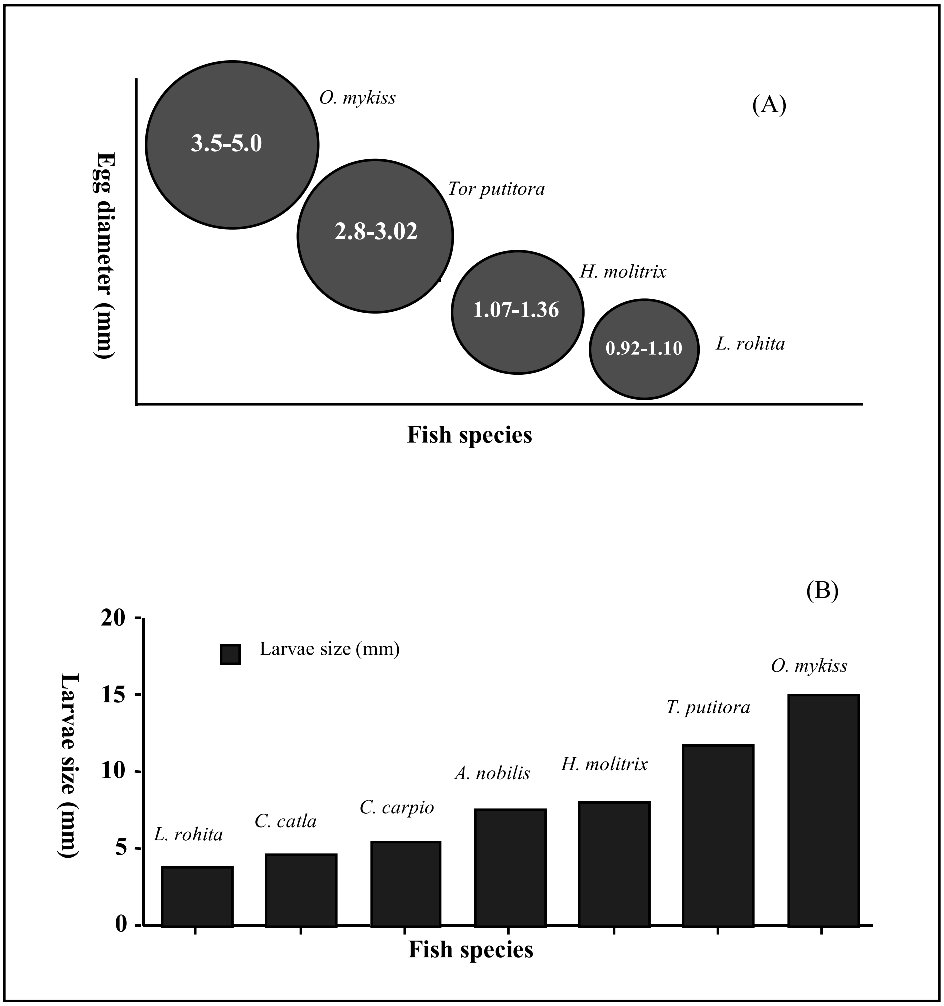

Fig. 7 - Egg diameter (A) and larval size (B) of different fish
(Source: Bardach *et al.* (1972); Jhingran and Pullin (1985); Huet (1972); Jhingran (1991)

Male mahseer larger than 100g could release milt throughout the year, indicating that males could be used for breeding more frequently, if mature female could be found. Such trends in other exotic carps such as bighead carp and silver carp are not recorded. They release milt only for a short time and soon loose their secondary sexual characters such as roughness of their pectoral fins and body after the breeding period is over.

It is yet to be demonstrated how many times a single female mahseer could attain sexual maturity in one year. The present study has reconfirmed that golden mahseer is a partial breeder as pointed out by Skene–Dhu (1923) seven decades ago. When we considered intermittent characteristics of golden mahseer, and compared the number, size, incubation period of eggs and larval size in relation to other species (Fig. 7A, B), the general trend suggests that fish possessing fewer eggs release relatively large ova; for example rainbow trout (*Oncorhynchus mykiss*) possess largest ova and lowest fecundity among all compared presently. In contrast, smaller ova bearers produce numerous ova, such as the Indian major carps *Labeo rohita* and *Cirrhinus mrigala*. Generally, incubation time for hatching and temperature were also related to egg size. Smaller eggs require relatively shorter incubation period but higher water temperature, while larger eggs require long incubation time but low water temperature. When golden mahseer is evaluated, the size of eggs, larvae, time for incubation and water temperature fall into intermediate category: fish spawning only once in a year release few ova if large, and numerous if they are small. Ova of mahseer are of moderate size therefore it seems that fecundity of golden mahseer is justified from energy investment in ova production.

In the present study stocking density of golden mahseer in ponds was kept lower than usual. For example carp broods are usually kept at a density of 2 000 kg/ha (Jhingran and Pullin, 1985). Mahseer broods were well fed with 30-40% protein-containing feed, thus it is possible that they had opportunity to consume natural food in ponds due to their low density. Thus abundant nutritious diet might have caused repeated sexual maturity in mahseer and intermittent breeding in pond condition. It is usually recommended that for successive development of reproductive cells it is essential to provide nutritious feed to brood fish (Horvath, 1972; Gurung *et al.*, 1993). In the present response study male and female mahseer were reared separately. It could be that separation of sexes could lead to an increased potency in mahseer for breeding. Such trend is known for *Cyprinus carpio* where with onset of summer male and female common carp are separated, which facilitates deposition and development of ova in female breeders (Gurung *et al.*, 1993). If male and female common carp are reared together usually such broods lack zest for breeding. It could be that naturally collected golden mahseer breeders responded to breeding only once in the monsoon season.

Mahseer have been well studied for their sport fishery values (Skene-Dhu, 1923; McDonald, 1942). Naturally these fish prefer fast flowing rivers and mountain lakes with clean water, high transparency and high dissolved oxygen content. In Nepalese rivers mahseer inhabit mid hills and inner Terai (Shrestha, 1997). Shrestha (1997) was breeding golden mahseer using mature male and female collected from the Tadi River at Trishuli.

The collection of naturally gravid broodstock and their spawning success showed that golden mahseer in Central Nepal breed during monsoon in inlet streams of lakes, when water temperature ranges from 26-30°C. Their collection is rigorous and labour intensive. The declining population of mahseer in natural habitats is a concern in most of the Trans-Himalayan countries. While it is important to have a good breeding technology, in-situ conservation and restoration of natural populations is also important. In rivers and lakes wherever mahseer spawn, their stocks could be enhanced by strict regulation of fishing and by restocking through community participation. In those countries where breeding technology has not yet been fully developed, habitat conservation of mahseer should be a priority.

Acknowledgements

This paper is dedicated to planners, scientists, technicians and administrators who have helped to promote mahseer in the past several years, and directly or indirectly assisted with the present study. We are thankful to all the staff at the Pokhara Fisheries Research Centre and the Trishuli Fisheries Research Centre for their kind cooperation for providing up-to-date information on mahseer. We are indebted to JICA for providing facilities and support to studies on mahseer.

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AQUACULTURE IN BANGLADESH: PROSPECT OF HIGH DENSITY MIXED CULTURE OF FISH WITH LOW COST DIETS

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ABSTRACT

To find out the maximum production potential of pond based aquaculture using low-cost diets on mono and mixed culture of three selected species experiments were conducted for a period of 18 months. Nine miniponds were used for monoculture of catfish (*Pangasius sutchi*), silver barb, (*Barbodes gonionotus*) and Genetically Improved Farmed Tilapia (GIFT), with three replications. Three other miniponds were used for mixed culture of the three above-mentioned fish. Initially, specific numbers of fish were stocked in miniponds and daily a mixture of low-cost supplemental feeds were applied to each group of ponds. Production of natural food in the investigated ponds was promoted to minimize supplemental feeding. Partial harvests of both stocked fish and newly produced ones were done periodically. Low-cost feed included pellets, mustard oil cake, wheat bran and rice bran with the same proportions (25%) for each trial. For the whole period of culture 1.5 m depth and deep green water colour were maintained by occasional intake or discharge of water and periodic fertilization. Two groups of fish, silver barb and GIFT, produced numerous new individuals both in mono and mixed culture. Cumulative total fish biomass production in each trial varied from 16.1 to 31.6 tons/ha with a feed conversion rate of 20.1 to 24.4% within the investigated period of 18 months. However, the projected feed conversion rate for a 12-month period was 31.0 to 50.4%. A huge cumulative amount of supplementary feed utilization (57.1 - 134.4 tons/ha/18 months) and high level of both plankton and fish biomass occasionally lowered the dissolved oxygen level to 0.7 mg/L but caused no fish mortality. So-called black soil formation at pond bottom was also minimal. The high level of fish biomass production resulted from the round-the-year equal water depth, presence of copious green algae, no fish mortality, negligible deoxygenation of the sediment resulting from the continuous stirring up of sediments by fish, and the ability of all three fish species to gulp air at the surface when the dissolved oxygen concentration declined.

1. INTRODUCTION

Tilapia (*Oreochromis mossambicus*) was introduced to Bangladesh from Thailand in 1954 (Rahman, 1985). It was expected at that time that tilapia would act as a miracle fish in aquaculture. While tilapias breed several times a year and depend mostly on vegetative food, their distribution and culture among rural farmers has not been as popular as expected. Gradually, nilotica (*O. niloticus) and* red tilapia (a mutant of *O. niloticus* x *O. mossambicus)* were imported to Bangladesh from Thailand (Gupta *et al*., 1992). Genetically Improved Farmed Tilapia strain known as GIFT (Eknath *et al*., 1993) was introduced to Bangladesh by ICLARM and BFRI during 1994. GIFT has now become a popular fish among farmers. Likewise, Thai silver barb (*Barbodes gonionotus*) and catfish (*Pangasius sutchi*) entered Bangladesh during 1985 and 1988, respectively, and soon became popular aquaculture species.

Seed production of these three species is easy. GIFT and silver barb naturally breed in closed water bodies. Seasonal water fluctuation in culture ponds due to seepage, and evaporation and turbidity during culture time is a problem in pond-based aquaculture. In view of the 21st century perspective, a minipond complex was constructed at the Marine Fisheries and Technology Station (MFTS), Cox's Bazar on sandy soils using concrete walls and polythene bottom laying (Hossain *et al*., 1994). The structural design made it possible to maintain water depth to a desirable level the year round and effectively stopped seepage and turbidity problems. Once water level and turbidity level stabilized natural productivity of the ponds dramatically improved and it is now possible to maintain rich phytoplankton for a long time with little initial fertilization.

Experimentally, mass production of both tilapia and GIFT as live food for sea bass showed very high rate of biomass production in miniponds with low-cost diets. Similarly, silver barb and Thai catfish production in those miniponds also showed a fairly high rate of biomass production (Hossain *et al*., 1999).

Next, an attempt was made to find out maximum production of these species individually and collectively using low-cost diets under pond-based aquaculture. Attention was focused on maximum utilization of natural productivity, and a low level of supplemental feeds was applied. The experiment was conducted for a period of 18 months and arrangements were made to discard or add water when necessary.

Twelve miniponds, each having identical size (200 m^2), depth (1.6 m) and standard bottom conditions (30 cm sand layer on polythene) were used. Three fish species were reared on a monoculture basis in different groups and a mixed culture using all three species in another group. To simplify management, a certain amount of daily supplemental feeds was allotted for each group for a 2-month period. Cummulative harvesting followed and at the end of the experiment, ponds were drained and harvested.

2. MATERIAL AND METHODS

Miniponds

12 miniponds out of 42 at MFTS were used. As mentioned earlier these ponds were identical in size, and constructed on totally sandy soil. Pond bottoms were level, underlaid by polythene. On polythene, a 30 cm layer of sand was deposited. Length, width and height of the miniponds were 25.0, 8.0 and 1.6 m, respectively. Water holding capacity of each minipond was roughly 320 tons. Each minipond was exactly 1/50th of a hectare. The 12 ponds were divided into 4 groups of 3 ponds each.

Pond preparation

Before starting the experiment all ponds were drained, the bottom dried and sand agitated. Calcium carbonate at a rate of 5 kg/pond (250 kg/ha) was mixed with bottom soil. Then the ponds were filled with ground water, and the water was fertilized with urea, TSP and potash at a rate of 1.0, 1.5 and 0.5 kg/pond, respectively (50, 75 and 25 kg/ha). Initially, some green water was pumped from the nearby ponds to each of the experimental ponds with the help of a submergible pump. When water turned deep green, fish were stocked.

Fish

Three species were used. GIFT juveniles were produced at the Freshwater Station of the BFRI with joint collaboration of ICLARM, who delivered them to the MFTS in 1996. Several successive generations were produced at MFTS. Adult fish of 80-100 g were used in the experiment. Each of three ponds were stocked with 100 GIFT. Silver barb juveniles raised to adult stage at MFTS were also used. 100 silver barb with a body weight range of 100-150g were stocked in each pond of a group. Similarly, catfish raised to 350-400 g using high density culture, were used in another group at a rate of 100 fish/pond. The remaining of 3 ponds were each stocked with a mixture of the 3 species (a total of 100 fish in each pond). All fish were stocked at the beginning of April, 1999. Stocking particulars are shown in Table 1.

Table 1
Details on stocking each pond of a group

	Monoculture			**Mixed culture**		
	Silver barb	**GIFT**	**Catfish**	**Silver barb**	**GIFT**	**Catfish**
No. of fish	100	100	100	100	100	100
Av. wt. of fish (g)	119.5	91.2	368.0	115.2	85.3	361.0
Male/female ratio	40:60	50:50	-	40:60	50:50	-
Water transparency (cm)	21	22	21	20	22	23
Total fish biomass (kg)	11.95	9.12	36.8	11.52	8.53	36.1

<u>Feed</u>
Four types of feeds were mixed together for each pond. The mixture consisted of commercial pellets (Saudi-Bangla Fish Feed Ltd.), mustard oil cake, rice bran and wheat bran. The feeds were mixed together for a couple of days, and divided into 12 parts and stored in medium plastic containers for each pond. In the container the feeds were dry, but before application to ponds a portion of water was mixed to give it a semi-solid form. Fish in ponds were fed twice daily.

<u>Feed ration</u>
To minimize the use of supplemental feeding and to encourage fish to depend on natural foods produced in the ponds, a strict feed ration was followed as shown in Table 2. The feed ration was modified for each two-month period and the daily ration was strictly maintained to avoid management problems.

<u>Rearing</u>
The culture continued for an 18-month period. Care was taken to maintain identical water level in each pond through inspections. This was ensured by pumping ground water through a pipeline network when the water level went down. During rains, excess water was automatically discarded through piped outlets connected to a drain. Outlets were guarded by nets to prevent fish from escaping. After stocking of fish, a current was occasionally produced in the ponds having silver barb to induce them to breed in captivity. For this purpose water was pumped and a part of it was then discarded from the ponds through outlets. Twice a day, a fixed amount of supplemental feed was provided to each group as shown in Table 2. Identical amount of feed was supplied in each pond of a group. Water quality parameters, such as temperature, transparency, pH, and dissolved oxygen levels in ponds, were recorded from time to time. Whenever transparency of water rose above 25 cm, water was fertilized by urea and TSP (50 percent of the initial dose given during the pond preparation).

Table 2
Feed ration given to each pond of a group (kg/day)

Period in months	Monoculture			Mixed culture
	Silver barb	GIFT	Catfish	
0-2	0.5	0.5	1.0	2.0
2-4	1.0	1.0	1.5	3.0
4-6	1.0	2.0	2.0	4.0
6-8	1.5	3.0	2.5	4.5
8-10	2.0	3.5	3.0	5.0
10-12	2.5	4.0	3.5	5.5
12-14	3.0	4.5	4.0	6.0
14-16	3.5	5.0	4.5	7.0
16-18	4.0	6.0	5.0	7.5
0-18 Total (kg)	1 142.0	1 773.0	1 624.0	2 688.0

Water quality analysis

Temperature was recorded by ordinary thermometer, pH by digital pH meter, water transparency by Secchi disc and DO by Hach kit. After 10-11 months of rearing, when the biomass of fish increased rapidly, DO was measured more frequently in the early mornings.

Non-target fish

Ponds designated for silver barb or catfish were invaded by GIFT, which were periodically harvested using seine net. Total weight of non-target fish harvested from each pond was recorded separately. Harvested fingerlings were weighed and their numbers were estimated. To get rid of non-target fish from ponds, dry feed particles were scattered to lure the fish to the surface and the fish were harvested into a fine mesh seine net.

Harvesting

Cumulative harvesting was done in 3 groups of ponds where numerous fry were found. Fingerlings and fry, specially those of GIFT and silver barb, were harvested 3-12 months after stocking. After 12 months there was no selective harvesting. The final harvest was done at the end of the 18-month period. Catfish were partially harvested at the end of 12 months both in mono and mixed culture groups. In mixed culture groups 25% of catfish were harvested before the final harvest. At the end of the experiment, all ponds were drained and all fish harvested. Fish harvested from each pond during the culture period or at the end of the experiment were recorded separately after weighing. To estimate the projected fish biomass in each pond of a group within a 12-month period, fish harvested from July 1999 to March 2000 were recorded and no further harvest during 13-18 months was done (Table 3). The projected figure includes actual harvest till the 12th month and an estimated quantity of fish remaining in each pond thereafter. Projected production/year is presented in Table 6.

Table 3
Cumulative harvest of fish from each pond of a group (average)

	Monoculture			Mixed culture		
	Silver barb	**GIFT**	**Catfish**	**Silver barb**	**GIFT**	**Catfish**
Selective harvest a. No of f ry	27 500	58 000	-	8 900	31 500	-
b. Wt. of fry (kg)	12.4	29.0	-	4.6	15.8	-
c. Wt. of juveniles (kg)	78.5*	118.7	62.7*	38.7	71.2	-
d. Wt. of adult fish (kg)	58.0*	91.2	77.5*	35.0	52.3	48.7
Final harvest (kg)	139.1* (7.0)	203.4 (10.2)	234.5* (11.7)	75. 8 (3.8)	117.5 (5.9)	172.8 (8.6)
Av. total fish biomass pond (kg)	288.0	442.3	374.7		632.4	
Av. production t/ha	14.4	22.1	18.7		31.6	

- included significant number of non-targeted species, mostly GIFT.

Figure in parenthesis indicates final harvest, t/ha

Apparent conversion

Conversion rate based on supplemental feed applied to each pond was calculated on basis of net weight gained by fish at the end of experiment and the total amount of feed utilized. Conversion rate of feed was calculated from the ratio of total feed supplied and net weight gained by fish as percentage. Projected conversion rate for a 12-month period was also calculated.

3. RESULTS

3.1 Natural fish food production in ponds

Liming of bottom soil with calcium carbonate ($CaCO_3$) and initial fertilization of water by urea (TSP) and potash created a plankton boom within 15 days in all ponds. As shown in Table 1, during stocking of ponds with fish, transparency levels were 20-23 cm only. On the other hand, when ponds were filled with ground water, the bottom of each pond was almost visible. During the whole period of culture, the colour of pond water remained deep green. During the initial 2-4 months, ponds were occasionally fertilized, especially when the water transparency exceeded 25 cm. After 4 months no fertilization was needed. The color of water indicated a high level of phytoplankton in all ponds during the whole period of investigations.

During partial harvesting and when bottom soil was examined to find out whether any so-called black soil formed at the bottom, surprisingly, no black soil was detected. Black soil formation at the end of the 18-month period was negligible in all ponds except those used for catfish monoculture, where a small amount of black soil was visible after the final harvest. A cumulative high level of supplemental feeds 1142 - 2688 kg/pond (57.1-134.4 tons/ha) as shown in Table 4, and absence of black soil indicated the energy budget in the pond ecosystem was also enriched with detritus-based food. Feed conversion rate or feed efficiency shown in Table 4 does not include natural food produced in the pond and ultimately consumed by fish.

Table 4
Gross and net production of fish biomass and feed efficiency

	Monoculture			**Mixed culture**
	Silver barb	**GIFT**	**Catfish**	**3 species together**
Gross production (kg)	288.0	442.3	374.7	632.0
Stocking biomass (kg)	11.95	9.12	36.80	56.12
Net production (kg)	276.05	433.18	337.9	575.88
Feed consumed wet wt. basis (kg)	1 142 (57.1)	1 773 (88.7)	1 624 (81.2)	2 688 (134.4)
Apparent feed efficiency (%)	24.2	24.4	20.8	21.4

Figure in parentheses shows amount of feed used, t/ha

3.2 Fish production in ponds

The average gross production of fish biomass in the 4 groups ranged from 288.0 - 632.4 kg/pond (Table 3). Highest average production of 632.4 kg/pond was recorded in the mixed culture group which corresponds to 31.6 tons/ha. Out of the total fish biomass produced in the mixed group silver barb, GIFT and catfish represented 24.4, 40.6 and 35.0 %, respectively. In this group no fish were listed as non-target species (Table 5) as both GIFT and silver barb were stocked in this group, whereas GIFT found in the silver barb group and vice-versa were listed as non-target species. The biomass of non-target species found in ponds was also included in the respective groups as they grew and took nutrition from those ponds. Size variations of GIFT and silver barb were remarkable, some GIFT were more than a kilogram in weight, some were tiny. The largest silver barb was 1369 g. Size variation in catfish was not so much although some individuals were more than 3 kg and some were slightly over 1 kg in body weight. The second highest production of fish biomass was recorded in monoculture of GIFT. An average 442.3 kg/pond (22.1 tons/ha) were harvested from this group within the 18-month period (Table 3). Final harvest for this group was 203.4 kg/pond, which represented GIFT of various sizes, some fish as big as 1125g and some smaller than 5g. The ponds designated for monoculture of catfish or silver-barb were heavily invaded by GIFT (Table 5), but presence of non-target species in GIFT ponds was minimal. Only an average of 10.6 kg of silver barb were present per pond, out of an average biomass production of 442.3 kg/pond during the 18-month period (Table 5). Monoculture of catfish yielded a cumulative biomass production of 374.7 kg/pond (18.74 tons/ha). However, some non-target species, especially GIFT, were found in the group which occupied 23.3% of the total biomass production. Biomass production from catfish alone was 287.4 kg/pond (14.4 tons/ha) as shown in Table 5.

Table 5
Fish biomass production based on target and non-target species (kg)

	Monoculture			**Mixed culture**
	Silver barb	**GIFT**	**Catfish**	
Total production (kg)	288.0 (14.40)	442.3 (22.12)	374.7 (18.74)	632.4 (31.62)
Target species (kg)	234.3 (11.72)	431.7 (21.59)	287.4 (14.37)	-
Non-target species (kg)	53.7 (2.69)	10.6 (0.53)	87.3 (4.67)	-

Figure in parentheses shows calculated production, t/ha

The lowest biomass of fish among the 4 groups was obtained in monoculture of the silver barb group. Gross production of the fish biomass was 288.0 kg/pond (14.4 t/ha). As already mentioned GIFT somehow entered all ponds of this group and average biomass from GIFT was recorded as 53.7 kg/pond. Therefore, production of silver barb alone was 11.72 tons/ha (234.3 kg/pond).

3.3 Feed efficiency

A cumulative total of 2688 kg of feed was used in each pond of the mixed species group (Table 4). The average production of fish was 632.0 kg/pond (gross weight). The initial stocking biomass of all 3 species in this group was 56.12 kg on average. Therefore, net biomass production stood at 575.88 kg/pond/18 month. The resultant feed efficiency was 21.4%, which means 4.7 kg of supplemental feeding were necessary to raise 1 kg of fish in this group. Feed efficiency was 20.8% for catfish, 24.4% for GIFT and 24.2% for silver barb. The apparent feed efficiency may be considered low when natural food production in ponds is taken in consideration. Here, it may be mentioned that initial stocking weight, especially that of catfish, was high (350 g or more), and the stocked biomass was also high, which reduced the apparent feed efficiency.

Projected production of fish and feed efficiencies 12 months from the beginning of experiment are summarized in Table 6. Projected feed efficiency varied from 31.0 to 50.4% when net fish biomass produced and the feed consumed during that period are considered. This feed efficiency is also apparent as natural foods produced in ponds were also utilized by fish.

3.4 Water quality parameters

Temperature throughout the investigation period ranged between 18.0 and 32.5°C (higher than in the nearby earthen ponds), pH was 7.9-9.0, dissolved oxygen (DO) level varied from 0.7 to 8.0 mg/L. Transparency in pond water varied from 25-45 cm throughout the investigation, after stocking fish.

Table 6
Projected production of fish and feed efficiency after 12 months

	Monoculture			Mixed culture		
	Silver barb	**GIFT**	**Catfish**	**Silver barb**	**GIFT**	**Catfish**
Biomass (kg) Actual harvest	148.9	238.9	140.2	78.3	139.3	48.7
Estimate of fish in pond	120.0	150.0	150.0	40.0	50.0	146.1
Gross total (kg)	268.9	388.9	290.2	118.3	184.3	194.8
					502.4	
Stocking biomass (kg)	11.95	9.12	36.80		5 6.12	
Net total (kg)	256.95	379.78	253.4		446.28	
Feed consumed (kg)	510.0	840.0	810.0	-	1 440.0	
Feed efficiency (%)	50.4	45.2	31.2	-	31.0	

3.5 Seed production in pond

Initial stocking numbers of GIFT and silver barb were deliberately kept low (5 000 fish/ha) in mixed and monoculture as these species breed in confined water. Initially little flow of water in ponds stocked with silver barb in mono or mixed culture induced silver barb to produce numerous fry. GIFT reproduced throughout the rearing period. Even an accidental entry of GIFT in the pond with monoculture of silver barb and catfish resulted in a high number of fry of GIFT. The fry of GIFT and silver barb were routinely harvested using fine meshed nets. Total biomass of fry and juveniles and their estimated numbers were recorded whenever those were harvested. This is shown in Table 3. The total number of fry harvested from monoculture of silver barb and GIFT were 27 500 and 58 000 on average, respectively. 40 400 fry of silver barb and GIFT were collected from the mixed group.

3.6 Behavior of fish during culture

Throughout the investigation period of 18 months no fish were fed to satiation except during the initial 2 months when it was difficult to determine the satiation level as fish seldom surfaced to take feed. After 2-3 months of rearing fish in all ponds were observed to come to the surface whenever supplemental feed was administered. Even catfish used to take feed from hand after 12-13 months of regular feeding. Broadcasting of dried feed on the surface of a pond always lured fish, especially fry and juveniles, to the surface, which helped selective harvesting. No feed remained uneaten when occasionally the daily ration of feed was placed on a feed tray made of mosquito net and steel frame, and placed on the pond bottom. Experimentally, feed was mixed with sand and placed on a feed tray, and it was found that fish plough the sand to find feed particles when the tray is placed at the bottom of the pond. When DO went below 1.5 mg/L level, all species were seen to gulp at the surface. Gulping of GIFT and silver barb was frequent. Catfish, unlike the other two species, used to come to the surface and soon dived after a quick gulp.

4. DISCUSSION

The experiment was conducted for a long period to find maximum production of fish under pond-based aquaculture utilizing low cost feed. In this respect, the trial was highly successful. Over 30 tons/ha/18months was recorded using low-cost supplemental feeds with 3 popular culture species together when a cumulative harvesting process was followed. In the investigation standing crop in a given time was not that high. At the end of investigation the highest standing crop in mixed culture was 366.1 kg (18.3 tons/ha) as shown in Table 3 (mixed: 75.8 + 117.5 + 172.8 kg, yield from final harvest). Besides, catfish and GIFT individually registered 234.5 kg/pond (11.73 tons/ha) and 203 kg/pond (10.2 tons/ha) on a monoculture basis when final harvest was made at the end of the experiment. The results indicate 10-12 ton of GIFT or catfish may be produced per year using low cost diets if species are cultured separately. When fed rice bran as supplemental feeding with 5-6% of estimated biomass, GIFT yielded an average gross production of 4 411 kg/ha/6 months. Culture of catfish (*P. sutchi*) with a stocking density of 12 500/ha fed on 100% pellets (same brand as used in this investigation) gave 11.4 tons/ha/10 months which also included 9.8% of non-target fish mostly tilapia, in an abandoned coastal farm initially used for semi-intensive cultivation of tiger shrimps (AFL, personal communication, 1999). Mixed culture of silver barb, GIFT and catfish may yield 18 tons/ha/year as was found in this investigation based on final harvest as standing crop (Table 3) or more than 25.1 tons/ha (502.4 kg/pond) based on projected production per year (Table 6). As for silver barb, final harvest gave 139.1 kg/pond (7.0 tons/ha) which also included some GIFT. Hussain *et al.* (1989) registered a production of 1952 kg/ha/5 months of silver barb feeding on rice bran with a stocking density of 1600/ha, where no fry was produced during the culture time.

Projected production within a year shows much higher rate of yield (Table 6). This is because a selective harvesting process was followed while rearing was in progress, and fish, especially silver barb and GIFT, renewed both their number and loss in biomass. Natarajan (1985) reported on the production of tilapia (*O. niloticus*) stocked at high density (70 000; 140 000; and 210 000/ha) in tanks manured with poultry manure. He found that total fish production (including fry) was highest at the lowest density. The maximum production was 39.3 kg/ha/day and minimum of 32.1kg/ha/day. Sariz and Arieli (1980) reported highest 25.0 tons/ha/200 days production of tilapia when oil-coated pellets were fed, with a stocking density of 100 000/ha. In case of standing crop the final harvest figure (Table 3) may be the limit under low-cost supplemental feeding in pond-based aquaculture.

The feed used in this investigation was a commercial pellet (Bangladesh Taka 19.00 - 20.00/kg), mustarded oil cake (Tk. 8.00 - 9.00/kg), rice bran (Tk. 4.00 - 5.00/kg) and wheat bran (Tk. 5.00 - 6.00/kg). Therefore, average cost of feed per kg was Tk. 9.00 - 10.00. The apparent conversion rate was 20.8 - 24.2%, which means roughly 4.1 to 4.8 kg of low-cost feed is necessary to raise one kilogram of fish. For a high density culture this cost may be viable if we consider the high price of the marketed fish. But if the culture period is shortened, feed efficiency will increase. This experiment was conducted to maximize the production to find out the potential of high biomass production under semi-controlled conditions. If projected production found in mixed culture within 12 months is considered, both feed efficiency and production rate tend to increase. Production rate of fish initially was very high compared to that of a later stage in terms of supplemental feed supplied. At the later stage of culture most of the feeds were utilized to sustain the standing biomass, not for its increase. Continued selective harvesting could have led to a better fish production during 12 - 18 months.

Most interesting in this experiment was that no reared fish died when the level of dissolved oxygen was low (0.7 mg/L) and that there was almost no accumulation of organic debris at the bottom of ponds in spite of the exceptionally high amount of cumulative supplemental feeding (134 t/ha/18 months) given during the 18 months of mixed culture. As all the test animals used in this experiment had gulping abilities, no mortality was observed. All three species used in this experiment had a habit of stirring up the bottom deposit.

The level of daily supplemental feeding in this experiment was kept deliberately low, which probably encouraged fish to continuously stir the bottom in search of food, thus agitating the bottom soil. This process helped to mineralize the accumulated organic material and encouraged plankton growth. That there was no need for fertilization to enhance plankton growth after 2-3 months of fish stocking was probably due to the fertility being recycled. The continuously high level of plankton in culture, which was indicated by richly green water during the investigation period, was due to the presence of the green alga *Chlorella*. *Chlorella* cannot be eaten by any fish employed in this investigation due to its size.

It may be concluded that the high fish biomass production in this investigation was possible due to the stability of the system, including undisturbed water volume, a continuously high level of natural food production, rational supplemental feeding, gulping and stirring abilities of the fish species used in this study.

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DOMESTICATION OF WILD GOLDEN MAHSEER (*Tor putitora*) AND HATCHERY OPERATION

by

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ABSTRACT

Wild breeders of golden mahseer (*Tor putitora*), both males and females, which since 1989 have been domesticated in a large earthen pond (0.10 ha) regulated with running water, were transferred to an earthen pond (0.08 ha) at the Fisheries Research Centre, Trishuli, from 2 February to 9 April 1993. There the feeding rate was 2 percent of the body weight and feeding frequency was once a day. The fish responded to hand stripping for the first time on 6 April 1993 without any hormonal injection. The operation has continued since then without any problem. Hatchery operation of wild breeders became easier with their increasing age of domestication. Eggs were artificially fertilized; mean fecundity was 3 048 eggs per kg body weight. The diameter of eggs varied from 2.65 to 2.85 mm and the eggs hatched 3-5 days after being incubated depending upon temperature variations from 19 to 26°C. At hatching the total length and weight of alevins averaged 9.9 mm and 9.6 mg respectively. The fertility rate was excellent, over 90 percent, and the hatchability was equally good ranging from 75 to 77 percent. Alevins became free swimming fry 6-7 days after hatching. The success of hatchery operation of golden mahseer is an indication that it is possible to restore the endangered species. It has widened the possibility of reintroduction of hatchery-reared progeny in the wild and culture of the species.

1. INTRODUCTION

Golden mahseer (*Tor putitora*) are found in most of the south Asian countries including Nepal, India, Bangladesh, Pakistan, Afganistan, Sri Lanka, Myanmar. This popular game fish attains over 50 kg (Thapa, 1994). The population of this fish has been declining because of overfishing, also using destructive fishing methods such as electrofishing and poisoning, and because of the degradation of aquatic environment. India has already identified this fish as endangered (Shrestha, 1988a). Nepal and some other countries are in a stage of enlisting the fish as an endangered species. Strict application of the Aquatic Act and regular restocking of natural water bodies with appropriately sized mahseer can revive their stocks. A joint effort of restocking this migratory fish in the respective water bodies in the region can help to restore their stocks, and all countries should join a programme to revive the fish stocks in the lakes and rivers of their own. Nepal, India and Bangladesh have been attempting to develop large scale seed production technology of mahseer. Information on breeding of golden mahseer is readily available (Tripathi *et al*., 1977; Pathani and Das, 1979; Masuda and Banstola, 1984; Joshi, 1984; Shrestha 1987, 1988; Shrestha *et al*., 1990; Sehgal, 1991), but information on domestication of wild broodstock and its hatchery production is scanty (Ogale, this volume). The old practice has been to rear the wild mahseer in captivity. Brood fish grown in captivity can produce the required quantity of seed. Masuda and Banstola (1980) did not foresee the possibility of growing the wild breeders to sexual maturity in captivity. Shrestha (1990) believes that mahseer do not breed in stagnant reservoirs where water circulation is poor. However, the wild breeders grown in earthen ponds, not supplied with running water, attain sexual maturity and exhibit sexual play with the male chasing the female making a loop during the spawning time. The fish spawn twice a year. Its first spawning in April/May is followed by the second one in August/September. Males grown in captivity but it is difficult to sort out females just ready to spawn. This study describes the hatchery operation of wild golden mahseer reared in an earthen pond.

2. MATERIAL AND METHODS

The study was carried out at the Fisheries Research Centre, Trishuli, from 2 February to 9 April 1993. Ten wild breeders including six males and four females stocked in an earthen pond of 0.10 ha were transferred to a smaller pond of 0.08ha on 2 February 1993. Wild breeders collected from the Trishuli River and its tributaries had been domesticated in the earthen pond and exposed to running water (<22°C) all year around since 1989. The females sorted out for breeding belonged to different age groups, all being more than five years old. The experimental pond, which had a mean depth of 1.25m, was stocked with fish at a rate of 500 kg/ha. It was manured with 50 kg dried cow dung mixed with 2 kg triple superphosphate every fifteen days. The fish were given 35 percent protein content pellet feed (Table 1) at a rate of 2 percent of their body weight.

Table 1
Feed ingredients and the composition of pellets fed to golden mahseer in 1993

Ingredients	Proportions
Soybean	35
Fish meal	20
Wheat flour	12
Corn	10
Rice bran	12
Oil cake	09
Vitamins	01
Minerals	01

The feeding frequency was once daily. Temperature, pH (glass electrode), total alkalinity, dissolved oxygen (Winkler method) and Secchi disc transparency were checked once a week. The fish were checked for ripeness; next day they were circling at the water surface. Breeders which extruded eggs or milt upon gentle pressure on the abdomen were selected as the best ones. Mature males and females were rushed to the hatchery and anaesthesized with benzocain. Their total length and body weight were measured to obtain condition factor. Females were caught by their flanks, wiped dry with soft cloth before the eggs were stripped into a pre-weighed clean and dry plastic bowl. The males were gently stroked from upside down to squeeze out milt. A few drops of watery milt were discarded and the rest collected into a clean and dried beaker. Nearly 2 ml of milt was spread over eggs collected from each individual female. The eggs were gently stirred with avian feather to complete fertilisation. A small quantity of spring water was added, eggs gently stirred and washed for about 5 minutes to prevent clumping. The milky water was poured out and fresh water added, and the process was repeated until the eggs were cleansed of milt.

After hardening (about 10 minutes) eggs were poured on screen trays of the size 33cm x 33cm. Screen trays were then tied tightly keeping one on the top of the other and placed in a glass fibre incubation apparatus (215cm x 35cm x 36cm) slanted at 30 degree to the incoming water. Eggs were incubated with spring water and spring water mixed with river water in the incubation apparatus, with water flow at a rate of 2 litres per second. Water temperature was measured four times a day to determine incubation period. The developing eggs were covered with black cloth to protect them against light. Dead eggs dull in color or attacked with fungus were removed 24 hours after the commencement of incubation.

3. RESULTS AND DISCUSSION

Water quality in the breeding pond of golden mahsee at the Fisheries Research Centre, Trishuli, was regularly assessed during the period February-April 1993. Water temperature in the pond remained below 20°C in February and was higher than 20°C in the spring, reaching up to 22.9°C. Carps are reported to feed best at 20-25°C (Woynarovich, 1975). pH values, initially 6.5, gradually increased to 8.8. Reproduction diminishes at pH values below 6.5 (Mount, 1973). Waters with high alkalinity tend to be more strongly buffered than waters with low alkalinity (Boyd, 1979). Total alkalinity measured as $CaCO_3$ in the pond supplied with Trishuli river water, ranged from 27.4 to 39.5 mg/L. Natural waters, which have total alkalinity of 40 mg/L as $CaCO_3$, are considered to be hard waters, which are generally more productive than soft waters (Moyle, 1946). Dissolved oxygen concentration was more than 5 mg/L throughout the experimental period. It is undesirable to have dissolved oxygen below 5.0 mg/L in the fish pond (Swingle, 1969). Secchi disc transparency ranged between 47.2 cm and 32.8 cm. The visibilities depended on the concentration of planktonic organisms.

Males and females of golden mahseer did not exhibit any variation in color during spawning time. Mature males had prominent tubercles on opercula and front paired fins. Females did not show any spawning features except a slightly swollen soft belly. Two ripe females responded to hand stripping on 6 April 1993. It was the first time the wild breeders reared in captivity spawned without any hormonal injection. These domesticated fish were never known before to spawn when they were subjected to hand stripping every year during spawning season. It seemed wild breeders of mahseer attained sexual maturity in captivity with increasing time of domestication. The diameter of sinking type eggs ranged from 2.65 to 2.85 mm. Eggs incubated at varied temperatures resulted in excellent fertility (over 90%) and hatchability was equally good ranging from 75 to 77 percent (Table 2).

The rate of fertilization and hatching rate were reported to range from 34-100 percent (Joshi 1982, 1986; Joshi and Malkani, 1986; Sehgal, 1991) and 90-97 percent (Shrestha *et al*., 1990; Sehgal, 1991), respectively. Eggs fertilized on 6 April 1993 were dark orange in colour. Two more spawners, which did not respond to hand stripping three days before, extruded over-mature eggs just three days later on 9 April 1993. Over-mature eggs were faint yellow in colour. This may mean that the fish has a very short spawning period, may be less than a week. It is advisable to check the readiness of the breeders in the spawning time at least twice a week if not alternate days. Hatching started after 72 hours and was completed in 108 hours based on temperature differences (Table 2). Usually, incubation hours decrease with the increasing water temperature. But there was controversy in the incubation hours reported by different authors (Masuda and Banstola, 1984; Joshi and Malkani, 1986; Shrestha, 1987; Shrestha *et al*., 1990; Sehgal, 1991; Tripathi, 1977). Alevins became to free swimming fry 6-7 days after hatching. Mortality from alevins to fry was as high as 63%. The survival rate of alevins to fry was reported over 90 percent by Shrestha *et al*. (1990) at 29-30°C. Higher mortality of sac fry might be associated with lower incubation temperature. Walker (1968) found that a higher mortality and weak larvae resulted from an abnormally low hatchery water temperature.

Table 2
The average time between fertilization and hatching of wild golden mahseer reared in captivity at the Fisheries Research Centre, Trishuli

Year 1993	Male		Female		No of eggs Released	Fertility (%)	Hatchability (%)	Average water temperature (°c)	Incubation period	Water Source
	Total length (cm)	Body weight (kg)	Total length (cm)	Body weight (kg)						
6 April	69	3.0	70	3.0	8 580	95	75	19.1-20.7	102-108	spring water mixed with river water
6 April	73	3.3	85	6.0	26 500	93	77	21.1-25.7	72- 75	
9 April	58	1.35	49	1.6	4 618 over ripe	nil	nil			spring water
9 April	62	2.5	67	4.9	9 955 over ripe	nil	nil			

From 1993 onward the wild breeders reared in captivity have been responding to hand stripping every year either in April/May or in August/September, their spawning seasons. Next year the same breeding pond stocked with four mature males of a mean weight of 3.5 kg and two ripe females averaging 5.2 kg, showed a lot of young fry on 12 May nearly a month after being stocked**.** Unyil May none of the females extruded eggs in spite of repeated checking for readiness until May. On 19 July 1994 when over 1 500 fingerlings of a mean weight of 5.2 g were seen in the same pond with some circular nesting pits in the marginal region. The diameter of the pits ranged from 15 to 20 cm. This may mean that mahseer spawn naturally in a pond under favorable conditions. This finding of natural breeding in captivity and the success of hatchery operation are an indication that there is hope for restoring this endangered species. The successful breeding operation of mahseer will provide stocking material for open waters as well as for aquaculture.

The number of eggs stripped from individual females differed with size and age (Table 3). The number of eggs increased directly with increase in body weight and age of fish. The condition factor remained highest during the spawning season (Khanna, 1989). But the fecundity per kg body weight did not increase proportionately with increase in condition factor (Table 3).

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Mean fecundity remained 3 048 eggs per kg body weight. The fecundity per kg body weight of wild ripe breeders ranged from 3 375 to 8 944 eggs (Das, 1984; Nautiyal and Lal, 1985). A little bit lower fecundity of the captive females might be caused by stress, not being well domesticated.

Table 3
Eggs released by wild golden mahseer reared in captivity, their condition factor and fecundity per kg body weight

Date	Female		No of eggs released	Condition factor	Fecundity /kg body weight
	Total length (cm)	Body weight (kg)			
6 April 1993	70	3.0	8 580	0.87	2 860
6 April 1993	85	6.0	26 500	0.97	4 417
9 April 1993	49	1.6	4 618	1.34	2 886
9 April 1993	67	4.9	9 955	1.63	2 032

4. CONCLUSIONS

Well domesticated wild breeders and young mahseer grown to maturity in captivity can be used for breeding without hormonal injection. The fish also spawn naturally in stagnant ponds and no running water is necessary for their gonadal development. The gonadal development is delayed when the broodstock is exposed to cold water, lower than 17°C for a long time (Martyshev, 1983). It is to be confirmed whether the same fish spawn twice a year or not. The spawning time differs a little bit from country to country depending upon climatic conditions. In Nepal the fish spawn from April/May to August/September. The success of breeding promises that it will be possible to produce stocking material under fish farm conditions both for open waters as well as for aquaculture, and to restore this endangered species in open waters. As the fish needs water temperature above 15°C to breed and can withstand temperature above 30-35°C it should not be called a cold water fish but rather a warm water fish (FAO, 1997). .

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ECONOMICS OF RAINBOW TROUT FARMING SYSTEM IN NEPAL

by

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ABSTRACT

Rainbow trout (*Oncorhynchus mykiss*) was first introduced in Nepal in the late 1960s and early 1970s from the United Kingdom, Japan and India, and was re-introduced from Japan in 1988. Now the breeding and culture technology of rainbow trout is well developed. The cost analysis of rainbow trout in this paper has been done on the basis of feed efficiency (50 percent) and feed conversion ratio (FCR) (2:1), as a result of experiments conducted at the Fisheries Research Station (FRS), Trishuli in 1997. There was no significant difference (P>0.05) in feed efficiency, FCR, survival rate and specific growth rate among and within experimental treatments where 70 g fish were grown to 161 g. Our study indicates that the application of prevailing technology can produce 100–200 t/ha in a 14-15 month period, starting with free-swimming larvae, but depending on water supply and culture practices and quality of the feed. Economic analysis of the production is based on the data collected from the FRS Trishuli and a small-scale private farm. Applying the data from the private farm, total costs including capital cost and consumption allowances give a very satisfactory result. The result shows that it costs about NRs 255 to produce one kilogram of trout, which is selling for NRs 300/kg. The analysis gives a profit of NRs 45/kg of fish and gives 19.5% rate of return on initial cost. The rate of return on operating cost is 17.6 percent. It shows that rainbow trout would be a profitable export if produced commercially.

1. INTRODUCTION

Fish production in Nepal is confined to inland waters including ponds, lakes, reservoirs and rivers. The southern Terai region of the country is the main area for warm water aquaculture. Aquaculture of common carp, Chinese carps and Indian major carps substantially increased from 1 150 tons to 15 023 tons from 1979 to 2000 (DOFD, 2001). However, cold water fish culture in the mid hills is at the very beginnings although a few ventures show that it is a profitable enterprise. Rainbow trout is the best suited exotic fish for growing commercially in mid-hills of Nepal. The culture technology and seed of rainbow trout are available in the country.

Rainbow trout (*Oncorhynchus mykiss*) was introduced to Nepal for the first time in the late 1960s and early 1970s from UK, Japan and India. It could not survive due to the lack of technical know-how and was re-introduced from Japan in 1988. During this period, the Nepal Agricultural Research Council developed the breeding and culture technology for this species. Rainbow trout is a carnivorous species which requires high protein feed and well oxygenated water. In nature it feeds on aquatic insects, small crustaceans and small fish. It can be cultured using artificial feed of no less than 20 to 30 percent of animal protein.
Rainbow trout is able to live within a temperature range of 0-25°C and it grows at the water temperature range of 10–20°C. The fish reaches commercial size (200-300 g) during the

second year (Huet, 1975). In Trishuli, Nepal, it reaches 200-300 g within 14–15 months from the free-swimming larval stage (FRS, Trishuli), depending on the quality of the feed, adequate supply of water of suitable quality, including a suitable temperature and dissolved oxygen concentration.

Rainbow trout was bred for the first time in Nepal in 1990 and its culture was initiated experimentally in 1993. Present trout production is more than 10 metric tons annually from two government stations, and about 2-3 metric tons from the private sector. Mr. Purna Bahadur Lama from Kakani Village Development Committee-4 of Nuwakot District is the first private trout culturist in Nepal. He started rainbow trout culture in 1998 on a trial basis. Presently, he has been growing 10 000–12 000 fingerlings of rainbow trout each year in an area of 136 m^2.

The main objective of this paper is to provide information on the economics of trout production in Nepal and it's potential for future expansion in the private sector.

Two Fisheries Research Stations, Godawari and Trishuli, under the Nepal Agricultural Research Council (NARC) are raising rainbow trout from eggs to adults and vice versa. Both stations are culturing the fish in concrete raceway ponds. As a source of water, spring water at Godawari and river (glacier and snow melt) water at Trishuli are used. The total area of ponds for trout culture at Godawari is nearly 300 m^2. Trishuli station has about 2 000 m^2 surface water area for trout farming of which about 1200 m^2 has been used for grow-out fish and the rest for broodstock of trout as well as for native fish species.

Presently, three private farmers including Mr. Lama from Nuwakot district and one farmer from Parbat culture trout. This is a positive sign in the development of trout aquaculture entrepreneurship. They can produce 4-5 tons of trout annually under present conditions. Some new areas are being surveyed to find out suitable sites for trout aquaculture. Water of the Modi Khola (Parbat), Khimti (Dolakha), Khokundol (Sindhupalchowk), Naubise (Dhading) have been found suitable, but sites for raceway construction still need to be identified.

2. BASIC REQUIREMENTS FOR TROUT CULTURE

2.1 Sites suitable for trout culture

A major constraint for expansion of trout culture is the availability of adequate year-round supply of water of required quality. A survey of year-round water quality and of water volume fluctuations should be carried out beforehand to know the conditions. If the water temperature remains in a suitable range for less than 6 months, the growth rate of rainbow trout will be very poor and the farm will not be commercially viable (Yamaha, 1991).

Another key factor is the land site, where ponds and hatchery are to be constructed. The soil should retain water and be suitable for concrete construction. Slope of the land should be 1-3 percent and should not be very steep, to permit an adequate flow of water. In addition, electricity supply and access by road are very important factors in site selection.

2.2 Water quality and quantity

The primary requirement for trout culture is an abundant supply of clean and cold water. Rainbow trout culture requires a permanent supply of water with a temperature range of 10 to

20°C, and optimum temperature of 15-18°C (Yamazaki, 1991). The water should be clear, not turbid. A pH value of 6.5 - 8.0 and dissolved oxygen above 8 mg/L are considered suitable for trout culture (Huet, 1975). Calcareous water is preferable (Leitritz, 1963). Water supply of at least 5 L/sec is necessary to produce a ton of trout, although less may be sufficient, when temperature decreases (Pillay, 1993). The quantity of water depends on the water quality, farming system and culture techniques.

FRS Trishuli has confirmed that water temperature range of 10-20°C is suitable for rainbow trout culture, if volume of supply is adequate and the water has a level of dissolved oxygen (DO) of 7-10 mg/L. Spring water is recommended for rearing alevins up to swim-up stage, because its temperature is warmer than that of a river. If the temperature of spring water is higher than 20°C it lowers the concentration of DO, therefore it should be mixed with cold water of snow and ice melt origin to adjust the temperature and DO. Water temperature should never exceed more than 23°C for rainbow trout culture (Sedgwick, 1985). Trout should not be kept for longer period in water temperature above 21°C as it stops feeding. It also stops feeding at temperatures les than 10°C. Sedgwick (1985) reported that a temperature of 18°C is regarded as the optimum for metabolism in rainbow trout. Higher temperature would assist higher level of metabolism and growth as well.

3. TROUT FARMING AND GROW-OUT TECHNOLOGY

Two systems are used. In full farming system trout are raised from the young stage to adults and there is a hatchery for breeding and fry production. A partial farming system grows advanced fingerlings to market size fish. A full farming system needs a heavy initial investment. The grow-out trout farm needs feeding tanks, fry growing ponds, feed store and residential and service accommodations.

3.1 Hatchery

Size, capacity and the type of hatchery depend on the quality and quantity of water and demand for fry to produce the table fish. Silt-free, clean and cold water are necessary in the hatchery for incubation of eggs and rearing of the fry. Spring water is recommended for rearing alevins up to swim-up stage, as it has warmer temperature than rivers fed by snow and ice melt. According to Pillay (1993), spring water may sometime have high dissolved iron content and can precipitate iron in the hatchery as a result of bacterial action and settle on eggs or the gills of fry. Such water should be avoided or treated to remove the iron before use.

For the purpose of incubation, Atkin’s incubation apparatus has been used at FRS Trishuli. This apparatus includes 5 compartments and each compartment is of 36 cm x 35 cm, with a height of 36+4 cm, having total length 215 cm, with bottom to the top water flow system in each compartment. Screen trays size of 33 cm x 33 cm are used, with a height of 3 cm or more, if there is no problem with silt in water. Water flow close to 20 L/min is sufficient to incubate about 100 000 eggs. Hatching and feeding tanks may be 55 cm wide, 35 cm in height and 250 cm long for rearing the fry before transferring them to nursery or raceway ponds. Outlet can be fixed with a movable pipe of “L” type to adjust the water depth. This equipment can be made from fiberglass or galvanized sheet. Normally fry are kept 10-12 weeks under controlled conditions with careful feeding and inside the hatchery to protect them against infections and diseases.

3.2 Ponds

Culture ponds must have good circulation of water as well as to be easy to clean. The shape of the pond is variable from elongated rectangle type to circular type and irregular type. However, the elongated rectangular type involves low construction cost and efficient use of water and is easy to clean compared to any other type of ponds (Yamaha, 1991). Feeding tanks may be made of fiberglass. Fiberglass or concrete cement feeding tanks of the dimensions 4 m x 0.9 m x 0.5 m (with a depth of 0.3 m) can hold 1 ton of water. Such a tank can hold 15-20 thousand fry (Joshi and Westlund Lofvall, 1996). The ponds are not necessarily always made of concrete. Construction of concrete ponds involves a heavy initial investment. Relatively cheaper and simple tanks can be made flat or circular from galvanized corrugated iron sheet. The iron surface should be periodically painted with bitumen coat to prevent rusting and seepage. Trout can grow in earthen ponds too, but water should not be turbid.

Raceway ponds are basically of two types: a linear type with ponds arranged in sequence and a lateral type with ponds laid out in parallel (Fig 1).

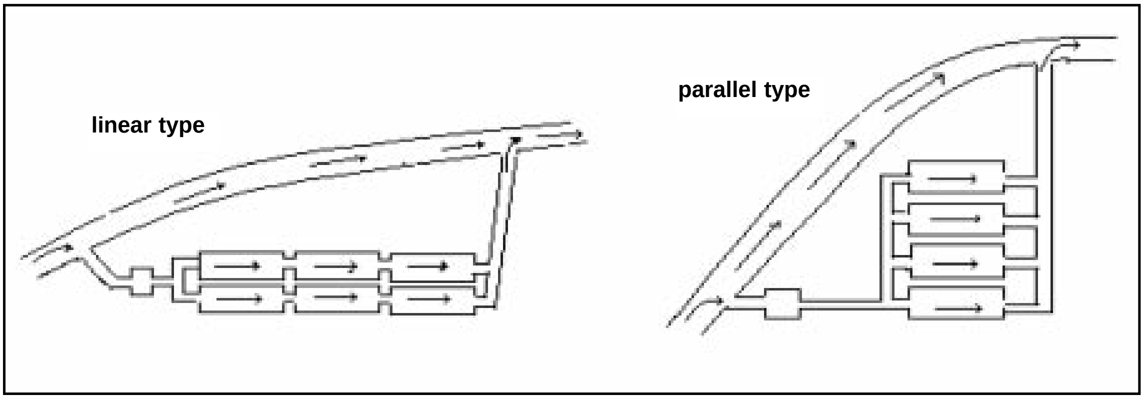

Fig. 1 - The position of ponds and water flow

In a linear type the volume of water entering each pond is larger and gives a better use of water within ponds. As the same water is used repeatedly from pond to pond, contamination of disease in initial ponds may directly affect the other connected ponds. Conversely, in a lateral or parallel type the volume of water entering each pond is smaller but a fresh supply of water is always ensured, and no contamination of disease from one pond to another takes place.

It is better to construct the raceway ponds rectangular with sufficient slope for grow-out. If the area of individual ponds is too small, it inhibits production, whereas if it is too large it becomes inconvenient from the standpoint of daily operations and maintenance. Generally, bigger than 100 m^2 ponds are not suitable for the areas where silt and sediment are a big problem like in Trishuli. Grow-out ponds for the fry with an area of 10-50 m^2, and for grow-out/market size fish pond with an area of 50-150 m^2, with a length of 5-10 m and 10-20 m, respectively, are considered suitable. But the size can be made narrower with a suitable length for easy cleaning in the case of higher silt content in water. The ratio of the bottom slope from both sides to the center and from inlet to outlet is preferably 2-3%. The appropriate depth for the ponds, considering water circulating capabilities and operational aspects, is about 50 cm for fry ponds and 60-90 cm for rearing ponds or grow-out ponds. When the ponds are too deep, the water tends to run along the upper layer, and water circulation in the bottom layer is poor. In case of earthen ponds water depth must be maintained at about 1 m to reduce the turbidity produced by fish contacting the bottom.

3.3 Stocking density

Stocking density is dependent more on the volume of water supply, temperature and oxygen concentration in water than the actual size of pond. Very fast running water is also not desirable. If the current is too fast, fish energy might be used more for swimming instead of growth. On the other hand slow current results in the accumulation of wastes. Water flow must be increased in summer when water temperature is higher and dissolved oxygen lower than in winter. Joshi and Westlund Lofvall (1996) recommended that as a rule of thumb water current should be sufficient to provide at least one complete exchange of water per one or two hours in the pond.

A well managed farm should be able to sustain 10 kg/m^2 of fingerlings. In general a pond with a flow of 1 m^3 of water per minute can support annual production of 1-2 tons of rainbow trout in Nepal. In a pond supplied with sufficient fresh water and quality feed, enough young fry can be stocked to give production of 20 kg/m^2 (200 t/ha). 70 g fish as initial weight, at 15 kg/m^2 should be able to produce about 32 kg/m^2 of fish 90 days after stocking, with water flow maintained at 2.5 L/sec in an area of 3.5 m^2 (Nepal *et al.*, 1998). Our recommended rate of stocking is 50-100 fry/m^2 depending on conditions, where harvest size would be 200 g. The weight rather than the numbers should be reduced, if water temperature reaches more than 21°C and the flow rate is not sufficient, and dissolved oxygen is less than 6 mg/L. It is believed that ponds with a high degree of aeration can support a stocking density up to five times greater than non-aerated ones.

3.4 Feeding

Feeding is a very important part of fish culture. Two types of feeding practices are used: a) machine feeding, which is used for well equipped and well managed farm, and b) hand feeding, which needs frequent supervision of the ponds, and is used on fish farms with less facilities. In case of hand feeding, young fish must be fed 7-8 times a day at 60-90 minute intervals. As the fish grow over 10 g feeding frequency can be reduced to 3-4 times a day. When the fish reach over 50 g feeding twice a day is sufficient. However, it must be noted that feed and size of pellets control the growth variation of fish among individuals of the same group. Lights off during nights lowers metabolism and preserves energy in the fish.

Trout needs a supply of high protein content feed in pellet form. Generally, more than 35% crude protein (CP) is necessary for trout. Growth of trout has not been satisfactory with feed containing less than 20 percent animal protein. More than 40 percent CP containing feed has been recommended for the newly swim-up young and for broodstock. 35 percent CP containing feed made with 30 percent animal protein (shrimp) has been used in Nepal. We have been supplying buffalo liver to the swim-up fry up to 5-10 g size at a rate of about 0.1 percent of body weight. The fry had a very good survival rate with good growth. The pellets and crumbles should be graded into different sizes suitable for the mouth size of the growing trout. Feeding rate varies on the basis of fish size and the water temperature. Young trout (< 30 g) need to be fed 3-10 percent of body weight per day, but 1-2 percent is sufficient for bigger ones. Leitritz (1963) prepared a chart for the feeding rate of rainbow trout per day in percentage (Table 1).

Table 1
Recommended amount of dry food to feed rainbow trout per day in percentage of body weight, for different size groups

BW (g) ⇓	0.18	0.18-1.5	1.5-5.1	5.1-12	12-23	23-29	39-62	62-92	92-130	130-180	180 ⇒
TL (cm) ⇓	2.5	2.5-5.0	5.0-7.5	7.5-10	10-12.5	12.5-15	15-17.5	17.5-20	20-22.5	22.5-25	25.0 ⇒
WT (ºC) ⇔	Feed (%) ⇑ ⇓										
2	2.6	2.2	1.7	1.3	1.0	0.8	0.7	0.6	0.5	0.5	0.4
3	2.8	2.3	1.8	1.4	1.1	0.9	0.7	0.6	0.6	0.5	0.4
4	3.1	2.5	2.0	1.6	1.2	1.0	0.8	0.7	0.6	0.6	0.5
5	3.3	2.7	2.2	1.7	1.3	1.1	0.9	0.8	0.7	0.6	0.5
6	3.6	3.0	2.4	1.9	1.5	1.2	1.0	0.8	0.8	0.7	0.6
7	3.9	3.2	2.6	2.0	1.6	1.3	1.1	0.9	0.8	0.8	0.7
8	4.2	3.5	2.8	2.2	1.7	1.4	1.2	1.0	0.9	0.8	0.7
9	4.5	3.8	3.1	2.4	1.8	1.5	1.3	1.1	1.0	0.9	0.8
10	4.9	4.2	3.3	2.6	2.0	1.6	1.4	1.2	1.1	0.9	0.8
11	5.3	4.5	3.6	2.8	2.1	1.7	1.5	1.3	1.1	1.0	0.9
12	5.7	4.8	3.9	3.0	2.3	1.8	1.6	1.4	1.2	1.1	1.0
13	6.2	5.2	4.2	3.2	2.4	2.0	1.7	1.5	1.3	1.1	1.1
14	6.7	5.6	4.5	3.5	2.6	2.1	1.8	1.6	1.4	1.2	1.2
15	7.2	6.0	4.9	3.8	2.8	2.3	1.9	1.7	1.5	1.3	1.3
16	7.7	6.4	5.2	4.1	3.1	2.5	2.0	1.8	1.6	1.4	1.3
17	8.3	6.8	5.6	4.4	3.3	2.7	2.1	1.9	1.7	1.5	1.4
18	8.8	7.3	6.0	4.8	3.5	2.8	2.2	2.0	1.8	1.6	1.5
19	9.3	7.9	6.4	5.1	3.8	3.0	2.3	2.1	1.9	1.7	1.6
20	9.9	8.2	6.9	5.5	4.0	3.2	2.5	2.2	2.0	1.8	1.7

(BW – body weight; TL – total length; WT – water temperature) (Leitritz, 1963)

Depending on quality of the diet and temperature rainbow trout can reach marketable size (200-300g) within 12-14 months from free-swimming larvae. It is more economical to reach marketable size as soon as possible (Huet, 1975).

3.5 Grading, growth checking and cleaning

All fish do not grow at the same rate, some grow faster, and other remain smaller. Active and bigger fish that become dominant within a group will eat more and grow fast, while the smaller and weaker ones will eat less and grow slowly. This phenomenon is especially prominent in the high-growth-rate fry stage and in its extreme will lead to cannibalism and thus a reduction in the culture population. Thus, it is necessary to periodically thin out and grade the stock to maintain steady growth. The bigger ones should be sorted out from the smaller ones, using a grader (a selection device) to reduce mortality rate. The sorting by body size should be done every one or two months, with the young every fortnight or monthly. Growth checking during the grading is necessary to determine the feeding rate, feed efficiency and condition of health. Pond cleaning is another very important part and frequent pond cleaning is necessary to avoid a disease outbreak.

3.6 Fry availability

The Fisheries Research Stations Trishuli and Godawari supply rainbow trout fry of average size 2-3 g from April to June at a rate of Rs 2.00/tail. Stations also provide advanced fingerlings of average size 50 to 100g in November and December and yearlings are sold by weight. Fry are delivered at the culture sites to encourage private trout aquaculture, but there must be an access for cars.

3.7 Harvesting and marketing

Rainbow trout is widely accepted as food fish of high quality (Martyshev, 1983). According to Pillay (1993), in countries where commercial trout farming is well developed, as in Europe, harvesting size ranges from 170-230 g to 350-450 g for the fresh market and 1.5-3 kg for fillets and smoked trout. 200-300g fish are the most suitable size for harvesting because of higher feed efficiency and low production cost. In Nepal most trout consumers prefer 200-300 g trout. Nepalese consumers believe that the smaller the size the more delicious the fish is. Restaurants and hotels request 200 g, 250 to 350 g and more than 1 000 g fish. Smaller sizes are served as a whole fish and bigger ones are for smoking. The smaller size is more profitable to sell in grow-out fish farms. Old broodstock is another source of income in the seed production or full system farms.

The trout is a perishable but high value food, and should be marketed in good quality. Post harvest handling of the fish therefore becomes very important. The transport system in Nepal is not very convenient for a quick distribution of perishable products like fish. The market for rainbow trout is not as good as for carp due to its lower production and higher price. It is necessary to improve the system for marketing trout in Nepal and abroad. It is believed that trout export has a good future.

3.8 Prevention of fish diseases

Pollution of pond water, high water temperature (>23°C), high water turbidity, high cultured stock density, overfeeding, rough handling, nutritional and vitamin deficiency and excessive nitrogen gas in water (>0.4 mg/L) are some of the primary causes of disease outbreak. Daily cleaning of non-consumed feed, excreta and unwanted deposits in the pond is the best way to prevent the outbreak of diseases. Some of the diseases found in raceway culture of trout in Nepal are as follows.

3.8.1 Bacterial diseases

Columnaris
The causative agent of this disease is *Flexibacter columnaris*. Highly lethal, often infects fingerlings when there is high temperature fluctuation in the early autumn and late spring. Dip in copper sulphate solution of 1:2 000 for 1-2 minutes and oral administration of Terramycin at the rate of 10-20 mg/kg feed, treat the disease weekly.

Tail and fin rot
The disease is caused by *Bacterium* belonging to *aeromonas* group. The disease usually manifests itself by the appearance of white edges on the dorsal and pectoral fins. Fins gradually rot away. The infected fish lose appetite and die. Treatment same as for columnaris.

Gill disease
The causative agent of this disease is *Myxobacterium*. In the early stage of disease the fish appears lethargic and has a poor appetite. Gills become swollen and a deeper red in color than normal. The fish can be treated in a copper sulphate solution of 1:2 000 for 1-2 minutes or 3-6 percent solution of common salt.

3.8.2 Fungal diseases

Water mold disease
Mold usually grows on dead eggs and sometimes parent fish are attacked by fungus after egg or milt collection. The problem may be associated with immature commercial sized fish. Application of Betadin solution at the rate of 5 mg/L and dipping in 3-6 percent salt solution treat the fungal disease.

Hepatoma disease
This disease is caused by *Aspergillus flavus*. The fish infected with this disease has enlarged abnormal liver and is pale in color. If feed contaminated with aflatoxin over 0.4 µg/L is fed for more than 4 months, the fish becomes victim of the disease. Exclusion of corn meal in the feed reduces the occurrence of this disease.

3.8.3 Protozoan disease

Trichodiniasis
The causative agent is obligatory parasites. Sometimes causing mass mortality of fish. Parasites are found on the body surface and gills. Occurrence of parasites under intensive rearing of fry and fingerlings is common. The disease can be treated by 1-3 bathing in 3-6 percent solution of common salt for 3-10 minutes.

4. ECONOMICS OF TROUT FARMING

4.1 Data collection and analysis

Precise and detailed data were collected for the analysis of economics of trout farming to assess its present status and viability. Trout production was virtually limited to the government farm and on an experimental basis until 1998. Some data in this paper came from the experiments at the research station. It was necessary to expand the data collection to include also private entrepreneurs.

Mr. Lama was the first private farmer farming trout in Nepal. He established a small farm at Ranipauwa of Kakani VDC, Nuwakot, where he has been farming rainbow trout since 1998. In 1999/2000 he sold 600 kg trout as a table fish. He hopes to increase the production to about 1800 kg in 2001/2002, using the raceway system area of 136 m^2. The source of water is a spring which comes to the surface at an altitude of about 2 000 m. Water temperature ranges from 7 to 20°C. DO and pH are 7mg/L and 8, respectively. Water flow remains at about 3-4 L/sec. The system of ponds (raceways) is of a linear type arranged in a zigzag way. The water is reused to the next pond downward. There is a potential for expansion, for which both land and water are available.

Trout growth experiments were carried out at the Fisheries Research Station, Trishuli. Three different stocking densities were tested in partitioned raceway ponds of 3.5m^2 area. Fish were fed 35 percent crude protein content at 2 percent of body weight, with 70 g sized fish growing well up to 161 g, with specific growth rate of 1.9–2.0%/day in a 90-day period from January to April (Table 2).

Table 2
Growth characteristics of rainbow trout at different stocking densities (1997)

Biomass of stock	**15.0 kg/m^2**	**12.5 kg/m^2**	**10.0 kg/m^2**
Total no. of fish stocked	785	623	494
Average total length (cm) ∂SD	18.1∂0.9	18.1∂1.1	18.4∂1.1
Individual mean body weight (g) ∂SD	66.9∂5.9	70.2∂11.2	70.7∂12.0
Average body length (cm) ∂SD at harvest	23.8∂1.1	23.5∂1.1	23.4∂1.2
Mean body weight (g) ∂SD at harvest	157.7∂25.2	161.6∂24.3	161.4∂26.1
Gross weight kg per m^2 at harvest	31.9	26.8	21.8
Percent body weight increase	112.5	114.3	118.4
Specific growth rate (%/day)	1.92	1.94	2.00
Survival (%)	90.2	93.1	95.7
Feed efficiency (%)	48.9	48.4	49.9
Feed conversion ratio (FCR)	2.04	2.06	2.00
Condition factor	1.2	1.2	1.2

Water temperature ranged from 9.7 to 17.0°C, DO from 5.4 to 8.5 mg/L, and pH from 7.2 to 7.5. Water transparency was 28 cm or higher. Survival rate was above 90% and feed efficiency was nearly 50 percent with a feed conversion ratio (FCR) of 2:1 (Table 2). There was no significant difference ($P>0.05$) in feed efficiency, FCR, survival and specific growth rate among and within experimental treatments. Thus the cost analysis for the private farm in this paper has been accounted for on the basis of feed efficiency and the FCR, nearly 50% and 2:1, respectively, where 70 g sized fish grew to 161 g. Joshi and Westlund Lofvall(1996) reported that the FCR of 1.8 produced 1 kg of 300 g sized trout.

4.2 Cost and earning analysis

4.2.1 Capital costs (assets and liabilities)

The initial capital costs for establishing and creating the assets and liabilities in a fish farm are generally higher. Investment cost for a trout farm is much higher in comparison with carp projects. This is because more expensive facilities are needed, such as concrete cemented ponds (raceways) and operating equipment. Depreciation should include the land, ponds and other structures in short-term projects, but in the case of Mr. Lama’s farm, depreciation has not been calculated for the land, because its value usually appreciates.

4.2.2 Variable/operating costs and fixed costs

Variable and fixed costs constitute the main input used in an aquaculture enterprise. Variable costs vary with the level of production, whereas fixed costs are not affected by it. Variable costs include the cost of production inputs such as pond preparation, fry/fingerlings, feed, electricity, tools, materials and the cost for manpower/labor. Salary, interest on borrowed capital and payback loan, depreciation of assets (excluding land cost), cost of maintenance, telephone/communications and travelling costs are included as the fixed costs (Table 3).

So far there is no thorough financial analysis of the trout production in Nepal. Based on the data collected from the FRS Trishuli and the small-scale private sector farm, some preliminary calculations can be made. Applying the data from the private farm, total costs including capital costs and consumption allowances give very satisfactory results (Table 3), with a cost of about NRs 255 to produce 1 kg of trout, which is sold for NRs 300/kg. This analysis assumes that fish seed is purchased by the owner and feed made by the government farm using the farmer's own ingredients. So neither investment cost for the hatchery nor feed production facilities are included. The cost of fish seed is calculated as the price at FRS Trishuli and feed cost calculated as the actual cost paid by the farmer at purchase, transportation with loading and unloading, cost for electricity and overtime for manpower. The cost of materials, tools and labour is lower than in the government farm, because the farmer himself is able to handle the farm very well with his family. The analysis gives a profit of NRs 45/kg of fish which gives a rate of return on initial cost of 19.5%, and the rate of return on operating cost is 17.6% (Table 3).

5. CONCLUSIONS AND RECOMMENDATIONS

The research works carried out at the Fisheries Research Station, Trishuli, found that Nepal is technically sound for rainbow trout culture. The culture technology has also been verified in the farmer's field to prove whether the technology is suitable to apply in the private sector or not. With regard to economic feasibility, the preliminary analyses carried out showed very positive results from the private sector. Trout farming provides a great opportunity for exploiting the abundant source of cold water in Nepal. However, a market survey is indispensable before promoting trout production. Over the last 4 years the demand for trout has been increasing in Nepal. The present domestic trout market is limited to certain hotels, restaurants, international organizations and some diplomatic offices in Kathmandu. Some Nepalis with a higher living standard have also been increasing trout consumption instead of other animal meat. This is because of its taste and recommendations to eat fish for health reasons. The export markets are virtually unknown and potential markets, both domestic and abroad, must be thoroughly studied before promoting trout farming.

Trout needs a regular flow of abundant cold and clean water in raceway ponds, with sufficient oxygen content. Water quality requirement and the availability of suitable land needed for raceway construction limit the number of trout culture sites. The site should not be far from a road, to make easy access for transfers of fish seed and feed. From a marketing point of view it is essential that the production is taken to markets fresh. Availability of sites near urban areas or accessible by road are the essential requirements for a successful farm. A proper marketing and an adequate distribution system also should be available to encourage the private entrepreneurs to establish or increase the production of trout in the country.

The technical and economic viability has confirmed that trout farming is "know-how intensive" and requires good management. The government should give priority to assistance to farmers in the private sector for the development of commercial trout farming in Nepal.

Government should assist with the transfer of technologies of fish seed, grow-out fish and feed production to private entrepreneurs. The Government should also be ready to invest in cold water hatcheries and fish feed plants. However, such infrastructures should eventually be taken over by the private sector.

Table 3
Cost and earning analysis of a production farm in private sector

1) Initial cost/capital cost

SN	Items	Cost (NRs)	Economic life (years)	Annual Depreciation (NRs)	Remarks
1	Land (1500 m^2)	150 000	-	-	
1	Raceway construction	150 000	20	7 500	No. of ponds: 6
2	Water Supply system/pipes	37 000	20	1 850	Area: 136 m^2
3	Stores/workshop	50 000	20	2 500	
4	Drag net (5m)	1 200	3	400	
5	Netlons/graders/cages/hapas	18 000	5	3 600	
6	Small pumps/equipment/balance	5 000	5	1 000	
7	Others (buckets, soft wood etc.)	3 000	2	1 500	
	Total	**414 200**		**18 350**	
8	Bank loan	350 000		-	

2) Annual operating costs

SN	Items	Quantity	Unit	Unit price(Rs)	Total (Rs)
A	**Variable costs**				
1	Feed for table fish	3 600.00	Kg	47	169 200.00
2	Feed for advanced fry (up to 10g)	200	Kg	58	11 600.00
3	Fry (2g size)	10 000	No.	2	20 000.00
4	Wages		Rs.		20 000.00
5	Glassware/tools/chemicals/nets		Rs.		5 000.00
6	Farm fuel		Rs.		1 000.00
7	Electricity		Rs.		6 000.00
8	Others (oil, medicines)		Rs.		5 000.00
	Sub-total		Rs.		**237 800.00**

SN	Items	Quantity	Unit	Unit price(Rs)	Total (Rs)
B	**Fixed/non-operative cost**				
9	Salary for manpower	365	Man/days	150	54 750.00
10	Bank interest (14%) for first year		Rs.		49 000.00
11	Payback of loan (1st installment)		RS.		70 000.00
12	Depreciations		Rs.		18 350.00
13	Maintenance (5% of capital costs without land cost)		Rs.		13 210.00
14	Telephone/communication		Rs.		4 000.00
15	Gasoline (for bike)/traveling		Rs.		12 000.00
	Sub-total		Rs.		**221 310.00**
	Total annual cost		Rs.		**459 110.00**
	Total fish production	1 800	Kg		

(10%mortality)				
Cost per unit production		Rs.	255.06	**Approx. Rs. 255**
Total income	1 800	Kg	300	**540 000.00**
Total annual cost				**459 110.00**
Profit				**80 890.00**
Rate of return on initial cost		%		**19.53**
Rate of return on operating cost		%		**17.62**

The Government should support the private sector through the following:

- Provide training for interested farmers/entrepreneurs.
- Provide technical services and support to private entrepreneurs.
- Establish a "survey team" to identify suitable farm sites.
- Assure the availability of quality feed in the market.
- Assist with the management of marketing system.

Setting up trout farms will raise the living standard of the people in the country. At the same time one should pay due attention to environment problems which may be created, as the development of trout farming needs be conducted in an environmentally conscious manner. Pollution aspects and interference with natural aquatic ecosystems should be closely monitored and managed for preservation of ecosystem diversity. Trout industry must develop in a sustainable manner without endangering the environment.

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MAHSEER BREEDING AND CONSERVATION AND POSSIBILITIES OF COMMERCIAL CULTURE. THE INDIAN EXPERIENCE.

by

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ABSTRACT

Mahseers (*Tor* sp.) have been a legendary sport fish of India with a very high table value. Mahseer, at one time considered to be of single species, is now represented by six valid species distributed all over India. Despite their abundance, at one time mahseer were reported to be declining in size and numbers and were feared to be in danger of extinction in some parts of the country. Unfortunately their catches have dwindled considerably due to illegal methods of fishing, habitat deterioration and introduction of exotic species. Studies on their feeding and spawning habits, eggs, larval development and especially the methods of artificial propagation have progressed in recent years. Breeding of four major species of mahseer, *T. khudree, T. mussullah, T. tor* and *T. putitora,* by collecting the brooders from the breeding grounds and then stripping them is possible. In the effort to conserve mahseer resources artificial propagation of the fish by stripping the spawners is not always possible unless they are dependably obtainable from natural waters. To overcome this difficulty mahseer fingerlings of all the species can be raised to maturity in captivity (small ponds) by following improved aquacultural practices. Breeding of four major species of mahseer, with and without hypophysation, in brood fish ponds using manipulation of water flow, exercise and high protein palletized diet has also been successful. Stripping the ripe fish becomes necessary and for convenience and surety, two doses of pituitary extract or a single dose of ovaprim/ovatide is desirable. The Tata Power Company's mahaseer hatchery is simple but most successful and can be replicated in remote centers. Approximately 500 000 eggs are collected and fertilized every year by using different methods. Over 8.1 million fry/fingerlings have been produced in the last 30 years. Cross breeding of mahseer species and producing F1 and F2 generations was also successful. Mahseer breeding is no longer in its infancy but the commercial culture is. The breeding successes have raised new hopes for the prospects of mahseer fishery. However there exists the need to intensify these efforts by undertaking large-scale regular cage culture and a mahseer seed ranching programme. Fry and fingerlings of major species are being distributed to many states of India and to angling associations in the country by the Tata Power Company as a measure of rehabilitation and conservation. Transport by air of eggs of mahseer in moist cotton has been successful. There is growing awareness about the need to conserve mahseer and there is ample scope for advancement in certain areas. The technique of cryopreservation of mahseer milt has been successfully developed and gene banking of endangered mahseer is technically feasible. Efforts on the induction of triploidy and gynogenesis in mahseer using heat shock treatment for manipulation of sex ratio are in progress. This paper reviews the present status and potential of further mahseer fishery development.

1. INTRODUCTION

Mahseer is acclaimed as a world famous, outstanding game and food fish of India. As a sport fish, it provides unparalleled recreation to anglers from all over the world, better than salmon. It is known as tiger in waters, because of the fight it musters to wriggle off the hook. In the past mahseer formed a substantial natural fishery in the major riverine and lacustrine ecosystems of India. In commercial fisheries it occupies an important position for its good quality. For the fishermen mahseer is of considerable importance because of its large size. As a food fish, it is highly esteemed and fetches the highest market price in north and northeast of India.

Day (1878) believed that mahseer constituted only one species. Hora (1940) confirmed the validity of six different species. A recent critical study on the subject by Menon (1992) confirmed 6 valid species. He has, however, described a new species from the Darna River (Godavari drainage) at Deolali, Nashik District of Maharashtra, and named it *Tor kulkarnii,* which he describes as a dwarf cognate of *Tor khudree*. Preserntly seven valid species are recognized for India:

Scientific Name	**Common name**
Tor putitora (Ham.)	Golden or putitora mahseer
Tor tor (Ham.)	Turiya or tor mahseer
Tor khudree (Sykes)	Deccan or khudree mahseer
Tor mussullah (Sykes)	Humpback or mussullah mahseer
Tor kulkarnii	Dwarf mahseer
Tor progeneius (McClelland)	Jungha of the Assamese
Tor mosal (Sykes)	Copper or mosal mahseer

In addition to the above, three sub-species, viz., *Tor mosal mahanadicus, Tor khudree malabaricus* and *Tor khudree longispinis* are considered by Desai (2002) as valid species, with some reservations.

Different species of mahseer occupy different ecosystems ranging from tropical waters where summer temperatures reach 35°C, to sub-Himalayan regions, where the temperatures fall to 6°C. Similarly, they occur in streams hardly above sea level and are also found at an altitude of 2 000 m above sea level. Jhingran and Sehgal (1978) remarked that the occurrence and distribution of mahseer is controlled by the prevailing water temperature of the streams and not by the altitude.

Mahseers were considered as carnivorous and slow growing and thus unsuitable for fish culture. However, a careful study of the feeding habits of mahseer indicating that it is omnivorous has dispelled the notion that mahseer are carnivorous. Studies on the anatomical adaptations of the alimentary canal system also confirm that mahseer are omnivorous. Tripathi (1995) suggested the inclusion of mahseer in polyculture, cage culture and for river ranching and has stated that mahseer would not compete with mrigal (*Cirrhinus mrigala*) and the common carp.

Despite their abundance at one time, the mahseer population has been declining in number and size in natural waters and is in serious danger of extinction. The National Commission on Agriculture (1976) in its report on fisheries had stated there was a general decline in mahseer fishery in India due to indiscriminate fishing of brood and juvenile fish and the adverse effect of the river valley projects and accordingly suggested extensive survey and detailed biological investigation on this alarming situation.

The biological investigations commenced in 1970 in Tata Power Company's lakes in Pune District of Maharashtra under the guidance of C.V. Kulkarni and eventually yielded very significant information on artificial propagation of mahseer. The downward trend in the commercial and sport fishing catches of mahseer due to various man-made and ecological factors could be obviated by a continuous stocking programme on a large scale and by strictly enforcing the prevailing legislation. This programme would require production of fry and fingerlings of this species on a very large scale and their release in depleted natural perennial waters.

During the last three decades of the 20th century extensive studies on the distribution, biology and fishery of the commercially important mahseers have been made by TPCL. This has led to development of techniques of breeding, larval rearing and cultural practices at TPCL hatchery farm Lonavla, which is now capable of producing fry and fingerlings of all the desired species of mahseer.

The mahseer hatchery technology developed by TPCL may well lead to the revival of mahseer fisheries in Indian waters, provided standardised simple mahseer hatcheries based on TPCL technologies could be set up in the rural areas adjacent to rivers and reservoirs.

Causes of depletion

The exponential increase in human population is the root cause for the loss of biodiversity and the depletion of natural resources. Much has already been said regarding the depletion of mahseer. The major possible factors for the depletion of mahseer stocks are :

- degradation of ecological conditions of aquatic systems,
- indiscriminate fishing of broodstock and juveniles,
- impacts of river valley projects,
- industrial and human pollution,
- the use of explosives, poisons and electrofishing by poachers,
- introduction of exotic species,
- population pressures on resources.

The above- mentioned factors combined with human greed are responsible for the reckless damage to this priceless national heritage.

The declining trend in the populations of mahseer needs immediate attention for its *in situ* conservation and rejuvenation in natural waters. The reasons for the conservation of this gene pool need no further emphasis. Several measures have been enumerated for their conservation (Kulkarni 1991; Ogale, 1997). The artificial propagation and distribution of resultant fry and fingerlings into different waters constitutes one of the most important steps to rehabilitate the species, as is being done for the well known salmon in American and European waters. However, for dependable and continued results, improved aquacultural practices for the breeding of mahseer under controlled conditions play a vital role.

2. METHODOLOGY

2.1 Artificial propagation

The artificial fertilisation of eggs of the true mahseer (*Tor khudree*) was successfully carried out on a large scale for the first time in 1970 by Kulkarni (1971) at the Tata Power Company's fish farm at Lonavla, District Pune (Maharashtra). Since then considerable knowledge has been gained and practical knowledge has been achieved in recent years on the spawning season and habits, methods of artificial propagation, hatchery management, rearing of fry, fingerlings and broodstock, and most importantly, on the success of hypophysation (induced breeding) of pond-raised stocks of all the major species, i.e. *Tor khudree*, *Tor mussullah*, *Tor tor* and *Tor putitora* in that order (Kulkarni and Ogale, 1986; Ogale, 1997).

2.2 Spawning season

Kulkarni (1971) reported that *Tor khudree* spawn in July and August (peak period) and sometimes in September in Walwhan and Shirwata lakes at Lonavla. This observation has been confirmed over the last 30 years by actually collecting the eggs at TPCL Mahseer Farm. In the case of *Tor tor* introduced in Walwhan, Shirwata and Telco lakes at Lonavla and Pune, gravid females and males were available for stripping generally in July, August and September and in one exceptional case in April in the Telco Lake, Pune. At Lonavla, *Tor putitora*, like other species, is observed to spawn naturally in lakes from July to September. Kulkarni and Ogale (1986,) were also able to breed *Tor khudree, Tor tor, Tor mussullah and Tor putitora* with hypophysation of the pond-raised stock from July to December.

Tor putitora females have responded to stripping, with hypophysation or even without it during ten months in a year. It would be worthwhile to try and breed *putitora* mahseer in the other two months, i.e. January and December, during which breeding has not been attempted due to shortage of brooders.

From the above observations it could be said that the breeding season of all mahseer species extends from July to September with a peak in July - August and in exceptional cases to October, and even beyond which has been observed by the author at Lonavla from 1997-2001. This has shown the adaptability of the species to different environments.

2.3 Spawning behaviour

Most mahseer species are known to have very similar spawning behaviour and breeding habits. The spawning and breeding habits of the mahseer received specific attention at the Tata Power Company’s farm at Lonavla (Kulkarni, 1971). Methods of artificial propagation on large scale were also studied and described (Kulkarni and Ogale, 1978). The natural spawning grounds in the reservoirs were discovered and their peculiarities were described. These habitats usually comprise the marginal lake areas where streams draining the adjoining hills cascade into the lake. The ripe fish in the lake are attracted by the sound and the incoming well oxygenated running water, which also gives the impression of possibilities of migration, and congregate in the area. If the streams are negotiable, the prospective broodfish migrate into them and cannot be captured for stripping and artificial propagation. The configuration of the marginal areas of the lakes has to be of an appropriate nature to enable the successful capturing of spawners. In addition to well oxygenated water, water temperature from 21°C to 26°C proves to be effective for final maturation, leading to a proper response to stripping and the ultimate release of eggs (ova). Mature fish in a ripe condition are useful for artificial fertilisation, proper hatching and further propagation (Kulkarni and Ogale, 1978). It is now known that the eggs are heavy and demersal unlike those of the major Indian carps.

The stripped eggs were then collected in plastic trays and the milt of the male spread over it as is usually done in the case of trout and salmon for fertilising the eggs. The fertilised eggs are demersal, lemon yellow or brownish golden in colour. They measure 2.8 to 3.2 mm in diameter and if kept in proper hatching trays with a direct water sprinkling arrangement, take 60 to 96 hours to hatch or even more, depending on water temperature which may vary from 20°C to 28°C (Kulkarni, 1980; Sehgal, 1991). Incidentally, almost the same size of eggs are reported for *Tor khudree*, *Tor putitora* and *Tor tor*. Since the spawning habits of *T. tor* and *T. putitora* are also similar to those of *Tor khudree*, TPCL's methodology was used to collect spawners in the Kumaon lakes of Uttar Pradesh by the National Research Center for Cold Water Fisheries (NRC-CWF) and Jammu and Kashmir.

The early hatchlings of mahseer are golden yellow and pass through a semi-quiescent stage during which they remain huddled in corners and crevices with their heads tucked away from light, as if they were negatively phototropic. In this condition, they are exposed to heavy predation by other predatory animals. This condition continues for about six days and forms the most critical period of its early life cycle. This mortality can be reduced by artificial fertilisation of eggs, hatching them in trays and nurturing the hatchlings in a protected manner in nursery ponds.

At Lonavla, after the hatchlings are grown into fry and fingerlings in nursery and rearing ponds, the grown-up fingerlings are released into the Tata Power Company's lakes. About 4 to 5 hundred thousand eggs are obtained in the above manner every year. Thousands of fry and fingerlings have also been supplied gratis for some years to different State Governments and Angling Associations in the country wherever there was commitment and opportunity to rehabilitate the fish. A consignment of mahseer fry has been sent to Laos PDR for stocking the Mekong River basin in that country.

2.4 Inherent constraints in natural breeding

While considering large scale propagation of the mahseer, the natural spawning behaviour and the inherent constraints in its early life cycle need to be understood. In nature, the spawners try to reach their favoured spawning grounds which may be in the vicinity or far away, traversing smoothly or ascending the overflowing monsoon streams. The actual spawning area needs to be comparatively calm, having well-oxygenated water and a bed of sand or gravel. The journey to these grounds may be safe or fraught with risks and dangers, but their inner instinct drives the spawners to meet the challenges in order to breed.

Our observations on stripping, hatching and larval growth of the *khudree, mussullah, tor* and *putitora* mahseer at Lonavla indicated that Mahseer species have very low fecundity of 10 000 to 15 000 per kg of body weight, though Desai (1970) had estimated a figure ranging from 7 000 to 106 500 from the ova count, depending on the size of the fish. The eggs of the mahseer are demersal and if there is loose mud on the bed instead of sand or gravel, they perish.

The hatching period of different mahseer species is 60 to 96 hours in water temperature of 20°C to 28°C as described by various authors, compared to 18 hours for catla (*Catla catla*), rohu (*Labeo rohita*), etc. If water temperature falls below 20°C, the hatching period extends beyond 96 hours. The semi-quiescent stage is three days for catla, rohu, etc. and six to ten days for *Tor* species. In this stage, the mahseer hatchlings tend to remain at the bottom, huddled in large numbers in corners and crevices as stated earlier. Their heads remain tucked away from light and their tails keep vibrating constantly. In this condition, they are highly vulnerable to all kinds of predators.

2.5 Hatchery management

Several systems of hatching fish eggs are being followed in different parts of the country, but the one developed at Lonavla (Kulkarni and Ogale, 1978) is the simplest. It involves cement cisterns, wooden floating trays and perforated pipes. The pipes have been specially punctured at regular intervals to provide oxygenated water directly into the trays and on the eggs.

The wooden hatchery trays used at Lonavla are 56 x 56 x 10 cm deep, with a suitable (1mm) plastic or velon mesh properly stretched and fixed to form the bottom of the tray. Eight such trays can be arranged and kept floating in a rectangular cement tank (hatchery), 2.5 x 1.2 x 0.75 m. deep. About 30 000 eggs can be conveniently accommodated in each tray, thus making a total of 240 000 for each hatching tank. More hatching tanks and trays can be arranged according to the requirement and the quantity of water available. TPCL Mahseer Hatchery at Lonavla has a capacity to hatch one million eggs at a time.

2.6 Water requirements for hatching

As mentioned earlier, water is sprinkled over the eggs placed in the hatchery tanks through perforated plastic pipes fixed on top of the sidewalls of the hatchery tank. The perforations are 1mm wide giving rise to jets falling directly but slowly into trays containing the eggs. Four such jets supply water to each tray at a rate of one litre per minute per tray. Thus, if eight trays are used at a time, 480 litres of water will be required per hour and 11 520 litres per day, the total quantity depending on the number of hatching trays being used.

The overhead tank supplying clean, silt-free water can be about three meters tall with a capacity of 10 000 litres. Water is drawn at a level of about 100 mm from the bottom to allow sedimentation of silt, if any. The tank is usually kept full to maintain pressure of water from the sprinkling jets. The outflow from the hatching tank is so arranged that only the bottom water is removed first by a siphon pipe system commencing near the bottom. Adjustments can be made depending on the local conditions prevailing at a given place, the quality of water being the most important. The dead eggs are constantly removed with a pipette or an ordinary ink-filler having a wide aperture.

3. BREEDING POND-RAISED MAHSEER

3.1 Hypophysation (induced breeding)

Efforts to propagate mahseer, especially *Tor khudree, Tor tor* and *Tor mussullah* at Lonavla lakes (Maharashtra) by Kulkarni (1971) and *Tor putitora* and *Tor tor* in Kumaon lakes by Tripathi (1978) consisted of procuring the spawners and stripping them for artificial fertilisation. Although this is a sure method and has been successful at Lonavla fish farm producing half a million fertilised eggs annually for the past 30 years, it has its own drawbacks. The method of collecting spawners for stripping has limitations in the open hilly terrain or rivers. Since the conditions for the collection of spawners are unlikely to be encountered in many other places, the only reliable method to obtain fry and fingerlings is to grow mahseer juveniles in ponds and breed the resultant adults with the help of hormones. This step ensures proper growth of gonads in ponds. Following this, Kulkarni and Ogale (1986) demonstrated that pond-raised *Tor khudree* and *Tor tor* can be successfully bred through hypophysation after growing them for three years in ponds. Stripping was done after administrating the second dose pituitary extract to the female, the male requiring only one dose. This success obviated the difficulty of obtaining spawners from widely spread spawning grounds.

Attempts to breed *Tor putitora* by hypophysation were first made by Sehgal and Kumar (1977) at Baintwali Mandi, Dehra Dun with little success. Pathani and Das (1978) also tried the induced breeding of *Tor putitora* without any success. Since the use of pond-reared brood stock of *Tor putitora* met with little success in induced spawning the induced breeding of natural stocks was resorted to. All efforts however remained unsatisfactory. Sehgal (1991) and Das (1992) reported that among the various species of mahseer, the golden mahseer was most affected and hence acquired the status of an endangered species. Kulkarni and Ogale introduced *Tor putitora* into the Lonavla lakes of the TPCL in January 1992 with the objective to breed the species both naturally and by hypophysation. Five hundred fingerlings were released and are thriving as evidenced by the catches of anglers in the lakes. However, no mature female was collected till 1997. As expected the golden mahseer adapted to the captive pond conditions and males started oozing in 1993 and were freely oozing by 1994. The females matured in 1995 (3 yrs) as could be seen from external features. The very first attempt to breed two pairs of golden mahseer at Lonavla with a single dose of Ovaprim was successful. Brooders were released in circular spawning tanks after injecting them with ovaprim. In both the experiments, stripping had to be done after 12 hours (Ogale, 1997). During the 1997 breeding season, *Tor khudree* and *Tor mussullah* were also bred with a single dose of ovaprim. Since then there has been a steady progress in the development of technique and the TPCL farm has produced 217 000 fry/fingerlings from 281 000 eggs of *Tor putitora* at Lonavla till May 2001. Hatching success has been over 90%.

3.2 Natural breeding in ponds

Success in breeding pond-raised mahseer and their hybrids was achieved at the Lonavla fish seed farm of the TPCL , where hybrids between *Tor khudree* and *Tor tor* (F-1 generation) were bred even without hypophysation (Ogale and Kulkarni, 1987). The factors facilitating the breeding were the protein-rich diet given to the brood fish and the running water in the pond on a small scale. Artificial fertilisation was achieved without the administration of pituitary gland extract or any other hormone. This was another milestone in breeding mahseer in confined waters without injections of any sort, and gave a new direction for propagating and perpetuating this endangered species. Moreover it was predicted that what has been found true in the case of these hybrids is likely to be true in the case of other mahseer species also.

Tor khudree was bred several times without hypophysation at Lonavla. Recently, *Tor putitora* and *Tor mussullah* have also been bred without hypophysation at Lonavla. It is thus seen that the difficulties faced in obtaining ripe males and females from natural waters for stripping can be overcome by following piscicultural practices for breeding and raising fry, fingerlings and brood fish. Another advantage of pond culture practice is that fingerlings and brood fish can be raised at any fish farm suitable for the purpose. Over 100 000 eggs have been collected from the farm-raised stock of *T. putitora* within one year during 2000 – 2001, just by keeping a close watch on the brood stock and catching them during the mating.

TPCL’s success in breeding pond-raised mahseers of all the species and *Tor putitora* in particular, with and without hypophysation in captivity, has led to development of many mahseer hatchery projects all over the country with the guidance of the TPCL.

3.3 Hybridization

In addition to the propagation of *Tor khudree* and *Tor tor* at Lonavla, they were hybridized with each other by using males and females of either species. The characteristics in both cases were intermediate as regards color and body form. The rate of growth is similar or slightly better than the pure strains but the hybrids are more active and agile.

After the introduction of *Tor putitora* in 1992 into the Walwhan lake and the proper identification of *Tor mussullah*, it was observed that any of the mahseer species could be hybridized. Even the F1 generation could be bred with hypophysation and sometimes even without it when provided with a proper protein diet, feed additives, exercise and running water. The eggs of the F1 generation could be fertilized successfully with the milt of any of the pure strains of mahseer to produce an F2 generation. Thus the Lonavla fish seed farm harbours most of the major species of mahseer and their hybrids and assumes the status of a National Center for Mahseer Studies.

3.4 Air transport of eggs

In order to facilitate the distribution of mahseer seed to distant places, efforts were successfully made to transport mahseer eggs by air in moist cotton from Bombay to Bangalore. In this method, fertilised eggs were allowed to harden for 24 hours, then placed on moist cotton in two layers in perforated plastic boxes and later packed in suitable tins. As the minimum hatching period is 60 hours, sufficient time is available for transport even over longer distances. The success of this method will enable transportation of fertilised eggs to any place in India and even abroad. The eggs can then be hatched in the normal manner and the resultant fry and fingerlings distributed in lakes and reservoirs (Kulkarni and Ogale, 1979).

3.5 Culture efforts

As regards commercial aquaculture, David (1953) has indicated the possibility of culture of *Tor mosal mahanadicus* recording a growth of 170-200 mm in four months, whereas the Deccan mahseer reared in Orissa could attain a growth increment of 107 mm in 254 days (Badapanda and Mishra, 1991).

Attempts have been made to culture mahseer in ponds. Investigations carried out by the NRC-CWF indicate that within a one-year period, a size of 210 mm length and 175 g weight can easily be obtained in properly managed ponds. However, stocking density and details of feeding were not mentioned in the report.

The author's experience in rearing *Tor khudree* shows that the species has a comparatively slow growth. Nevertheless, in village ponds near Lonavla, *Tor khudree* has grown between 600-900 g in one year. In the Bhatgar reservoir near Pune, the fish is reported to be growing even faster. In the Powai lake, Mumbai an angler landed a mahseer weighing 13 kg which was reported to be 9 years old. In the Shivsagar lake (INS Shivaji), a newly built reservoir, mahseer were released in 1991 and anglers are already landing fish weighing between 1 and 5 kg. The fish has established itself in this reservoir and started spawning in 1995. In 1997, *Tor putitora* fingerlings were introduced into the same reservoir and it would be interesting to note the growth rate of this species in Lonavla.

The TEC bought 1 200 fry of *Tor putitora* in January 1992 for raising in ponds and breeding by hypophysation. Approximately 500 fingerlings were released into the Walwhan Lake in July 1992. Recent reports by anglers indicate the weight ranges between 1.3-3 kg.

Though many state Fisheries Departments have taken fry and fingerlings of *Tor khudree* for TEC's fish farm at Lonavla for culture and artificial propagation there are no data available for proper comparison. In most cases, mahseer fry were raised to fingerlings and stocked in reservoirs and rivers. In very few cases have the khudree fry been raised in ponds for more than 3 years. In Sikkim, khudree has grown to 750 g in 3 years (Bhutiya, 1995). In Karnataka the brood stock of *Tor khudree* has been developed from fry obtained from Lonavla. Their weight has reached up to 3kg but the time taken for this growth increment has not been recorded.

In Lonavla, experiments conducted on the culture of khudree have indicated that mahseer fingerlings could be grown to 110-120 g in monocultures at a stocking density of 11 000/ha in 8 months. This was tried a number of times with reduced and increased stocking densities with more or less the same results. In all these experiments the fish were grown only on artificial conventional feed of rice bran and groundnut cake (1:1). Professor Keshavnath at the College of Fisheries, Mangalore, conducted experiments on *Tor khudree* brought from Lonavla during 1983-1988. He reported an average growth of 113.02 g, 147.16 g and 159.72 g at stocking densities of 3 000, 4 500 and 6 000/ha, respectively, at the end of eight months.

Recent trials with the monoculture of *Tor putitora* in ponds at Lonavla were encouraging. The mahseer fingerlings were given only pelletized feed made of rice bran, groundnut cake and fishmeal (30:30:40), with a mineral mix. The average growth reported was 110 g and 90 g at stocking densities of 10 000 and 20 000/ha, respectively, at the end of eight months. Water temperature during the growth period was between 24°C and 28°C. Fresh water was released into the pond from February to May and then in September to October. The release of fresh water was not required during the interim due to heavy showers.

The trials have shown that the stocking density does not adversely affect the growth rate. The fry of golden mahseer brought by the TEC (Tata Electric Companies) from Himachal Pradesh in January 1992 has been grown and used as brood stock from 1995 onwards. In 1995 most of the female breeders were 600 g except for a few which ranged from 1 to 1.7 kg. In 1996 they had grown to 900 g and to 2 kg and in 1997 almost all specimens were over 1 kg and had matured fully. In Walwhan Lake golden mahseer introduced in 1992 grew to 3-6 kg and became established.

Based on the growth performance, conversion and feed utilisation a 40% protein content in the feed is optimal (Keshavnath, 1985). The compatibility of mahseer with other major carps under composite fish culture was tested at different densities and feeding the fish on a fish meal based diet. Mahseer growth was higher under composite culture yjam umder monoculture.

The results of these studies indicate the suitability of mahseer not only for inclusion in composite fish culture but also for monoculture. Since mahseer accepts pelleted feed and is capable of utilizing it efficiently, the species can also be used for river ranching and cage culture. Studies carried out at the TEC's fish farm also confirm that mahseer grown on pelletised feed develops into excellent broodstock for induced breeding.

3.6 Ranching of mahseer

With aquaculture acquiring the status of an industry a new phase is emerging. Wild fish stocks are supplemented substantially by hatchery-reared juveniles/fingerlings and later harvested when they grow up to table size. This release and recapture system is termed ‘ranching‘ where hatchery reared seed of migratory fish are released into the wild with reliance on their homecoming instinct for recapture.

Ranching is defined as an aquaculture system in which juveniles are released to grow unprotected on natural foods in waters from which they are harvested at marketable size. Bardach (1980) said that in ranching the anadromous fish are reared for the early part of their life cycle, sent out to pasture in open waters and harvested when they have reached a certain size either by intercepting them on a known path or by directing their movements to facilitate recapture. Ranching is thus an effective method of retrieving the released dispersed fish. Ranching must not be confused with what is called enhancement or planting or augmenting fish stocks. Ranching means releasing eggs, fry and fingerlings in sections of reservoirs and rivers which the adult fish cannot reach on their spawning migration or which are unsuitable as spawning ground but can provide useful rearing areas for the young fish

Ranching could be a timely and promising measure for rehabilitation of the endangered mahseer.The lack of a well established hatchery technology for mahseer and for rearing of its seed was one of the major obstacles in introducing the mahseer ranching. The others are mahseer’s short-range migration for breeding and feeding and its ability to support riverine fishery above dams. The first problem has been solved and the latter two problems could be viewed as a blessing. Mahseer have a short return migration and will burn less fat while travelling back to their parent rivers. This makes it a very promising candidate species for ranching. The sole purpose of mahseer ranching would be the rehabilitation of this fish in all rivers, lakes and reservoirs where they were in abundance or could be established. A method of artificial imprinting coupled with ranching is also suggested for conservation of the species.

3.7 Imprinting

Imprinting is an irreversible learning process in which at a critical impressional age of its life span an animal gets a life-long imprint of any chemical or sound to which it is introduced and this has a bearing on its future behavior. Two promising techniques are known. Imprinting could be sound or chemicals. The large aquatic environment in which ranched fish stock may migrate to feed or for other reasons will make it potentially important to train and recall them by some means. It has been demonstrated that it is the sense of smell by which some fish recognize the waters in which they hatched and from where they migrate to the sea. This phenomenon has been termed ‘imprinting’ and such fish are called anadromous fish, such as salmon and hilsa.

3.7.1 Imprinting with sound

In this method the mode of recall is by sound. It has been observed at TPCL’s Walwhan fish farm that it is possible to train the mahseer to congregate near a sound source in the ponds, lakes and reservoirs. Initially the cement nurseries at the farm were chosen for training the fish. For generating sound a plastic bucket was tapped a few times before the feed was given at a fixed time twice a day. Though the method was crude it proved to be successful. The mahseer fry (20 mm) can be trained in 15 - 30 days in cement cisterns and they continue to respond in the bigger ponds/lakes as well even after they grow up to 300 mm and even more. If this fish is released after the completion of training it will continue to respond even in natural habitat.

The Tata Power Company Ltd. has done some preliminary work on mahseer ranching at Walwhan. In the first experiment trained fish from the farm ponds were released in the protected site in Walwhan Lake, undisturbed by currents and high noise level. In another experiment floating cages with synthetic fiber netting of different mesh sizes were employed for cage culture experiments and also simultaneously for training the fish to sound impulses. The cages for the experiments had a size of 3 x 3 x 3 m. Trained fingerlings of mahseer of average 13 cm and 35 g were stocked from farm ponds into the cages, 500 in each cage (half a million/ha). For generating the sound plastic bucket was tapped with hand for a period of 30 seconds and then the feed was given. The already trained fish started responding within a week of their stay in cages. After the cage culture experiments were over the trained fish were released in the protected area very near to the cages. Releasing time was the same as the daily feeding time and the bucket tapping was continued. In both cases the trained fish released in the protected area of the lake started responding to the bucket tapping and came for feeding regularly, near the source of sound. The place and time of feeding, the source of sound, and the feed is same every day. Moreover it was observed that the fish from the wild (bigger size) also started responding during the duration of the cage culture experiments and were also attracted to the bucket tapping (sound impulse) and congregated near the source of the sound. It was observed that the fish from the lake followed the boat from the shore to cages and back expecting the food.

TPCL has been doing this work on training mahseer in small ponds since 1972, though this was the first time the observations were recorded in Walwhan Lake of The Tata Power Co. Ltd. Fujiya (1980) has done pioneering work on training of sea bream for ranching. At the TPCL mahseer farm, fish of all stages were trained to congregate near a sound source by feeding the fish at fixed intervals immediately after the sound was made. In a few days (15-30 days) several fish gathered near the origin of the sound. Almost all the sizes of mahseer (fry, fingerlings and adults) could be trained to respond to the sound within 15-30 days. It would be interesting to record how long this conditioning lasts.

3.7.2 Imprinting with chemicals

The other mode of recall is by scent rather than sound. Artificial imprinting with chemicals may be tried on mahseer but we must try and find out whether they can recognize the spawning site by odour. The other aspects, which need to be investigated are, various aspects of imprinting processes, age span at which successful imprinting can be accomplished, peak period at which imprinting is most effective and how long the conditioning will last, and the concentrations of various chemicals used for imprinting and special preferences of the mahseer species for various chemicals at different concentrations.

Once the fish are trained it is suggested that the same conditioning procedures are used but the amount of food should be reduced to encourage the fish to use natural food (Fujiya *et al.*, 1980). For successful ranching, the recapture or harvesting methods must be refined. The recapture operations should be carried out several times but at intervals, to be effective.

Ranching is basically a means of taking advantage of the natural growth of the fish in open waters. Ranching is a highly attractive proposition, which could go a long way in conservation and rehabilitation of the mahseer fishery in India.

With the possibility of transporting mahseer eggs or fry by air or train a centrally located national fish seed farm would be able to meet the demand from other areas for ranching this fish. Trained personnel who look after the eggs and fry would be necessary for achieving success. Proper selection of ranching and farm sites and organised effort to continue the work year after year would be essential to rehabilitate and preserve mahseer resources, especially when numerous dams and river valley projects are changing the ecosystem in which mahseer migrates and breeds.

3.8 Cage culture

In the year 2001, for the first time culturing of golden mahseer and Deccan mahseer in floating net cages has been tried at Walwhan Lake of the Tata Power Company Ltd. The size of the net cage is 9 m^2 (3m x 3m), with a depth of 3 m. The net is made of synthetic fibre supported on a pipe frame floated with the help of nine 200 litre drums. The top of the cage is covered to prevent the fish from jumping. It is advisable to have a double walled synthetic netting on the side and bottom as a precaution to prevent escape of fish. The corners are anchored to the bottom of the lake and also secured to the shore. Four net cages are floated and all are accessible by a floating walkway. The net cages are fixed in the lake over more than 4 meter depth. Fingerlings, each of 35 to 40 g, were stocked in January 2001 at a rate of 450 per cage. The stocking density is approximately half a million/hectare. The fish are being fed twice a day for 10 to 15 minutes with pelletized feed. The mahseer have grown to an average of 170 g in 5 months.

Recent observations predict excellent results and would promote cage culture in India. These cage culture experiments are being coupled with ranching and imprinting with sound. In earlier experiments the imprinted fish released in the ranching area of Walwhan Lake responds to the sound impulse to which they were trained while in cages and come to the shore.

4. CONSERVATION AND PROTECTION OF MAHSEER

Action plan for conservation of mahseer should include:

- Stricter enforcement of fishing rules to prevent fishing with explosives, poisoning, etc.
- Prevention of killing brood fish and juveniles.
- Replenishment of stock by artificial propagation.

In case of reservoirs, following steps are recommended to conserve mahseer:

- fish farm should be constructed in close proximity of every dam,
- a few tanks and ponds should be reserved in each farm for mahseer,
- mahseer should be bred by collecting ripe spawners from the streams joining the reservoir and stripping them for artificial fertilisation of eggs or using pituitary hormones.

Hatchlings should be grown to the fingerling size and then released into reservoirs and downstream rivers.

Further trials of methods of transporting mahseer eggs in moist cotton (Kulkarni and Ogale, 1979) are needed to easily transport the eggs to any part of the country.

Tata Electric Companies are involved in the rational management of the entire environment of the catchment areas of their hydroelectric reservoirs from forest to fish. TPCL has taken the initiative and undertaken excellent work in regarding environment protection, adopting a holistic view by taking care of the catchment area, including erosion, afforestation, and breeding of mahseer for its conservation and rehabilitation.

The annual average collection of eggs for the last 30 years is four to five hundred thousand per year, the maximum being a little over one million in 1988. The total tally of fertilised eggs collected from 1970 to 2001 breeding seasons is over 10.4 million, with 8.1 million of fry/fingerlings produced (Annex 1). Approximately 0.2 million mahseer fingerlings are released annually in the hydroelectric reservoirs of TPCL and the mahseer population therein has increased substantially. Over 1.06 million fry and semi-fingerlings have been given to 20 State governments and 4 angling associations during the last 30 years (Annex 2). For a summary of results of induced and natural spawning of golden mahseer at the Lonavla fish farm see Annex 3.

Extension

Four workshops were organised in 1986, 1987, 1991 and 1995 to focus attention on the need for urgent steps to be undertaken to conserve this important game fish of India. The experience gained and the results obtained by TPCL at the Walwhan fish seed farms were shared with eminent scientists and environmentalists, directors of fisheries from different states, and senior officials of agriculture I.C.A.R. and directors of the I.C.A.R and other fisheries institutes from all over India. TPCL has also extended training facilities to many state government officers and also organised a short course for officers from the Northeastern Hill Council. Scientists from the Laos P.D.R. also participated in the training programme.

5. CONCLUSIONS

All the species of mahseer are amenable to hypophysation, egg taking and artificial fertilization. At least one large size hatchery is required in each state. Efforts must be made to breed mahseer species on a large scale. Breeding of mahseer without hypophysation is perhaps the easiest method of egg collection. The TPCL design of hatchery and culture techniques are very simple and most successful and are recommended for adoption. Once the mahseer seed is available state governments of India and fish farmers can use mahseer fry and fingerlings for river ranching, raceway ponds and running water culture. Introduction of mahseer in aquaculture will be excellent for increasing the spectrum of fish species under culture. Thus if the suggested remedial measures are implemented in stages the mighty mahseer of India can be restored to its glory much to the delight of anglers and scientists in the country.

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ANNEX 1
Mahseer eggs/fry/fingerlings produced at the Tata Electric Companies Mahseer Farms Lonavla, District Pune (Maharashtra)
(For both species, total of eggs: 14 272 752; fingerlings: 8 126 130)

A*) Tor khudree and Tor mussullah*

Number	**Year**	**Number of fertilised eggs**	**Number of fry and fingerlings produced**
1	1970	14 000	10 000
2	1971	76 500	46 500
3	1972	133 000	80 000
4	1973	234 000	127 000
5	1974	272 000	165 000
6	1975	220 000	131 000
7	1976	238 000	124 000
8	1977	416 000	208 500
9	1978	563 000	212 500
10	1979	574 000	290 500
11	1980	417 000	180 000
12	1981	492 000	280 500
13	1982	520 000	250 500
14	1983	430 000	233 000
15	1984	593 000	340 000
16	1985	651 000	361 000
17	1986	520 000	332 000
18	1987	700 000	483 000
19	1988	1 080 000	682 500
20	1989	800 000	430 000
21	1990	464 000	290 000
22	1991	421 000	185 000
23	1992	300 000	150 000
24	1993	587 500	293 500
25	1994	480 000	288 000
26	1995	510 000	306 000
27	1996	619 000	341 000
28	1997	450 000	270 000
29	1998	436 600	292 000
30	1999	400 000	298 000
31	2000	380 000	228 000
Total	**1970 to 2000**	**13 991 600**	**7 909 000**

B) (*Tor putitora*)

1	1995	10 450	2 000
2	1996	27 400	16 000
3	1997	26 000	12 400
4	1998	44 000	42 069
5	1999	40 900	28 702
6	2000	132 402	115 959
Total	**1995 to 2000**	**281 152**	**217 130**

ANNEX 2

Semi-fingerlings and fingerlings of *Tor khudree* and *Tor mussullah* have been given gratis to the following State Governments, agencies and angling associations

NAME	QUANTITY
Laos PDR (south-east Asia)	1 500
Government of Maharashtra	5 15 000
Government of Karnataka	1 70 000
Government of Jammu and Kashmir and Council of Scientific and Industrial Research	12 000
Government of Haryana	50 000
Government of Punjab	5 000
Government of Orissa	8 000
Government of Goa	5 000
Government of Manipur	5 000
Government of Rajasthan	10 000
Government of Gujarat	10 000
Government of Andhra Pradesh	15 000
Government of Sikkim	5 000
Government of Himachal Pradesh	10 000
Maharashtra State Angling Association	40 000
Wildlife Association of South India	10 000
Coorg Wildlife Sanctuary	15 000
Karakal Sanctuary of Tamil Nadu	15 000
Bhilai Steel Plant	2 000
Tata Engineering and Locomotive Co. Ltd.	70 000
College of Fisheries, Manglore	25 000
National Defence Academy, Khadakvasla	2 000
Central Inland Fisheries Research Institute, Barrackpore	3 000
Assistant Director of Fisheries, Madikeri	10 000
Fish Farmers Development Agency, Yadavgiri, Mysore	30 000
Baron Hotels Pvt. Ltd., Panshet, Pune District.	20 000
Karnataka Power Corporation	25 000
Indo-German Reservoir Project (Kerala)	15 000
M. P. SCIENCE & Technology, Bhopal	5 000
M.P. Matsya Maha Sangh, Bhopal	5 000
Panna Wild life Sanctuary	10 000
TOTAL	**1 123 500**

ANNEX 3

Summary of results of induced and natural spawning of Golden Mahseer (*Tor putitora*) at the Tata Electric Companies' Mahseer Farm, Lonavla, District Pune (Maharashtra, India)

Date	Weight of female (g)	No. of eggs	Temperature of water (^oC)	Hatching (%)	No. of fry or semi-fingerlings produced
30 / 07 / 95	600	5 800	21 C	35 %	650
14 / 08 / 95	600	4 650	22 C	90 %	1 350
03 / 08 / 96	1 700	1 800	23 C	25 %	302
03 / 08 / 96	1 300	9 200	23 C	91 %	5 632
03 / 08 / 96	900	2 800	23 C	93 %	1 754
27 / 08 / 96	1 000	8 000	24 C	90 %	4 846
27 / 08 / 96	1 250	5 600	24 C	92 %	3 466
05 / 08 / 97	1 750	2 400	23 C	94 %	1 060
05 / 08 / 97	2 000	6 800	23 C	5 %	160
09 / 08 / 97	850	10 400	23 C	92 %	9 090
10 / 08 / 97	900	2 200	23 C	61 %	635
21 / 08 / 97	1 200	1 000	24 C	66 %	310
28 / 08 / 97	1 500	3 200	25 C	80 %	1 145
11 / 08 / 98	1 200	4 400	24 C	74.18 %	3 264*
27 / 08 / 98	1 225	8 200	23 C	90 %	7 380
27 / 08 / 98	1 200	3 400	23 C	93 %	3 147
29 / 08 / 98	2 200	2 400	24 C	93 %	2 243
29 / 08 / 98	2 000	11 600	24 C	99 %	11 500
14 / 09 / 98	1 500	4 800	24 C	72.12	3 462+
05 / 10 / 98	1 800	9 200	25 C	88.04	8 100+
10 / 02 / 99	1 750	3 600	22 C	84.44 %	3 040+
12 / 02/ 99	2 500	4 800	22 C	71.16 %	3 416+
18 / 02 / 99	1 500	2 000	22 C	92 %	1 840+
18 / 03 / 99	2 500	100	24 C	52 %	52+
18 / 03 / 99	2 250	180	24 C	80 %	144+
18 / 03 / 99	2 000	100	24 C	10 %	10+
11 / 08 / 99	4 250	10 500	23 C	96 %	10 080*
16 / 08 / 99	1 500	5 800	24 C	81 %	4 698+
24 / 08 / 99	1 500	5 200	24 C	91 %	4 732
24 / 08 / 99	500	2 800	24 C	94 %	2 632
24 / 08 / 99	1 500	4 220	24 C	15 %	631
24 / 08 / 99	500	1 600	24 C	25 %	400
14/03/2000	2 000	1 400	26 C	92 %	1 290
23/03/2000	500	4 435	26 C	97 %	4 335
23/03/2000	500	1 045	26 C	78 %	824
24/03/2000	500	1 972	26 C	62 %	1 222
24/03/2000	500	1 050	26 C	78 %	824
14/06/2000	500	600	25 C	98 %	588
17/06/2000	600	1 200	25 C	75 %	900

Date	Weight of female (g)	No. of eggs	Temperature of water (^oC)	Hatching (%)	No. of fry or semi-fingerlings produced
17/06/2000	500	2 100	25 C	86 %	1 806
16/07/2000	5 500	13 600	24 C	95 %	12 920*
16/07/2000	2 500	5 200	24 C	96 %	4 992*
28/07/2000	5 500	5 600	24 C	87.50 %	4 900*
07/08/2000	300	2 100	26 C	85. 71 %	1 800+
07/08/2000	500	5 200	26 C	99 %	5 170
07/08/2000	600	2 600	26 C	77 %	2 002
07/08/2000	300	1 100	26 C	76 %	836
08/08/2000	300	900	26 C	78 %	702
08/08/2000	400	800	26 C	77 %	616
23/08/2000	2 000	6 500	22 C	92 %	6 000*
28/08/2000	2 000	8 000	22 C	95 %	7 600*
08/09/2000	500	2 800	24 C	94 %	2 630+
08/09/2000	550	2 000	24 C	75 %	1 500+
08/09/2000	600	4 500	24 C	80 %	3 600+
08/09/2000	700	5 200	24 C	82 %	4 264+
08/09/2000	500	3 500	24 C	70 %	2 450+
09/09/2000	600	3 000	24 C	85 %	2 550+
09/09/2000	400	1 200	24 C	60 %	720+
09/09/2000	550	2 600	24 C	77 %	2 002+
09/09/2000	550	5 200	24 C	80 %	4 160+
09/09/2000	500	1 000	24 C	70 %	700+
19/09/2000	700	4 200	23 C	90 %	3 780+
19/09/2000	1 250	1 600	23 C	90 %	1 440+
21/09/2000	2 000	14 400	25 C	90 %	12 960+
22/09/2000	400	800	25 C	73 %	584+
29/09/2000	500	3 000	26 C	92 %	2 760+
04/10/2000	300	1 000	26 C	95 %	950+
13/10/2000	400	1 800	25 C	89 %	1 615+
13/10/2000	500	2 500	25 C	81 %	2 025+
13/10/2000	400	1 000	25 C	96 %	960 +
16/10/2000	300	800	26 C	92 %	736+
16/10/2000	1 750	600	26 C	92 %	552+
16/10/2000	600	1 400	26 C	92 %	1 288+
30/10/2000	550	1 800	24 C	91 %	1 638+
01/11/2000	600	1 200	24 C	64 %	768+
02/03/2001	350	1 700	21 C		+
02/03/2001	475	800	21 C		+
02/03/2001	550	4 000	21 C		+
02/03/2001	400	100	21 C		+
03/03/2001	1 800	700	22 C		+
06/03/2001	400	800	21 C		+
06/03/2001	450	1 000	21 C		+
Total		281,252			217,130

+Females collected from brood stock pond in oozing condition while being chased and directly stripped to collect eggs. (Fry – 83 194)

*Females collected from Walwhan Lake along with the brooders of Deccan mahseer during the rainy season and found in oozing condition and stripped for artificial fertilization. (Fry - 49 756)

Females bred by hypophysation (induced breeding) with either Ovaprim or Ovatide. (Fry – 84 180)
Total: 217 130.

Males of Golden mahseer were observed to be in oozing condition through out the year. If properly reared it will be possible to breed Golden mahseer throughout the year. The above data confirm that Golden mahseer can adapt to any conditions and breed in captivity with or without injections.

PRESENT STATUS OF SNOW TROUT IN NEPAL

by

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ABSTRACT

Snow trout, a cold water riverine and short migratory fish is locally known as asla. It belongs to the family Cyprinidae and sub-family Schizothoracinae which are widely distributed in the Himalayan and sub-Himalayan region and much of the rest of Asia. Altogether 28 species of snow trout are reported of which 6 species of genus *Schizothorax* and 3 species of genus *Schizothoraichthys* are recorded in Nepal. *Schizothoraichthys progastus* (altitude distribution 300-1 820 m), locally called Chuche asla, and *Schizothorax plagiostomus* (altitude 345-3 323 m), called Buche asla, are high value sport fish and are common in Nepal. Asla is a phytophagous fish and has developed a special mouth to scrape the algae attached on stones. Asla spawn twice a year during September/October and March/April, but September/October is the best season for spawning. Clear water, stony bottom of creeks composed of fine pebbles and gravel, and water flow of 2.8-4 m/sec, pH 7.5 and dissolved oxygen concentrations of 10-15 mg/L form good spawning conditions in the natural environment. Asla has been bred artificially in the Fisheries Research Centre Trishuli since 1971 but the hatching rate is low and mortality of alevins is still high (>50%). Fully mature females release orange and sticky eggs when gently pressed on the abdomen but it requires a very specific time for spawning to get good quality of eggs.

Asla brood fish maintained in concrete raceway ponds and fed 35% protein content diet at 1-2% of body weight produce about 12 000 eggs/kg. Hatching takes place within about 11 days at water temperature 15-20°C and Buche asla is easier to breed than Chuche Asla. The development from one- day hatchling to free swimming stage varies inversely with temperature, ranging from 5 days at 24°C to 24 days at 12°C, and the survival rate is higher (>90%) at 20-24°C, lower (65%) at 17°C and <50% at 11-14°C. Hatching rate is higher (50%) during October/November than during February/March (<25%). Asla grow up to 20-25 g in two years and reach 100 g in the third year and increase considerably in the following years. Asla has specialized feeding habit due to its mouth structure, which cannot take larger size of food. No technology has been developed yet for commercial culture, particularly due to not being able to develop appropriate feed for asla. Further studies are needed, with emphasis on suitable feed development required for larval rearing, which seems to a very important as well as critical stage.

1. INTRODUCTION

Nepal, a Himalayan kingdom, covers about 147 000 km^2 with the altitude varying from 60 to 8 850 m above sea level. Geographically it is divided into Himalayan region, mountain region, mid-hill region and Terai - the flat area region. The climatic conditions vary with the altitude. There are also seasonal changes that can be defined as autumn, winter, summer and monsoon seasons. The water originates in the Himalayas in the north and flows to the lowlands in the southern part, with water temperature increasing accordingly. The air temperature varies from below 0°C in the Himalayan region to about 44°C in the southern Terai region of the country. Therefore temperature of water bodies differs from place to place and depends primarily on altitude and whether the water source is snow-fed or not. Nepal is rich in water resources, with more than 6 000 rivers and rivulets cover an estimated area of 395 000 ha, lakes 5 000 ha, and small reservoirs 1 500 ha (FDD, 1998). Koshi, Gandaki and Karnali are the three major river systems, which are fed by hundreds of small rivers originating from the snow-capped Himalayan mountains and flowing south.

The great variation in climatic conditions between the north and the south of the country is due to the great differences in altitude.The rivers accordingly exhibit a wide variation of aquatic habitats. The difference in ecological conditions ranging from oligotrophic glacial cold waters in mountainous and hilly regions to slow flowing or stagnant eutrophic warm waters in the lowland Terai is also reflected in the diversity of fish species. Fish species have different form adaptations, different feeding habits and different special organs to be able to attach themselves to rocks in the fast current. Shrestha (1995) has reported a total of 186 fish species in Nepal, of which she identified 18 species as cold water fish. An updated list (Shrestha, J., this volume) mentions 163 freshwater fish species for Nepal.

2. ASLA (*Schizothorax* and *Schizothoraichthys*)

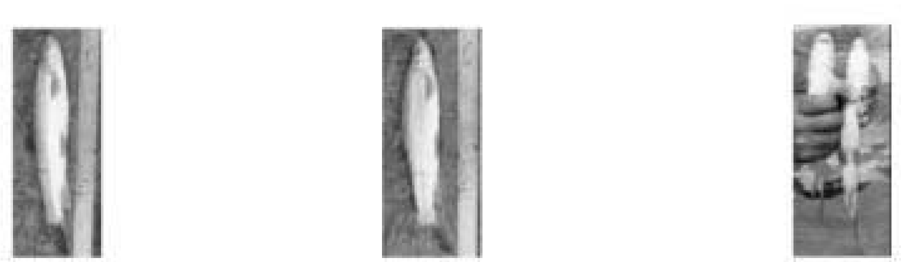
2.1 Description

Asla has a conical head with slender, elongated and strong body to resist the strong water current of the hill streams and rivers. The body is covered with minute silvery scales and the abdomen with lighter brown scales. Snout bears nuptial tubercles and the size and number are well developed in males. They are grayish black on the dorsal side and silvery on belly and sides. A distinct suctorial disc in addition to 4 barbels is present on the chin for attachment to stones. Maximum weight and size are 1.5 kg (48 cm) reported by Rajbanshi (1971), but up to about 5.0 kg in the Seti River and about 2.5 kg in the Trishuli River and Sunkoshi River according to the local fishermen.

Schizothorax plagiostomus, locally called Buche asla (Fig.1a), and *Schizothoraichthys progastus*, called Chuche asla (Fig. 1b) are present at altitudes 300-1820 m and 345-3323 m (Shrestha 1995), respectively. Misra (1959) has described *Schizothorax* and *Schizothoraichthys* based on the shape of snout, with *Schizothorax* having a blunt snout and suctorial lip whereas *Schizothoraichthys* has a pointed snout and no suctorial lip (Fig. 1c). *Schizothorax plagiostomus* and *Schizothoraichthys progastus* are common and dominant fish in most of the rivers and lakes of Nepal and are good sport fish as well as delicious to eat. *Schizothorax plagiostomus* is called golden snow trout by virtue of its silvery golden colour. These two species have been studied at the Fisheries Research Centre, Trishuli since 1971. Culturing of these species is still not fully developed due to the problem of developing appropriate feed. Snow trout is a short-distance migratory fish which enters tributaries for breeding. The presence of dam blocks its migrations. It migrates downstream during winter and upstream during early June when water becomes turbid. The migration pattern varies from species to species and also depends on the volume of water in rivers and on water temperature.

2.2 Distribution

Genus *Schizothorax*, a cold water river fish locally known as asla and more generally as snow trout, (Cyprinidae, Schizothoracinae), is widely distributed in the Himalayan and sub-Himalayan region of the Indian-Chinese sub-continent. In the Tran-Himalaya region snow trout is found in India in cold waters from Jammu and Kashmir (Sunder and Bhagat, 1979) to Nainital where Menon (1971) reported a new species *Schizothorax kumaonensis*. *Schizothorax plagiostomus* (McClelland) forms significant indigenous fishery in upland waters of Jammu and Kashmir and represents about 10-20% in total commercial landings (Raina *et al.*, 1985). Jhingran (1982) reported that this species is distributed from Asam and eastern Himalayas through Bhutan and Sikkim at an altitude of 1 180-3 000 m. In Nepal this fish species has been reported from rivers and lakes/reservoirs at an altitude of 300-3 323 m (Shrestha, 1981). It needs a high dissolved oxygen concentration as also required by the rainbow trout. Some of the high altitude lakes in Nepal are inhabited only by *Schizothorax* spp (Ferro, 1977; Pradhan, 1982).



(a) Buche asla (b) Chuche asla (c) Buche & Chuche asla

Fig. 1 - (a) Buche asla *Schizothorax plagiostomus*; (b) Chuche asla *Schizothoraichthys progastus*; (c) Buche and Chuche asla.

Shaw and Shebbeare (1937) also reported *Schizothorax plagiostomus* from Nepal. *Schizothorax* spp. generally prefer rapids and pools of snow-fed torrential streams with temperature ranging from 8°C to 22°C (Sharma, 1989) and can tolerate the high range of water temperature of 0-32°C (FRC, personnel communication). It is also present in lakes without a connection to flowing rivers or streams (Pradhan, 1982). Sharma (1989) has reported 28 species of snow trout in Himalayan and sub-Himalayan regions including Tibet, China and Pakistan. In Nepal 9 species have been recorded of which 6 species are of the genus *Schizothorax* and 3 species of the genus *Schizothoraichthys* (Shrestha, 1995). *Schizothorax macrophthalmichthys*, *S. nepalensis* and *S. raraensis* recorded by Terashima (1984) are endemic to Rara Lake (2 900 m altitude) situated in north-western Nepal. However, the populations are decreasing rapidly due to a heavy fishing pressure, natural calamities, as well as human disturbances such as construction of dams and roads.

2.3 Feeding habits

Asla is a phytophagous fish, with its mouth adapted to scraping attached algae from the surfaces of stones. The feeding habits of asla have been reported by many authors (Shrestha, 1979; Masuda and Karki, 1980; Terashima, 1984; Sharma, 1989). It feeds on attached algae including *Spirogyra, Ulothrix, Oedogonium,* as well as on the benthic insect larvae of mayflies, caddis flies, ephemeropterans, etc. Fry feed on larvae of chironomids and caddis flies, but also on microscopic algae. *S. plagiostomus* is herbivorous and feeds on aquatic plants and algae attached to stones and rocks (Shrestha, 1979). Asla food was found to contain predominantly green and blue-green algae, folllowed by detritus and aquatic insects. Diatoms attached to rocks, stones and boulders as aufwuchs form the primary source of food in torrential streams whereas aquatic macrophytes, decayed organic matter and green algae are minor diets.

2.4 Spawning

Asla spawns when two years old, depending on food supply. Sexual dimorphism is developed in *S. plagiostomus* (Rajbanshi, 1971) and in *S. macrophthalmichthys, S. nepalensis and S. raraensis* (Terashima, 1984) in anal fin, presence of nuptial organs and size of the basal sheath scale. Mature asla has a change in colour during the breeding time. Mature males develop tubercles on either side of the snout, faint yellow colour of the body, and reddish colour of fins. Females spawn in natural as well as in artificial environments. Asla can spawn naturally or by stripping the wild/cultured mature female during the spawning season. It spawns in September/October and March/April.

2.4.1 Natural spawning

Sexually mature asla spawn naturally when they reach 18-24 cm length. They attach eggs to the substrate. Fry stay on sand and gravel bottom. Asla spawn naturally in clear water on gravelly/stony grounds or on fine pebbles at 1-3 m depth (Shrestha and Khanna, 1976). Water current of 2.8-4 m/sec, pH 7.5, dissolved oxygen concentrations of 10-15 mg/L, and gravel size of 50-80 mm are the optimal conditions for spawning (Shrestha and Khanna, 1976).

2.4.2 Artificial spawning

Fully mature female fish both wild and raised in captivity release eggs when gently pressed on the abdomen but have a very specific time for spawning, which should be checked frequently to know the right ovulation time to get good quality eggs during stripping. Since 1971 the Fisheries Research Centre, Trishuli, has been breeding asla. It is still experiencing low hatching rates as well as high mortality of alevins (>50%), which might be due to not being able to develop proper feed for alevins as well as for brood fish. Spawning is better during September/October than in February/March, which means temperature and spawning are closely related. The optimal water temperature is 15-16°C (FRC, personnel communication). Mature females need to be checked at 2/3 day intervals during the spawning season otherwise over-ripe or under-ripe eggs are squeezed out, which affects the hatching and survival rates. Males produce sperm throughout the year. Proper broodstock management with good nutritive feed helps to develop good quality eggs and October/November is probably the best season for spawning of *Schizothorax plagiostomus* and *Schizothoraichthys progastus.*

Asla broodstock are maintained in concrete raceway ponds (23.3 m^2) in the Fisheries Research Centre, Trishuli. They are fed 35% protein content pellet diet at 1-2% body weight daily, depending on temperature. Broodstock used for spawning are 3-6 years old, and males and females are kept separately 2 months prior to spawning. Females are checked weekly or twice a week during the spawning season. Eggs are fertilized with milt collected from male by stirring them gently with avian feather. Fresh water is added and eggs are washed 3/4 times till they are clean, swollen and not clinging. After about 5 minutes, fertilized eggs are poured in incubation trays made of screen which is placed in a fiberglass incubation apparatus (215 x 35 x 36 cm) (Fig. 2). The incubator is shaded from direct light, inclined at 30 degrees, and has a constant water flow of 20 litres per minute. Unfertile or damaged eggs become dull and may be attacked by fungus. They must be separated from the good eggs so as not to contaminate them. The mean fecundity of asla ranges from 5 000 to 12 000 eggs/kg body weight (FRC, Trishuli, 1994). Shrestha (1978) has reported about 25 000-40 000 eggs per fish. The eggs are sticky, orange in colour, toxic and cause diarrhea and dizziness when eaten. They lose the toxicity after being kept in water for some time. Two females of 242 g and 261 g, respectively, with the egg size of 2.54 mm ±0.2 - 13.3 mg ±3.0, released 11 713 and 11 697 of eggs per one kg of body weight.

Fig. 2 - Incubation trays made of screen and placed in fiberglass incubation apparatus

Incubation water temperature of 15-20°C might be the optimum temperature as it takes about 11 days for hatching (FRC, 1991). Shrestha (1978, 1979) has also reported that hatching takes place within 11-18 days at water temperature of 18-21°C. Buche asla is easier to breed than Chuche asla but egg fertilization from artificial breeding is low. This could be due to the stripped eggs being mixed with blood, faeces and scales during stripping. Eggs have to be cleaned with salt water or other chemicals before fertilizing them with milt. Asla fry were similar to Ayu fry in Japan (Wada, personnal communication). Ayu fry was fed every 2 hours after hatching and then twice a day after one month. The development from one day hatchling to free swimming stage varied inversely with temperature ranging from 5 days at 24°C to 24 days at 12°C and the survival rate was also higher (>90%) at 20-24°C and lower (65%) at 17°C and <50% at 11-14°C (FRC 1994). The hatching rate was higher (>50%) during October/November than during February/March (<25%) (Fig. 3) and October/November might be the best time for spawning. The size of hatchlings varied from 3.9-9.6 mg and survival was about 47%.

2.4.3 Growth

Chuche asla fed 35% protein content diet at 2-5% body weight grew from 0.7 to 7.2 g in 359 days but lost weight in December/January when temperature was 10-12°C. Buche asla grew better than Chuche from 1.8 g to 17 g in 295 days and females grew faster and larger than males (FRC, 1991). *S. plagiostomus* grow up to 226 g and *S. progastus* grew up to 363 g in the fourth year (Masuda, 1979). The growth of asla is very slow reaching 20-25 g in two years and 100 g in the third year (FRC, personnal communication). Dhar (1967) reported the fish to reach 175 g in the second year and 330 g in the fifth year. Alevins at 20-24°C reached the free swimming stage within 5-6 days and swam at the surface in 8-10 days.

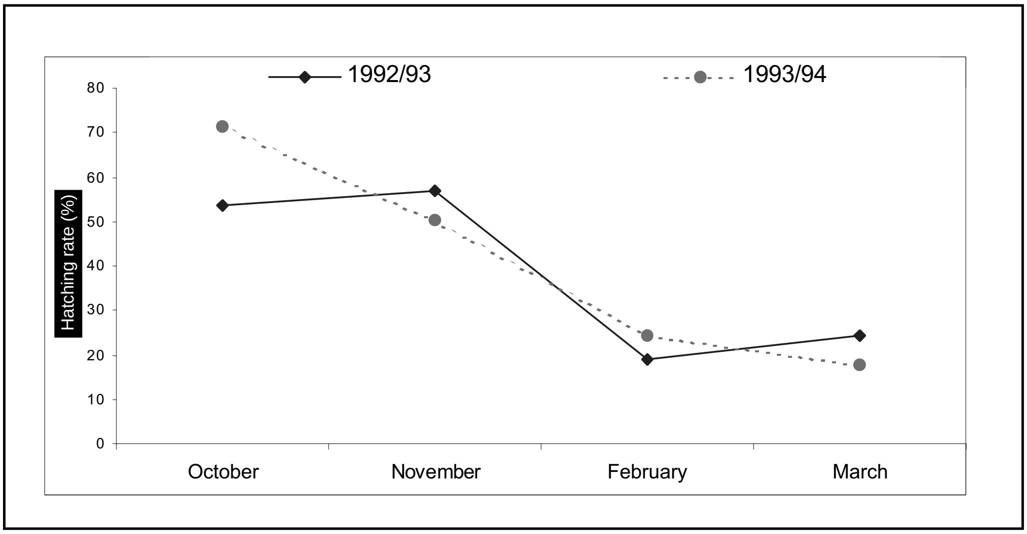


Fig. 3 - Hatching rate is higher (>50%) during October/November and lower (<25%) during February/March.

2.5 Potential

Asla is a very good sport fish, tasty and liked very much by the people. It also fetches high price compared to other fish species. Asla is considered as an economically important high value fish of the Himalayan and sub-Himalayan regions. To bring it under culture needs proper feed and this is a major task for research. Without it asla cannot be yet produced for markets under aquaculture conditions. Asla is a sport fish and could support sport fishery in the mid-hill region. From this the local people could benefit as it would encourage tourism. The required habitat for asla is present in the hills and mid-hill regions. Once the feed problem is solved production of stocking material for regular releases into streams and rivers can be made. This would also make possible full-cycle fish production under aquaculture conditions. Overcoming difficulties of mass production of asla stocking material will require regional cooperation in which scientists of the countries of the Trans-Himalayan region closely collaborate.

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ZOOGEOGRAPHICAL DISTRIBUTION AND THE STATUS OF COLD WATER FISH IN NEPAL

by

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ABSTRACT

The paper reviews the old and new reports and records on fish of Nepal. On the basis of their distribution in Nepal water bodies, a distribution list of 76 indigenous cold water fish has been compiled. Amongst the cold water fish the family Cyprinidae dominates with 46 species. It is followed by families Sisoridae and Balitoridae. In the cold waters of mountains the cyprinids *Schizothorax* and *Schizothoraichthys* dominate. In high hills and the hill region they are joined by *Tor*, *Neolissocheilus*, *Barilius*, *Chagunius*, *Semiplotus*, *Glyptothorax*, *Botia* and *Clupisoma*. These cold water fish provide food and income to the local people. In Nepal cold water fish are considered tastier than other fish, therefore they are preferred and in demand and fetch a high price in the markets. Species of the genera *Tor*, *Neolissocheilus*, *Barilius* and *Schizothorax* are also known as sport fish. Some other cold water species have decorative and academic values. At present none of the cold water fish species of Nepal is listed as endangered or threatened. Due to the continuing deterioration of the aquatic environment the status of cold water fish needs to be revised through an in-depth assesement of the current situation, and if the situation is found serious, a long-term action plan for the preservation of the endangered species should be prepared and implemented. Aquaculture of cold water fish as well as establishment of sport and recreational fishery centres at appropriate points in mountains and hills would not only enhance the production of fish as food for the local population but it would also be a good opportunity for providing employment, including a stimulus for eco-tourism to earn foreign currency. This would also reduce the need for the people to leave the mountains in search of employment in the southern Nepal.

1. INTRODUCTION

Nepal lies at the center of 2 500 km long Himalayas which start at Namcha Barwa (7 756 meter above sea level) in the east and end at Nanga Parbat K2 (8 125 m) in the west. The part of Himalayas within the Kingdom of Nepal between 80^0 22' E to 88^0 12' E and 26^0 20'N to 30^0 27'N is also called Central or Nepal Himalaya (Jairajpuri, 1993). It shares to over one third length of the Himalayas.

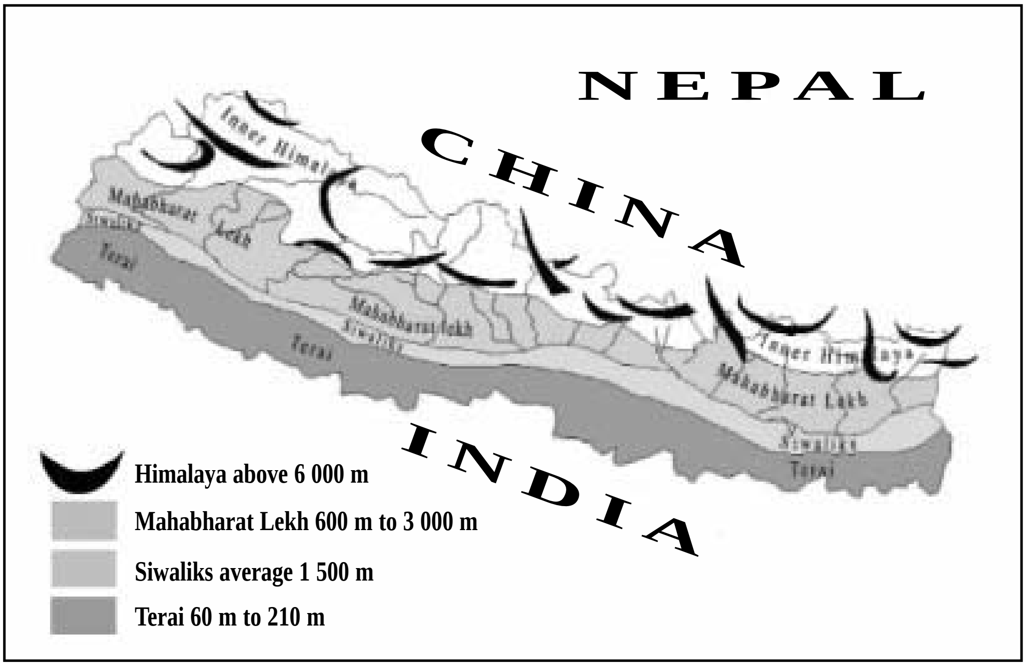


Fig. 1 - Physiographic map of Nepal

On the map, Nepal looks like a humped rectangle of about 845 km from east to west and between 145 km to 225 km in width from north to south. It covers an area of 147 181 km². Its elevation ranges from the lowest point of 60 m to 8 848 m, the world's highest peak Sagarmatha (Mount Everest). On the southern border, a strip of land of about 40– 45 km wide called Terai has tropical climatic conditions and is part of the Gangetic plains. It occupies the whole length of southern Nepal and represents approximately 17% of the total area of the country. This strip of land is very productive and is considered the grain basket of the country. To the north of Terai there are two hill ranges - the Siwalik hills with an average altitude of 1 500 – 2 000 m, and further north the Mahabharat hills with a range of 2 000 – 3 000 m. In between the two hill ranges, there are a number of small and medium sized productive valleys called "doons". Further north are high hills - an extension of the Mahabharat hills which ranges from 2 000 to 5 000 m and roughly covers about 55% of the total area of the country. The extreme north of the country includes 10 of the world's 14 highest peaks above 8 000 m. These high peaks typically stand in clusters and in rows, are covered in snow and ice and are the perennial source of water for Nepal.

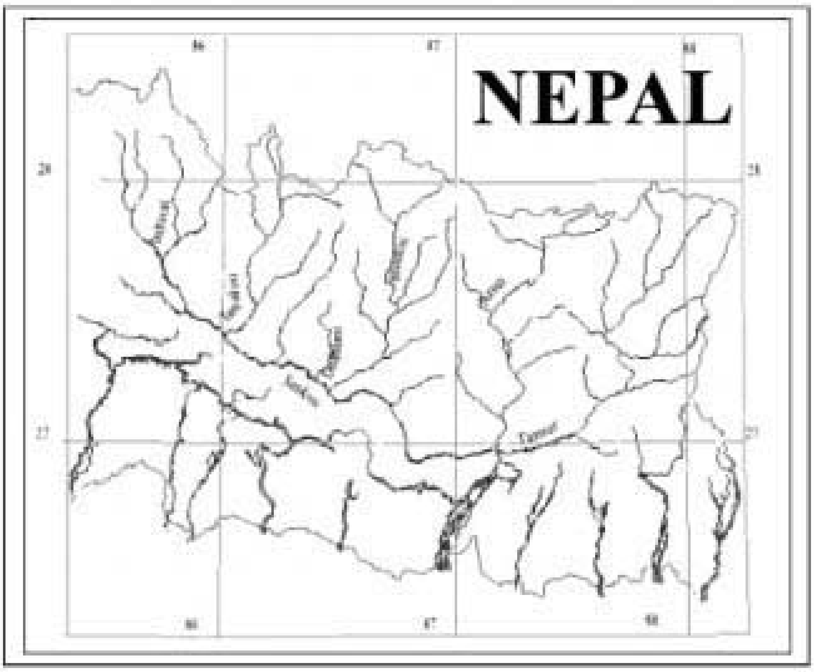
2. WATER RESOURCES

The River Ganges has a large number of tributaries rising from the Himalayan ranges, of which the drainage system of Nepal contribution is the largest. Based on their origin and water discharge, the rivers of Nepal are broadly classified into three categories; major, medium and minor. The first category includes four major rivers – the Koshi in the eastern region, the Gandak in the central region, and the Karnali and Mahakali in the far-western region (Sharma, 1977). The first three major rivers, River Koshi, R. Gandak (or Gandaki) and R. Karnali originate from the northern slopes of the greater Himalayas and subsequently cross the Himalayas, while the fourth river, the Mahakali, originates from the high mountains of Nepal

Himalayas. The total area drained by the major rivers of Nepal alone is more than 60 % of the total drainage area of the country. Each major river, besides the Mahakali, has seven large tributaries draining large catchments. Many more medium and small sized rivers and streams originate from the mountains, high hills of the Mahabharat and Siwalik regions and form a complex network of the river system. Most of these rivers and streams drain from north to south with some exceptions from west to east. These rivers traverse from the alpine to the tropical climatic zones. They are torrential in the north and almost stagnant in the south and ultimately drain into the River Ganges to which they are the largest water contributor, bringing in about 41 % of the annual flow and about 71 % of the dry season flow of the Ganges (Abbas, 1982).

2.1 Rivers

2.1.1. Major rivers



RIVER KOSHI

Fig. 2 - River Koshi

The Koshi River is also called Sapta Koshi and is the largest river of Nepal and the largest tributary of the River Ganges. The Koshi drains the region lying east of Gosainsthan to west of Kanchangjunga, covering a total drainage area of 60 400 km^2 , of which about 47% lies in Nepal (Dixit, 1995). The rivers Tamurkoshi, Arunkoshi, Dhudkoshi, Tamakoshi, Sunkoshi, Bhotekoshi and Indrawati are the main tributaries of the Koshi basin. Some of its major tributaries such as the rivers Arunkoshi and Bhotekoshi are antecedent to Himalayas and originate in the Tibet Autonomous Region of China. The Koshi has steep gradient in the mountains and hills while on the plains it forms numerous channels. It carries a high silt load and forms sandbars and islands. Thus, it always tends to change its course and each year causes high flooding. The Koshi has an average flow of 1931 m^3/sec. Being dammed by a 1150 m long barrage its water is being used for hydropower production as well as for irrigation. Under an extensive flood control programme 40 km and 12 km embankments were constructed along the eastern and western bank within Nepal. Extensive embankments of about 220 km length are constructed on either side of the river in India to confine the river flow and protect land beyond it from floods (Malla, 1995). To facilitate the upward and downward movement of aquatic animals, especially fish, the barrage has two fishways on its both sides. The effectiveness of these structures has yet to be fully evaluated.

RIVER GANDAKI

Fig. 3 - River Gandaki

The River Gandak is also called Sapta Gandaki. It originates in the north in the main Himalayan range. It drains the area lying in-between Gosainsthan (north of Kathmandu) to Dhaulagiri region, covering total drainage area of 34 960 km^2, of which 90% lies in Nepal (Dixit, 1995). Its major tributaries are Trishuli, Budhi Gandak, Marshyangdi, Madi, Seti Gandak, Daraudi and Kali Gandak. Of these the Kali Gandak is antecedent to Himalayas as it originates in the Tibet Autonomous Region of China. The River Gandaki spreads out at Narayanghat, a doon valley of Chitwan, and after a short run it enters the Indo-Gangetic plains at Tribeni in Bihar, India. The River Gandaki has an average flow of 283 m^3/sec (Uprety, 1993). It has a barrage to regulate the flow of water for irrigation and hydroelectric power production. Two irrigation canals take off from either side of the barrage. In aggregate, the irrigation canals irrigate 57 900 ha of land of Nepal and over 1.8 million hectares of land in India. The project also generates 15 000 KW of power. The barrage has no fishway.

RIVER KARNALI

Fig. 4 - River Karnali

The Karnali River originates from the southern region of Mansarovar and Rokas Lake in Tibet. It covers a total drainage area of 44 000 km^2 of which 773 km^2 lies in Tibet and 43 227 km^2 in Nepal (Dixit, 1995). It drains the Far-West Development Region of Nepal through its tributary rivers Sano Bheri, Thulo Bheri, Tila, Mugu Karnali, Humla Karnali, River Burhi Ganga and River Seti (west). The River Karnali has an average flow of 510 m^3/sec (Uprety, 1993). The hydropower potential of the river has been estimated at 32 000 MW (Shrestha, 1969).

RIVER MAHAKALI

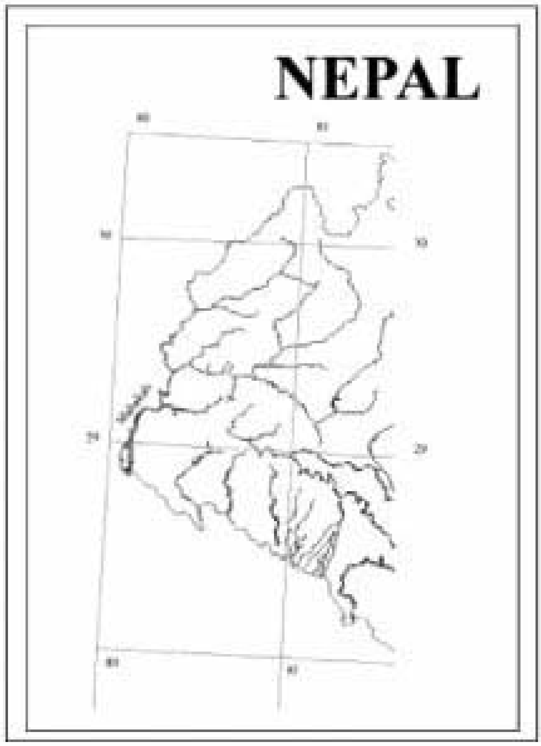


Fig. 5 - River Mahakali

The River Mahakali originates in high mountains of Himalaya of Nepal and it flows south forming western international boundary between Nepal and India. In the upper region of the river, it flows in deep gorge. The river basin has a total drainage area of 15 640 km^2. The river has three major tributaries; rivers Chamelia, Surnayagad and Rongun Khola (Sharma, 1997). The river has also a barrage to regulate the flow of water for irrigation and hydroelectric power purposes.

Medium rivers

The second category of rivers from east to west are the rivers Mechi, Kankai, Kamala, Bagmati, Tinau, Rapti (west), and Babai. They originate in high mountains of Himalaya or Mahabharat ranges and are fed by annual precipitation as well as sub-surface drainage. These rivers are perennial but are characterized by a wide seasonal fluctuation in discharge.

Minor rivers

The third category rivers are many but they are small and originate from Siwalik or Bhabhar ranges. These rivers are mainly rain-fed. Most of these rivers have less than 350 km^2 catchment area and are characterized by little or no flow of water during the dry season (ADB/HMG, 1982). These rivers have highest discharges during the monsoon season.

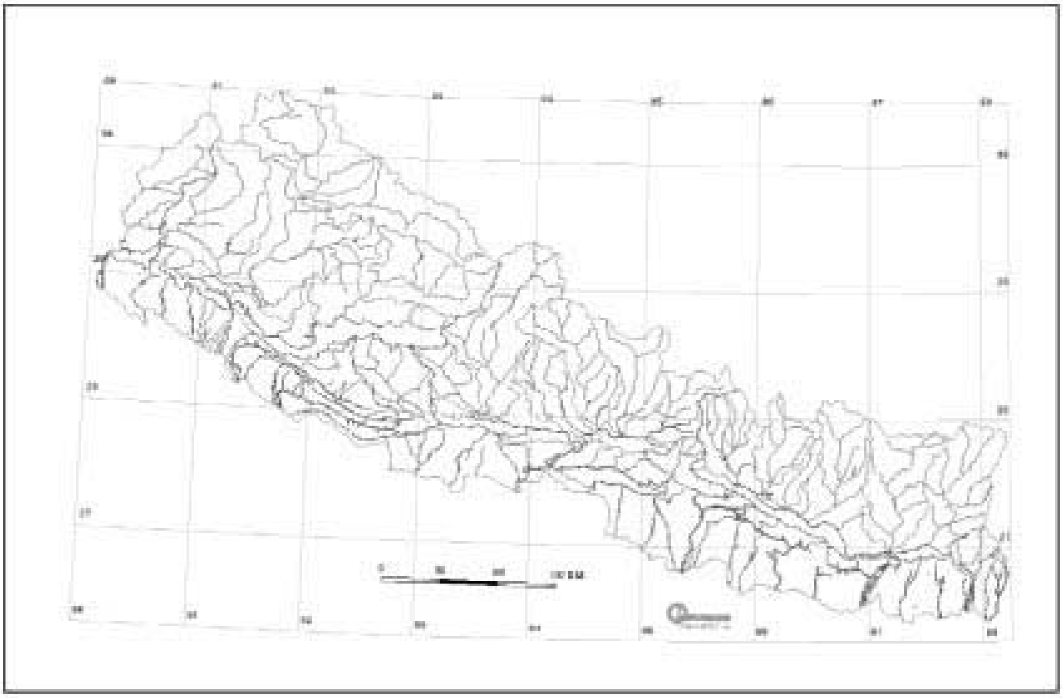


Fig. 6 - Network of rivers in Nepal

2.2. Lakes

A number of medium and small lakes are scattered throughout the country ranging from sub-tropical warmer areas to freezing altitudes. The lakes located in the high mountains are glacial in origin and are less productive compared to mid-hill tectonic lakes and the lowland ox-bow lakes. Information on the high altitude lakes and their fish fauna is meager compared to mid-hill lakes, as no biological study has been carried out. Out of many high altitude lakes, the Mahendra Tal (Lake Rara) is the biggest lake. Biology and limnology of this lake has been studied (Ferro, 1978; Swar, 1979; Terashima, 1984). The lake has three endemic fish species (Terashima, 1984), while some of the other glacier water lakes, e.g. Phoksundo and Gosainsthan, probably have no fish. There are many small lakes at high altitude. Out of the 90 high altitude lakes from 4 000 to 6 000 m of Khumbu (Mt. Everest) region, 69 lakes have been recently mapped and had studied their limnological and biological parameters (Tartari et. al., 1998; Manca et. al., 1998; Lami et. al., 1998). These studies do not mention the presence of any fish in these lakes. Much studied tectonic lakes of Pokhara valley – Lake Phewa (523 ha), Begnas (328 ha) and Rupa (135 ha) have well established aquaculture and capture fishery (Rai, 1995). From the lakes of Pokhara, 25 indigenous fishes have been reported (Ferro and Badgami, 1980; Pokharel, 1999).

2.3 Reservoirs

The first commissioned man-made reservoir for hydropower was Indra Sarovar at Kulekhani, with water surface area of 220 ha. The reservoir fish have been studied and there is now a well established fishery. The future development plans of hydropower and irrigation expansion envisage an increase in the number of reservoirs to eventually cover 153 200 ha (Pradhan, 1987), thus offering a great scope for expansion of fisheries, including aquaculture.

2.4 Other water bodies

Wetlands and waterlogged areas, paddy fields and village ponds of various sizes are scattered throughout the country and represent a considerable area of water bodies. Such aquatic habitats are often reconnected with rivers during monsoon floods and are rich in fish.

3. FISH RESOURCES

The distribution of fish in the Eastern/Assam and Western/Kumaon Himalayan region within the territory of India has been studied by a number of ichthyologists, including Hamilton (1822), Day (1878–81), McClelland (1839), Shaw and Shebbeare (1937), Hora (1951, 1952), Menon (1954, 1964), Srivastava (1968) and Jayaram (1981, 1999). However, the Nepal Himalayan region was left out as then Nepal was closed to the outsiders. The lack of information on the distribution of fish within Nepal always caused difficulties in drawing conclusions on their geographical distribution along the southern region of Himalaya. In those days no mission besides political was allowed to enter the country. Even under such conditions, some of the members of the political missions made their best effort to collect information and samples of fish from various water bodies. However, the information on fish fauna was confined along the trek route to Kathmandu and adjacent areas due to restrictions on movements of foreigners. More recently the fish fauna of vaarious water bodies has been studied by a number of developmental as well as educational institutions and individual biologists and ichthyologists. These studies have added a new records as well as new species to the country list.

3.1 Review of literature

The oldest report of fish of Nepal dates back to the year 1793, however, the credit of scientific record goes to Hamilton for his work of 1822. In the 19th century a number of other ichthyologists, including McClelland (1839), Gunther (1861), Beaven (1877) and Day (1889) studied the fish fauna of Nepal. In the 20th century, Regan (1907) studied seven fish species sent to him by Dr. N.Annadalei, India, out of which five species were reported from Nepal. These fish were collected by Hodgard on behalf of the Indian Museum, with the support of the then British Legation in Nepal in 1906. The fish samples were collected from Kathmandu and adjacent areas like Sundarijal and Pharping. Out of the reported fish species, one species *Diptichus annandalei sp. nov.* was found then new to science (it is now considered as synonymous to *Schizothorax richardsonii*). Hora (1937) also studied 158 fish species from Hulchowk, Mugling, Nagarkot and Sundarijal collected on his request by the Resident, British Legation in Nepal. A list of 52 fish species was made for the River Koshi, Eastern Nepal, by Menon (1949).

After 1951 fish and fisheries were studied by a number of people, e.g. Taft (1955), DeWitt (1962), Menon (1962), Thapa and Rajbanshi (1968), Majpuria and Shrestha, J. (1968), Bhatt (1970), and Atkinson (1974). Shrestha, J. (1978) studied the fish fauna of Nepal and reported 118 fish species out of which she described two new species and one sub-species (*Barilius jalkapoorei* sp. nov., *Lepidocephalichthys nepalensis* sp. nov., *and Pseudeutropius murius batarensis* sub sp. nov.). Shrestha, S. et. al. (1979) have reported 82 fish species from downstream of the River Bagmati. Ferro and Badagami (1980) reported 22 fish species from lakes Begnas and Rupa in Pokhara valley while McGladdery et al. (1980) reported 62 fish species from the Gandak River system of Chitwan valley. Robert (1980, 1982) studied the genera *Macrognathus* and *Wallago*. Jayaram (1981) reported 106 species under 61 genera, 21 families and 8 orders from Nepal of which one species *Myersglanis blythi* Day has been specified as being endemic in Nepal. The first compilation of the reported fish fauna for the Central or Nepal Himalaya within the boundary of the Kingdom of Nepal for the period 1793–1982 was prepared, and it contained 171 fish species, of which 164 were indigenous and 7 exotic (Rajbanshi, 1982). Terashima (1984) reported three new species endemic to Mahendra Tal (Lake Rara). Edds (1985) has further reported a list of 111 and 113 native fish species from the River Kali Gandak/ Narayani River and the waters of the Royal Chitwan National Park, Chitwan, respectively. Jha and T. K. Shrestha (1986) have studied fish fauna of the River Karnali and have reported 57 fish species under 38 genera, 19 families and 9 orders from the River Rapti and the River Narayani.

Shrestha, T. K. (1990) has recorded 108 fish species from the River Koshi, 102 fish species from the Gandak, 74 fish species from the Karnali, 82 fish species from the Bagmati (downstream reach near Karmaiya), 34 fish species from the Trishuli and 69 fish species from the Mahakali. Shrestha, T. K. (1990) has also stated that 130 species of fish occur in the snow-fed rivers and mountain lakes of the Nepalese highlands. Talwar and Jhingran (1991) have reported 96 fish species representing 19 families and 5 orders from Nepal in their book "Inland Fishes of India and Adjacent Countries". A number of other workers including Kadga (1989), Shrestha, T. K. (1991), and Shah et. al. (1992) have explored the lower stream of the River Arun in eastern Nepal and have reported 46 fish species from there. Ormedo et. al. (1994) has assessed the hydrobiological changes along an altitudinal transect of eighteen to twenty three tributaries in 600 – 3750 m altitude. In adjacent river systems (six streams of Likhu Khola valley) of central Nepal they reported *Neolisocheilus hexagonolepis* (McClell.), *Puntius conchonius* (Ham.), *Nemacheilus rupicola* (McClell.), *Ophiocephalus gachua* (Ham), *Barilius* spp. and *Garra* spp. An Environment Impact Assessment (EIA) study of the Ilam Hydroelectric Project has reported the presence of 14 fish species in Puwa Khola of Ilam (Chaudhury, 1994). A leaflet of Applied Data basis for integrated Biodiversity Conservation in Nepal has reported a total of 179 fish species (The Mountain Institute, 1995). Shrestha, J. (1994) has reported a total of 188 fish species from Nepal, out of which 179 indigenous and 9 exotic. But in 1985 Shrestha, J. (1995) listed only 185 species, representing 11 orders. Shrestha, T.K. (1995) records a total of 183 species, out of which 173 indigenous and 10 exotic fish species. Out of the reported exotic fish, two species – *Oncorhynchus rhodurus* Jordon et Mcgregor and *Salmo trutta* L. do not exist presently in the country. Subba (1995) has reported a new record on the occurrence of a hill stream fish *Olyra longicaudata* McClelland from a tributary of the River Trijuga, a tributary of the Koshi River, Saptari district, Eastern Nepal.

An Environment Impact Assessment (EIA): Study of a Hydroelectric Project on River Kali Gandaki, has reported 57 fish species (Shrestha, T. K., 1996). Subba and Ghosh (1996) have reported a new record of the pigmy barb – *Puntius phutunio* (Ham.) from the Koshi Tappu Wildlife Reserve's lowland catchment area. Smith et al. (1996) have studied aquatic biodiversity in the Karnali and Narayani River basins of Nepal and have recorded 141 fish species (including *Glyptothorax ribeiroi* synonymous to *Laguvia ribeiroi*), of which 121 and 134 fish species have been reported from the Karnali and Gandaki rivers, respectively. However, an Environment Impact Assessment Study of the Upper-Karnali Hydropower Project has reported 48 fish species from the project area (Shrestha, T. K., 1997). A study on the Kulekhani Phase – III Project has reported only 8 fish species (Anonymous, 1997). Another EIA Study on Dudh Koshi Hydroelectric Project has recorded 40 fish species from the River Dudh Koshi (Shrestha, T. K., 1998). An EIA study for the Tamur Hydropower Project has reported the presence of 19 fish species in the River Tamur (Shrestha, J. and Swar, 1998). Bhagat (1998) has studied fish of the Morang district of eastern Nepal and has reported 86 fish species. A study on Likhu – IV Hydroelectric Project has reported only 11 fish species (Thakur, 1998), and study on Budhi Ganga Hydropower Project has listed 18 fish species (Shrestha, J. et al., 1998). Another EIA Study Report on Melamchi Diversion Scheme (MDS) shows the presence of 32 fish species (Shrestha, J., 1999). A study on 'Cold Water Fish and Fisheries in Nepal' has reported 59 indigenous and 2 exotic fishes species (Shrestha, J., 1999). A study on the "Fish Bio-diversity of the Lakes of Pokhara Valley" has reported 25 fish species from the seven lakes of Pokhara (Pokharel, 1999). An EIA study for the Bheri – Babai Hydroelectric Project has reported 46 fish species out of which 21 fish species for the River Bheri and 19 fish species for the River Babai (Shrestha, B. C., 1999). A study for the West – Seti Hydroelectric Project has reported 13 fish species (Rai, 2000). In his recent book "The Fresh Water Fishes of the Indian Region", Jayaram (1999) has reported 108 fish species from Nepal.

3.2 Diversity, distribution and adaptations of indigenous cold water fish

Information on the distribution of the indigenous fish is not yet comprehensive as many streams and rivers have not been studied. A compilation of cold water fish for mountains, high hills and hilly areas gives 76 indigenous fish species representing 7 families (for details see Annex 1). The fish classification follows that of Jayaram (1999).

The family Cyprinidae dominates with 46 species, followed by Sissoridae (sucker catfish) with 13 species, and Balitoridae (loaches) with 6 species. Psilorhynchidae and Cobitidae are represented with 4 species each, Schilbeidae has 2 species, and Amblycepidae is represented by a single species.

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The cold waters of hill region have fish fauna rich in species and numbers, while the waters of the mountain region (Inner-Himalaya) have a poorer fish fauna due to low water temperature and fast current which may be torretial in places. In the cold waters of the mountain region *Schizothorax* and *Schizothoraichthys* are the dominant fish, followed by *Glyptothorax,* and the small loaches of Balitoridae group. In the cold waters of high hills the above mentioned fish species are accompanied by the cyprinids *Tor*, *Neolissocheilus* and *Barilius*, followed by *Glyptothorax*, and in the hill region besides the above species appear *Chagunius, Semiplotus*, *Botia, Clupisoma* and *Amblyceps*. The overlapping of species increases at low or lower altitude rather than at higher altitude and it also varies seasonally. A large number of Schizothoracinae migrates from the mountain region to the hill and low-hill region during winter to avoid low temperatures in higher streams, and fish of lower streams migrate upstream during summer to spawn.

Amongst the recorded fish, one species varies from other in shape, size and weight. Some of the fish are small and may weigh a few grammes, e.g. *Danio*, *Nemacheilus* and *Schistura*, while the biggest fish range to over one metre, e.g. *Bagarius,* and weigh over 200 kg. Most of the indigenous fish have not yet been domesticated for aquaculture.

The fish also show diversity on the basis of their feeding habits, ranging from herbivorous to larvivorous and from insectivorous to omnivorous. Under aquaculture conditions the herbivorous and omnivorous fish can be produced more economically as food fish than the carnivorous fish. In cold waters there are less predatory fish and predation on other fish is considerably lower than in warm waters.

Some indigenous cold water fish species have special adaptations for the fast water current. The genera *Nemacheilus* and *Schistura* are small in size, while *Schizothorax,* *Schizothoraichthys* and *Tor* have developed conical or pointed head with slender and strong tail.. *Barilius* have a laterally compressed body to resist the water current. *Glyptothorax, Glyptosternum, Garra* and some others have an adhesive organ on the ventral side of the flattened head to get attached to a rock. *Bagarius* prefers deep water pools. *Schizothoraichthys niger* (Hickel) and *S. curviforns* (Heckel) reported from the River Trishuli in Central Nepal have resemblance with the fish of Kashmir, India and Afghanistan.

3.3 Endemic fish

Out of the reported 9 endemic fish species of Nepal, the following 5 fish species inhabit cold waters:

Myersglanis blyrhii (Day)	1952
Psilorhynchus pseudecheneis Menon & Dutta	1962
*Schizothorax macrophthalmus (*Terashima)	1984
*S. nepalensis (*Terashima)	1984
*S. raraensis (*Terashima)	1984

The last three endemic fish species have been reported from Mahendra Tal (Lake Rara), situated at an altitude of 2 990 m. (Terashima, 1984). More exploratory studies may discover more endemic species.

3.4 Status of cold water fish

No fish species has yet been officially listed as protected by His Majesty's Government of Nepal. The leaflet on "Endangered Wildlife Nepal's Threatened Animals" in the IUCN Red list, 1994, as well as "Nepal's Flora and Fauna" in the current CITES list, 1995, have not shown a single fish species under alarming status. So far no specific study has been conducted to assess this issue. An EIA study on Ilam hydroelectric project has reported 14 fish species from Puwa Khola out of which 2 species (*Neolissocheilus hexagonolepis* and *Tor tor)* and one species (*Anguilla bengalensis*) has been claimed as endangered and threatened fish species, respectively (Chaudhary, 1994). Shrestha, J. (1994) has not listed any fish under threat in her book " Fishes, Fishing Implements and Methods of Nepal", but she has expressed a potential threat to *Tor, Neolissocheilus* and *Schizothorax* from the increasing number of hydropower projects. In the study on "Enumeration of the Fishes in Nepal" under the Bio-diversity Profile Project, she concluded that 34 fish species (about 18 % of the total reported fish species) are threatened (endangered – 1, rare – 24 and vulnerable – 9). The study has further recommended legal protection for ten fish species: *Tor tor* as endangered, *Neolissocheilus hexagonolepis, Chagunius chagunio, Tor putitora, Danio rerio, Schizothorax plagiostomus, S. richardsonii, Schizothoraichthys progastus, Psilorhynchus pseudecheneis* and *Anguilla bengalensis* as vulnerable (Shrestha, J., 1995). Shrestha, T. K. (1995) in his book "Fish catching in the Himalayan Waters of Nepal" has described 22 species as rare and 26 species as pristine rare fish species. An EIA Study for the Kali Gandak "A" Hydroelectric Project has listed three species (*Tor tor, T. putitora and Amblycesp mangois)* as endangered and five species (*Schizothorax richardsonii, Schizothoraichthys progastus, Euchiloglanis hodgarti, Anguilla bengalensis* and *Rita rita)* as threatened. Most of the listed fish are from the cold waters of high Himalaya. A study on the "Conservation Status of the Inland Fish Fauna of Nepal" has not spelled out any fish under threat or alarm conditions. However, this author endorses the general view of sharp depletion of fish stocks in many water bodies around densely populated areas and development projects (Rajbanshi, 1996). The deteriorating environment, increased industrial activities with a consequent draining of the industrial waste in rivers and lakes, construction of hydropower dams without any appropriate and adequate provision for fish migrations, and indiscriminate killing of indigenous fish using illegal fishing methods are considered to be responsible for the depletion of the indigenous fish.

3.5 Economically important indigenous fish of Nepal

3.5.1 Fish as food

Culturally, fish is considered as an auspicious item in Nepal. Thus fish is used in all social and religious ceremonies. A fish dish is always considered a delicacy and valued food in the Nepalese society. Of the cold water fish, the following species have a good economic value:

Tor tor, Tor putitora, Tor mosal, Neolissocheilus hexagonolepis, Naziritor chilynoides, Chagunius chagunio, Labeo dero, L. angra, Barilius barila, B. barna, B. guttatus, B. bola, B. bendelisis, Semiplotus semiplotus, Schizothorax richardsonii, S. sinuatus, Schizothoraichthys macrophthalmus, S. nepalensis, S. raraensis, S .esocinus, S. labiatus, Schizothoraichthys nige,r Clupisoma garua, Bagarius bagarius, and *B. yarelli.*

These economically important fish are famous for their value as food, sport/recreational fishery, decorative/aquarium value, and academic value. Fish of food and sport value are usually larger while the fish of decorative and academic value are small. But there is no bar on the species and its size for its consumption. Cold water fish are considered tastier than other fish, and are therefore preferred to warm water fish and in high demand. Because of this, cold water fish always fetch a good market price in rural as well as urban markets. *Schizothorax, Schizothoraichthys, Clupisoma, Barilius, Tor* and *Neolissocheilus* are considered of exceptionally good quality food. Asla (*Schizothorax* and *Schizothoraichthys*) and Jalkapoor (*Barilius guttatus*) have a long tradition of being a delicacy.

Fish are mostly consumed fresh but in case of surplus catches they are sun dried and smoked. The sun dried and smoked fish are also considered a delicacy and are in high demand. They fetch very good price in the markets.

The capture fishery for cold water fish is at subsistence level, not well organised, and widely scattered throughout the country. and is not well organized. No reliable catch statistics are available, but effort is being made to establish a database, which would include information on fish catch, fish species composition, number of fishermen and families involved in cold water capture fisheries.

More information is also needed on the biology, behavior, reproduction, domestication and culture of cold water fish. Studies on the aquaculture potential of *Tor, Neolissocheilus, Schizothorax, Schizothoraichthys* and *Barilius* are in progress.

3.5.2 Sport and recreational fishery

The cold water fish *Tor tor, T. putitora, T. mosal, Neolissocheilus, Schizothorax, Schizothoraichthys* and *Barilius* are well known by anglers. These fish migrate downstream in winter and upstream in summer seeking rapid current. They are very strong and grow to big size. *Schizothorax, Schizothoraichthys* and *Barilius* are small but active, in which respect they are similar to trout. Therefore the first two are also called **“**snow trout**”** and *Barilius* is known as “Himalayan trout**”**. The smaller fish do not fight as well as Tor and neolissocheilus and it is easy to land them into net. Therefore, it is said that the small-sized fish are exciting to angle until they bite while *Tor* and *Neolissocheilus* are most exciting once they bite as it requires a good fight to land them in net.

For catching the snow trout the local people have invented a simple loop made of monofilament thread. The fishing method is called “looping of Asla” and while simple it is an effective method of fishing in hill streams. It is in wide use by the locals fishing the hill streams of Central Nepal (Rajbanshi, 1976). While some water bodies have regulated fishing with license, fishing in most mountain and hill streams and rivers is free.

Sport and recreational fishery can bee further developed with the involvement of the local population which would benefit from job opportunities and income. With the increased job and income opportunities in the north, southward migration of the local people seeking employment opportunities could be reduced.

3.5.3 Fish of decorative and academic values

The fish of hill region such as *Nemacheilus* and *Botia*. are not multicolored as some fish of the warm tropical waters, but their peculiar morphology and coloration are of interest to aquarists. Morphological structure, especially adaptations to fast current as seen in a number of species, are of academic interest.

3.6 Future opportunities for indigenous fish

Effort should focus on the development of aquaculture technologies to provide stocking material for enhancing fish stocks in rivers, streams and lakes, as well as to initiate their culture. Good stocks of cold water fish in rivers would support the development of sport and recreational fisheries, and this would assist with the development of ecotourism in remote areas. Aquaculture of cold water fish species and production of aquarium fish would lead to employment opportunities and to raising living standard through marketing the produce. This would help in slowing down the outward migration of the hill people seeking employment ouside the region.

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4. CONCLUSIONS

Nepal consists in the south of a strip of very productive land called Terai, bordered in the north by hills with valleys, then of middle and high hills and snow covered mountains further north. The hills and mountains are a major source of water. The water resources appear in a diverse form and support a diverse fish fauna. There are 92 indigenous cold fish species in Nepal. The family Cyprinidae dominates with 46 species, followed by the family Sisoridae with 13 species and the family Balitoridae with 6 species. Some of the Nepal cold water fish species show a resemblance with the fish from Kashmir of India and Afghanistan.

Five fish species are endemic in the cold waters in Nepal. Three of them are found in the high altitude lake Mahendra Tal (Rara Lake – Rara National Park) at 2 990 m. Fish fauna of high altitude water bodies is still poorly known and requires more studies. *Schizothorax, Schizothoraichthys, Glyptothorax, Nemacheilus* and *Schistura* always dominate the waters of mountains and high hills even at low water temperatures, fast flow and torrential conditions. At the low or lower altitude they are accompanied by *Tor, Neolissocheilus, Barilius, Chagunius, Semiplotus, Botia, Clupisoma* and *Amblycep*. There is some seasonal variation of species composition.

The present list of fish of Nepal has been compiled from a number of publications and reports and it should not be considered as final. This will require a systematic survey of all water bodies of Nepal. Not all water bodies in high altitude and rugged mountains and hills have been visited yet and further investigation are needed to complete this task.

In Nepalese society the fish is considered as an auspicious item, and is used in all social and religious ceremonies. A fish dish is always considered a delicacy as well as valuable food. Cold water fish has a special value and is considered tastier than other fish. Other fish, especially *Tor* and *Neolissochielus* are are valued as sport fish by anglers. In markets cold water fish fetch a good price. Capture and culture of cold water fish, as well as angling are the most promissing avenues for providing not only fish as food but also commercial opportunities for the local people.

The purpose of this paper is to assist in charting a future course of action for the development of cold water fisheries for economic growth of the ever overlooked mountain and hill regions of this region.

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Distribution List of Cold Water Fishes in Nepal

APPENDIX 1

S. No.	Fish Species	River Koshi							
			R. Tamar	R. Arun	R Dudh Koshi	R. Tama Koshi	R. Sun Koshi	R. Bhote Koshi	R. Indrawati
1	*Chagunius chagunio* (Hamilton-Buchanan) [1]	+	+	+	+		+		
2	*Labeo angra* (Hamilton-Buchanan)	+	+	+	+		+		
3	*L. dero* (Hamilton-Buchanan)[2]	+	+	+	+		+		
4	*L. dyocheilus* (McClelland)[3]	+			+				
5	*L.gonius* (Hamilton-Buchanan)	+		+			+		
6	*Neolissocheilus hexagonolepis* (McClelland)[4]	+	+	+	+		+		
7	*Tor tor* (Hamilton-Buchanan) [5]	+	+	+	+		+		
8	*T. putitora* (Hamilton-Buchanan)	+	+	+	+		+		
9	*T. mosal* (Hamilton-Buchanan)	+							
10	*Puntius conchonius* (Hamilton-Buchanan)	+	+	+	+		+		
11	*Naziritor chilynoides* (McClelland)	+							
12	*Semiplotus semiplotus* (McClelland)[6]	+							
13	*Barilius barila* (Hamilton-Buchanan)	+	+	+	+		+		
14	*B. barna* (Hamilton-Buchanan)	+	+	+			+		
15	*B.. bola* (Hamilton-Buchanan)[7]								

[1] Synonymous to *Barbus chagunio* –Taft (1955) and DeWitt (1962), *Puntius spilopholus* – Menon (1962), and *Catla chagunio* – Shrestha (1978).
[2] Synonymous to *Labeo almorai* Chaudhuri – Menon (1962), *Labeo tezpurensis* Chaudhuri – Menon (1962).
[3] Synonymous to *Labeo kunki* Chaudhuri – Menon (1962), *Labeo rilli* Chaudhuri – Menon (1962).
[4] Synonymous to *Lissocheilus hexagonolepis* (McClell.) – Hora (1937), *Barbus hexagonalepis* (McClell.) – Taft (1955) and DeWitt (1962), *Acrossocheilus hexagonolepis* _ Menon (1962).
[5] Synonymous to *Tor progeneius* (McClell.) – Menon (1962).
[6] Synonymous to *Cyprinon semiplotum* (McClelland) – Shrestha (1995)
[7] Synonimous to *Barilius* (*Opsarius*) *bola* – Hora (1937), *Barilius* (*Raiamas*) *bola* (Ham.) – Taft (1955), *Raiamas bola* (Ham.) – Shrestha (1995)

S. No.	Fish Species	River Koshi							
			R. Tamar	R. Arun	R Dudh Koshi	R. Tama Koshi	R. Sun Koshi	R. Bhote Koshi	R. Indrawati
16	*Barilius bendelisis* (Hamilton-Buchanan)	+	+	+	+		+		+
17	*B. guttatus* (Day)	+			+				
18	*B. radiolatus* Gunther								
19	*B. tileo* (Hamilton-Buchanan)	+			+				
20	*B. vagra vagra* (Hamilton-Buchanan)	+	+				+		
21	*B. shacra* (Hamilton- Buchanan)	+							+
22	*Danio acquipinnatus* (McClelland)	+	+				+		
23	*D.dangila* (Hamilton-Buchanan)	+					+		
24	*D. devario* (Hamilton-Buchanan)	+		+			+		+
25	*Brachydanio rerio* (Hamilton-Buchanan)[8]								
26	*Esomus danricus* (Hamilton-Buchanan)	+							
27	*Chela (Chela) laubuca* (Hamilton-Buchanan)[9]	+	+				+		
28	*Securicula gora* (Hamilton-Buchanan)[10]	+		+					
29	*Salmostoma acinaces* (Hamilton-Buchanan)[11]	+		+					
30	*S. bacaila* (Hamilton-Buchanan)[12]	+		+					
31	*Garra annandalei* Hora	+	+	+			+		
32	*G. gotyla gotyla* (Gray)	+	+	+	+		+		
33	*G. lamta* (Hamilton-Buchanan)	+	+	+	+		+		
34	*G.lissorhynchus* (McClelland)[13]								
35	*G. nasuta* (McClelland)								
36	*G. rupecola* (McClelland)	+				+	+		
37	*Crossocheilus latius latius* (Hamilton-Buchanan)	+			+				

[8] Synonymous to *Danio (Brachydanio) rerio* (Ham.) – Menon (1962).
[9] Synonymous to *Laubuca laubuca* – Hora (1937) and Taft (1955)
[10] Synonymous to *Chela gora* (Ham.)
[11] Synonymous to *Chela argentea* (Day)
[12] Synonymous to *Chela bacaila* (Ham.)
[13] Synonymous to *Garra modestus* (Gray)

S. No.	Fish Species	River Koshi							
			R. Tamar	R. Arun	R Dudh Koshi	R. Tama Koshi	R. Sun Koshi	R. Bhote Koshi	R. Indrawati
38	*Schizothorax richardsonii* (Gray)[14]	+	+	+	+		+	+	+
39	*S. sinuatus* (Heckel)								
40	*Schizothoraichthys macrophthalmus* (Terashima)								
41	*S. nepalensis* (Terashima)								
42	*S. raraensis* (Terashima)								
43	*S. esocinus* (Heckel)	+	+		+		+		+
44	*S. labiatus* (McClelland)	+							
45	*S. niger* (Heckel)	+							
46	*S. curvoforns* (Heckel)								
47	*S. progastus* (McClelland)[15]	+	+	+	+		+		
48	*Dipticus maculatus* Steindachner								
49	*Psilorhynchus balitora* (Hamilton-Buchanan)								
50	*P. sucatio* (Hamilton-Buchanan)	+					+		+
51	*Psilorhynchoides pseudecheneis* (Menon & Dutta)	+	+	+	+		+		
52	*P. homaloptera* (Hora & Mukherjee)	+				+			
53	*Balitora brucei* (Gray)	+	+	+			+		
54	*Acanthocobitis botia* (Hamilton-Buchanan)[16]								
55	*Nemacheilus corica* (Hamilton-Buchanan)								
56	*Schistura beavani* (Gunther)[17]								
57	*S. rupecula rupecola* (McClelland)[18]								
58	*Schistura scaturigina* (McClelland)[19]								
59	*Acanthophthalmus pangia* (Hamilton-Buchanan)[20]	+					+		

[14] Synonymous to *Schizothorax plagiostomus* (Heckel), *Schizothorax molesworthii* (Chaudhuri) & *Dipticus annandalei* or *Schizothoraichthys annandalei Regan.*
[15] Synonymous to *Schizopyge progastus* – Edds (1986)
[16] Synonymous to *Nemacheilus botia* (Hamilton -Buchanan)
[17] Synonymous to *Nemacheilus beavani* (Gunther)
[18] Synonymous to *Nemacheilus rupecola rupecola* (McClelland)
[19] Synonymous to *Nemacheilus shebbearie* (Hora)
[20] Synonymous to *Pangio pangio* (Hamilton-Buchanan) – Shrestha (1995)

S. No.	Fish Species	River Koshi							
			R. Tamar	R. Arun	R Dudh Koshi	R. Tama Koshi	R. Sun Koshi	R. Bhote Koshi	R. Indrawati
60	*Lepidocephalus guntea* (Hamilton-Buchanan)[21]	+	+	+	+		+		
61	*Botia almorhae* (Gray)	+			+		+		
62	*B. lohachata* (Chaudhuri)	+	+	+	+		+		
63	*Amblyceps mangois* (Hamilton-Buchanan)	+	+	+			+		
64	*Bagarius bagarius* (Hamilton-Buchanan)	+	+	+	+		+		
65	*B. yarrelli* Sykes								
66	*Gagata cenia* (Hamilton-Buchanan)	+	+	+			+		
67	*Myersglanis blythi* (Day)								
68	*Glyptosternum maculatum* (Regan)								
69	*G. reticulatum* McClelland								
70	*Glyptothorax cavia* (Hamilton-Buchanan)	+	+	+	+		+		
71	*G. pectinopterus* (McClelland)		+		+				
72	*G. conirostrae* (Steindachner)								
73	*G. gracile* (Gunther)								
74	*G. telchita telchita* (Hora)	+	+		+		+		
75	*Glyptothorax trilineatus* (Blyth)								
76	*G. indicus* Talwar[22]	+	+	+			+		
77	*G. annandalei* Hora	+	+	+			+		
78	*G. kashmirensis*								
79	*Pseudecheneis sulcatus* (McClelland)	+	+	+	+		+		
80	*Euchiloglanis hodgartii* (Hora)								
81	*Clupisoma garua* (Hamilton-Buchanan)	+							
82	*Pseudeutropius atherinoides* (Bloch)	+							
83	*P.murius batarensis* Shrestha								

[21] Synonymous to *Lepidocephalichthys guntia* (Hamilton-Buchanan)- Edds (1986) & *L. nepalensis* Shrestha – (Menon, 1992)
[22] Synonymous to *Glyptothoras horai* (Shaw & Shebbeare)- (Jayaram, 1999)

S. No.	Fish Species	River Gandakl							
			R. Rapti	R. Trishuli	R. Budhi Gandaki	R. Marshyangdi	R. Madi	R. Seti	R.Kali Gandaki
1	*Chagunius chagunio* (Hamilton-Buchanan)	+	+	+			+		+
2	*Labeo angra* (Hamilton-Buchanan)	+	+	+			+		+
3	*L. dero* (Hamilton-Buchanan)	+	+	+			+		+
4	*L. dyocheilus* (McClelland)	+	+					+	
5	*L.gonius* (Hamilton-Buchanan)	+	+	+			+		+
6	*Neolissocheilus hexagonolepis* (McClelland)	+	+	+			+	+	+
7	*Tor tor* (Hamilton-Buchanan)	+	+	+			+		+
8	*T. putitora* (Hamilton-Buchanan)	+	+	+			+		+
9	*T. mosal* (Hamilton-Buchanan)	+							
10	*Puntius conchonius* (Hamilton-Buchanan)	+	+	+			+		+
11	*Naziritor chelyinoides* (McClelland)	+		+					
12	*Semiplotus semiplotus* (McClelland)	+	+	+					+
13	*Barilius barila* (Hamilton-Buchanan)	+	+	+			+		+
14	*B. barna* (Hamilton-Buchanan)	+	+	+			+		+
15	*B. bola* (Hamilton-Buchanan)	+	+	+			+		+
16	*B. bendelisis* (Hamilton-Buchanan)	+	+	+			+		+
17	*B. guttatus* (Day)	+							
18	*B. radiolatus* Gunther								
19	*B. tileo* (Hamilton-Buchanan)	+	+	+			+		+
20	*B. vagra vagra* (Hamilton-Buchanan)	+	+	+			+		+
21	*B. shacra* (Hamilton-Buchanan)								
22	*Danio acquipinnatus* (McClelland)	+	+	+			+		+
23	*D. dangila* (Hamilton-Buchanan)	+							+
24	*D. devario* (Hamilton-Buchanan)	+	+	+			+		+
25	*Brachydanio rerio* (Hamilton-Buchanan)	+	+	+			+		+
26	*Esomus danricus* (Hamilton-Buchanan)	+	+	+			+		+
27	*Chela laubuca* (Hamilton-Buchanan)	+	+	+			+		+
28	*Securicula gora* (Hamilton-Buchanan)	+	+	+					+

S. No.	Fish Species	River Gandakl							
			R. Rapti	R. Trishuli	R. Budhi Gandaki	R. Marshyangdi	R. Madi	R. Seti	R.Kali Gandaki
29	*Salmostoma acinaces* (Vallenciennes)								
30	*S. bacaila* (Hamilton-Buchanan)	+	+	+	+				+
31	*Garra annandalei* (Hora)	+	+	+			+		+
32	*G. gotyla* (Gray)	+	+	+			+		+
33	*G. lamta* (Hamilton-Buchanan)								
34	*G. lissorhynchus* (McClelland)	+		+					
35	*G. nasuta* (McClelland)	+		+					
36	*G. rupecola* (McClelland)								
37	*Crossocheilus lalius latius* (Hamilton-Buchanan)	+	+	+			+		+
38	*Schizothorax richardsonii* (Gray)	+	+	+			+		+
39	*S. sinuatus* (Heckel)	+		+					
40	*Schizothoraichthys macrophthalmus* (Terashima)								
41	*S. nepalensis* (Terashima)								
42	*S. raraensis* (Terashima)								
43	*S. esocinus* (Heckel)	+		+					
44	*S. labiatus* (McClelland)	+							
45	*S. niger* (Heckel)	+		+					
46	*S. curviforns* (Heckel)	+		+					
47	*S.progatus* (McClelland)	+	+	+			+		+
48	*Dipticus maculatus* Steindachner								
49	*Psilorhynchus balitora* (Hamilton-Buchanan)	+	+	+			+		+
50	*P. sucatio* (Hamilton-Buchanan)	+	+				+		
51	*Psilorhynchoides pseudecheneis* (Menon & Dutta)	+		+					+
52	*P. homaloptera* (Hora & Mukherjee)	+							
53	*Balitora brucei* (Gray)	+	+	+			+		+
54	*Acanthocobitis botia* (Hamilton-Buchanan)	+	+	+			+		+
55	*Nemacheilus corica* (Hamilton-Buchanan)	+	+	+			+		+
56	*Schistura beavani* (Gunther)	+	+	+			+		+
57	*S. rupecola rupecola* (McClelland)	+	+	+			+		+

S. No.	Fish Species	River Gandakl							
			R. Rapti	R. Trishuli	R. Budhi Gandaki	R. Marshyangdi	R. Madi	R. Seti	R.Kali Gandaki
58	*S. scaturigina* (McClelland)	+							
59	*Acanthophthalmus pangia* (Hamilton-Buchanan)	+		+					
60	*Lepidocephalus guntea* (Hamilton-Buchanan)	+	+	+			+		+
61	*Botia almorhae* (Gray)	+	+	+			+		+
62	*Botia lohachata* (Chaudhuri)	+	+	+			+		+
63	*Amblyceps mangois* (Hamilton-Buchanan)	+	+	+			+		+
64	*Bagarius bagarius* (hamilton-Buchanan)	+	+	+			+		+
65	*B. yarrelli* Sykes								
66	*Gagata cenia* (Hamilton-Buchanan)	+	+						
67	*Myserglanis blythi* (Day)								

THE CURRENT STATUS OF CAPTURE FISHERY IN THE UPPER SUNKOSHI RIVER

by

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ABSTRACT

The capture fishery status of the upper Sunkoshi River was surveyed from 1998 to 2001 from Tatopani to Dollalghat. In the region hill stream fish were common and *Schizothorax* was the dominant fish. The most commonly used fishing gear was loop while electrofishing was also practiced. There were 45 full-time, 211 temporary and more than 500 occasional fishermen. Fishing spot visits and market surveys estimated an average of 22 tons of fish harvest per year from 800 ha of water surface area. Including electrofishing, the fish harvest of 27.5 kg per hectare of water surface area is considered to be rather low. The full time fishermen fulfill only 49% and temporary fishermen fulfill 27% of the basic needs of life indicating a weak socio-economic status of these fishermen. Due to the depleting tendency of the fishery resources the young generation of such communities has been leaving the fishing profession.

1. INTRODUCTION

Nepal has vast river drainages in the form of white energy. Water resources cover about 2.7% of the land area and are ideal habitats for indigenous fish fauna which supports capture fishery in the country. Traditionally, the capture fishery is carried out by fisher communities as the main profession. Therefore, the river basins play a vital role in the socio-economic status of the people of Nepal.

The Sunkoshi is an important river of the Koshi basin originating from a Tibetan mountain at an altitude of 5 646 m. It can be divided into upper mountainous course from Tatopani to Dollalghat and lower middle hill course from Dollalghat to Tribeni Dovan. The Upper Sunkoshi is a rhithron type of river and is 56 km long. Twenty-nine fish species have been recorded from the river during the present investigations. The river is a good fishing spot for asla (*Schizothorax* and *Schizothoraichthys*).

Recently, habitat destruction and overexploitation of the river resources by human activities have resulted in a decline in fish catches in the upper Sunkoshi River. There is a need for conservation strategies and mitigation measures. The paper discusses the present status of capture fishery and the potential for restoration of fish stocks in order to provide a sustainable fishery in the upper Sunkoshi River.

2. RIVER CAPTURE FISHERY IN NEPAL

Surface water resources of Nepal are represented by rivers and streams, lakes, reservoirs and swamps, covering nearly 420 500 hectares (IAFS, 1998). Among these, river basins represent 395 000 hectares (94 %) of the surface water resources including rivers, river basins and river floodplains (Shrestha, 1992, as quoted in Bhandari, 1992) (Table 1).

Table 1
Approximate water surface areas of rivers/streams

	Sunkoshi River				**Indra bati**	**Lwr Sun-koshi**	**Balfi Kho la**	**Sun-kosi Kho-la**	**Cha ku Kho la**	**Other tribut aries**	**Total area**
	St. 1.	**St. 2.**	**St. 3.**	**St. 4.**							
Width of rivers (m)	42	75	80	85	86	85	32	22	18	4- 14	
Lenth of rivers (km)	10	15	16	15	16	10	10	12	10	100	
Area (ha)	42	112.5	128	127. 5	137.6	85	32	26.4	18	90	800

The rivers descending high mountains to lowland plains of Nepal are inhabited by diverse fish fauna. So far 186 indigenous fish species (Shrestha, 1994) have been recorded from river drainages of Nepal. These fish species exhibit a great diversity and have developed plasticity in response to the Nepal's varied topography.

The rivers of Nepal are used for drinking water, electricity production, irrigation, recreational activities and municipal uses. They have been traditionally used to catch fish. Thus the water systems provide employment opportunities, income generation and food for the local people.

Capture fishery is carried out by several fisher communities. The settlements of such traditional fisher communities are scattered along rivers. It has been estimated that about 24 167 (Pradhan and Shrestha, 1997) families were engaged in inland capture fisheries in 1995/1996. Fishing is now mostly supplementary to the traditional agriculture activities. The young people in such communities have been changing their profession and becoming only temporary fishermen, often as a supplement to other activities.

In Nepal the major river fishery sites are Tumlingtar on the Arun River, Khadichaur and Dollalghat on the Sunkoshi River, Chhatara and Koshi barrage area of Saptakoshi River, Malekhu, Rijalghat and Benighat of the Trishuli River, Deughat and Gaughat of the Narayani River, Dailekh and Chisapani of the Karnali River. In the fiscal year 1999/2000 river drainages of Nepal produced a harvest of 4 397.5 t (FDD, 2000) of fish .

3. STUDY AREA

Sunkoshi is an important river system of Saptakoshi drainage basin in the northeast of the Kathmandu valley. It is 256 km long with a catchment of 14 500 km^2 (Shrestha, 1983). The uppermost portion of the river is known as Bhotekoshi and originates from a Himalayan mountain (5 646m) on the Tibetan plateau. It enters Nepal near Tatopani from where it continues south. At Dollalghat the Indrabati River joins the Sunkoshi and flows east to the rivers Arun and Tamor which eventually pass south as Saptakoshi drainage. The Sunkoshi river system can be divided into the upper stretch from mountainous Tatopani to mid-hill Dollalghat region, flowing rapidly south, and the lower stretch from Dollalghat to Tribeni Dovan flowing southeast to the Siwalik range, having a moderate water current. The upper Sunkoshi River is 56 km long. Altogether it has 78 tributaries of which the important are Jung Khola, Bhairabkund Khola, Khokundol Khola, Chaku Khola, Sunkoshi Khola, Balefi Khola, Adheri Khola and Bhushae Khola.

A hot spring with sulphurated water in the upper Sunkoshi River at Tatopani station is popular for religious baths. At Lamusagu there is a 10 MW electricity power station. However, the Sunkoshi River has power potential of 4 800 MW (Water Resources Commission). The Bhotekoshi River has a 36 MW power station at Phulpingkatti. Rafting is practiced on the Sunkoshi River.

4. METHODOLOGY

The study objective was an assessment of the status of capture fishery in the upper Sunkoshi River. The river was surveyed annually from Tatopani to Dollalghat along the Kodari roadside during three seasons (winter, summer and autumn) from 1998 to 2001.

Water quality was assessed at Tatopani, Barabise, Balefi and Dollalghat stations. Early in the morning fish landing sites were visited to make enquiries about fish species and their numbers, gear used as well as other details. The fishermen community residences were visited and individuals interviewed to obtain information on the fishermen's socio-economic status. During the visits fish species were collected from the landing sites and some from the markets.

Fish markets and fishing areas were visited once a month from December 1998 to May 1999 at Chhaku, Jambu, Barabise, Khadichaur, Balefi, Sukute, Chehere and Dollalghat. Later on quarterly visits were paid to the stations. An assessment of human interventions such as damming, poisoning, electrofishing, and habitat destruction along the river course were also made.

For physico-chemical water analyses the procedures as in the APHA (1989) were followed. Fish samples were processed in the laboratory. Questionaires were compiled and evaluated for the socio-economic status of the fishermen.

The fishermen were categorised as permanent or full-time, temporary or part-time, and occasional. The mean catch per day per fisherman and catch per fisherman per year were also assessed. The capture fishery in the upper Sunkoshi was estimated from regular market visits assessing fresh fish availability.

5. RESULTS

The altitude of the upper Sunkoshi River ranges from 492 m at Dollalghat to 1668 m at the Tatopani station. The upper Sunkoshi River has fast flowing water with a steep slope near the Tatopani station, a middle torrential course, followed by a lower moderate velocity course near the Dollalghat station.

5.1 Water quality and fish fauna

In the upper Sunkoshi water temperature was between 4°C-23°C, pH 6.4-8.3, dissolved oxygen 6-4 mg/L, alkalinity 45-62 mg/L, hardness 52-96 mg/L and conductivity 75-102 mmhos/cm. *Schizothorax*, *Schizothoraichthys*, *Garra*, *Crossocheilus*, *Barilius*, *Psilorhynchus*, *Neolissocheilus*, *Botia*, *Pseudecheneis*, *Glyptothorax*, *Nemacheilus*, *Anguilla* and *Channa* were common fish in the area and *Tor*, *Labeo*, *Pseudeutropius*, *Bagarius* were also found in seasonal catches. During the surveys altogether 29 fish species belonging to 18 genera, 6 families and 3 orders were recorded (Table 2). Fish composition by number and weight in the upper Sunkoshi River is shown in Table 3.

5.2 Fishermen and fishing methods

In the upper Sunkoshi River a total of 256 fishermen have been identified. Of these 45 were permanent or full-time fishermen, 211 were temporary or part-time fishermen, and more than 500 were occasional fishermen (Table 4). Among the 211 temporary fishermen 176 were legal fishermen and 35 were illegal electrofishing persons.

The most common fishing method was by nylon loop called *paso*. Normally the fishermen set the *paso* in the evening to be taken out early in the morning and repaired during the day. Depending on the season other methods such as cast nets, rigid push nets (*ghorlangs*) and rods are also used. Illegal fishing using electrofishing, poisoning, diversion of river channel and fry catching were also observed .

5.3 Fish catch and fishery potential

In the upper Sunkoshi the fishing activities take place for 8 months of the year during spring, summer, autumn and the early winter months. There is usually no fishing during floods and part of the winter season. The full-time fishermen fish for 6 months and catch 0.2-1.2 kg per day. The individual catch is around 126 kg per person per year. The 176 professional part-time fishermen generally fished 2-5 months per year and were labourers, mechanics, a few businessmen and a few job holders. The fish catches ranged between 0.4 and 1.0 kg per person with an average catch of 73.5 kg per person per year. However, the electrofishing fishermen caught fish in the range of 2-4 kg, with an average of 315 kg per fisherman per year, and they fished in groups of 3-5 people. Basically, occasional fishermen were non-fisher groups and fished for recreation. Such groups fished 2-10 times per year and caught 0.2-0.5 kg per day, with an average of 2.1 kg per person per year for consumption.

The fishermen fish in the main Sunkoshi river system and its tributaries. The estimated total length of the river with its tributaries is 214 km, with an average water depth of 1.2 m. The width of the Sunkoshi and its tributaries is 70 m and 53 m, respectively, covering approximately 800 ha of water area.

Table 2
List of fish species for the Upper Sunkoshi River

Family	Scientific Name	Family	Scientific Name
1. Cyprinidae	Barilius barila	2. Cobitidae	Nemacheilus beevani
	Barilius bendelensis		Nemacheilus rupicola
	Barilius vagra		
	Barilius sacra	3.Sisoridae	Glyptothorax telchita
	Garra annandalei		Glyptothorax cavia
	Garra gotyla		Glyptothorax sulcatus
	Garra rupecula		Glyptosternum blythi
	Labeo dero		Bagarius bagarius
	Labeo angra		
	Labeo boga	4.Schilbeidae	Pseudeutropius atherinoides
	Labeo dyocheilus		
	Neolissocheilus hexagonolepsis	5. Anguillidae	Anguilla bengelensis
	Schizothorax richardsonii		
	Schizothoraichthys macrophthalmus	6. Channidae	Channa stewartii
	Schizothoraichthys progastus		
	Psilorhynchus pseudecheneis		
	Tor putitora		
	Crossocheilus latius		
	Botia almorae		

The fishermen sold 95% of the captured fish in the nearby local markets and the remaining 5% of fish they consumed themselves. The price of fresh fish ranged between 100 and 150 rupees according to the fiscal year. The total catch for year 1998/99 was estimated at 31 tons from the upper Sunkoshi River including the main upper Sunkoshi River, its tributaries and the lower Sunkoshi down to Deurali Daada. Twenty-four tons of fish harvest were estimated from markets and fish landing surveys (Table 5). For the years 1999/2000 and 2000/2001, 10 tons and 25 tons of fish harvest were estimated, respectively. The peak season for fish catch was in April and early May. Generally January and February were off-months. The average fish harvest of three fiscal years (1998/1999-2000/2001) was 22 tons including 5% individual consumption and the occasional fishermen harvests. In terms of monetary value, at the rate of NRs 125 per kg, it comes close to NRs 2 750 000 on average per year. From fish sales and availability of fish in the markets during three fiscal years (1998/1999 - 2000/ 2001), an average harvest of 27.5 kg per hectare of water surface area has been estimated.

Table 3
Fish population composition by numbers and weight in the Upper Sunkoshi River

Fish genus / species	Total No.	Percentage number	Total weight kg	Percentage weight
Schizothorax and Schizothoraichthys	608	24.9	21.3	35.9
Barilius	878	36.0	4.1	6.8
Garra	125	5.1	4.6	7.7
Glyptothorax	149	6.1	3.0	5.0
Pseudecheneis sulcatus	108	4.4	1.9	3.2
N. hexagonolepsis	117	4.8	4.8	8.0
Nemacheilus	41	1.7	0.077	0.1
P. pseudecheneis	338	13.9	2.0	3.3
Labeo	36	1.5	10.0	16.7
Others	38	1.6	8.0	13.3
Total	2438	100	59.8	100

Table 4
Classification of fisher groups and status of capture fishery in the Upper Sunkoshi River

Full time fishermen (45)			Temporary fishermen (211)							Occasional fishermen (> 500)			
			Legal methods			Illegal methods							
Fish catch wt kg/ day/ fisher man	Fish-ing days / year	Total fish wt kg	Fish catch wt kg/ day/ fisher man	Fish-ing days / year	Total fish wt kg	Fish catch wt kg/ day/ fisher man	Fish-ing days/ year	Total fish wt kg	Total fish catch kg	Fish catch wt kg/ day/ fisher man	Fish-ing days / year	Total fish wt kg	Total fish catch kg
0.2 – 1.2	180	5 670	0.4 - 1.0	105	12 936	2-4	105	11 025	23 961	0.2-0.5	6	1 050	30 681

Table 5
Fish market record in the Upper Sunkoshi River

Fiscal Year 1998/1999		FiscalYear 1999/2000		FiscalYear 2000/2001		Average harvest/ year
Date	Fish catch (kg)	Date	Fish catch(kg)	Date	Fish catch(kg)	
16/12/1998	44	15/12/1999	25.0	20/12/2000	46.5	
18/1/1999	18.7					
17/2/1999	11.9	20/2/2000	5.4	19/2/2001	17.2	
17/3//1999	70.4					
15/4/1999	147.7					
20/5/1999	94.9	18/5/200080	51.9	1/ 5/ 2001	142.5	
Average	64.5/day		27.4/day		68.7/day	
Total average harvest /year (kg)	23,542.5		10,000.1		25,075.5	19,539.4

5.4 Socio-economic status of fishermen

The total population of 256 fisher households had 1682 people of which 830 were males and 852 were females. The ratio of male to female was 49:51 and the average family size was 6.5 members. The main fisher group in the upper Sunkoshi River belongs to Majhi community, some to Dhami community and some to other communities representing 58% (149), 10% (25) and 32% (82) respectively. There were 342 school age children of which only 37% (126) attended schools (Table 6). The literacy rate of these fishermen was 11%, 25% and 57% among Majhi, Thami and other communities, respectively. The fishermen communities in the upper Sunkoshi River owned 0.244 hectare of land per family on average. But Majhi community owned only 0.142 hectare of land per family. The full-time fishermen were mostly older than the temporary fishermen.

The individual full-time fishermen were reported to earn 16 000 rupees per person per year, and the part-time fishermen earned 10 000 rupees per year. But from individual fishermen interviews the earning was estimated at around 27 000 rupees and 15 000 rupees by full-time and part-time fishermen, respectively.

5.5 Human intervention

Due to dam construction and diversion of river water for hydropower station about 3.2 km of the Sunkoshi River stretch below the dam site were without water flow. Fish habitat destruction due to sand quarrying and frightening of fish by splashing or whistling were also observed along the river course. Electrofishing was frequent.

Table 6
Socio-economics of fisherfolk in the Upper Sunkoshi River

Num-ber of homes	Total popula tion	Population		Family size	Visiting school		Land (hectare)		Economic status	
		Male	Female		Boys	Girls	Average /Family	Majhi community /Family	Basic need fulfill-ment (fulltime)	Basic need fulfillment (part-time)
256	1 682	830	852	6.5	89	37	0.244	0.142	49%	27%

6. DISCUSSION

The upper Sunkoshi River is a rhithron type of river (Jha, 1992). Due to topographic differences the river shows variations in water velocity and water quality. Above the Sunkoshi hydropower dam the number of fishermen and the fishing declined and near Tatopani no fishermen were found. The reason may be the fast water current due to steep topography. Hence the potential area for fishery activities was a stretch of 28.5 km from below the dam at Lamusagu to Dollalghat.

In the upper Sunkoshi River water temperature, pH and alkalinity decrease with increasing altitude. Dissolved oxygen and total hardness follow a reverse pattern. The conductivity of water gives higher values at two stations. The most common fish are *Schizothorax* and *Schizothoraichthys* of which *S. richardsonii* and *S. progastus* are the dominant species by weight. The genus *Barilius* is dominant by number. *Psilorhynchus*, *Glyptothorax*, *Garra*, *Pseudecheneis* and *Neolissocheilus* represent a good percentage in the fish species composition.

Above Lamusagu sahar (*Tor putitora*) and gounch (*Bagarius bagarius*) have not been found since the construction of the dam due to the obstruction preventing migration of these fish. In late 2000 the frequencies of electrofishing declined compared to the previous fiscal years due to the decrease in fish stocks. Fry netting in spawning and nursery grounds and use of poison are still practiced. Market surveys also showed a steep decline in fish catches in 1999/2000. However in fiscal year 2000/2001 fish catches have been improving due to a decrease in electrofishing. A negative impact of stone quarrying was observed in 2000/2001.

In the upper Sunkoshi River fishery resources contributed to the economy of the region, even though the economic status of fishermen is lower than that of other communities. The earnings of fishermen are very low. The permanent fishermen can cover only 49% and the part-time fishermen only 27% of the basic needs of life by fishing. The information collected on the fishermen’s economics showed that the community needs to be supported by having other professions. And as the fish catch has been decreasing fishermen belonging to Majhi community have been taking up other professions. Recently most of them are labourers making gravel from stones along the river banks. Only a few members of fisher communities are going into fishing and mostly such persons are young boys without other employment opportunities. Female participation in fishing activities is negligible in the area.

When electrofishing is included, the upper Sunkoshi River harvest is estimated to be 27.5 kg per hectare of water surface area. This is considered to be below the fishery potential of rivers of Nepal.

To better understand the reasons for the decline in fishery resources in the upper Sunkoshi River the Inland Aquaculture and Fisheries Section has conducted several programmes:

- Limnological /biological investigations of the upper Sunkoshi River, in 1998/1999
- Awareness programme to control illegal fishing practices, especially electrofishing, in 1999/ 2000
- Community concept programmes and fisher group formation programmes which started in 2000.

7. CONCLUSIONS AND RECOMMENDATIONS

The upper Sunkoshi River contains the important indigenous hill stream fish *Schizothorax*, *Schizothoraichthys*, *Glyptothorax*, *Garra* and the less common *Psilorhynchus*, *Pseudecheneis*, *Glyptosternum blythi* and *Nemacheilus rupicola*. Traditionally the system has been supporting a significant fishery by local fisher groups and the water body has a vital role in the economic status of fisher groups in the region. But due to destructive fishing practices and overfishing the fish stocks have been declining and the situation is in need of strategies for protection of fishery resources. The following recommendations intend to assist in maintaining a sustainable fish catch from the upper Sunkoshi River:

- Laws/regulations regarding aquatic life conservation should be implemented as soon as possible to protect fishery resources.

- The Fisheries Development Directorate should organize awareness programmes for fishermen to highlight the importance of fish diversity, of fishery resources sustainability and of impacts of destructive/ illegal fishing methods on fish.

- Community concept of fisher groups living along the river should be launched effectively covering the whole river stretch.

- River improvement should be effectively conducted through interdisciplinary management as well as coordination among line agencies. For the effectiveness of such regulations the Fisheries Development Directorate should coordinate administrative authorities, local authorities and fisher groups activities.

- As the upper Sunkoshi River is a good site for asla and the fish is economically important, stocking of asla should be encouraged.

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PRESENT STATUS AND PROSPECTS OF MAHSEER FISHERY IN GARHWAL REGION OF CENTRAL HIMALAYA

by

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ABSTRACT

The newly created hill state, Uttaranchal, located in the Central Himalayan region of India, is endowed with vast natural freshwater resources. *Tor putitora* (golden mahseer) is one of the main game and food fish in the Central Himalayan region. However, the population of *Tor putitora* has greatly dwindled over the years, so much so that it constitutes only a negligible part of fishery in the majority of rivers and streams. The present study, carried out in six rivers of the west Uttaranchal, i.e. Garhwal region of Central Himalaya, has revealed that it contributes significantly only in one river, i.e. Nayar (32.8%). It constitutes about 9.7% of the total fish catch in the river Song, while in other rivers the percent population ranges between 0.8 and 3.1%. The catch size has also greatly decreased, ranging from 28.0 g and 13.5 cm to 1 650.0 g and 52.5 cm only. The average catch per unit effort of mahseer in the river Nayar was recorded as 67.92 g/man/hr with the minimum and maximum values being 25.0 and 875.5 g/man/hr. On the basis of ecodatabase, availability of the brooders, fry and fingerlings, only the river Nayar could be considered as a potential mahseer stream. The paper discusses the present status and prospects for the development of the fishery of golden mahseer in the Garhwal region of the Central Himalaya and the measures to be adopted for the rehabilitation of its stocks in suitable streams.

1. INTRODUCTION

The abundant surface water resource in the Central Himalayan region of India provides a great opportunity for the development of fishery of the golden mahseer. These denizens of Himalayan waters are a source of recreation for people from India and abroad and also have great food potential for hill people. Therefore, the mahseer may play a great role in the socio-economic development of the hill region. However, due to unthoughtful exploitation by man, the stocks of mahseer have greatly dwindled in these waters.

Though mahseer has great game and food value, the various attributes of its fishery have not been investigated comprehensively, especially in the Central Himalayan waters (Mishra *et al.*, 2000). Even the catch data from the major rivers are not available. Whatever studies have been done are sporadic and preliminary in nature, therefore the correct picture of mahseer fishery cannot be construed. The majority of the studies conducted until now are confined only to the biological aspects such as taxonomy, morphology, food and feeding, physiology, distribution, life history stages, length-weight relationships (Desai, 1972; Badola and Singh, 1980; Sen and Jayaram, 1982; Nautiyal and Lal, 1982, 1984 and 1984a, 1988).

The research work on the aquaculture feasibility, hatchery production of fish seed, development of suitable feeds, intensive culture in cages/raceways/running water systems is warranted for developing the technology package for the conservation, rehabilitation and propagation of mahseer in the Central Himalayan region.

The present paper deals with the above aspects for the development of fishery of golden mahseer in the Garhwal region of Central Himalaya.

2. DESCRIPTION OF THE STUDY AREA

The Garhwal Himalaya forms the western part of Central Himalaya. It is situated between the latitudes $29^0 26'$ – $31^0 28'$ N and longitude 77^0 49' – 80^0 6' E . The region has a total area of 30 090 km^2. The fresh water resources in the Uttaranchal State include 2700 km of rivers and their tributaries, 31 lakes spread over an area of about 300 ha, and 6 reservoirs encompassing 18 931 ha. There are also 1 341 ponds covering an area of 628 ha. The majority of the water resources are located in the Garhwal region. The geographical and physical features of selected streams, including the place(s) and altitude of sampling points, of Garhwal Himalaya are given in Table 1.

Table 1
Geographical and physical features of the selected streams of Garhwal Himalaya

Stream	Altitude (m) and the source	Type	Working place	Altitude of working place	Temperature range (^0C)	Tributary of the major river
Bhagirathi	3 920 (Gomukh)	Snowfed	Sirai to Old Tehri	750 -640	10.2-23.5	Ganga
Bhilangana	3 560 (Khatling and Photling)	Showfed	Bhado Ki Magari to Old Tehri	770-640	10.8-23.5	Bhagirathi
Western Hiyunl	2 250 (Girkunda)	Spring fed	Nagani to Khadi	1 000-950	13.5-27.0	Ganga
Song	- (Sirkunda)	Spring fed	Doiwala to Raiwala	425-380	18.5-27.5	Ganga
Khoh	1 951 (Langur)	Spring fed	Dogadda to Kotdwar	615-375	16.0-26.5	Ramganga
Nayar	2 835 (Doodhatoli)	Spring fed	Satpuli to Vyasghat	760-442	14.0-26.0	Ganga

The rivers Bhagirathi, Alaknanda, Ganga, Yamuna and Western Ramganga constitute the main drainage system in Garhwal region. Alaknanda is the largest river, covering a distance of about 240 km. Bhagirathi is second largest and takes its origin at Gaumukh Glacier near Tibet border at an altitude of 3 600 m. It slopes down to Gangotri and Uttarkashi and receives the Bhilangana River at Tehri (Fig. 1). At Deoprayag the Bhagirathi and Alaknanda confluence to form the holy river of India, the Ganga.

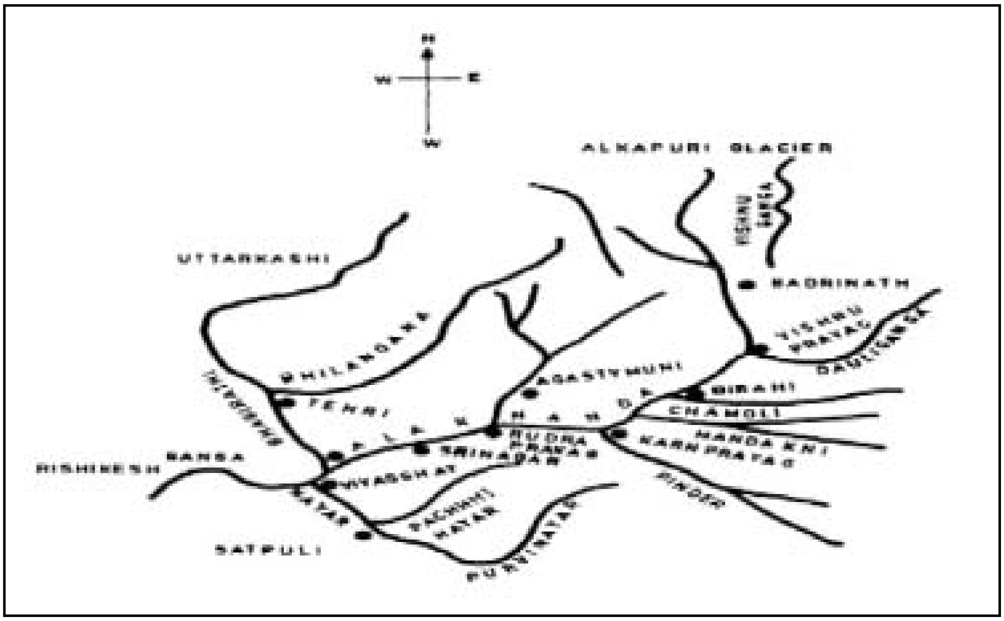

Fig. 1 - Drainage system of Garhwal Himalaya

The river Bhilangana, which arises from Khatling Glacier (3658 m), confluences with the Bhagirathi at Old Tehri, where Asia's biggest dam is under construction.

The Nayar river in the Garhwal Himalaya is a spring-fed stream with rocky/sandy basin. Nayar receives two tributaries, Eastern and Western, near Satpuli and joins the river Ganga at Vyasghat. The eastern and western tributaries of Nayar originate from northern and southern peaks of Doodhatauli hills. The Song is a right side tributary of river Ganga. This is a spring-fed river with sandy and rocky substratum. The Khoh River is also a spring-fed stream with rocky/sandy substratum; it is a tributary of the river Ramganga.

The river Hiyunl originates from Devidanda Hills and passes through Dhangoo block in Lansdown sub-division of Garhwal. It is also a tributary of the river Ganga.

In the present study 6 rivers were selected for the preparation of ecodatabase and evaluation of status of mahseer fishery. Among the selected rivers, four are spring-fed (Western Hiyunl, Song, Khoh and Nayar) while two are snow-fed (Bhagirathi and Bhilangana). The rivers are located between altitudes 425 and 1 000 m. The selection of study sites was based on habitat characteristics and potential for mahseer.

3. MATERIAL AND METHODS

Fifteen sampling sites spread over six rivers were selected. The study was conducted during April 2000 to March 2001. Fish sampling was done monthly at all selected sites, up to a 1 km in each river, by use of cast net and gill net. The mesh size of cast net and gill net were 2.0-3.0 cm and 2.0-10.0 cm, respectively. The observations were made on fish species, percent population, proportion of mahseer in the total catch, average body weight and length and age of mahseer. The fish records from local fishermen were also regularly noted at each site.

The analysis of physical and chemical characteristics of water was done fortnightly at the sampling stations. The flow rate, average span and depth of the river were recorded using standard methods. Water temperature was recorded using mercury thermometer calibrated to 0.1°C. The pH and dissolved oxygen were analyzed using digital analyzers at the site. Free CO_2, total alkalinity and silicate were estimated following standard methods (APHA, 1985). Length, weight and width of fish were measured using measuring scale and monopan balance. Age of mahseer was determined by counting the annual rings in scales.

4. RESULTS

4.1 Physico-chemical characteristics

To find out the suitability of the selected streams for mahseer, an ecodatabase was prepared. The data on various physical and chemical characteristics of water of various rivers are given in Table 2.

During the study period the average water temperature ranged from 9.0 to 27.8°C. The snow-fed river Bhagirathi had the lowest and spring-fed river Nayar had the highest temperature. Average water temperature fell below 6°C in the Bhagirathi River. Excepting Bhagirathi and Bhilangana, the average depth of the rivers was between 0.4 and 1.75 m. Bhilangana and Bhagirathi are deeper, with depth ranging between 1.0 and 8.0 m. Water current was faster in the snow-fed rivers Bhagirathi and Bhilangana, with maximum values of 1.6 to 2.0 m/s, than in the spring-fed rivers (0.5 to 0.7 m/s). The average width was highest in Bhilangana (17.1m) and Bhagirathi (21.0 m), while it varied between 6.8 and 12.9 m in the rivers Hiyunl, Song, Khoh and Nayar. The water of all rivers had almost similar average transparency (30.1-32.4 cm), but individual values reached up to 44 cm in the river Nayar during February. Rivers Nayar and Bhagirathi had highest concentrations of total dissolved solids (161.0-162.8 mg/L); relatively lower values were recorded in rivers Hiyunl, Song and Khoh (114.5 to 132.2 mg/L). Excepting Bhilangana, which had a mean pH value of 6.0, the water of other rivers was neutral to slightly alkaline (pH 7.0-7.5). The maximum pH (7.9) was recorded in the river Song during April. All rivers and streams had good concentrations of dissolved oxygen (range 6.0 to 12.0 mg/L). The maximum concentration was found in the river Bhagirathi during January and the minimum was recorded during July in the river Song. The free CO_2 showed wide fluctuation in concentration from 0.0 to 8.0 mg/L, but its values ranged between 2 and 4 mg/L in most of the selected rivers during the study period. Higher concentrations occurred during the monsoon period. Marked differences existed in the total alkalinity concentrations. While the Song had an average value of 184.3 mg/L, the mean concentration in the Bhilangana was only 38.6 mg/L. In general, alkalinity is higher in spring-fed than snow-fed rivers. The silicate content was higher in snow-fed (0.5-0.6 mg/L) than in spring-fed rivers (0.1-0.4 mg/L).

4.2 Biological characteristics

The average periphyton (aufwuchs) densities ranged from 170 no/cm^2 (Western Hiyunl) to 490 no/cm^2 of substrate (Nayar). Hiyunl and Khoh had lower densities than other rivers (Table 3). Bhilangana and Bhagirathi both supported moderate densities of periphyton.

Table 2

Annual mean and range of water quality parameters in different rivers in Garhwal region

The data are averaged across the various sampling stations

Parameter		River-Western Hiyunl	River -Song	River-Khoh	River-Nayar	River-Bhilangana	River-Bhagirathi
Water temperature (^0C)	Average	20.6	22.3	22.0	20.1	17.8	16.9
	Range	13.0-26.9	15.0-27.0	13.4-27.8	10.0-26.4	9.5-25.5	9.0-25.5
Water depth (cm)	Average	0.79	0.83	0.61	0.84	2.02	4.48
	Range	0.45-1.3	0.35-1.75	0.4-0.85	0.7-1.2	1.0-2.8	2.0-8.0
River width (m)	Average	8.6	11.85	6.88	12.97	17.1	21.0
	Range	6.0-11.2	7.5-14.5	4.4-9.6	7.0-18.5	12-22.6	12-290
Flow rate (m/s)	Average	0.6	0.7	0.5	0.6	0.9	1.2
	Range	0.4-0.9	0.5-1.0	0.4-0.8	0.5-1.2	0.6-1.6	0.9-2.0
Transpa-rency (cm)	Average	31.9	32.12	33.22	30.70	30.17	32.43
	Range	27.2-42.0	26.5-42.0	27.5-42.0	23-44	14.5-40.0	15.4-29.0
Total solids (mg/L)	Average	123.4	132.2	114.5	162.8	156.2	161.
	Range	102-150	92.0-195.0	92.2-128	110-210	136.8-165.61	145-171
PH	Average	7.0	7.5	7.0	7.0	6.	7.0
	Range	6.8-7.2	7.4-7.9	6.9-7.2	6.8-7.2	6.6-7.0	6.8-7.0
DO (mg/L)	Average	8.0	7.8	7.6	8.1	8.0	7.9
	Range	7.4-8.8	7.2-9.0	6.8-8.2	6.0-8.8	6.6-8.8	7.2-9.2
Free CO_2 (mg/L)	Average	1.74	1.66	2.2	2.3	2.7	2.31
	Range	0-8.0	0-8.0	0-4.0	0-6.0	0-6.0	0-6.0
Total alkalinity (mg/L)	Average	122.6	184.3	89.4	80.9	58.6	73.1
	Range	106-142	150-210	72-106	56-112	44-84	56-90
Silicate (mg/L)	Average	0.1	0.3	0.3	0.4	0.5	0.6
	Range	0.34-0.22	0.05-0.88	0.1-0.66	0.22-0.70	0.45-0.65	0.60-0.71

Table 3
Periphyton (aufwuchs) densities in selected rivers of Garhwal Himalaya
The data are averaged across all sampling stations in the rivers

Density (no/cm^2)	**River-Western Hiyunl**	**River-Song**	**River-Khoh**	**River-Nayar**	**River-Bhilangana**	**River-Bhagirathi**
Average	170	247	188	490	305	370
Range	11-542	6-1 183	40-701	40-1 208	12-1 329	14-655

In terms of group composition, Chlorophyceae (green algae) and diatoms were the sole components of periphyton (Fig. 2). Chlorophyceae comprised 24.4 to 47.9%, whereas diatoms constituted 52.1 to 75.6% of the total annual population. Green algae were most dominant in Khoh; the maximum population of diatoms was recorded in river Nayar (75.6%).

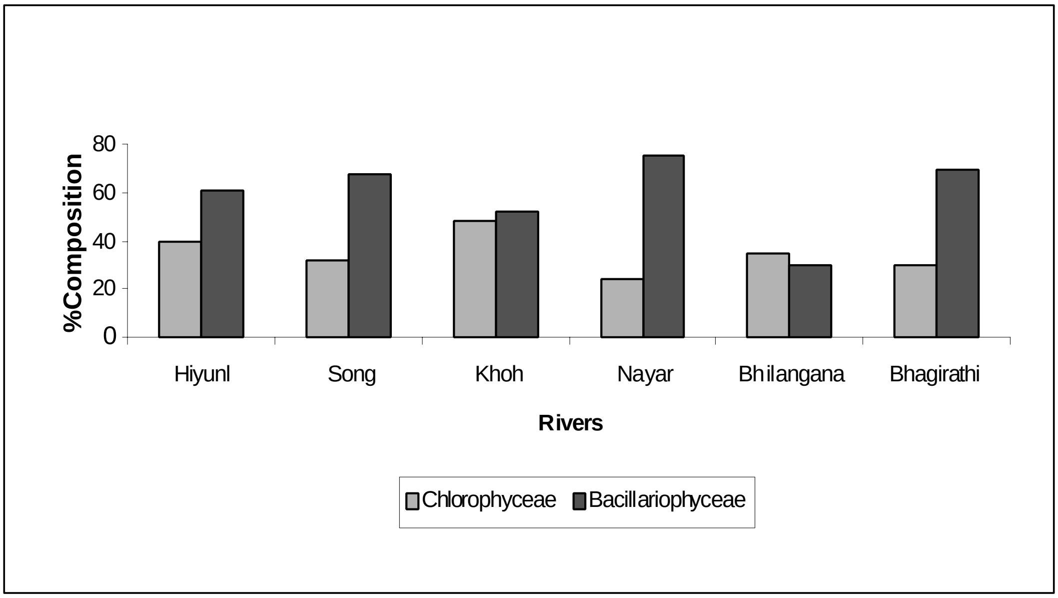

Fig. 2 - Mean percent composition of periphyton groups in different rivers of Garhwal Himalaya

The zooplankton population ranged between 58 and 77 ind./L (Table 4). The lowest and highest population was recorded in the rivers Bhilangana and Song, respectively.

Table 4
Mean standing crop of zooplankton in different rivers of Garhwal Himalaya
The data are averaged across all sampling stations

Standing crops (no/L)	River-Western Hiyunl	River-Song	River-Khoh	River-Nayar	River-Bhilangana	River-Bhagirathi
Average	59	77	75	67	58	77
Range	10-208	1-288	19-182	9-198	16-125	12-166

Protozoans, rotifers, copepods and cladocerans represented the zooplankton community. Protozoans comprised 24.0 to 44.7% of the total zooplankton (Fig. 3). The percent population of the other zooplankton varied from 59.1 to 76.0%. Annually, the population was apportioned between protozoans (35.6%) and other zooplankters (64.4%).

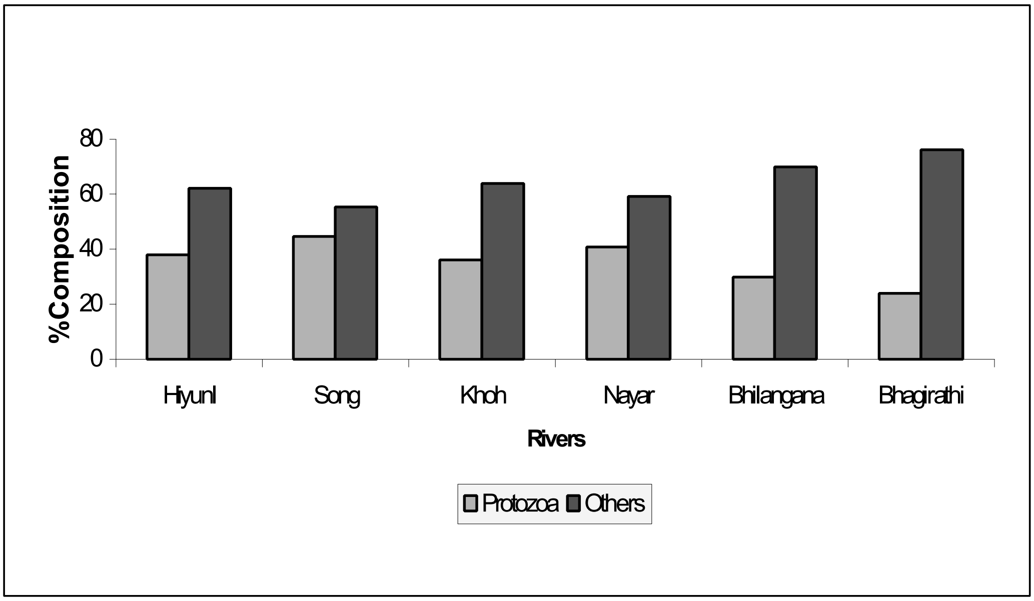

Fig. 3 - Mean percent composition of zooplankton groups in rivers of Garhwal Himalaya

The benthic fauna in the rivers comprised of Ephemeroptera, Odonata, Plecoptera, Hemiptera and Diptera. The annual range of the benthic fauna varied most in the Nayar River (Table 5). The Nayar River was the richest while the Bhagirathi had the lowest population. In general, spring- fed streams had more benthic fauna than snow-fed rivers.

Table 5
Mean abundance of macrobenthic fauna in different rivers of Garhwal Himalaya
The data are averaged across all sampling stations

Mean abundance (no/m^2)	River-Western Hiyunl	River-Song	River-Khoh	River-Nayar	River-Bhilangana	River-Bhagirathi
Average	920	1411	1188	1624	698	429
Range	196-2 003	285-3 126	290-3 116	125-3 415	245-1 341	111-1 200

The ephemeropterans were most abundant with annual mean percent population in different rivers varying between 32.4 and 47.2. Again, the lowest and highest values were recorded in the rivers Bhagirathi and Nayar, respectively (Fig. 4).

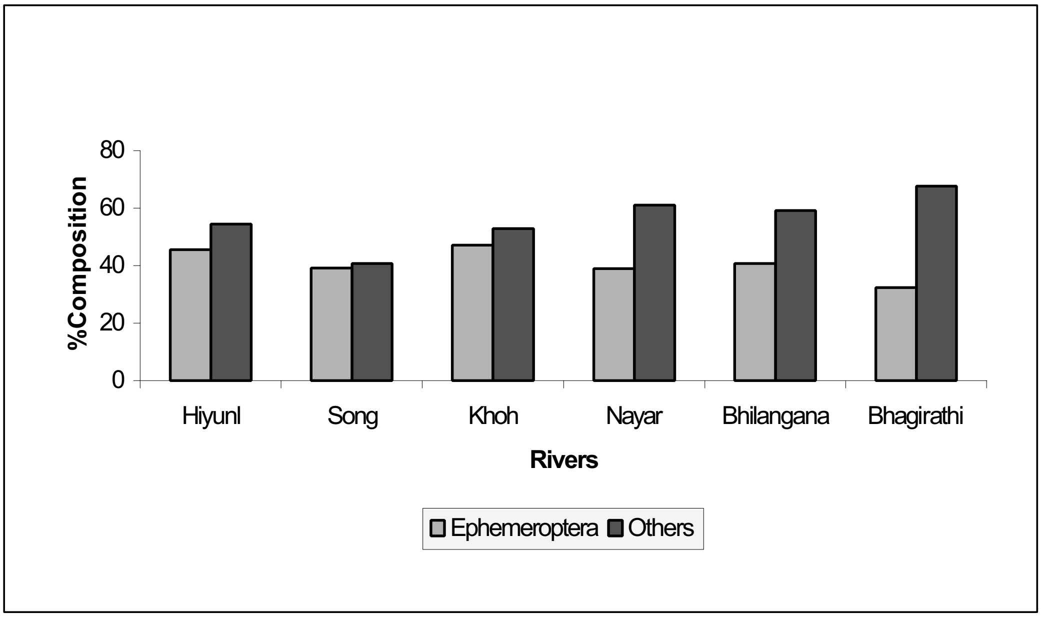

Fig. 4. Mean percent composition of macrobenthic groups in different rivers of Garhwal Himalaya

4.3 Ichthyofauna

The fish fauna of the rivers of Gahrwal Himalaya is represented by *Schizothorax* spp., *Tor putitora*, *Labeo dero*, *Labeo dyocheilus*, *Garra gotyla*, *Crossocheilus latius*, *Barilius bendelisis*, *Glyptothorax pectinopterum*, *Mastacembelus armatus* and *Botia* spp (Table 6).

Table 6
Fish species found in rivers of Garhwal Himalaya

River/Stream	Fish Species
Western Hiyunl	*Tor putitora, Schizothorax* spp., *Labeo dero, Crossocheilus latius, Barilius bendelisis, Botia* spp., *Glyptothorax pectinopterum*
Song	*Tor* spp., *Mastacembelus armatus, Labeo dyocheilus, Labeo dero, Schizothorax* spp., *Barilius bendelisis*
Khoh	*Schizothorax* spp., *Tor putitora, Barilius bendelisis, Garra gotyla*
Nayar	*Tor putitora, Barilius bendelisis, Schizothorax* spp., *Mastacembelus armatus, Labeo dero, Labeo dyocheilus, Garra gotyla*
Bhilangana	*Schizothorax* spp., *Tor putitora, Garra gotyla*
Bhagirathi	*Schizothorax* spp., *Tor putitora, Garra gotyla*

Schizothorax spp. are most important in the rivers, with total contribution of 52.6% on the basis of the mean values of the fish catch from 15 sampling stations on 6 representative rivers/streams (Fig. 5).

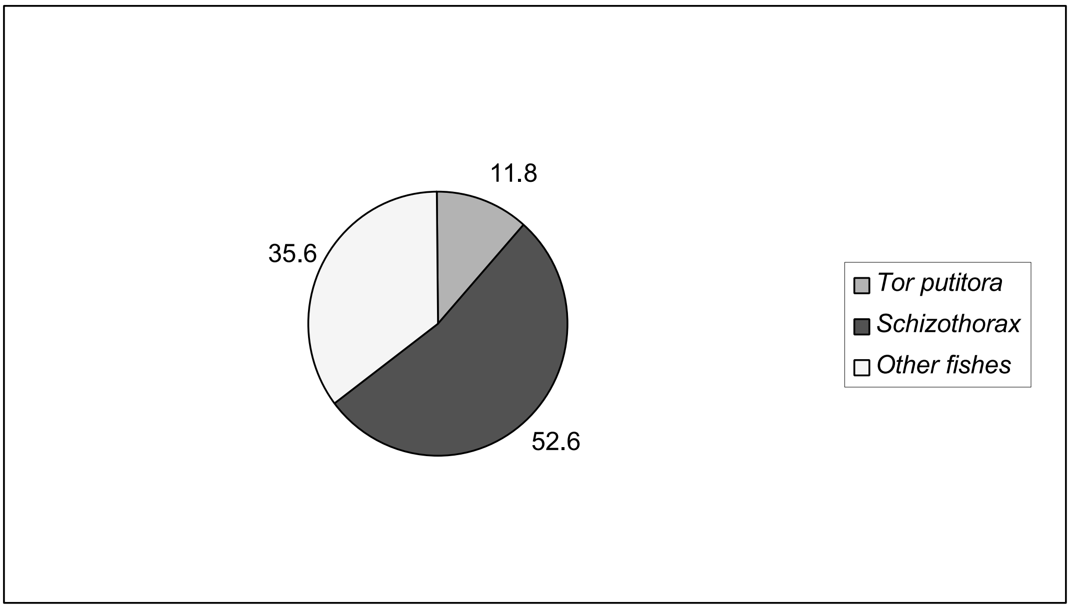

Fig. 5 - Percent composition of fish in the Central Himalayan rivers

The mean contribution of *Tor putitora* comes to only 11.8%. After *Schizothorax*, the major fishery is comprised of species of subsistence values, *viz*. *Barilius* spp., *G. gotyla*, *Labeo* spp.

The catch data in terms of numbers and percentage of *Tor putitora*, *Schizothorax* spp. and other fish are given in Table 7. *Tor putitora,* with percent contribution of 32.8% of the total fish population, is the most dominant fish in the river Nayar; Song, with 9.7% population of *T. putitora,* ranks second.

Table 7
Fish catch statistics at various sampling stations in different rivers of Garhwal region

Groups	Western Hiyunl	Song	Khoh	Nayar	Bhilangana	Bhagirathi
Tor putitora						
Total No.	1.67	30.67	1.5	119.33	5.5	4.5
Percentage	0.8	9.7	0.9	32.8	3.1	2.6
Schizothorax spp						
Total No.	84.33	80.33	81.5	181.33	141.5	156.5
Percentage	48.1	26.4	25.4	51.5	84.2	90.6
Miscellaneous						
Total No.	87.67	193.67	120.5	55.33	21	12
Percentage	51.0	63.8	73.6	15.5	12.6	6.7

The data are averaged across all the sampling stations

The percentage catch of *T. putitora* in the selected rivers is shown in Fig. 6. The percent catch is 0.0-6.0% in the rivers Bhilangana and Bhagirathi, while in the river Nayar it comes to 2 to 60%, with a maximum being recorded during May, September and October.

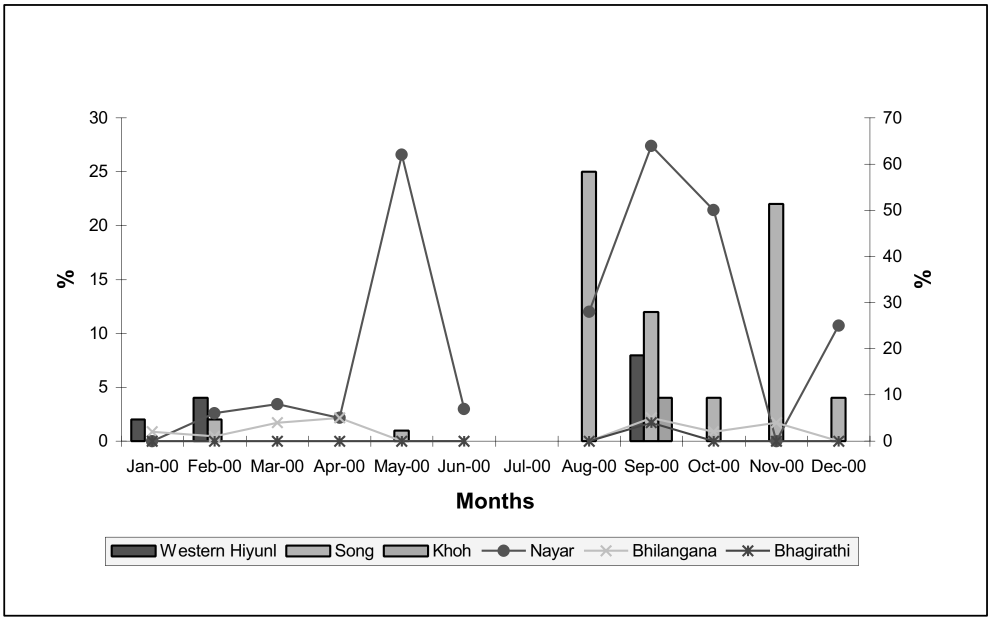

Fig. 6 - Percentage catch of golden mahseer in selected rivers of Garhwal Himalaya

In the river Song, the maximum population (20%) was also recorded during monsoon season. In other rivers of the Garhwal region, the catch percentage is quite low and is between 0 and 1% of the total catch.

The total catch per unit effort (CPUE) of *T. putitora* ranged from 4.3 to 270.6 g/man/h in the selected rivers (Fig. 7). The highest CPUE was obtained from the river Nayar. The total CPUE ranged from 340.1 to 1 891.0 g/man/h.

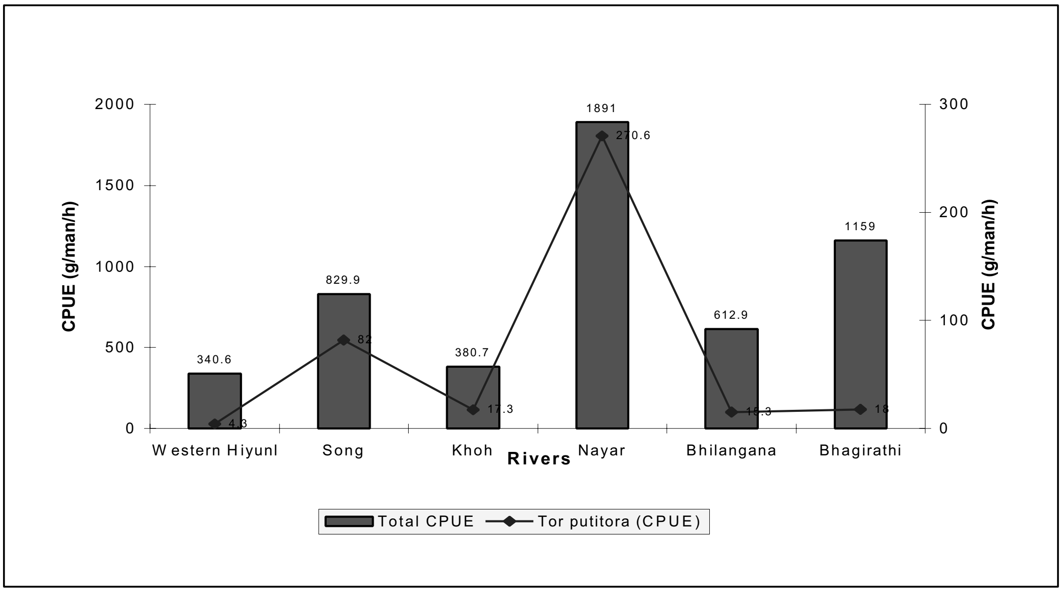

Fig. 7 - Mean CPUE of total fish population and *Tor putitora* in different rivers of Garhwal region

In terms of weight, maximum catch size of mahseer varied between 200 and 400 g. Only during July-September were mahseer above 1.0 kg weight recorded from the rivers Nayar and Song. From the other selected rivers the catch of mahseer was very low, with weight range of 200 to 500 g. Overall, weight range of *T. putitora* during the period of investigation ranged from 25 to 1 650 g, their body length ranged from 10.5 to 52.5 cm and width from 2.0 to 9.5 cm (Table 7). The harvested golden mahseer were in the age group of under one year to above three years.

5. DISCUSSION

An appraisal of the ecosystem characteristics of the selected rivers/streams of the Ganga river system in the Garhwal region of Central Himalaya reveals that all spring-fed rivers are ‘placid eurythermal’, with increased range of temperature. The glacier-fed rivers, on the other hand, can be classified as ‘torrential stenothermal’. Singh *et al*. (1991) have recognized the altitudinal range of 600-1 200 m as the mahseer zone. All the sampling sites of the selected rivers in the present study were located in the range of 425-1 000 m altitude. In general, the glacial-fed streams Bhagirathi and Bhilangana had low temperature, steep gradient, swift water current, high dissolved oxygen content and mildly acidic to slightly alkaline pH. All these factors together determine the distribution and abundance of periphyton and benthos.

Table 7
Total weight, total length and width of the harvested mahseer from the selected streams of Garhwal Himalaya

Total weight (g)	Total length (cm)	Width (cm)
25	10.5	2.0
50	16.0	2.6
75	17.0	3.0
100	20.0	3.0
150	24.0	4.0
175	23.0	4.3
200	23.0	4.4
350	28.5	5.0
550	32.0	5.5
800	39.5	7.8
1 000	49.2	9.0
1 650	52.5	9.5

The spring-fed streams of the Central Himalayan region have relatively high temperature (10.0 to 27.5°C), low current velocity (0.4 to 1.2 m/s), and a relatively confined channel basin (4.4 to 18.5 m). The dissolved oxygen content was also lower than in the glacier-fed streams (6.6 to 8.8 mg/L). However, pH was slightly higher (7.0-7.9) and total alkalinity was much higher (0.9 to 184.3 mg/L). Current velocity and water temperature greatly influence the periphyton (aufwuchs) density in the streams of Central Himalaya. It was higher in spring-fed streams than glacier-fed ones. The river Nayar had higher plankton population than the rivers Bhagirathi and Bhilangana. Singh *et al.* (1991) and Dobriyal and Singh (1989) also reported a similar trend in some hill streams of Garhwal Himalaya.

Like periphyton, the macrobenthic invertebrate fauna was also higher in spring-fed streams. The higher temperature, moderate current, good periphyton and allochthonous matter coupled with a high substrate heterogeneity enhance the density of macrobenthic fauna in spring-fed streams. Dobriyal and Singh (1990) reported that this provides a good base for the development and growth of minor carp fishery in Central Himalayan waters.

The golden mahseer is the most important game and food fish in the Central Himalaya. It contributes greatly to the commercial fishery in the foothills. The fish migrates considerable distances upstream in the search of suitable spawning grounds (Badola and Singh, 1984; Nautiyal and Lal, 1984; Singh, 1988). However, once found in abundance, the stocks of the Himalayan mahseer are depleted to the extent that it is now considered as an endangered species (Singh *et al.*, 1991). The decline of mahseer fishery has also been reported from the other Himalayan waters such as the Ganga river system (Chauhan *et al.*, 1992), Brahmaputra river system (Dey, 1992), Govind Sagar reservoir (Johal and Tandon, 1981), Kumaun lakes (Sharma, 1991) and some other waters.

The present investigations also reveal that the population of golden mahseer has greatly declined in the waters of Western Central Himalaya. It contributes significantly to the fishery only in the spring-fed river Nayar where it comprises 32.8% of the total catch. The second best contribution (9.7%) was in the river Song. In other streams the contribution ranges only between 0.8 and 3.1%. The brooders, yearlings, fry and fingerlings of golden mahseer were observed in the river Nayar only. The average seed density was between 300-400 no/m^2 at the confluence of the rivers Nayar and Ganga at Vyasghat (Fig. 1).

Himalayan mahseer population undertakes contranatant migration from the foothill sector of the Ganga, often ascending into the rivers Bhagirathi and Bhilangana. These major tributaries serve as the only routes through which the fish can have easy access to the spring-fed placid streams providing congenial environment for the fish to breed (Nautiyal and Lal, 1984). However, the present observations reveal that only Nayar is a potential mahseer spring-fed stream in the Western Central Himalayan region. However, the size of the catch was also very low from Nayar (25 to 1 650 g) as per observations during the period of investigation.

The factor that has brought Himalayan mahseer to the brink of extinction is indiscriminate killing of juveniles and brooders.

Mass slaughter of fish through toxicants and dynamite is common, particularly in uplands. Fishing by fixed gears is also a common example of indiscriminate fishing. Intensification of fishing effort during the pre-monsoon period, when water level in rivers is low, adds to the problem. Changes in the habitat due to construction of dams, barrages and weirs under river-valley projects adversely affect the biology of this fish.

Prospects of mahseer fishery development

In spite of depletion of the population of golden mahseer, there is tremendous scope to develop its fishery for both commercial and recreational purposes. Based on the present investigations a three-fold strategy is suggested for the development of the fishery of *Tor putitora* in Garhwal Himayala:

(i) Preservation of existing stocks:

Fish protection in the rivers and other water systems of the region will be helpful in preserving valuable fish genetic resources (Singh and Singh, 1991). The following conservation measures are suggested:

- proper stock assessment should be undertaken for determining the present status of commercial fishery and its subsequent level of exploitation,
- ban on indiscriminate fishing should be strictly enforced,
- closed seasons should be rigidly enforced and there should be a total ban on capture of juveniles and spawners,
- selected stretches of water bodies should be declared as mahseer sanctuaries.

(ii) Promotion of natural propagation:

- the spawning and nursery habitats of Himalayan mahseer in small hill streams, which contain abundance of benthic entomofauna and serve as natural nurseries for the breeding population of mahseer, should be identified and protected,
- foliage cover should be provided on banks of streams to prevent wide fluctuations in temperature and to prevent soil erosion,
- artificial pools should be created in rivers for better spawning conditions,
- hindrances to spawning migration should be cleared,

- collection of post-larvae and fry/fingerlings, their rearing up to advanced fingerling stage on formulated feeds, and restocking in natural waters for better survival should be the future strategy for enhancing mahseer stocks in Himalayan waters.

(iii) Hatchery development and seed production of *Tor putitora*

Successful breeding and seed production programme of *Tor khudree* has been carried out for two decades at the Fish Seed Farm of the Tata Electric Company at Lonawala (Ogale, 1992). However, efforts made to induce-breed pond-reared broodstock of *T. putitora* by hypophysation have not been very successful (Joshi, 1994). Further, the availability of broodstock from nature is still minimal. The studies on the maturity and fecundity have shown that eggs mature in batches (Bhatnagar, 1967). The total number of eggs taken from females varied from 500 to 10 000 (Sehgal, 1991).

For the protection, rehabilitation and aquaculture of Himalayan mahseer the following is needed:

- a reliable breeding technology be developed, trial tested and replicated,
- hatchery, nursery and rearing technologies of *T. putitora* be developed,
- selective breeding of mahseer using brooders from nature be done for stock improvement,
- mahseer hatcheries be established near the stocking sites,
- hatchlings of mahseer be raised on formulated diets up to fingerling stage.

The hatchery-produced fingerlings of mahseer should be stocked regularly in selected streams and lakes to replenish their mahseer fish stocks and the feedback data from mahseer fishery should be collected and analysed.

There is good scope for the extensive and intensive culture of *T. putitora* in the Garhwal Himalaya. The streams located in the suitable altitudinal zone can be selected for the culture of Himalayan mahseer. There are innumerable spring-fed perennial streams where water could be diverted into narrow ponds or raceways alongside such streams. The fish can be raised on protein rich pelleted feed. The development of hatchery production of fish seed and its ranching in rivers and lakes of Central Himalaya can successfully bridge the gaps in production. Mahseer aquaculture in suitable localities should also be tested through pilot studies.

Acknowledgements

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TAXONOMIC REVISION OF COLD WATER FISHES OF NEPAL

by

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ABSTRACT

Different authors have listed different total numbers of fish species for Nepal and there has been some confusion in the fish genera, species and synonyms. A total of 81 cold water species under 37 genera belonging to 2 orders, 7 families and 10 subfamilies is listed, with their updated nomenclature and systematic position according to the recent classification of Jayaram (1999). Genera *Naziritor* Mirza and Javed, *Salmostoma* Swainson, *Securicula* Gunther, *Acanthocobatis* van Hasselt and *Lepidocephalus* Bleeker are revised here. A number of species have been either synonymised or merged with others. Many species need further study.

1. INTRODUCTION

The large diversity of fish species in Nepal is explained by the diversity of climatic zones, from subtropical to high mountains, and the fact that Nepal lies at the transition point of the Indo-Malayan and Palaearctic biogeographical realms. Therefore it is not surprising that a large number of fish species occur in Nepal. The ichthyofauna of Nepal has been studied by a number of scientists, *viz*. Atkinson (1974), Banarescu (1972), Boulenger (1907), Menon and Datta (1964), Hamilton (1822), Hora (1937, 1940, 1952), Gunther (1861), Regan (1907), Menon (1949, 1964, 1999), Day (1878, 1889), McClelland (1839), Shaw and Shebbare (1937), Hora (1952), Misra (1959), Jayaram (1981 -1999), Talwar and Jhingran (1991), De Witt (1960), Terashima (1984), Evans (1985) and Edds (1985 -1986).

The contribution made by Nepalese scientists are Jha (1986), Jha and Shrestha (1980), Rajbanshi (1982), Shah et al. (1992), Shrestha, J. (1981, 1978, 1994, 1995, 1998, 1999), Shrestha, T.K. (1990), Subba (1995, 1996). All these scientists variably reported the total number of indigenous fishes of Nepal. There has been a great confusion regarding genera, species, synonyms, nomenclature and systematic position. Therefore taxonomic revision of these species has been urgently needed. Shrestha (2001) has reported for Nepal a total of 182 fish species belonging to 92 genera under 31 families and 11 orders, as compared to 186 species of 75 genera, 31 families and 11 orders reported earlier. Shrestha (1999) for the first time made a list of cold water fishes in Nepal, with 59 indigenous and two exotic fish species. Shrestha (1990) has reported 31 species including *Rita rita* (Hamilton-Buchanan) as the threatened species of Himalayan waters of Nepal.

2. LIST OF COLD WATER FISH SPECIES OF NEPAL

The list of cold water fishes of Nepal is increasing with new reporting from inland waters, but at the same time there has been duplication and confusion of genus and species nomenclature as well as the use of outdated classification. The present paper is an attempt to update the taxonomy of cold water fishes of Nepal. The classification follows that of Jayaram (1999), however works of other authors such as Menon (1999) and Talwar and Jhingran (1991) have also been consulted. A total of 81 species under 37 genera belonging to 2 orders, 7 families and 10 subfamilies are listed in the present text.

Table 1
List of cold water fish with revised classification
(based on the classification of Jayaram, 1999)

Superclass	- Gnathostomata
Class	- Actinopterygii
Subclass	- Neopterygii
Division	- Teleostei
Subdivision	- Euteleostei
I. Order	**Cypriniformes**
Family	- Cyprinidae
Subfamily	- Danioninae (Rasborinae)
Tribe	- Oxygasterini
Genus	- *Securicula* Gunther 1868
	1. *Securila gora* (Hamilton-Buchanan) 1822
Genus	- *Salmostoma* Swainson 1839
	2. *Salmostoma acinaces* (Valenciennes) 1842
	3. *Salmostoma bacaila* (Hamilton-Buchanan) 1822
Genus	*Barilius* (Hamilton-Buchanan 1822)
	4. *Barilius barila* (Hamilton-Buchanan) 1822
	5. *Barilius barna* (Hamilton-Buchanan) 1822
	6. *Barilius bendelesis* (Hamilton-Buchanan) 1822
	7. *Barilius bola* (Hamilton-Buchanan) 1822
	8. *Barilius guttatus* (Hamilton-Buchanan) 1822
	9. *Barilius radiolatus* (Hamilton-Buchanan) 1822
	10 .*Barilius shacra* (Hamilton-Buchanan) 1822
	11. *Barilius tileo* (Hamilton-Buchanan) 1822
	12. *Barilius vagra* (Hamilton-Buchanan) 1822
Tribe	- Danionini
Genus	- *Chela* Hamilton-Buchanan 1822
	13. *Chela laubuca* (Hamilton-Buchanan)1822
Genus	*Esomus* Swainson 1839
	14. *Esomus danricus* (Hamilton-Buchanan) 1822
Genus	*Brachydanio* Weber and Beaufort 1916
	15. *Brachydanio rerio* (Hamilton-Buchanan) 1822
Genus	*Danio* Hamilton-Buchanan 1822
	16. *Danio aequipinnatus* (McClelland) 1839
	17. *Danio dangila* (Hamilton-Buchanan) 1822
	18. *Danio devario* (Hamilton-Buchanan) 1822

Subfamily	- Cyprininae
Tribe	- Cyprinini
Subtribe	- Tores
Genus	- *Tor* Gray 1833
	19. *Tor mosal* (Hamilton-Buchanan) 1822
	20. *Tor putitora* (Hamilton-Buchanan) 1822
	21. *Tor tor* (Hamilton-Buchanan) 1822
Genus	- *Naziritor* Mirza and Javed 1985
	22. *Naziritor chelynoides* (McClelland) 1839
Genus	- *Neolissocheilus* Rainboth 1985
	23. *Neolissocheilus hexagonolepis* (McClelland) 1839
Tribe	- Systomini
Subtribe	- Poropurtii
Genus	- *Chagunius* Smith 1945
	24. *Chagunius chagunio* (Hamilton-Buchanan) 1822
Subtribe	-Systomi
Genus	- Puntius Hamilton-Buchanan 1822
	25. *Puntius conchonius* (Hamilton-Buchanan) 1822
Tribe	- Semiplotini
Genus	- *Semiplotus* Bleeker 1859
	26. *Semiplotus semiplotus* (McClelland) 1839
Tribe	- Labeonini
Subtribe	- Labeones
Genus	- *Labeo C*uvier 1817
	27. *Labeo angra* (Hamilton-Buchanan) 1822
	28. *Labeo dero* (Hamilton-Buchanan) 1822
	29. *Labeo dyocheilus* (Hamilton-Buchanan) 1822
	30. *Labeo gonius* (Hamilton-Buchanan) 1822
Subfamily	- Oreininae (Schizothoracinae)
Genus	- *Schizothorax* Heckel 1838
	31. *Schizothorax richardsonii* (Gray) 1832
	32. *Schizothorax sinuatus* (Heckel) 1838
Genus	- *Schizothoraichthys* Misra 1959
	33. *Schizothoraichthys esocinus* (Heckel) 1838
	34. *Schizothoraichthys curvifrons* (Heckel) 1838
	35. *Schizothoraichthys labiatus* (McClelland) 1839
	36. *Schizothoraichthys macrophthalmus* (Terashima) 1984
	37. *Schizothoraichthys nepalensis* (Terashima) 1984
	38. *Schizothoraichthys niger* (Heckel) 1838
	39. *Schizothoraichthys progastus* (McClelland) 1839
	40. *Schizothoraichthys raraensis* (Terashima) 1984
Genus	- *Diptychus* Steindachner 1866
	41. *Diptychus maculatus* Steindachner 1866

Subfamily	- Garrinae
Genus	- *Garra* Hamilton-Buchanan 1822
	42. *Garra annandalei* Hora 1921
	43. *Garra gotyla* (Gray) 1832
	44. *Garra lamta* (Hamilton-Buchanan) 1822
	45. *Garra lissorhynchus* (McClelland) 1843
	46. *Garra nasuta* (McClelland) 1839
	47. *Garra rupicola rupicola (*McClelland*)* 1839
Genus	- *Crossocheilus* van Hasseltt (1823)
	48. *Crossocheilus latius* (Hamilton-Buchanan) 1822
Family	- Psilorhynchidae
Genus	- *Psilorhynchus* McClelland 1839
	49. *Psilorhynchus balitora* (Hamilton-Buchanan) 1822
	50. *Psilorhynchus sucatio* (Hamilton-Buchanan) 1822
Genus	- *Psilorhynchoides* Yazdani, Singh and Rao 1989
	51. *Psilorhynchoides homaloptera* (Hora and Mukerji) 1935
	52. *Psilorhynchoides pseudecheneis* (Menon and Datta) 1961
Family	- Balitoridae
Subfamily	-Balitorinae
Genus	- *Balitora* Gray 1832
	53. *Balitora brucei* Gray 1832
Subfamily	- Nemacheilinae
Genus	- *Acanthocobatis* Peters 1861
	54. *Acanthocobatis botia* (Hamilton-Buchanan) 1822
Genus	- *Nemacheilus* Bleeker 1863
	55. *Nemacheilus corica* (Hamilton-Buchanan) 1822
Genus	- *Schistura* McClelland 1839
	56. *Schistura beavani* (Gunther) 1868
	57. *Schistura rupecola* (McClelland) 1839
	58. *Schistura scaturiginia* (McClelland) 1839
Family	- Cobitidae
Subfamily	- Botinae
Genus	- *Botia* Gray 1831
	59. *Botia almorhae* Gray1831
	60. *Botia lohachata* Chaudhari 1912
Subfamily	- Cobitinae
Genus	- *Acantophthalmus v*an Hasselt 1823
	61. *Acantophthalmus pangia* (Hamilton-Buchanan) 1822
Genus	- *Lepidocephalus* Bleeker 1859
	62. *Lepidocephalus guntea* (Hamilton-Buchanan) 1822

II Order	**- Siluriformes**
Family	- Schilbeidae
Subfamily	- Schilbeinae
Genus	- *Pseudeutropius* Bleeker 1862
	63. *Pseudeutropius atherinoides* Bloch 1794
	64. *Pseudeutropius murius batarensis* Shrestha 1981
Genus	- *Clupisoma* Swainson 1839
	65. *Clupisoma garua* (Hamilton-Buchanan) 1822
Family	- Amblycipitidae
Genus	- *Amblyceps* Blyth 1858
	66. *Amblyceps mangois* (Hamilton-Buchanan) 1822
Family	- Sisoridae
Genus	- *Bagarius* Bleeker 1853
	67. *Bagarius yarelli* Sykes 1841
Genus	- *Glyptosternon* McClelland 1842
	68. *Glyptosternon reticulatum* McClelland 1842
	69. *Glyptosternon maculatum* (Regan) 1905
Genus	- *Glyptothorax* Blyth 1861
	70. *Glyptothorax annandalei* Hora 1923
	71. *Glyptothorax cavia* (Hamilton-Buchanan) 1822
	72. *Glyptothorax conirostre* (Steindachner) 1867
	73. *Glyptothorax gracile* (Gunther) 1864
	74. *Glyptothorax indicus* Talwar nom.nov. 1991
	75. *Glyptothorax kashmirensis* Hora 1932
	76. *Glyptothorax pectinopterus* (McClelland) 1842
	77. *Glyptothorax telchitta* (Hamilton-Buchanan) 1822
	78. *Glyptothorax trilineatus* Blyth 1860
Genus	- Euchiloglanis Regan 1907
	79. *Euchiloglanis hodgartii* (Hora) 1923
Genus	- *Myersglanis* Hora and Silas 1952
	80. *Myersglanis blythi* (Day) 1952
Genus	- *Pseudecheneis* Blyth 1860
	81. *Pseudecheneis sulcatus* (McClelland) 1842

3. UPDATED TAXA

According to Jayaram (1999) there is yet no comprehensive work embodying all the freshwater species of the Indian region (India, Bangladesh, Myanmar, Nepal, Pakistan and Sri Lanka). His work is based on Talwar and Jhingran (1991), Roberts (1989), Kottelat (1990), Rainboth (1991), Nelson (1994), Howes (1991) edited by Winfield and Nelson. The cold water fishes of Nepal fall under two orders: Cypriniformes and Siluriformes. Berg (1947) classified the order Cypriniformes into two divisions on the basis of scales present and absent; viz., Cyprini: body with scales and Siluri: body without scales. The division Siluri of order Cypriniformes of Berg (1947) has been changed into the separate order Siluriformes. According to Jayaram (1999) these two orders come under subdivision Euteleostei of division Teleostei, subclass Neopterygii and class Actinopterygii. The family Cyprinidae is further divided into subfamilies, tribes and subtribes. Among families Cyprinidae, Psilorhynchidae, Ballitoridae and Cobitidae are prominent under order Cypriniformes. Similarly under order Siluriformes families Schilbeidae, Amblycipitidae, Sisoridae are important. Psilorhynchinae is described as a subfamily of family Cyprinidae by Berg (1947). Many subfamilies like Danioninae, Garrinae, Balitorinae under order Cypriniformes and subfamilies like Schilbeinae under Siluriformes order are new creation. Similarly, tribes Oxygasterini, Danionini, Cyprinini, Systomini, Semiplotini, Labeonini with their respective subtribes viz. Tores of tribe Cyprinini, Poropuntii and Systomi of tribe Systomini, and Labeones of tribe Labeonini are formed for convenience.

The following are updated taxa of those cold water species of Nepal, which have caused a great deal of confusion.

3.1 Species which need further study

A number of species which are reported as cold water species by different scientists need further study to be declared as cold water fish species.

Labeo boga (Hamilton-Buchanan) 1822
Schismatorhynchos (Nukta) *nukta* Sykes 1841
Chela cachius (Hamilton-Buchanan) 1822
Gagata cenia (Hamilton-Buchanan) 1822
Laguvia ribeiroi (Hora) 1921
Nangra nangra (Hamilton-Buchanan) 1822
Coraglanis kishinoyei Datta 1962
Rita rita (Hamilton-Buchanan) 1822
Anguilla bengalensis (Gray) 1831
Clupisoma montana Hora 1937
Bagarius bagarius (Hamilton-Buchanan) 1822

Bagarius bagarius (Hamilton-Buchanan) ‘’The Nepali gounch’’, the only species reported earlier as the largest fish of Nepal from the Karnali River, needs further confirmation for its existence in Nepalese water. It inhabits rapids and rocky pools and being sluggish in habit, is not a good game fish according to Talwar and Jhingran (1991) and Jayaram (1999). It attains more than 2 m, a maximum weight of 250kg, lives at the bottom bottom but withstands strong current. It spoons easily and is a voracious feeder. The species *Bagarius bagarius* (Hamilton-Buchanan) has been renamed as *Bagarius yarelli* Sykes (Shrestha, 2001).

3.2 Synonymised species

A number of species have been synonymised as follows:

Naziritor chelynoides (McClelland) 1839

Puntius chilinoides (karang of Nepal) is synonymised as *Naziritor chelynoides*. The following are the synonyms adopted by different authors:

*Naziritor chelynoides (*McClelland) 1839, *Naziritor* Mirza and Javed, 1985, Pakistan, J. Zool. 17(3): 226 (type species *Tor zhobensis* Mirza)
Puntius chilinoides Jayaram 1981, The Freshwater Fishes of India: 99
Barbus chelynoides (McClelland) 1839, Asiat. Res. 19, 2271, 340, p. 57, Fig. 5 (type locality Simla)

Barbus chilinoides Day 1878, Fishes of India: 563, fig. 5; Day, 1889, Fauna Br. Fishes 1:304
Tor zhobensis Mirza 1967, Pakistan, J. Sci. Res, 19(1): 54 (type locality: Zhob river basin, Pakistan).
Tor (*Naziritor*) *zobensis* Mirza and Javed 1985, Pakistan J. Zool. 17 (3): 226
Tor chelynoides Talwar and Jhingran 1991, Inland Fishes, vol. I: 302-303
Naziritor chelynoides Jayaram 1999, The Freshwater Fishes of Indian Region: 97

***Neolissocheilus hexagonolepis* (McClelland) 1839**

The Nepalese katle was included in the genus *Barbus* by McClelland (1839). Later Weber and de Beaufort (1916) placed this fish in the genus *Lissochilus* and Oshima (1919) created a new genus *Acrossocheilus*. Recently Rainboth (1985) proposed and described the genus *Neolissocheilus* (Swar, 1996). The synonyms adopted by different authors at different times are given below:

Barbus hexagonolepis McClelland 1839, Asiat. Res., 19(2): 270, 340, pl. 41, fig. 3
Barbus hexagonolepis Day 1878, Fishes of India: 564, pl. 137, fig. 4
Barbus hexagonolepis Day 1889, Fauna of India Fishes, 1: 305
Barbus dukai Day 1878, Fishes of India: 564, pl. 143, fig. 3
Barbus (Lissocheilus) hexagonolepis Hora 1940, J. Bombay Nat. Hist Soc., 42 (1): 78, figs 1-4
Acrossocheilus hexagonolepis Tilak and Sharma 1982, Game Fishes of India and Angling: 56, fig. 13
Acrossocheilus hexagonolepis Shrestha 1981, Fishes of Nepal: 19-20
Neolissochilius hexagonolepis Rainboth 1985, Beaufortia, Vol. 35, No3
Neolissochilius hexagonolepis Talwar & Jhingran 1991, Inland Fishes, Vol.1
Neolissochilius hexagonolepis Swar 1996, Taxonomic review, J. Nat. Hist. Mus., Vol.15: 37-48
Neolissochilius hexagonolepis Jayaram 1999, The Freshwater Fishes of Indian Region

***Barilius guttatus* (Day) 1869**

The delicious jalkapoor (water camphor) of the Koshi River reported earlier as *Barilius jalkapoorei*, Shrestha (1981) is synonymised as *Barilius guttatus* (Day) 1869. The synonyms are as follows:

Opsarius guttatus Day 1869, Proc. zool. Soc. : 620
Barilius guttatus (Day) 1878, Fishes of India: 593, pl. 149, fig.3
Barilius guttatus (Day) 1889, Fauna Br. India, Fishes, 1: 351
Barilius guttatus Menon 1952, Rec. Ind. Mus. 50(2): 268
Barilius jalkapoorei Shrestha 1981, Fishes of Nepal, p. 34, Fig. 13
Barilius jalkapoorei Shrestha 1982, Wild is Beautiful: 102
Raimas guttatus Talwar and Jhingran 1991, Inland Fishes, Vol. 1: 386
Barilius guttatus Jayaram 1999, The Freshwater Fishes of the Indian Region: 70

***Labeo dero* (Hamilton-Buchanan) 1822**

Labeo dero (Hamilton-Buchanan) 1822 and *Labeo sindensis* (Day) were reported as two separate species from Nepal earlier (Shrestha, 1995). *Labeo sindensis (*Day) is also reported by Jayaram (1981) from Nepal but the locality is not mentioned. The species is also listed by Rajbanshi (1982) from the Koshi River. According to Jayaram and Dhas (1999) *Labeo sindensis* Day is synonymised with *Labeo dero* (Hamilton-Buchanan). The synonyms are as follows:

Cyprinus dero Hamilton-Buchanan 1822, Fishes of Ganges: 277, 385, pl. 22, fig. 78
Labeo cephalus Valenciennes 1842, Hist. nat. Poiss. 16: 347, pl. 487
Labeo diplostomus Day 1877, Fishes of India: 546
Labeo diplostomus Hora 1942, Rec. Indian Mus. 44 (1): 6
Labeo diplostomus Hora and Mukerjii 1936, Rec. Indian Mus. 38(2): 142
Labeo almorhae Chaudhuri 1912, Rec. Ind. Mus. 7: 438, pl. 38, fig. 2.
Labeo rilli Chaudhuri 1912, Rec. Ind. Mus. 7: 439, pl. 38, fig. 4
Labeo dyocheilus Mukerjii 1934, J. Bombay Nat. Hist. Soc. 27(1): 35
Labeo dero Hora and Mukerjii 1936, Rec. Indian Mus. 38(2): 142, fig. 3
Labeo dero Shaw and Shebbeare 1937, J Roy Asiat. Soc. Bengal Sci. III: 53, fig. 49
Labeo dero Shrestha 1981, Fishes of Nepal: 71 –72, fig. 3
Labeo dero Talwar and Jhingran 1991, Inland Fishes, Vol. I: 204 -205
Labeo dero Jayaram 1999, The Freshwater Fishes of Indian Region: 133

***Brachydanio rerio* (Hamilton-Buchanan) 1822**

The smallest fish of Nepal (zebra fish) of maximum size 26 mm was reported earlier as *Danio rerio* by Shrestha (1981). *Brachydanio* was proposed as a subgenus of *Danio* by Weber and Beaufort in 1916 and this was used for many years until Kottelat (1985, 1989) raised it into a separate genus on the basis of changes like dorsal fin with 6-7 branched rays and lateral line incomplete or absent. However, Talwar and Jhingran (1991) have described 28-30 scales on lateral line without any comments about incompleteness and absence of scale. The synonyms are as follows:

Cyprinus rerio Hamilton-Buchanan 1822, Fishes of Ganges: 323 390
Danio rerio Day 1878, Fishes of India: 597, pl. 151, fig. 4
Danio rerio Day 1889, Fauna Br. India, Fishes I: 358
Danio (*Brachydanio*) *rerio* Shaw and Shebbeare 1937. J Roy Asiat. Soc. Bengal Sci., III, p 29
Brachydanio rerio Hora, Rec. Indian Mus., Vol. XL: 173
Danio rerio Shrestha 1981, Fishes of Nepal: 57-58, fig. 25
Brachydanio rerio Talwar & Jhingran 1991, Inland Fishes, Vol. I: 360
Brachydanio rerio Jayaram 1999, The Freshwater Fishes of Indian Region: 79, fig. 48.

***Salmostoma acinaces* (Valenciennes) 1842**

Salmostoma is the generic name given by Swainson (1839) for type species *Cyprinus bacaila* Hamilton-Buchanan. *Chela (Oxygaster) argentea* (Nepali local name deduwa or chalwa) has been reported from the Koshi River and the Tribeni - Arun River and is insufficiently known. The generic name of this species falls under the genus *Salmostoma* Swainson and the species is synonymised as *Salmostoma acinaces* (Valenciennes). The synonyms are as follows:

Leuciscus acinaces Valenciennes 1842, Hist. Nat. Poiss. 17: 509
Chela argentea Day 1867, Proc. zool. Soc. Lond.: 301

Chela argentea Day 1878 Fishes of India: 601, pl.153
Chela argentea Day 1889 Fauna Br. India, Fishes 1: 364
Oxygaster argentea Shrestha 1990, Resource Ecology of the Himalayan Waters: 160
Salmostoma acinaces Talwar and Jhingran 1991, Inland Fishes, Vol. I: 321
Salmostoma acinaces Jayaram 1999, The Freshwater Fishes of the Indian Region: 65, fig. 42

***Salmostoma bacaila (*Hamilton-Buchanan) 1822**

Chela (*Oxygaster*) *bacaila* local name chelwa is synonymised as follows:

Cyprinus bacaila Hamilton–Buchanan 1822, Fishes of Ganges: 265, 384, pl.8, fig. 76
Chela bacaila Day 1878, Fishes of India, 603 pl.152, fig. 5
Chela bacaila Day 1889, Fauna Br. India, Fishes J. 367
Chela bacaila Shaw and Shebbeare, J. Roy. Asiat. Soc. Bengal, Sci III: 19, fig II
Oxygaster bacaila Chauhan and Ram Krishna 1953, Rec. Indian Mus. L. I. p. 399
Oxygaster bacaila Misra 1959, Rec. Indian Mus., Vol. 57: 140
Oxygaster bacaila Shrestha 1981, Fishes of Nepal: 81-82, fig. 39
Salmostoma bacaila Banarescu 1968, Rev. Biol. (Zool.) 13(1): 4, fig.1
Salmostoma bacaila Talwar and Jhingran 1991, Inland Fishes, Vol. I: 321–322, fig. 115
Salmostoma bacaila Jayaram 1999, The Freshwater Fishes of the Indian Region: 65, fig. 43

***Securicula gora (*Hamilton-Buchanan) 1822**

The genus *Securicula* Gunther was created by Gunther in 1968, Cat. Fishes, Fishes Br. Mus. 7: 332 type species *Cyprinus gora* (Hamilton-Buchanan). The O*xygaster gora* (local name darai) is reported from Narayani and is insufficiently known. The fish is synonymised as *Securicula gora* and the synonyms are as follows:

Cyprinus gora Hamilton -Buchanan 1822, Fishes of Ganges: 263 384
Leuciscus cuttelus Valenciennes 1844, Hist. Nat. : 17-341
Leuciscus cuttelus Banarescu 1967, Revue roum. Biol. (Zool.), 12 (5): 308
Chela gora Day 1878, Fishes of India: 600, pl. 151, fig 8
Chela gora Day 1889, Fauna Br. India, Fishes 1: 362
Oxygaster gora Rahman 1974, Bangladesh J. zool. 2(2): 192
Securicula gora Talwar and Jhingran 1991, Inland Fishes, Vol. I: 329
Securicula gora Jayaram 1999, The Freshwater Fishes of Indian Region: 64, fig. 41

***Schizothorax richardsonii* (Gray) 1832**

All snow trouts and snow minnows are included under subfamily Schizothoracinae of family Cyprinidae under which *Diptychus* Steindachner, *Schizothoraichthys* Misra and *Schizothorax* Heckel are listed from Nepal. *Diptychus maculatus* Steindachner has been reported from Nepal (Jhingran and Talwar, 1991; Jayaram, 1999). However, their location and distribution in inland water bodies of Nepal are not mentioned. Seven species of *Schizothorax* Heckel and six species of *Schizothoraichthys* Misra were reported by Shrestha (1995). According to Jayaram (1999) the two species of *Schizothorax* Heckel, *viz*., S. *molesworthi* Chaudhuri and *S plagiostomus* Heckel, are the synonyms of *Schizothorax richardsonii* (Gray).

Schizothoraichthys annandalei Regan is also included under *Schizothorax richardsonii* (Gray), (Jayaram, 1999). According to Jayaram (1999) all the three species of *Schizothorax* reported from Lake Rara, Nepal, by Terashima (1984) are transferred to genus *Schizothoraichthys* Misra. This system seems to be adopted also by Jhingran and Talwar (1991). However, Menon (1999) has proposed the genus *Racoma* McClelland (1839) for the species *Schizothorax macrophthalmus* Terashima and *Schizothorax raraensis* Terashima and both these species are merged with *Racoma progastus* McClelland (1839).

The present text is adopted after Jayaram (1999); there are two species of *Schizothorax* (Heckel) and eight species of *Schizothoraichthys* Misra known to exist in cold waters of Nepal. With these changes the total number of snow trouts in Nepal including *Diptychus maculatus* Steindachner is eleven (Table 1). The synonyms of *Schizothorax richardsonii* are as follows:

Cyprinon richardsonii Gray 1832, Illustrations of Indian Zoology, (10), pl. 14, fig. 2
Oreinus plagiostomus (Heckel) Day 1877, Fishes of India: 530
Oreinus plagiostomus (Heckel) Day 1889, Fauna Br. India, Fishes 1 :250
Oreinus richardsonii Day 1877, Fishes of India: 530, pl. 125, fig .4
Oreinus richardsonii Day 1889, Fauna Br. India, Fishes 1: 250
Diptychus annandalei Regan 1907, Rec. Indian. Mus. 1: 158 (type locality Nepal)
Diptychus annandalei Mukerjii 1931, Rec. Indian Mus. 33: 63 (status discussed)
Oreinus molesworthi Chaudhuri 1931, Rec. Indian Mus. 8: 247, pl. 7, type figs 2, 2a, 2b.
Schizothorax richardsonii Tilak 1987, Fauna of India, Pisces: 50, figs 12-24
Schizothorax richardsonii Shrestha 1981, Fishes of Nepal: 113–114, fig. 56
Schizothorax richardsonii Talwar and Jhingran 1991, Inland Fishes, VoI. I: 411–412, fig. 145
Schizothorax richardsonii Jayaram 1999, The Freshwater Fishes of the Indian Region: 142, fig. 77

***Garra lissorhynchus* (McClelland) 1843**

Six species of *Garra* have been reported from cold waters of Nepal (Table 1). The earlier reported species *Garra modestus* (Day) has been synonymised as *Garra lissorhynchus* (McClelland) 1843. The synonyms are as follows:

Platycara lissorhynchus McClelland 1843, Calcutta, J. Nat. Hist. 2: 587, pl. 68
Discognathus modestus Day, 1877 Fishes of India: 528, pl. 122, fig .5
Discognathus modestus Day 1989, Fauna of Br. India, Fishes, 1 : 247
Discognathus modestus Hora 1921, Rec. Indian Mus. 22 (5): 663
Garra lissorhynchus Hora 1921, Rec. Indian Mus. 22 (5): 662, pl. 26, figs 2, 2a
Garra lissorhynchus Talwar and Jhingran 1991, Inland Fishes, Vol. I: 427-428, fig. 150
Garra lissorhynchus Jayaram 1999, The Freshwater Fishes of the Indian Region: 154

***Psilorhynchoides homaloptera* (Hora and Mukerjii) 1935 and *Psilorhynchoides pseudecheneis* (Menon and Datta) 1961**

The genus *Psilorhynchoides* Yazdani, Singh and Rao is created for species *Psilorhynchus homaloptera* Hora and Mukerjii. Similarly *Psilorhynchoides pseudecheneis* (Menon and Datta) is also synonymised as *Psilorhynchoides pseudecheneis* (Menon and Datta).

***Acanthocobatis botia* (Hamilton-Buchanan) 1822**

Acanthocobatis Peters, 1861 is a genus created for the species *Acanthocobitis longipinnis* Peters, *Cobitis pavonaceus* McClelland by monotype. Menon (1987) has proposed it as a subgenus in Fauna India 4(1), p. 140. According to Jayaram the body of this species is deeper than in most other nemacheilines, strongly compressed posteriorily. Snout blunt, upper lip covered by two or three rows of papillae, lower lip broad on both sides interrupted in the middle and with numerous papillae. Many changes have been made for genus *Nemacheilus* Bleeker under subfamily Nemacheilinae. Eight species of *Nemacheilus* Bleeker were reported earlier (Shrestha, 1995). *Nemacheilus botia* Day is a synonym for *Acanthocobatis botia* (Hamilton-Buchanan).

Cobitis botius Hamilton-Buchanan 1822, Fishes of Ganges: 350-394
Botia nebulosa Blyth 1861, J. Asiat. Soc. Beng. 29: 165
Nemacheilus botia Day 1877, Fishes of India: 614, pl.156, fig. 5
Nemacheilus botia Day 1989, Fauna of Br. India, Fishes 1 : 227
Nemacheilus mackenzies Chaudhuri 1910, Rec. Indian Mus. 5(3): 183
Nemacheilus botia Menon 1987, Fauna of India, Pisces 4: 141, pl. 5, fig. 5
Acanthocobatis botia Jayaram 1999, The Freshwater Fishes of the Indian Region: 173-174, fig. 92

***Schistura beavani* (Gunther) 1868**

Genus *Schistura* McClelland (1838/1839) is a genus created for *Cobitis* (*Schistura*) *rupicola* McClelland. Menon (1987) also described it as a subgenus in Fauna India 4(1): 37. In his revision of the Nemacheilines Menon grouped 45 species falling under *Schistura* into four groups and 11 complexes.

Nemachilus beavani Gunther 1868, Cat. Fishes Br. Mus. 7: 350
Nemachilus beavani Hora 1935, Rec. Indian Mus. 37 (1): 63, pl. 3, fig. 2
Nemachilus beavani Menon 1987, Fauna of India, Pisces, 4: 84, pl. 13, fig. 4 & 5
Nemachilus beavani Talwar and Jhingran 1991, Inland Fishes, Vol.1: 472
Schistura beavani Jayaram 1999, The Freshwater Fishes of the Indian Region: 181

***Schistura rupecula rupecula* (McClelland) 1838**

Nemachilus rupecula has been synonymised as *Schistura rupecola rupecola* (McClelland) 1838 and the synonyms are as follows:

Schistura rupicola McClelland 1838, J. Asiat. Soc. Beng. 7: 948, pl. 55, fig.3
Nemachilus rupicola Day 1878, Fishes of India: 616, pl.153, fig-9
Nemachilus rupicola Day 1989, Fauna of Br. India, Fishes 1: 229
Nemachilus rupicola Menon 1987, Fauna of India, Pisces 4: 49, pl. 13, fig.6
Nemachilus rupicola Talwar and Jhingran 1991, Inland Fishes, Vol.1: 500
Schistura rupicola rupicola Jayaram 1999, The Freshwater Fishes of the Indian Region: 183

***Schistura scaturigina* (McClelland) 1839**

Nemacheilus scaturigina is synonymised as *Schistura scaturigina* (McClelland), 1839.

Cobitis (*Schistura) scaturigina* McClelland 1839, Asiat. Res. 19: 308, 443, pl. 53, fig.6
Nemacheilus zonatus Day 1878, Fishes of India: 618, pl.156, fig. 2
Nemacheilus zonatus Day 1989, Fauna of Br. India, Fishes 1: 233
Nemacheilus shebbearei Hora 1935, Rec. Indian Mus. 37 (1): 52
Nemacheilus subfusca (McClelland) Hora and Mukerjii 1935, Rec. Indian Mus. 37 (1): 40, fig.1
Nemacheilus scaturigina Menon 1987, Fauna of India, Pisces 4: 86, pl. 3, figs 2& 3 & pl. 13, figs 8&9
Nemacheilus scaturigina Talwar and Jhingran 1991, Inland Fishes, Vol.1: 501 -502, fig. 164
Schistura scaturigina Jayaram 1999, The Freshwater Fishes of the Indian Region: 183

***Botia almorhae* Gray 1831**

According to Menon (1992) *Botia dayi* Hora 1932 is a synonym of *Botia almorhae* Gray 1831. Menon (1999) further stated that *Botia dayi* is merged with *Botia almorhae* Gray. The synonyms are as follows:

Botia almorhae Gray 1831, Zool. Misc., 8
Botia almorhae Day 1878, Fishes of India: 602, pl. 154, fig. 5
Botia almorhae Day 1889, Fauna of Br. India, Fishes 1: 217
Botia dayi Hora 1932, Rec. Indian Mus. XXXIV: 571
Botia dayi Shaw and Shebbeare 1937, The Fishes of Northern Bengal, Vol. III: 66-67
Botia almorhae Talwar and Jhingran 1991, Inland Fishes vol.1: 535
Botia almorhae Jayaram 1999, The Freshwater Fishes of the Indian Region: 210

4. CONCLUSIONS

More detailed studies on many fish species inhabiting inland water bodies of Nepal are clearly needed, especially regarding their occurrence, especially their altitudinal distribution, ecology, migrating behaviour, and on limnological parameters, such as temperature tolerance. Most of the data presented in the literature are either based on the previous publications or on short studies. A long study period of more than one year of a particular water body would be helpful to explain the species diversity and species composition of aquatic biota, frequency occurrence and seasonal changes. At present no institute in Nepal carries out regular surveys and monitoring programmes, and there is an urgent need to establish a depository of specimens including holotype and paratypes which would serve for taxonomic studies, for confirmation and comparison to avoid confusion and duplication. The paucity of literature also hampers the taxonomic work. Such constraints may not only lead to taxonomic duplication but also to misleading interpretations.

This revision has attempted to cover all cold water fish species of Nepal using the latest classification and findings of fish species in Nepal. Many species need to be further studied especially for their distribution, altitudinal range and affinity for cold waters. Some species are needed to reconfirm their presence in cold waters of Nepal. With the inclusion of *Dipticus* *maculatus* Steindachner from Nepal by Jhingran and Talwar (1991) and Jayaram (1999), the total number of fish species in Nepal is now 183 as compared to182 reported by Shrestha (2001).

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PROSPECTS OF FISHERIES ENHANCEMENT AND AQUACULTURE IN LAKES AND RESERVOIRS OF NEPAL

by

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ABSTRACT

Aquaculture in open waters is limited to three Pokhara Valley lakes, i.e. Phewa, Begnas and Rupa, and to Kulekhani reservoir. Cage culture in lake Phewa has increased from 66 cages, with 1 800 m^3 cage volume, to 340 cages with 15 300 m^3 cage volume, during the last 20 years. Pen culture increased from 0.2 ha to 5.5 ha in the last 7 years. In lake Begnas the increase in cage culture was disrupted by a dam, which resulted in an increase of the water surface area, but in a decrease in lake productivity. In lake Rupa, the most productive of the three, a steady increase for 14 years was disrupted by siltation. There is also cage culture in Kulekhani reservoir. Every year fish stocks of lakes and the reservoir are enhanced by stocking fingerlings of planktivorous carps.

1. INTRODUCTION

Nepal is a landlocked country and its natural waters are classified into five categories: (i) rivers and streams, (ii) lakes, (iii) reservoirs, (iv) swamps, and (v) lowland paddy fields. Natural waters are defined as water bodies that are relatively large, without control or little control by humans and balanced by natural ecosystem with indigenous biodiversity. However, swamps and paddy fields are seasonal resources and dry up during the dry period of the year. Rivers and lakes are the non-expandable resources whereas reservoirs are expandable. In Nepal reservoirs are constructed primarily for hydropower generation and irrigation purposes. New reservoirs are under construction, with many reservoirs expected to be completed in the future (Table 1).

Table 1
Water resources of Nepal

Resource	Estimated area (ha)	Coverage (%)	Future potential (ha)
Rivers and streams	395 000	98.4	-
Lakes	5 000	1.2	-
Reservoirs	1 500	0.4	78 000
Total	401 500	100.0	

Water bodies including rivers, streams, lakes and reservoirs, are used for multiple purposes such as drinking and other household water uses, industrial use, irrigation, aquatic crops production, hydropower generation, recreation and tourism, fisheries, including conservation of aquatic genetic pools, etc. They also provide a habitat for aquaculture production. However, overexploitation of the natural fisheries resources due to high fishing pressure, including damaging fishing methods, has led to decline in natural fish stocks. To improve the fisheries potential, enhancement of wild fish stocks and aquaculture has been initiated in a limited number of lakes and reservoirs of Nepal. This paper describes the status and prospects of fisheries and aquaculture enhancement in lakes and reservoirs of Nepal.

2. LAKES

There are many medium and small lakes in the country, with about 5 000 ha of water surface area (FDD, 1998). These lakes have different origins and can be classified as (a) glacial, (b) tectonic, and (c) oxbow lakes. The high-altitude mountain lakes are glacial, mid-hill lakes are tectonic and most of the Terai lakes are of the oxbow type. Based on the nutrient status of lake water, mountain lakes, mid-hill lake and oxbow lakes are oligotrophic, mesotrophic and eutrophic, respectively (Bhandari, 1998). For the major lakes of Nepal see Table 2.

Table 2
Major lakes of Nepal

Lake	Location	Water surface area (ha)
Mountain lakes:		
Rara Tal	Mugu	1 000
Shey-Phoksundo Tal	Dolpa	180
Tilicho Tal	Manang	-
Gosikund Tal	Rasuwa	-
Mid-hill lakes:		
Phewa Tal	Kaski	523
Begnas Tal	Kaski	328
Rupa Tal	Kaski	135
Deepang Tal	Kaski	20
Khaste Tal	Kaski	16
Gunde Tal	Kaski	9
Maidee Tal	Kaski	8
Syarpu Tal	Rukum	75
Low-land lakes:		
Mahadev Tal	Kailali	50
Rupia Tal	Kailali	50
Gadhbhijala Tal	Kailali	300
Ghodaghodi Tal	Kailali	138
Nakhrodi Tal	Kailali	70
Badhaiya Tal	Bardia	105
Sakhunia Tal	Kapilbastu	50
BudhiTal	Kapilbastu	50
Gaindhawa Tal	Rupendehi	50
Beesh Hazar Tal	Chitwan	100
Halkhoria Tal	Bara	50

3. RESERVOIRS

At present Nepal has only a small number of reservoirs: Jagadishpur, Trishuli, Marshyandi, Kulekhani, Gandaki, Saptakoshi, Andhikhola and Panauti. Their total water surface area is approximately 1 500 ha (Table 3). These reservoirs serve hydropower and irrigation purposes (FDD, 1998).

Table 3
Major reservoirs

Reservoirs	Water surface area (ha)
Jagadishpur	175
Trishuli	16
Marshyandi	62
Kulekhani	220
Gandaki	500

4. AQUACULTURE IN LAKES AND RESERVOIRS

Aquaculture is limited to three lakes of the Pokhara valley (Phewa, Begnas and Rupa lake) and one reservoir (Indrasarobar reservoir) of Kulekhani in Nepal. Cage culture as well as pen culture have been practiced in lakes Phewa, Begnas and Rupa since the late 1980s. Technology of cage culture was transferred from the lakes to Indrasarobar reservoir in 1985, but full expansion by private farmers started in 1993 only. Planktivorous carp are now commonly used in extensive cage culture. Cage culture expansion in the four major water bodies of Nepal is presented in Table 4.

Table 4
Cage culture in lakes Phewa, Begnas and Rupa, and in Kulekhani reservoir, Nepal (public and private sector)

Year	Phewa		Begnas		Rupa		Kulekhani	
	Cages (No.)	Cages volume (m^3)	Cages (No.)	Cages volume (m^3)	Cages (No.)	Cages volume (m^3)	Cages (No.)	Cages volume (m^3)

Cage culture in Phewa lake has increased from 66 cages with 1 800 m^3 cage volume to 340 cages with 15 300 m^3 cage volume during the last 20 years. Pen culture area increased from 0.2 ha to 5.5 ha in the last 7 years. A similar trend of cage culture expansion was observed in Begnas lake from 1980 to 1990, however, this trend was disrupted due to a dam construction in Begnas, which increased the water surface area but decreased the lake productivity. Pen culture in Begnas has been almost constant for the last 7 years. In lake Rupa, one of the most productive lakes, the number of cages grew for 14 years, but this has been followed by a decrease to less than half due to heavy siltation which has resulted in shallowing of the lake. This has led to an increase in pen culture area in lake Rupa (Table 5). Technology of carp cage culture has been successfully transferred to Kulekhani reservoir (Table 4).

Table 5
Pen culture in lakes Phewa, Begnas and Rupa, Nepal (public and private sector)

Year	Phewa		Begnas		Rupa	
	Pens (No.)	Pens area (ha)	Pens (No.)	Pens area (ha)	Pens (No.)	Pens area (ha)
1993	3	0.2	5	5.0	2	5.0
1994	3	0.2	5	5.0	2	5.0
1996	5	3.6	5	5.0	7	17.0
1997	7	5.5	6	5.5	7	17.0
1998	7	5.5	6	5.5	8	18.5
2000	7	5.5	7	6.2	8	18.5

Fish growth and fish production in extensive cage culture largely depend on the lake trophic status and lake productivity. Fish yields from cage fish culture are presented in Table 6. While the fish production in lakes Phewa and Begnas has been stable, there has been a decrease in lake Rupa. Fish cage culture production in Kulekhani reservoir has been increasing. The total fish production from pen culture in these lakes is about 2.5 t/ha/yr (Pradhan and Shrestha, 1997).

Table 6
Fish production/yields from cage culture in lakes Phewa, Begnas and Rupa and in Indrasarobar reservoir, Nepal

Year	Phewa fish yield (kg/m^3/yr)	Begnas fish yield (kg/m^3/yr)	Rupa fish yield (kg/m^3/yr)	Kulekhani reservoir fish yield (kg/m^3/yr)
1979	5.5	3.8	7.4	-
1980	3.4	4.7	5.0	-
1985	3.4	4.7	5.0	-
1990	1.3	1.8	2.6	NA
1998	5.0	3.0	2.0	1.0
1999	NA	NA	NA	1.1
2000	NA	NA	NA	2.9

5. FISHERY ENHANCEMENT IN POKHARA VALLEY LAKES AND IN KULEKHANI RESERVOIR

In the past, lakes and reservoirs were used primarily for capture fisheries. Fisheries enhancement through open water stocking of hatchery-bred carps was initiated 23 years ago in three lakes of Pokhara, and 15 years ago in Kulekhani reservoir (Table 7). Since then the fish production in these lakes and the reservoir has increased considerably, except for some accidental fish losses as a result of a substantial water drawdown in Kulekhani reservoir (Table 8).

Table 7
Fingerling stocking in lakes Phewa, Begnas and Rupa, and in Kulekhani reservoir

Year	Phewa (No.)	Begnas (No.)	Rupa (No.)	Kulekhani reservoir (No.)
1977	NA	22000	NA	-
1978	NA	20000	NA	-
1979	NA	20000	NA	-
1980	NA	19000	NA	-
1981	NA	10000	NA	-
1982	NA	20000	NA	-
1985	NA	NA	NA	25 000
1994	225 000	150 000	75 000	25 000
1995	225 000	150 000	75 000	NA
1996	225 000	150 000	75 000	NA
1997	225 000	150 000	75 000	110 000
1998	225 000	150 000	75 000	NA
1999	225 000	150 000	75 000	30 000
2000	245 000	160 000	80 000	30 000

Table 8
Fish yield (kg/ha/yr) in lakes Phewa, Begnas and Rupa, and in Kulekhani reservoir

Year	Phewa yield (kg/ha /yr)	Begnas yield (kg/ha/yr)	Rupa yield (kg/ha/yr)	Kulekhani reservoir yield (kg/ha/yr)
1978	32	24	37	-
1982	NA	26	NA	-
1994	78	86	90	NA
1995	75	105	47	54
1996	88	103	49	66
1997	103	127	47	16
1998	97	129	59	99
1999	83	128	49	69
2000	NA	NA	NA	130

6. FUTURE PROSPECTS OF FISHERIES ENHANCEMENT AND AQUACULTURE

Fisheries development in lakes and reservoirs can be achieved through aquaculture (cage culture and pen culture) and fisheries enhancement (open water stocking). Breeding ground protection, selective and seasonal fishing will further improve fish catches. As the lakes and reservoirs are also places attracting tourism and recreation, they must be used judiciously for fisheries development. Lakes can be categorized as (i) protected and conserved lakes, (ii) semi-conserved lakes, (iii) production lakes (Shrestha, 1999).

6.1 Lake fisheries

Protected and conserved lakes: Where natural fish biodiversity can be protected, tourist recreation and boating can be maintained; selective seasonal sport fishing should be allowed. Such lakes are the lakes in national parks and sanctuaries for example lake Rara of Mugu; Bees Hazar Tal of Chitwan; and Badhaiya Tal of Bardia.

Semi-conserved lakes: Where a balance of tourist recreation, boating, sport fishing and fish production needs to be maintained: lakes Phewa and Begnas in Pokhara valley.

Phewa lake: Increasing eutrophication of this lake due to sewage drainage needs to be strictly controlled. Stocks of planktivorous fish species as well as those supporting recreational and sport fishery need to be enhanced. Cage culture of planktivorous fish utilising the natural food (i.e. phytoplankton) should not be expanded beyond 1-2% of water area, and no pen culture should be installed in this lake.

Begnas lake: This lake is oligotrophic in nature. To balance between tourist attraction and recreation and fish production, cage and pen culture should not expand beyond 2-3% of the water surface area. Pen culture should be minimal and not encroach on breeding and nursery grounds of important indigenous species.

Production lakes: All such lakes except those mentioned above can be exploited for fish production both by aquaculture (cage and pen culture) and fisheries enhancements, along with a limited fishery for the indigenous species. Cage culture and pen culture may be expanded to 5% of the total water surface area.

6.2 Reservoir fisheries

Reservoirs are mainly built by damming rivers either for hydroelectricity generation or for irrigation. Damming of rivers disrupts the routes of migratory fish species, affecting their population dynamics, diversity and species composition in the upstream as well as in downstream sections of the rivers. The river fish production may also be affected. Reservoirs are water bodies which offer fish production potential, both for capture fisheries as well for aquaculture. To maintain fish stocks both in the rivers affected by dams, and in reservoirs, the following is considered to be essential:

- fish ladders with sufficient water flow for fish migration should be provided wherever applicable,
- local fish hatchery should be established for stock enhancement in reservoirs and rivers,
- priority for stock enhancement should be given to economically important local species,
- cage and pen culture should be given to economically important species wherever applicable.

7. CONCLUSIONS

Fisheries enhancement of capture fisheries and aquaculture in lakes and reservoirs of Nepal are two important strategies for meeting the increasing demand for aquatic products in the country. However, fisheries resources need to be used judiciously to preserve the fish genetic biodiversity, and to remain an attraction as well as source of food for tourists and nationals. Good environment protection and fishery management of lakes and reservoirs are essential for keeping good fish stocks in these water bodies. Community ownership and participation in the management of water bodies will assist in developing and maintaining sustainable fisheries.

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RANCHING MAHSEER (*Tor tor* and *Tor putitora*) IN THE RUNNING WATERS OF NEPAL

by

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ABSTRACT

Mahseers (*Tor tor* and *Tor putitora*) have a potential for being ranched in rivers/artificial channels of Nepal and other countries of the Trans-Himalayan region. This is one of the hopes for rehabilitating mahseer stocks in rivers and to enhance them to a sustainable fishing level. It is proposed to spawn mahseer in artificial channels alongside streams and rivers, to be followed by releases of fry and fingerlings into streams and rivers for their downstream migration and feeding in the lower reaches of rivers. Protection of growing fish will be essential, especially of the mature stocks migrating upstream for breeding.

1. INTRODUCTION

The mahseers (*Tor tor* and *Tor putitora*) are superior game fish of the cold water streams of Nepal. Few fishes of the mountain stream illustrate vagaries of human taste better than the mahseer. Their sporting attributes plus good public image provide a background for expanding recreational fisheries in the Himalayan waters. The mahseer fishery has declined much owing to ecological changes in waterways brought about by barrier effects of dams, inroads of pollution and harmful fishing practices. At many places river courses have changed and spawning beds were destroyed. Destruction of spawning beds and resultant failure of spawning affected seed and fry resources greatly. If the natural spawning of mahseers goes unmonitored, the valuable mahseer fishery resource of Nepal will become extinct. Mahseers do not breed in a closed system of impoundments although they can grow to maturity there. They need free-flowing turbulent water fed by melting snow. Their spawning beds must have good-sized pools and rapids, sand bars and gravel. In a closed system of pond water, all these basic habitat needs are not met; therefore, mahseers refuse to breed. In many pristine rivers of Nepal, spawning beds are destroyed by dams which can never be compensated. To evolve the original spawning beds takes a long time. But a new spawning channel or incubation channel can be created by habitat manipulation, which can be done by diverting an original river course or side channel at a desirable spot. In rivers of Nepal, such ideal channels are many and can be utilized with little effort. The channel so created may act as fish sanctuary or buffer zone or escape area and help to conserve upstream migrating spawners year after year. Along the diversion side, a river can be tamed so as to create a full-fledged riverine fish farm, where migratory stock of mahseer can be regularly ranched. This will greatly help to conserve fish seed resources and bring back depleted fish stocks to the original level of abundance.

2. MAHSEER RANCHING AND WILD STOCK ENHANCEMENT CONSIDERATIONS

The mahseers have complete freedom to migrate to and from feeding and breeding grounds. The improvement over nature is obtained by artificially incubating and hatching eggs of the fish, as rearing the young is the greatest natural loss in the wild. It must not be confused with what is called enhancement. This means releasing eggs, fry and fingerlings of fish in sections of river or reservoir which the adult fish cannot reach on their spawning migration or which are unsuitable spawning grounds, but can provide useful rearing areas for young fish. The development of artificial spawning channels for migratory fish is a half-way stage between full ranching and enhancement. Gadkhar creek, joining the Tadi River, serves as a natural spawning creek. A typical spawning channel is an artificial channel made beside a natural river, or across the loop of a wide bend. The bed of the channel is covered by graded gravel of correct size to be used as spawning substrate by fish. The inflow and outflow of water are controlled by sluices and valves and the length of the channel may be divided by screens or weirs. Adult fish returning into the channel spawn there naturally. Alternatively, fish can be stripped and fertilized eggs deposited in an artificial nest or gravel incubator. The method is of real value only for species which migrate downstream as fry. If the young fish have to be fed artificially for a longer period, it is better and more easily done in tanks with free flowing water through a cascade system. The ranched mahseer therefore have complete freedom to migrate to and from large river to creek, i.e. from feeding grounds to spawning grounds, and vice versa. The improvement over nature is made by artificially incubating and hatching eggs and rearing. In the USA the use of spawning channels has increased harvest of Pacific salmon. This method is to be tested on mahseer migrating from a river to creek and vice versa. In the incubation channel young fish can be fed, but this is better and more easily done in tanks.

2.1 Open water - artificial river

The artificial river made near a natural river course or incubation channel meets all habitat needs and has an advantage over the traditional “Put” and “Take” systems. In this system, spawners are encouraged to use the spawning channel and some of them are subjected to captive breeding and rearing experiments. Hatchery-bred fry could be stocked and raised to fingerling stage on a mass scale and released back into the river. This will rebuild fish population in the river and counteract forces of overfishing. In other words, this new system is called an open water “Raise and Release” system, as this system enhances controlled breeding of fishes and helps to preserve gene pools of rare stock of the Himalayan fish.

2.2 Difference between mahseer ranching and farming

In fish ranching, as opposed to farming, fish are kept in captivity during the early stages of their life. When bigger they are allowed to spend life as free ranging animals. Mahseers, which spawn in hill-streams and brooks, but spend most of the later part of their lives in large rivers, are well suited for fish culture. In culture the mahseer *Tor putitora* can be hatched and confined until it reaches advanced fingerling stage (about one year old), at which time it should be released for the journey to the rivers where it will stay and grow to maturity, to return to the historical spawning beds to spawn. Mahseer ranching differs from actual fish farming in several ways. While farming involves cultivation of many species, commercial fish ranching has so far been broadly successful with single or monospecies of migratory fish only. This does not rule out the commercial possibility of ranching free ranging river carps. So far they have not been ranched and the ranching potential has not been tried. The second main difference lies in feeding, i.e. farmers must provide all food for fish they rear, either directly or indirectly. This is not the case with mahseer. The present investigator has estimated that 1% of mahseer growth occurs while it is in the hatchery. For the two, three or four years in the large river, the mahseers forage on their own.

2.3 Dynamics of the mahseer ranching

Many feeder streams and rivers joining the Trishuli River have spawning grounds. Spawning beds of the Tadi River located near the Gadkhar fish farm may be selected for mahseer ranching. This area is ideal because traditional mahseer stocking ponds are located very near to the Tadi and its feeder stream, Khahare Khola. The confluence of the Tadi and Khahare Khola is an ideal site for collection of migrating spawners which were used by us as spawners. In the entire stretch of the Khahare Khola up to 3 kms upstream are ideal environmental conditions for mahseer spawning: gravel beds, suitable water current, high dissolved oxygen content, good water quality. If this stream is changed into artificial mahseer running channel in conjunction with an existing fish farm, it would certainly help the mass production of mahseer in semi-natural conditions. Mahseer ranching would represent a visible step in transition from a hunting to farming economy in the Himalayan waters of Nepal. In an open water system much depends upon the hydrological regime of the mountain river, such as flood and drought. The changing river conditions affect abundance of mahseer. Seasonal variations lie beyond the control of man, but can be manipulated to some extent. Other factors are however within our power. The basic content of mahseer ranching is that the mahseer population of each river and feeder stream must be treated as a separate breeding unit and for each a sufficient number of adults must be allowed to escape fishery and spawn in clear, undamaged environment. If this is done, strong migration may become an annual phenomenon, perhaps exceeding the runs of the past.

2.4 Rivers suitable for ranching

It is a waste of time and money to try to start ranching in an area where there is an intensive fishery. The mahseer need a clear run home for their riverine feeding grounds, without being captured on their way. There are not many places such as Gadkhar fish farm where ranching is possible. It is quite possible to induce the return of mahseer to a small creek near the farm, where produced fish will return to a small shallow area where they can be captured easily. Small creeks can be made attractive to river running mahseer, and entry can be facilitated by artificial spates created by releases from a low stone dam.

2.5 Basic analogy between salmon and mahseer

Mahseer ranching can be achieved by stocking fingerlings in natural water in the same manner as has been done in case of the salmon in the U.S.A. Salmon hatcheries in the U.S.A. are established near dams where ripe male and female salmon trying to migrate upstream are stripped, egged, and fertilized and hatched, and the resultant fingerlings released downstream to go to sea, grow and migrate back again to serve as commercial stock and also spawn into a new generation of salmon. Likewise, the migratory male and female mahseers could be collected at the confluence of river and stream, stripped, fertilized, and egg-reared to fingerling stage in specially designed riverside hatcheries fed with river water. The fingerlings so produced would be released back into the river to grow further and come back to spawn in the stream where they were born. Experience of the past decades within traditional ponds of Nepal has shown that female mahseers grow to maturity in the stagnant water of a pond, but do not develop their gonads and spawn there. The sexually ripe female with running ovaries, if put in a pond for breeding, absorbs ripe eggs within a few days. Male mahseers are known to mature in impoundments and produce milt and would be useful as standby stock or a milt-bank. The one would need to capture only the females on their spawning grounds of the river. In the United States, salmon ranching has been carried out with great success (Bakkala, 1964; Lucas, 1960; Mackinnon, 1960; McNeil and Baily, 1975; Shrestha, 1986; and Thomas and Shelton, 1969).

2.6 Transition to mahseer hunting and farming economy

A mahseer ranching programme is based on the homing instinct of this fish. Like the salmon, mahseers when released in an unnatural setting, manage to find their way back home years later at the time of breeding. Such unerring homing instinct ensures the mahseer return to their birth place; they are therefore exceedingly easy to harvest when they arrive. In order for mahseer ranching to succeed, enough mahseer must survive to return to point of release, at a spot where they can be captured on a profitable scale. The possibility of raising mahseer in cages and raceways suspended in a reservoir or lake is still to be assessed.

The attraction of Himalayan mahseer ranching is that the investment in feed is limited to one or two seasons; mahseer need to be fed between the time of hatching and the point when tiny fingerlings or smolts are ready for their long feeding migration to the river. Feeding strategy of the mahseer during the course of its river migrations depends on the water quality and other factors, such as temperature, photoperiod, rainfall, presence of prey organisms. During its up river and down river migrations in June-October it feeds on zooplankton, fish fry and larger fish, crabs and molluscs. The mahseer heading towards itsspawning creek may have a long journey from the large river. This is an important consideration in ranching because the fish will be in better condition if it has a short return migration.

Ranching mahseer by taking advantage of the growth of the fish in the open water of a large river, is an attractive proposition, and one of the most exciting possibilities of mahseer farming in the various open waters of the Himalaya. The future success of any kind of ranching and the status of the natural stock of river-going mahseer each year depends upon the cooperation of fishermen, anglers and national conservation agencies.

An imaginative design of mahseer running ranch-cum-fish farm would be welcomed by cold water aquaculturists in the countries of the Trans-Himalayan region and some adjacent countries as well.. Establishment of mahseer ranches at suitable places alongside rivers would help not only to enhancce its production, but also to save its dwindling stocks, preserving gene pools for posterity.

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KATLE (*Neolissocheilus hexagonolepis* (McClelland) REPRODUCTION IN THE INDRASAROBAR RESERVOIR AND THE TADI RIVER, NEPAL

by

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ABSTRACT

A comparative study on the reproductive biology of katle, *Neolissocheilus hexagonolepis* (McClelland), was carried out in the Tadi River and in the newly created Indrasarobar reservoir, Nepal. The intensive field survey and laboratory examination revealed that the gonads started to develop in March and the reproductive phase lasted from April to October, which is consistent with the reproductive cycle of the other cyprinids. Katle from the river were less fecund than the reservoir katle at smaller size, however, absolute fecundity seemed to increase with size more rapidly in the river fish, and they were more fecund than the reservoir fish at the higher total length. The average relative fecundity in the reservoir population was 19.13 ±1.56 eggs g^{-1} compared to 22. 57±1.41 eggs g^{-1} for the riverine population. Occurrence of different size groups (batches) of oocytes indicates the multiple spawning characteristic of katle. The upstream migration of ripe females in the reservoir and river suggested that katle was very selective in finding a suitable place to spawn.

1. INTRODUCTION

Studies on the reproduction of cyprinids on the Indian subcontinent have concentrated mainly on two groups, the Indian major carps, *Labeo* spp, *Cirrhinus* spp and *Catla catla*, and the hill stream fish *Tor* spp (mahseer), *Neolissocheilus hexagonlepis* (katle) and *Schizothorax* spp (snow trout). The Indian major carps tend to be single spawners while the latter are mainly multiple spawners.

Despite interest in economically important cyprinids and the development of their aquaculture, the reproductive biology of katle is poorly known. Langdale Smith (1944) carried out one of the earliest documented observations on the reproductive ecology of katle. Ahmed (1948) collected and incubated the fertilised eggs of katle and studied their embryonic development. Rai (1978) stripped eggs from mature katle captured in the Trishuli River, central Nepal. The eggs were fertilised and incubated at 18-21°C. Dasgupta (1988) estimated the fecundity of katle collected from the Simsang River, India. He found that the katle was a prolific breeder but less fecund than mahseer.

The present study investigated the reproductive adaptability of katle by comparing its reproductive season, spawning behavior and migrations, and fecundity in the Tadi River with those in the Indrasarobar reservoir, Nepal.

2. MATERIAL AND METHODS

Katle were collected from the Indrasarobar reservoir and the Tadi River from January 1988 to December 1990 (Swar, 1994). The fish were sexed from external and internal examination. Total length (mm) and weight (g) were recorded. Pectoral fin rays were used to age the fish (Swar, 1994). The gonads were removed and weighed and the stages of development were noted (Laevastu, 1965). The outer ovarian walls were removed and the ovaries stored in Gilson's fluid (Bagenal, 1971) for about one month. After cleaning, three egg fractions, according to diameter, were collected using sieves with mesh sizes of 1 000 and 1 700 ìm. From each fraction, four sub-samples of 1000 eggs were air-dried for 48 h together with the remaining eggs. Total numbers of eggs were calculated from the weight of the known number and the total weight. All eggs were counted when the total was <4000. Fecundity was determined for 84 ripe females from the Indrasarobar reservoir and 35 from the Tadi River.

To determine the size of ova at different stages of maturity, 200 preserved eggs were randomly selected from both the anterior and posterior parts of the ovary in the second, third, and fourth stages of maturity from both the reservoir and river fish. Egg diameters were measured using an ocular micrometer. To examine the size range of ova in mature ovaries, 100 eggs from each of the three fractions were measured.

Radio tags (49 MHZ) were used to investigate the spawning migration and to locate the breeding sites of reservoir female katle. Four sexually mature, spawning females were collected from the reservoir during 26-27 August 1990. Fish were 360-520 mm in total length and 450-1400 g in weight. They were anaesthetised with benzocaine (25 mg/L) (Laird and Oswald, 1975), transmitters were placed beside the dorsal fin (Winters, 1978) and then all were released at the same place. The fish were followed with a radio receiver either from land or from a boat between 26 August and 15 September 1990.

The spawning behaviour of katle was observed in the Tadi River in 1991. The Khahare Khola, an afferent stream of the Tadi River, had already been identified as a spawning site (personal communication with local fishers). Intensive observations were conducted from 15 August to 7 September 1991. In addition fyke nets were set in the Khahare Khola near its confluence with the Tadi River. The nets were checked at intervals of 4 hours from 1900 to 0600 h. Water temperature, pH, turbidity and dissolved oxygen were measured during the period of observation. The shallow areas with gravel bottom were surveyed for fish eggs once a day using a dip net.

3. RESULTS

3.1 Sex ratios

The proportion of females was significantly higher than that of males ($p<0.05$) in the reservoir samples in all years studied. Males were more numerous in the river sample in 1988 ($p<0.05$), but there were no differences in the sex ratios in 1989 and 1990 (Table 1). The sampling areas in both habitats were extended during the second half of 1989 and in 1990. The upper area of the Indrasarobar reservoir was fished with different gears such as cast net and local traps and the area covered in the Tadi River was extended by 2 km to the north and south beyond the normal 10 km stretch. Although the abundance of the males in the reservoir increased slightly and the proportion of females increased in catches from the river, the ratios did not change significantly.

3.2 Maturity stages

Seven stages of gonad development were identified for female and male katle from both habitats (Table 2). At the first and second stages of maturation, the ovaries appeared as two small organs of compact tissue under the air bladder, and the oocytes were not visible to the naked eye. The oocytes became visible at stage three. The ovaries gradually increased in size and the oocytes became more distinct and translucent at successive stages. At stage 1, the testes were very thin, thread like, paired organs under the vertebral column. They gradually increased in size and ultimately occupied about two thirds of the ventral cavity. The margin became convoluted with transverse grooves. At stages 5 and 6, the testes were pinkish white and turgid, and milt ran with slight pressure. The 'partly spent' stage expected to be found in a multiple spawner like katle was not found in either sex.

Table 1
The sex ratios of katle in the reservoir and river

Year	Location	Number of females	Number of males	Female:male
1988	Reservoir	535	26	1:0.05
1988	River	13	27	1:2.08
1989	Reservoir	482	32	1:0.06
1989	River	34	39	1:1.15
1990	Reservoir	379	118	1:0.31
1990	River	301	287	1:0.95

Table 2
Stages in the development of the ovaries and testes of katle

Stage 1: State: virgin :

Ovaries: Thin, small, two pieces of compact tissue underneath the air bladder, gray. Oocytes not visible to the naked eye.

Testes: Very small paired organs, close under the vertebral column, connected to the air bladder, transparent.

Stage 2: State: Maturing virgin and recovering spent:

Ovaries: Ovaries with compact lobes, creamy to pale yellow, ova spherical, particularly laden with yolk, eggs visible with magnifying glass.

Testes: Slightly larger than stage 1, length about _ of the ventral cavity, transparent, reddish gray.

Stage 3: Developing:

Ovaries: Light yellow with distinct blood capillaries, eggs opaque, visible with naked eye, whitish and granular.

Testes: Opaque and reddish with blood capillaries, occupy about half the length of the ventral cavity.

Stage 4: Developed:

Ovaries: Large and bright yellow with conspicuous blood capillaries and oval shaped oocytes.

Testes: Reddish white with wavy margins and distinct blood capillaries, occupy about 2/3 of the ventral cavity.

Stage 5: Gravid:

Ovaries: Enlarged and fill ventral cavity, yellow eggs completely round and semi-transparent; primary oocytes as in stages 1 and 2 present.

Testes: White, waxy margin with transverse grooves; occupy the length of the ventral cavity; drops of milt exuded on pressure.

Stage 6: Spawning:

Ovaries: Distended, yellowish white, jelly-like, eggs run with slight pressure, most eggs translucent.

Testes: Occupy the length of the ventral cavity; pinkish white, turgid and milt runs with slight pressure.

Stage 7: Spent:

Ovaries: Empty, shrunken, baglike, a few residual oocytes may be visible.

Testes: Flaccid, gray, without milt.

3.3 Maturation cycle

Since the annual maturation cycle of the katle appeared to be regular, the years 1988 to 1990 for each sex and each habitat were pooled. Reservoir females at stages 1 and 2 were found throughout the year. More than 60% of the katle were at stage 2 except in March. In March stages 3 and 4 were observed and all stages, 1 to 6, were present from April to October. Gravid females were caught from April to October but formed a small percentage of the total catch. No running or spent females were ever found.

As in the females, stage 2 development was dominant among the reservoir males and all fish were either at stages 1 or 2 from November to February. Stage 3 was observed every month from March to October except May. Males at stage 4 were present in the reservoir in April, July and August. Males of stages 5 were found only in July and August. No males of stages 6 and 7 were ever caught in the reservoir.

The general cycle of gonadal maturation of the katle in the Tadi River was similar to that in the Indrasarobar reservoir. Females and males at stage 2 were found throughout the year. Females at stage 3 appeared in March and were frequently caught until October. Stage 5 was observed from July to October and stage 6 from September to October. Males at stages 3, 4 and 5 were found from March until October. Spent males and females were encountered only in September and October, respectively.

3.4 Age at first maturity

About 50% of the river males were mature at age 2 yr and >90% at 3 yr; only 5% of river females were mature at 2 yr but nearly 100% were adult at 3 yr. No male fish <3 yr were caught in the reservoir. Most of the 3-yr-old males there were mature. In the reservoir about 50% of 3-yr-old and 100% 4-yr-old females were mature. The immature fish were significantly smaller than mature fish of the same age in both sexes in both the reservoir and river populations.

3.5 Fish movements

Four mature female fish fitted with radio tags, released at point A (Map 1) on 26 and 27 August 1990, remained at first near the release site (Table 3). All then migrated upstream. Three moved towards the Kulekhani River and the fourth towards Chitlang Khola.

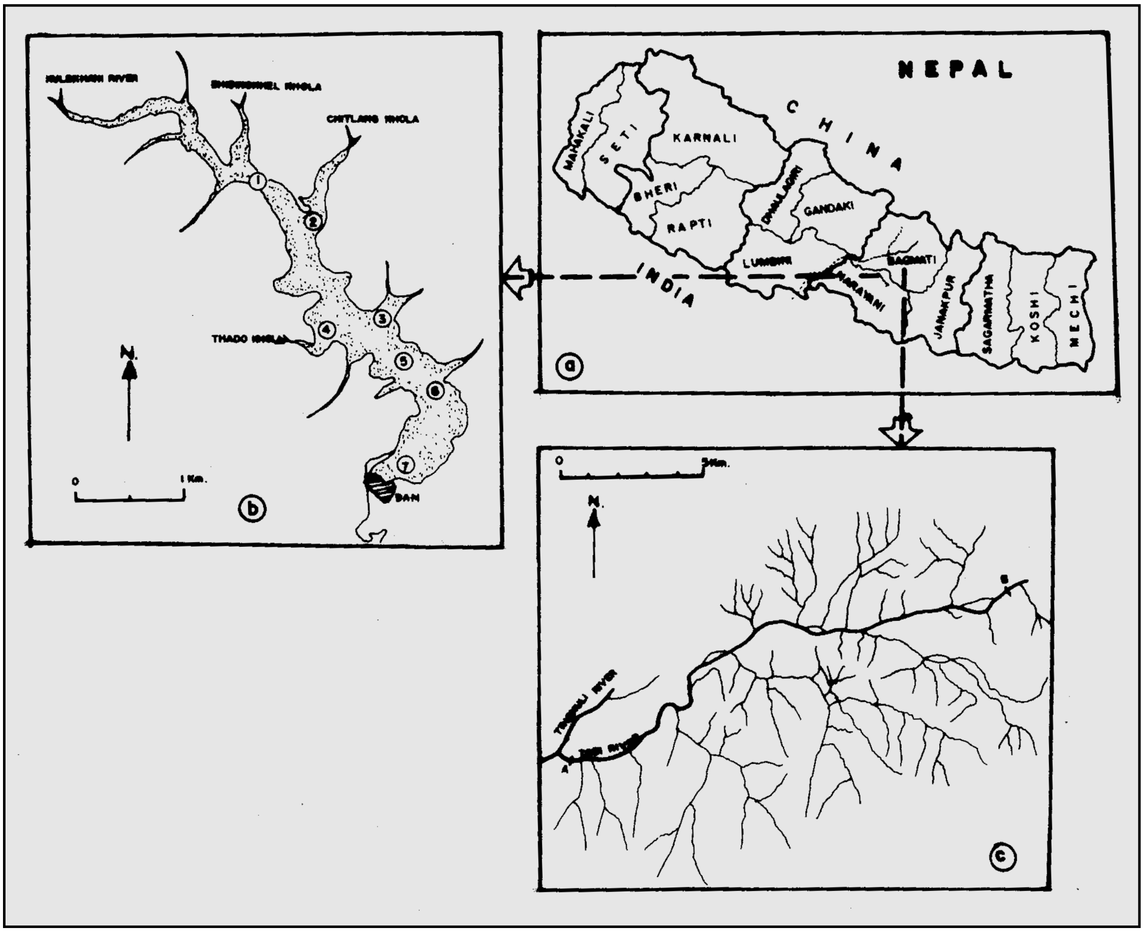

Fig. 1 - Map of Indrasarobar reservoir showing the areas where radio tagged fish were located

Table 3
Movements of katle as determined by radio tagging in the Indrasarobar reservoir. R=release (date and place). For locations see Map 1 (* = not located)

Date	Fish 1	Fish 2	Fish 3	Fish 4
26/08/90	AR	AR	*	*
27/08/90	B	A	AR	AR
28/08/90	B	C	A	A
29/08/90	B	C	D	A
30/08/90	C	*	D	D
31/08/90	*	A	C	C
01/09/90	*	A	C	C
02/09/90	D	D	*	G
03/09/90	D	E	*	G
04/09/90	D	E	D	H
05/09/90	A	F	E	H
06/09/90	C	F	F	I
07/09/90	C	I	G	I
08/09/90	C	I	H	I
09/09/90	C	*	H	I
10/09/90	C	*	I	J
11/09/90	C	*	I	J
12/09/90	C	*	J	J
13/09/90	C	*	*	*
14/09/90	*	*	*	*
15/09/90	*	*	*	*

3.6 Visual observations of katle spawning behavior

The upstream movement of 3 fish to the Khahare Khola stream from the Tadi River was observed on 20 August at about 1600 h. They appeared to move rapidly for the first 300 m. They slowed down after they reached the shallow and slow moving part of the stream. The largest fish, probably female, was leading and two smaller fish, presumably males, followed her. As soon as they found a wide, shallow pool with a gravel bottom, they stopped. They then started to swim in a non-directional manner, over and around the spawning substratum. Some movements were circular (anti-clockwise and clockwise), whereas others were spiral. Both the males were seen to be equally active and swam alongside the female. After _ h the same fish were noticed entering the Khahare Khola. Two spent fish, one of each sex were later caught in a fyke net. Eggs were found on the gravel bottom of the spawning site the next morning. One thousand fertilised ova were collected and incubated at the Fishery Research Station, Trishuli. The water temperature at the spawning ground ranged from 20-22°C, the mean dissolved oxygen was 6.98 ± 0.98 mg 1^{-1}, and pH 6.73 ± 0.11.

3.7 Egg diameter and fecundity

At stage 2, one batch of oocytes was present, at stage 3, there were two distinct batches and at stage 4, three types, immature, maturing and mature. Data on the diameters of mature eggs at

>1.60 mm, and on the diameters of mature eggs at stage 5 from the reservoir and river from July to October were analyzed by ANOVA. The location on its own did not appear to influence the size of the eggs, but the time of maturation (month) was statistically significant. The largest eggs were produced in September. Absolute fecundity of katle in both the river and reservoir varied considerably amongst individuals. It ranged from 1 387 (in a fish of length 160 mm and weight 53.8 g) to 33 270 eggs (535 mm and 1750 g) in the reservoir population, and from 760 (155 mm and 40 g) to 8 951 (395 mm and 500 g) in the river population. The mean relative fecundity in the reservoir population was significantly different ($p < 0.01$) from that of the river, 19.13±1.56 compared to 22.56±1.41 eggs per gram, respectively.

4. DISCUSSION

Males were normally more numerous in the river catches. This trend has been reported in other stream-living cyprinids (Siddique *et al*., 1976; Mann, 1980; Cooper, 1983). The imbalance was probably related to differences in age-related mortality and spawning migrations. Al-Kholy (1972) observed that *Puntius barberinus* females stayed longer in the spawning areas than males and this significantly reduced the proportion of females in the main population. In this study, katle were found to have a prolonged breeding season from April to October and most of the mature females probably migrated to suitable breeding grounds and remained there longer than the males. It seems that the higher ratio of males to females during 1988 was the result of the upstream spawning migration of the females in the Tadi River, beyond the sampling area. This was confirmed by the increased proportion of females during the second half of 1989 and in 1990 when the sampling areas were extended by 2 km. The extremely low number of male fish in the reservoir is difficult to explain. Males may prefer to live in a riverine environment and reside in the Kulekhani River. The males appear to have a higher mortality rate so there were fewer older males. No males >350 mm were caught in the reservoir. The use of different sampling gears may have been a reason for the variability in the proportion of males in the two habitats. The reservoir fish were sampled using multi-mesh gill nets and the smallest fish caught were 130 mm. The smallest males caught in the river were 80 mm. Therefore, it seems possible that males between the sizes of 80 and 130 mm constituted a higher percentage of the reservoir katle.

Temperature and photoperiod modulate sexual development and spawning in cyprinids, although the former is the predominant factor in their reproductive cycle between November and February. The gonads started to develop in March and the main reproductive phase lasted from April to October. The mean surface water temperature in both the reservoir and river began to rise in March, decreasing again in November and reaching its lowest levels in January and February (Swar, 1994). Mean day-length varied from 625 minutes in December to 831 minutes in June. From March to October longer day–length and higher temperatures coincided with increased reproductive activities. This is consistent with the reproductive cycles of other cyprinids (Hyder, 1970; Abidin, 1986). Ahmed (1948) observed that katle bred from April to October with a peak in August and September.

As katle has a prolonged spawning season, which extends before and after the monsoon (May to September), flooding does not seem to be an essential factor. However, katle may take advantage of flood water to reach breeding areas. Desai (1973) recorded migrations of *Tor tor* during monsoon floods in the River Narmada, India. The spawning movements of ripe females in the reservoir and river suggested that katle was very selective in finding a suitable place to spawn.

The percentage of different size groups (batches) of oocytes indicates the multiple spawning characteristics of katle. In several studies on the fecundity of multiple spawners, attempts have been made to estimate both batch size and number of batches (Mackay and Mann, 1969; Macer, 1974). Batch size can be defined as the number of oocytes released together. The number of batches during the spawning period depends on temperature, photoperiod and food supply, which will affect the physiological state of the fish. In multiple spawners, egg release would appear to be very flexible, since the process of synchronous oocyte development and oocyte reabsorption makes it possible to control egg numbers. Nikolsky (1969) stated that multiple spawning was only successful when there was a long period of adequate food supply for the larvae. However, he warned that it would be wrong to regard this life history strategy as an adaptation to food supply alone because it could also be an adaptation to unsuitable spawning conditions. Burt *et al*. (1988) suggested that multiple spawning within a season was associated with less seasonal variation (single spawners were constrained by more severe environmental conditions), small body size and small relative ovary size. Although these conditions may be true for fish in general, they do not seem to be applicable to katle in central Nepal which are subjected to seasonal changes in environmental conditions and whose body size is relatively large. In this low fecundity species, multiple spawning may have developed as an adaptation (Swar, 1994) . Extreme conditions such as flooding in the fast flowing rivers caused by monsoon rains and the substantial annual drawdown in the reservoir probably cause these mortalities.

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PROJECT INDUCED IMPACTS ON FISHERIES RESOURCE AND THEIR MITIGATION APPROACH IN THE KALI GANDAKI ”A” HYDROELECTRIC PROJECT, NEPAL

by

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ABSTRACT

The Kali Gandaki “A” Hydroelectric Project is under construction in Western Nepal. The project will have significant impacts on the fisheries resources of the River Kali Gandaki. Environmental Impact Assessments (EIA) recommended mitigation and protection measures to include trapping and hauling fish up and downstream, screened intakes, riparian release facility and a fish hatchery. The mitigation programme has encountered several challenges related to extreme river conditions, lack of biological information, and difficult logistics. In addition, Nepal has little experience in developing and implementing environmental mitigation for hydroelectric projects. The lessons learned will have positive implications for mitigation of other hydropower projects in Nepal and Asia.

1. BACKGROUND

Nepal has extreme topography that shapes its natural resources. The altitude varies from 8848 m to 500 m north to south and the associated climate diversity supports rich flora and fauna. Nepal has high Himalayan mountains in the north; to the south are mid-hills, foothills and the lowland Terai with broad valleys, fertile plains and tropical jungles. Approximately 6 000 rivers and streams fed with snowmelt and rainwater traverse the mountain ranges, valleys and plains to feed into the Bay of Bengal, India.

Despite the abundant water resources Nepal experiences lack of electricity, which affects its economy. Out of its 25 million people only 10% have access to electricity. Looking at this great demand, His Majesty’s Government of Nepal (HMG/N), Ministry of Water Resources (MWR) and Nepal Electricity Authority (NEA), with the help of international funding agencies, is supporting the development of several hydropower projects. Kali Gandaki “A” Hydroelectric Project (KG”A”HEP) is the biggest undertaking in Nepal capable of supplying 144 MW. The Project has been under construction from 1997 and was expected to be completed by 2001.

An Environmental Impact Assessment (EIA) was conducted as part of feasibility studies as required by Nepalese regulations. EIA has included physical, biological, socio-economic and cultural considerations. One of the major concerns was impact on fisheries resources of the Kali Gandaki River, which supports a diverse fish community which is heavily fished.

This paper briefly describes the project, its impacts and mitigation efforts. The mitigation programme is in its 4th year and has made significant progress. However, limitations are apparent, largely driven by biological, hydrological, cultural and management factors. We speculate on the nature of these challenges and how these might be avoided in future such projects in Nepal and other developing countries.

2. BRIEF DESCRIPTION OF THE PROJECT (Fig.1)

The KGA project is located 500 m below the confluence of the Kali Gandaki and the Andhikhola at Mirmi. The river flows west, turns south and east to form a 50 km loop and reaches the powerhouse site at Beltari. Both Mirmi and Beltari villages are in the Sri Krishna Gandaki Village Development Comity of Syangja District. A 44 m high by 110 m long concrete diversion dam will create a reservoir of 65 ha stretching 5.3 km, with an average depth of 12 m and operating level between 518-524 m. From the desanding basin at the head works site, water low in sediments will be routed into a 5.9 km tunnel and enter a power plant equipped with a surge tank, pressure shaft, three power units, transformer, draft tube gate and a tailrace where it will be released back into the river. Power will be distributed to Nepal’s national power grid using transmission lines that tap into substations at Pokhara and Butwal. Annual generation is estimated at 840 GWh. Figure 1 shows the location.

Morrison Knudsen International (MKI), USA, provides the engineering design for the project and Impregillo S.p.A. (IGL), Italy, is doing the civil construction. The KGA project is owned and operated by the NEA.

3. RIVER CONDITIONS AND FISHERIES RESOURCES

3.1 River conditions

The Kali Gandaki River originates from Tibetan Plateau, north of Nepal. The river runs between elevations 5 500 m and 1 250 m forming deep gorges. Four tributary streams join it as the river loses elevation and enters the KGA project area. Above the dam it is joined by the Andhikhola; between the dam and powerhouse Badigarh and Ridikhola join it. Below the powerhouse, it joins with the Trisuli and forms the Narayani River before it flows into the Gangetic plains of India and finally into the Bay of Bengal.

Various sections of the river have different gradients. The upper section is snow-fed, steep and with swift current flowing over rocks; the middle is rain-fed, has flatter profile; and the lower section has warm water, low gradient and the river is productive. At the dam site the suspended sediment load reaches up to 50 g/L during high flows. During dry season the river is clear. Water current velocity ranges from 1.5-2.5 m/sec, but reaches 10 m/sec during monsoon. The riverbed is covered by boulders, rocks and gravel.

3.2 Fisheries resources

The Kali Gandaki River has a number of fish species adapted to the extreme gradient. The fish support subsistence, commercial and sports fisheries. The annual catch from the river is estimated at between 80 to 150 tons. The principal species are snow trouts, mahseer, carp, catfish, eel, murrel, loach and barbs. Mahseer (sahar), snowtrout (asla), catfish and eel are sport fish.

Feasibility studies recorded 57 species within the project area. These fish have adapted to the extreme flow and turbidity. Migration patterns include long distance (to and from Terai or Bay of Bengal); medium distance, and residents (moving from the mainstream to immediate tributaries). Upstream migration starts at the beginning of monsoon which triggers spawning behaviour, and downstream migration starts when water levels in the tributaries subside. The catadromous eel is also abundant in the Kali Gandaki River.

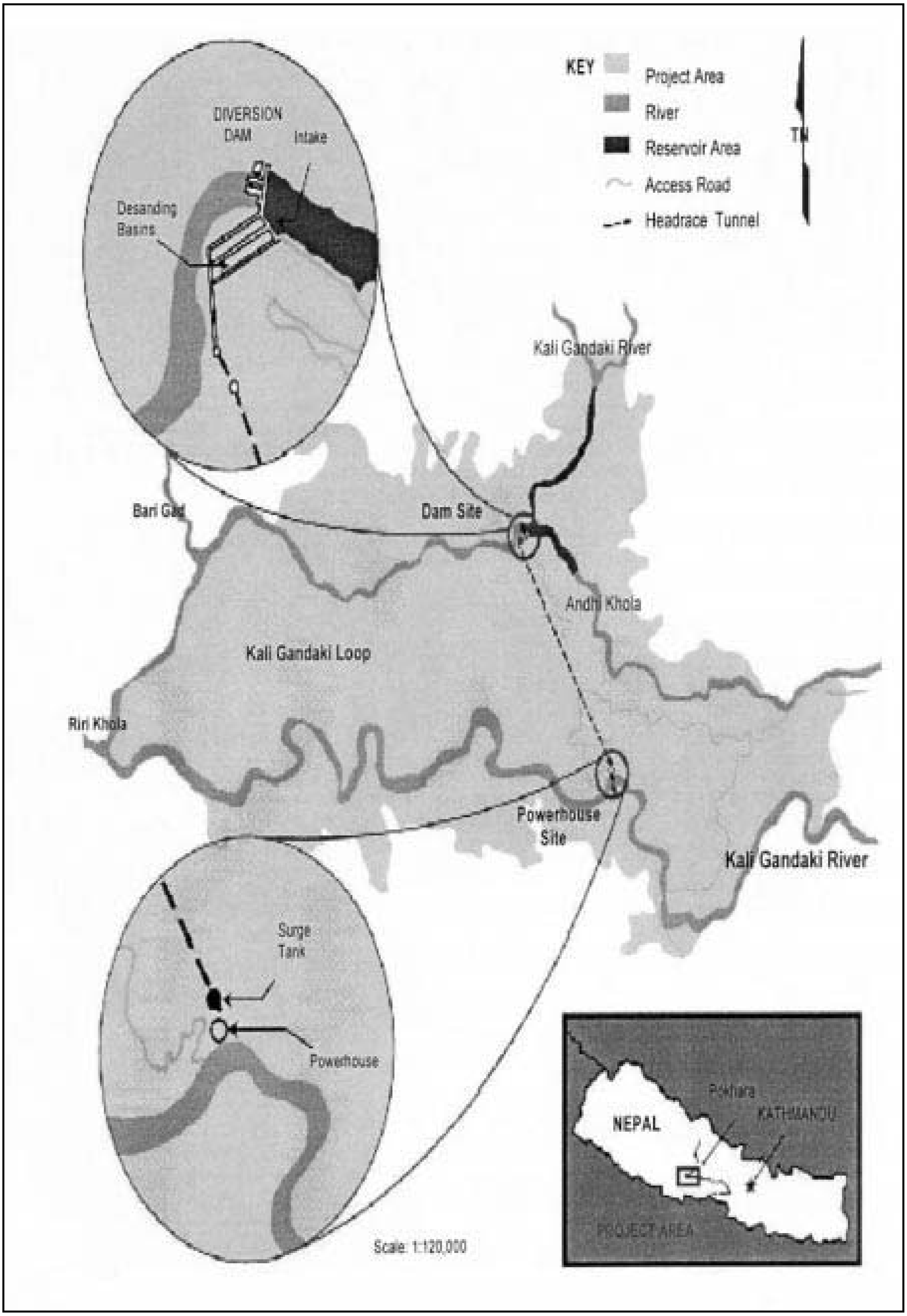

Fig. 1 - Location of the kali Gandaki 'A' Hydroelectric Project area and major project features

4. PROJECT IMPACTS AND MITIGATION MEASURES

The Environmental Impact Assessment (EIA) was the framework used to identify project impacts and mitigation measures for the fisheries resources and these are represented in Table 1.

4.1 Barrier effect

The diversion dam will physically block the upstream and downstream migration of fish resulting in reduction in spawning success due to loss of habitat and ultimately reduction of fish stocks. Evidence of these effects has been observed in the rivers Andhikhola, Marsyangdi, Trishuli and other hydropower or irrigation dams of the country.

Table 1
Summary of the Kali Gandaki 'A' Hydroelectric Project impacts on fisheries and ethnic groups

Impact	Mitigation measure	Purpose	Targeted populations
Upstream barrier	Trapping and hauling	Facilitate upstream fish passage	In-migrating fish
Entrainment	Trash rack; gratings of collector channel/louver; downstream migrant release facility	Facilitate downstream fish passage	Out-migrating fish
Dewatering of the Kali Gandaki loop	Minimal in-stream flows (4cm)	Protect aquatic and riparian habitat between diversion dam and powerhouse	All fish
Incidental fisheries impacts	Hatchery	Supplementation of existing fish stocks	Mahseer, copper mahseer, snow trout, jalkapoor and eel
Incidental fisheries impacts	Creation of reservoir	Opportunities for aquaculture and reservoir fisheries	Cage culture fish; murrel, catfish, stone loach, carp-minnow, minor carp and snow trout
Displacement of Botes	Employment and training of Botes	Provide livelihood and source of income; improve local economy	Botes; local communities

A fish trapping and hauling programme would facilitate upstream passage and could be coordinated with hatchery operation. Fyke nets, hoop nets and fish wheel traps were considered for testing along with local dipnets, cast nets, sakhar and bamboo traps. Current efforts focus on establishing an effective manner in which to do live trapping. However, the testing of these traps showed low catch per unit effort, with total catches ranging from a few kilograms to several hundred kilograms of targeted species. The testing has been difficult due to large fluctuations in water level (1 to 9 m), high sediment load rendering fish capture techniques that rely on visual observation unusable, disturbances due to project construction activities (regular gravel and boulder takeout, muck disposal in the river), etc. In addition, due to lack of proper gears and equipment, inconsistent staffing and inexperience, the programme has had to run on a limited scale. The diversion dam is the most suitable place for establishing a permanent trapping station as migrating fish become stranded and congregate there.

4.2 Entrainment

Entrainment rate could not be quantified due to lack of biological information on downstream migration pattern. Entrainment of out-migrants is a major concern because the river will be 90% diverted during the dry season. To avert entrainment, a trash rack and louver system will be incorporated into the dam. Out-migrants will be diverted away from the intake and into a downstream riparian release facility.

4.3 Dewatering

During the dry season the 50 km reach between the diversion dam and the powerhouse (Kali Gandaki Loop) may be dewatered to a point where there is a substantial loss of aquatic habitat, no migration, and reduced access to spawning or nursing grounds. The uppermost 13 km is particularly vulnerable as there are no tributaries to contribute flows.

A 4 m^3/sec minimum riparian release is suggested to be viable in terms of the amount of habitat saved and cost.

4.4 Fish hatchery

A fish hatchery is being constructed to mitigate the combination of impacts caused by the project. This is a multiple species (both cold and warm water) fish hatchery with a main hatchery building, hatching and holding facility, indoor and outdoor nursing/rearing facility, a laboratory and raceways. The hatchery will use water from the tailrace to supply a terraced system of ponds and raceways.

Targeted species are mahseer or sahar (*Tor* spp), asla or snowtrout (*Schizothorax* spp), katle (*Neolissocheilus* spp), jalkapoor (*Clupeisoma* spp), gonch or bagarid catfish (*Bagarius* spp), rajbam or fresh water eel (*Anguilla* spp) and others. Annual goals are 30 million eggs, 10 million hatchlings or fry and 2 million fingerlings to be produced and released into the Kali Ganga River system.

The reservoir will create opportunities for aquaculture in net cages and enclosures, sport fishing and boat transportation. However, the previously available five-day rafting trips (from Baglung to Ramdi) will be limited to three days (Baglung to Setibeni or Mirmi).

4.5 Bote ethnic group

Approximately, 150 Bote families reside near the KGA project area including Andhimuhan, upstream and downstream of the Kali Ganga River. They make their living by fishing, boat handling and as labourers. When completed the project may displace or reduce fishing opportunities. As mitigation, the project has provided employment during construction, housing and school facility for these poor communities.

Mitigation in the KGA project is implemented through an adaptive strategy that evaluates existing measures and develops alternatives, as information becomes available, involving continued monitoring, development and testing of new strategies. A large component of this adaptive management will be new and ongoing research to understand native fish populations.

4.6 Concerns

Lack of biological information: There is little information on fish abundance, migration and spawning behavior in the Kali Gandaki River.

Interim mitigation: The construction company is responsible for implementing mitigation measures directed by engineers but lacks qualified personnel for interim mitigation. The construction of the project is a higher priority for the IGL engineers and the employer whereby little response is given to mitigation efforts. Environmental mitigation for hydroelectric projects is very new to Nepal. There is little awareness of environmental issues that influence the success of mitigation efforts.

5. CONCLUSIONS

The fisheries mitigation programme is new and in its infancy. Challenges to be faced are lack of biological information and awareness, difficult trapping conditions, logistics and management inconsistencies. It is hoped to overcome obstacles as construction is completed, techniques are refined and more biological information becomes available. On-site research is needed to understand how the fish population responds to a new hydroelectric project. Mitigation efforts should consider what biological information exists prior to construction, especially in countries that emphasize economic development over environmental concerns.

SURVEY OF CAPTURE FISHERIES IN THE KOSHI RIVER BASIN

by

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ABSTRACT

The Koshi River has a vast catchment area varied in nature, draining the high altitude Himalayas covered in permanent ice, entering mid hills, to eventually discharge itself onto alluvial plains of lowlands. The study site lies within 86°55’ - 87°05’ E longitude and 26°24’ - 26°45’ N latitude, on the alluvial floodplains of Sapta Koshi. Ninety-six species of fish were identified during the study period of four months. Of these, 11 species are very common. Fishermen use more than 15 types of fishing gear to catch the fish. The catch per unit area is estimated as 1.14 kg/ha/day in the Koshi River (1.2 km times 4 km) while in the other water bodies it is 3 kg/ha/day. Observations have shown that fish yield from the Koshi River has not been commensurate with the productivity of the system and certain stretches have been subjected to intensive exploitation. The fishermen belong to a number of ethnic groups such as Godhi, Mallah, Mukhiya, Bahardhar. There are ten main villages of fishermen. The total population is estimated to be 2 937 in 484 households in all ten villages, of which 445 households are solely dependent on the fishing while the rest of the families have switched from the traditional occupation to agriculture, rickshaw pulling, working as carpenters and field labourers. 133 families other than traditional fishermen, especially Muslims, have been found to be attracted to the fishing. The fishermen communities in all ten villages of the Koshi basin have similar social structure, with minor variations in caste titles and living styles. All of them depend basically on the capture fishery. The socio-economic status of the fishermen communities is the lowest in the society. 46% families were found to be landless while 54% of the population owned less than 0.2 ha of land. 93% respondents earned less than NRs. 5 000 per annum and 7% NRs. 5 000 - 10 000, while none had more than NRs. 2 000. Improving the social status of the fishermen communities is urgently needed, but among the major problems figure prominently the disturbance in the catchment and overfishing, both of which require urgent attention.

1. BACKGROUND

Nepal is a landlocked country between India and China. It extends from 26°30’ to 30°15’ N and from 80° to 88°15’ E. In the north are the ranges of the Himalayas, with the highest peak at 8848 m, and in the south the humid hot Terai plains. This tremendous altitudinal difference produces great biological variations, including a great variety of fish in Nepal’s 6 000 rivers and streams, lakes and swamps. Water bodies cover about 3% of the total land area of the country.

Koshi, Gandaki and Karnali are the principal river systems fed by hundreds of small rivers and streams originating in the Mahabharat and Siwalik mountain ranges. Snow and glacial melt from the Himalayas continuously feed these rivers, augmented by rainfall runoff, particularly during monsoons.

The waters of Nepal provide a variety of habitats for indigenous fish, water for irrigation and for hydropower generation.

2. FISH AND FISHERIES

Koshi is the largest river of Nepal, with the largest catchment area. This river is formed by the rivers Indrabati, Tama Koshi, Likhu Khola, Sun Koshi, Dudh Koshi, Arun and Tamor. Another large river is Sapt Koshi, with a catchment of approximately 60 000 km^2, 55 percent of which lies in Nepal and 45 percent in Tibet. About 10 percent of the catchment is covered with ice and snow. The climate of the river basin is of monsoon type with a mean annual rainfall of 2 110 mm, mean maximum air temperature of 37°C, and a mean minimum temperature of 8°C (Scott, 1989, as cited in the Woodlands Mountain Institute and IUCN/Nepal, 1994).

2.1 Capture fisheries

Fisheries has been an important occupation in many parts of Nepal. In spite its significance and the institutional efforts the contribution of fisheries to employment, national income and exports has been far from satisfactory. Government fisheries institutions have been able to make estimates of fish catches in some fresh waters and have studied the people involved in it.

Capture fisheries in Nepal is widely scattered and not organized. Scanty records are available on capture fisheries. However, in view of its fisheries importance, preliminary surveys of a number of water bodies have been carried out by the Fisheries Development Directorate to assess the level of capture fisheries (Table 1). As Nepal is a landlocked country, capture fishery has an important role. In 1998 it was estimated that 204 000 people were actively involved in capture fisheries. Most of them were living scattered along the rivers and lakes and were not organized or supported. The communities used traditional fishing gear for subsistence fishery, generating marginal economic benefits. Destructive devices such as dynamite, fish poisons, electrofishing, etc., were common, having a negative impact on fish by destroying broodstock, spawning and nursery grounds.

Table 1
Water resources and capture fish production (FDD 2000/2001)

Resources	Estimated area (ha)	Coverage (%)	Productivity (kg/ha/yr)	Production (tons)
Rivers	395 000	48.64	12.5	4 937.5
Lakes	5 000	0.62	155.0	775.0
Reservoirs	1 500	0.18	225.0	337.5
Marginal swamps	12 500	1.54	374.4	4 680.0
Irrigated paddy fields	398 000	49.02	15.0	5 970.0
Total	812 000	100	?	16 700.00

Table 2
Families involved, active members, beneficiaries and value from capture fisheries
(Matsya Palan Srinkhala – 5, 1999)

Resources	Families involved	Active members	Beneficiaries from	Beneficiaries to	Value in million NRs.
Rivers,lakes, reservoirs, swamps	24 200	96 800	121 000	145 200	571.58
Irrigated paddy fields	26 800	107 200	134 000	160 800	328.35
Total	51 000	204 000	255 000	306 000	899.93

In Nepal about 51 000 traditional fishermen families as well as others are involved in culture fisheries, with total active members of 204 000 (Table 2). This represents nearly one percent of the total population of Nepal, contributing 0.81 percent to the national GDP. The national records of capture fisheries show that the production is increasing per unit area, but the rate of increment is very low (11 kg/ha/yr and 12.5 kg/ha/yr in 1997/98 and 2000/01, respectively). The increment per unit area is the effect of a higher fishing intensity.

2.2 Constraints

Observations have shown that fish yield from the Koshi River has not been commensurate with the productivity of the system and certain stretches have been subjected to intensive exploitation. The river fisheries range from localized subsistence fishing to highly mobile and intensive operations (Srivastava and Vathsala, 1984). The intensity of fishing, nature of exploitation and species-orientation are governed by an array of factors such as

- seasonality of riverine fishing activity;
- unstable catch composition;
- conflicting use of river water;
- lack of understanding of the fluvial system and poor data base;
- inadequacy of infrastructure and supportive services to the fishermen;
- socio-economic and socio-cultural determinants.

It is therefore evident that a number of diverse and complex problems confront the fishery of the Koshi basin. The constraints have wider dimensions and can be broadly grouped under four major categories.

2.2.1 Biological constraints - In the Koshi basin fisheries are affected directly by recruitment and age structure, and indirectly by ecosystem, influenced by food supply and habitat alteration. In a fluvial system, the biological productivity is governed by primary production, thermodynamics of the eco-system and exchange of organic matter. The nature of flood regime is one of the most important parameters influencing the riverine fisheries. In the Koshi River frequent changing of fluvial features largely determines the success of breeding of most of the important species and affects the migratory fish. There is a need for a more profound studies of fish population dynamics.

2.2.2 Environmental constraints

The deleterious effects of dams, weirs and barrages on river fish species are well known. The Koshi river basin has experienced changes due to the construction of several structures, of which the Chatara irrigation canal and barrage near the Indo-Nepal border has affected migration and breeding of important species. The increasing human immigration from other parts of the country has a negative impact on the riverine environment of the Koshi River.

2.2.3 Socio-economic constraints

Fishing in the Koshi River has been an age-old source of livelihood for thousands of riparian fishermen. They are more apt to have the traditional social structure suited to existing conditions. They manage their every social need by fishing and marketing the catch. To introduce new and suitable management is socially difficult. The cultural values are so firmly established that any change in this superstitious, educationally-backward fishing community will run up against accepted social habits, belief and attitude. However, such barriers can be surmounted through a rational programme of extension, education and training.

2.2.4 Legal constraints

Despite legal prohibition (Jalchar Ain, 2017 B.S.) indiscriminate capture of spawners and juveniles and destructive fishing practices of dynamiting and poisoning the water bodies have been going on due to lack of awareness. Fishery regulations have played a subordinate role since they have been ineffective, mostly due to enforcement problems and difficulties in subsequent monitoring of the activities.

3. PRESENT STUDY

The paper addresses the following main objectives of the study:
- fish yields in the Koshi River;
- revision of the checklist of indigenous fish of the Koshi River and other water bodies in its basin;
- the fishermen community and the social structure, and
- the status of the ecology of the Koshi river basin.

The usefulness of the work for the purpose of planning and designing for further development of the river basin has been the primary objective.

3.1 Study site

Since the Koshi basin includes a vast area along the river in the plains as well as seven catchment rivers feeding the Sapta Koshi, it was not possible to conduct a study of the whole basin. The study was therefore limited to the river between Tribeni and the Indo-Nepalese border (Bhimnagar barrage). The Koshi River receives seven major rivers - this is why it is named Sapta Koshi. These are: Indrabati, Tama Koshi, Likhu Khola, Dudh Koshi, Sun Koshi, Arun and Tamor.

The study site is the major part of the Koshi Tappu Wildlife Reserve (KTWR), a rich Nepalese wildlife natural reservation famous for wild water buffaloes *(Bubalus bubalis).* The study site lies within 86º55' - 87º05' E longitude and 26º24' - 26º45' N latitude, on the alluvial floodplain of Sapta Koshi. Increasing difficulties faced in sustainable biodiversity conservation led the

Ministry of Forest of the HMG of Nepal and UNDP to initiate in 1995 the Park and People Programme (Nikunj - Janta - Karyakram) (PPP, 2000). The programme aims to prevent the people interfering with the wildlife area. The programme helps the people by providing soft loans, short-term training, exposure visits and other technical support through group mobilization and saving and credit systems. Presently, fifteen ponds of around ten hectares in area have been constructed in the wetlands and operated successfully with good returns.

3.2 Ecological features

The ecology of the surface runoff waters plays the most important role and determines the flora and fauna in the different sections of the river. The Koshi River has a vast catchment area varied in nature, with the high altitude of the Himalayas, hills, and alluvial deposits in lowlands. With the increase of the volume of runoff water and the slope gradient, erosion also becomes faster and consequently the channel becomes larger and carries more runoff.

In the Koshi River basin forest, agriculture lands and aquatic environment interact, which results in a complex ecological network with a substantial impact on the fish fauna of the river. The large number of cows and buffaloes interacts with the river water by supplying nitrogenous waste. Likewise the forest ecology enriches water with organic matter and products of its decomposition.

3.2.1 Physico-chemical parameters

Due to the high precipitation, in its upper and middle courses the river has a torrential flow. Further downstream, near the Indo-Nepalese border, the current velocity decreases. Higher silt due to the upstream soil erosion also retards the velocity of flow. The silt records at the origin of the Chatara Irrigation Canal showed that the highest suspended load of 2 277 g/L was carried in August 1999, while the minimum of 1 g/L was in December 1999. The water temperature ranged from 17 to 24°C, with a very narrow range in the upper course as compared to the lower course. Dissolved oxygen ranged from 7.5 to 9.0 mg/L, being higher in the upper course while lower in the lower course. The pH ranged from 8.0 to 11.5, alkalinity from 69.0 to 85.5 mg/L, and hardness from 130.3 to 136.9 mg/L.

3.3 Fish and fisheries

The Koshi river basin in the Nepalese lowlands plays a vital role and constitutes one of the principal sources of fish. The study concerning fish fauna in Koshi basin is meager. Rajbanshi (these proceedings) listed 75 species for the Koshi River. The author, as per interviews through questionnaires and discussions with fishermen at different fishing sites, mallaha’s village, vendors and the fish sellers, found 93 species.

3.3.1 Fishing methods

Fishing in the Koshi River changes with the season and the location. It is very diffused. Most of the fishermen use a small wooden canoe. Canoes made of sal wood last longer than those made of siso wood. Most fishermen use canoe and cast net while the use of canoe and drag net is the second most common method.

A number of fishing devices are used. These are: cast nets, gill nets, lift nets, and various other nets with indigenous names, such as tunny jal, chatti jal, chauki or chanki jal, sohat, hapa, different types of traps, baskets, rod and line. Poisoning , bombing and hand picking are frequent.

One of the several traditional methods is the use of extracts from local plants as fish poison. In the Koshi basin in lakes, swamps, streams and oxbows the plants *Agave americana*, *Sapium insinge*, *Dioscorea deltoidea*, *Euphorbia voyelana* are, as reported by the fishermen, commonly used.

3.3.2 Catch per unit of area and catch records

Catch statistics from the Koshi River are based on interviews with fishermen and personal observations. Due to the difficulties of collecting data from fishermen who operate from many sites along the river the catch per unit area is computed by taking a total average weight of the catch per fisherman, from which the catch per unit area is calculated. The effort made by the craft used, tackle and fishermen population in the entire region was considered as uniform. The illiteracy and social backwardness of the fishermen community also greatly hampered the collection of the data. The catch per unit area is estimated as 1.14 kg/ha/day in the Koshi River (1.2 km times 4 km) while in the other water bodies it is 3 kg/ha/day.

3.3.3 Fisher community

The fishermen community is commonly understood as a group fishing in some area and engaged in more or less the same pattern of fishing (Biswas, 1996). In such a community, fishermen often mutually assist each other, not only in fishing, but also in social functions such as marriage ceremonies and village festivals. The river basin is rich in cultural heritage with various ethnic groups, predominantly Yadav, Muslim, Brahmin, Chhetri and other castes of low profile. Fishermen community, also called Mallah, Godhi, Mukhiya, Bahardhar, Bin, etc., are the poorest among the poor and scattered.

During the visit, the random sampling was done in the traditional villages. There are four main villages of fishermen in Sunsari District and six in Saptari District (Table 3). The total population was estimated to be 2937 in 484 households in all ten villages, of which 445 households are solely dependent on the fishing while the rest of the families have switched from the traditional occupation to agriculture, rickshaw pulling, working as carpenters and field labourers. 133 families other than traditional fishermen, especially Muslims, have been found to be attracted to the fishing .

The fishermen communities in all ten villages of the Koshi basin have similar social structures, with minor variations in the caste titles and living styles. All of them depend basically on the capture fishery. The socio-economic status of the fishermen communities is the lowest in the society. Eighty-six percent of families of the fishermen were of nuclear type and 75% of families had 5-10 members. Age distribution data show that the economically active group represents only 29% and they support the rest of the family members by fishing. Even if those in the 11-20 year-old age group, who are considered dependent, is taken into consideration, 52% of the population has to support the rest. The high population growth rate in this society is associated with the lack of awareness of family planning. Family planning activity is related to educational status and in the fishermen communities 61% of the population is illiterate while only 3% had the School Leaving Certificate. The most striking situation in the communities was the land holding capacity, a prestige symbol in Nepalese society. Forty-six % of families were found to be landless while 54% of the population owned less than 0.2 ha of land. Eighty-nine % of fishermen owned only traditional fishing nets and gears and 43%, 38% and 14% fishermen had bicycle, radio and television, respectively. No cattle were owned by 43% of respondents while only 39% owned a goat and 18% owned cows. Ninety-three % of respondents earned less than NRs. 5 000 per annum and 7% NRs. 5 000 - 10 000.

From the socio-cultural point of view they are maintaining the same social activities as their ancestors, but every activity is firmly connected with the river and catch. Illiteracy, high population growth, low risk bearing capacity and unskilled youth in the community bind them to go on with their traditional occupation even if it is no longer beneficial.

Table 3
Fishermen population in different VDCs of Koshi basin

Sn.	V.D.C.	Total no. of households	Total no. of population	Family size	Fishing households	Population in other jobs	Fishing population from other castes
Dist.	Sunsari						
1.	Mahendra Nagar	6	40	7	6	-	-
2.	Madhuban	50	385	9	45	5	10
3.	Kushaha	15	125	8	12	3	15
4.	Haaripur	70	500	7	60	10	50
Dist.	Saptari						
5.	Hanuman Nagar	70	250	4	68	6	3
6.	Bhardhaha	40	300	8	39	30	55
7.	Jagatpur	26	147	6	25	2	-
8.	Kamalpur	50	355	7	45	5	-
9.	Odaraha	85	460	5	85	-	-
10.	Pipara purba	72	375	5	60	15	-
11.	Total	484	2 937	6	445	76	133

3.3.4 Fishery resources

Through interviews and discussions with fishermen it appears that the fish stocks in the Koshi River have decreased considerably. Some species have become rare while others have disappeared. The reasons are: overfishing, high population pressure along the river banks, entry of other castes into fishery, use of improper and illegal fishing gears and methods, heavy floods and siltation, habitat degradation, erosion, impact of the Koshi barrage, degradation of environment. Some of these factors have disturbed or damaged the fish habitats, especially spawning and nursery grounds. Monitoring of the average catch per month of some commonly found species for three months showed that *Garra gotyla* and *Labeo boga* represented the first and the second most common fish captured during winter. The fishermen reported that after rains the catch composition changes and *Cirrhinus reba* and *Labeo rohita* become the major catch. With commencement of the rain fish migrate upstream for breeding and the spawn drifts with the water current downstream where there is richer planktonic food. Once the rain is over, the juveniles migrate upstream in large groups and this lasts for about a month. Thus the fish movement in the river system is a continuous process and fishing is changing with time and seasons. Consequently, broodstock and juveniles are also targeted.

3.3.5 Human intervention

The high growth rate of human population has resulted in immigration and settling of more people in the area. The alluvial fertile soil along the river has attracted people as well. During the last two decades the water of the Koshi River has been subjected to a wide range of stress factors caused by human activities directly or indirectly. Indiscriminate deforestation, dams and water diversion for irrigation, improper fishing practices, disposals of city effluents and use of chemicals for different purposes, with residues ending in rivers, have had a damaging impact on the river fish. Siltation has resulted from deforestation and conversion of forest land into agriculture land. Road construction, especially on steep slopes, has also caused soil erosion in the monsoon period. Lakes and swamps receiving river water loaded with sediments are silting over.

3.3.6 Dams and reservoirs

There is only one dam on the Koshi River, which was constructed at the Indo-Nepalese border. It has a fish ladder which is known to be inefficient for migratory fish. The reservoir has been undergoing sedimentation, and deep layers of sediment are exposed by seasonal drawdown.

4. RECOMMENDATIONS

The Koshi River is a unique ecological zone from the point of view of biological importance. It has a large and varied topographical diversity which harbors unique fish fauna. To preserve it and to use it in a rational way the following activities are proposed:

- detailed survey of the fish fauna in the catchment water bodies with the purpose of updating the knowledge about the basin,
- immediate ban on deforestation, sand and boulder removal from the river bed, on illegal settlements along river banks and on other activities damaging the riverine ecology,
- reforestation of steep slopes in the catchment in order to arrest the land erosion.

The government, NGO, INGO should take over the responsibilities for improving the social status of the fishermen communities by uniting them in groups or cooperatives, and providing them with informal education through training with special reference to fish and riverine fisheries in order to develop and conserve this precious natural resource. Area-based riverine fishery development projects should be started. These projects should integrate the whole fishery system including extension, training, research and marketing. Development of fisheries in wetlands through public as well as private interests, using community mobilization, would help to establish a buffer zone between the conservation and agriculture lands and prevent interaction between wild animals and people. The programme should be initiated with a proper model by the government to demonstrate its feasibility to the community.

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PRODUCTION AND CULTURE OF TROUT IN THE NORTH WEST FRONTIER PROVINCE AND NORTHERN AREAS OF PAKISTAN. A REVIEW

by

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ABSTRACT

The paper gives the history of the introductions of brown trout and culture of rainbow trout in North West Frontier Province and Northern Areas of Pakistan. There are 738 km of rivers with trout, 8 state run hatcheries, 18 private hatcheries and 28 private trout farms, the estimated production of which is 162 120 tons per year.

1. INTRODUCTION

Pakistan is a country of a great variety of landscapes and environmental conditions. This variety of habitats is especially remarkable in the North West Frontier Province (NWFP). In addition, there is a critical constrast between winter and summer seasons. The rivers and streams are deep or shallow, clear or muddy, cold or warm, fast or slow and may have stony, sandy or muddy bottom and rich or scanty vegetation along the banks. Suitable species were designed by nature itself for this region (Butt, 1994).

The trout fishery of Pakistan prevails particularly in the NWFP and Northern Areas, where two species of trout, though exotic in origin, have established themselves in rivers of this province. They are brown trout (*Salmo trutta*) and rainbow trout (O*ncorhynchus mykiss*).

2. BROWN TROUT (*Salmo trutta*)

The species was introduced in Gilgit from Europe by political officers in 1916. It has large scales, thickly spotted dark and red spots on the sides. The body is short but stout, suitable altitude for its culture is about 1 000 m above sea level. The fish becomes adult after two years and breeds in natural waters. In hatcheries it can be made to spawn by stripping which is quite successful. Its fecundity is about 1 500 eggs. Due to low temperature, its incubation period extends from 40 to 70 days. In Saif-ul-Maluk Lake (Kaghan Valley) the fish has reached 7 kg. Trout is a tasty fish, sometimes considered a delicacy. It is also a game fish caught with zeal by anglers. It usually reaches a total length of about 45 cm. Being carnivorous, the fish feeds upon a variety of aquatic animals including small fish (Ahmad and Niazi, 1988).

The major districts in federally administered Northern Areas are Gilgit and Skardu. The major fishery of this area is brown trout. It was introduced there in 1908. Now it is established, mainly supporting sport fishing (Lone, 1983). According to Hussain (1965), trout in Gilgit was first introduced in 1916 and has been established there since then. In 1963 more eyed ova were introduced from the Shinu hatchery, Kagan Valley, hatched and also established a fish stock.

Trout culture began in NWFP in 1928, when brown trout was first brought from Kashmir and kept in a nursery tank in the Shinu hatchery. In 1930 it was introduced in Swat and Chitral by

H.R. Hay, Political Agent, Malakand, and by Captain B. Woods Ballard, Assistant Political Agent, Chitral, respectively, but did not succeed as the total stock died. Later some efforts were made again in both areas but could not achieve the objectives. Thereafter the matter was dropped for seven years. In 1946 Maj. B. H. Cobb, Political Agent, Gilgit, initiated more introductions with about 120 adult brown trout stocked directly in the Lutkoh River, Chitral. They self-reproduced and established a good population. At present this valley is unique for trout angling. Introductions elsewhere, including Swat, were unsuccessful. Interest in trout was revived in 1960 when a fully fledged project was approved and implemented by the Fisheries Department of the NWFP. In 1961, a trout hatchery was constructed at Madyan, Swat, and trout were imported from Kaghan. The first breeding was conducted in January 1962 and the resultant fry were stocked in the upper reaches of the Swat River, which proved successful (Naveed, 1994).

There are brown trout hatcheries at Hosho, Kargah and Chilas in Gilgit and Skardu areas.

3. RAINBOW TROUT (*Oncorhynchus mykiss*)

Rearing of this fish is easier than that of brown trout. It can tolerate a higher water temperature, is less carnivorous and grows faster. Its hatching time is 33 days (Hussain, 1994). It sometimes escapes from culture and enters open waters (Hussain, 1997). Rainbow trout was first introduced in NWFP during 1928 (ADB, 1984).

In view of the great potential for further increase of trout culture, a consignment of 20 000 eyed ova of rainbow trout were imported from Japan in 1973. Later on during 1984-85 and 1986, 500 000 eggs of the Kamloop strain of rainbow trout were imported from the USA under the Pakistan Aquaculture Development trout farming project in NWFP. Most of the resultant fry were kept in the raceways for growing to table size and some of these were restocked in various water bodies. This built a sustained population in the rivers, streams and lakes of the northern districts (Naveed, 1994). The resources and trout hatcheries/farms in NWFP and Northern Areas are presented in Tables 1-3.

Table 1
Extent of water bodies with trout in the NWFP (Naveed, 1994)

	Length of rivers (km)	Number of lakes
Hazara (Kaghan Valley)	248	3
Swat (Upper Valley)	180	4
Dir (Dir Kohistan)	120	2
Chitral (Upper Valley)	190	-

Table 2
Trout hatcheries in the NWFP **(Naveed, 1994)**

Name of hatchery	Production capacity in million
*Shinu (Mansehra)	0.300
Madyan (Swat)	0.600
*Alpuri (Swat)	0.050
Dubair (Kohistan)	0.100
**Kalkot (Dir)	0.100
Jaghoor (Chitral)	0.120
Bombret (Chitral)	0.130
Alai (Batgram)	0.100
Total	**1.500**

* Under reconstruction
** Needs renovation

Table 3
Private trout farms/hatcheries (Brief on Fisheries, NWFP)

District	Number of farms	Number of hatcheries	Estimated production (kg)
Chitral	9	2	58 190
Kaghan	2	-	36 000
Kohistan	2	-	6 630
Swat	15	8	60 300
Total	28	10	162 120

Small trout are fed liver, ground to very fine particles, and also chicken eggs made into a thin paste using the yolk. A trout feed is being used for trout culture at NWFP trout hatcheries. The feed formula is given in Table 4.

4. IMPACT OF TROUT FISHERY

Trout fishing is not only a part of the integrated development strategy of northern districts of NWFP but is also an essential source of recreation in these areas. Trout fishery as a sport has contributed a lot to the economy of local communities in the northern districts through the tourist trade. Direct and indirect economic benefits are accrued from trout fishing by tourists in Kaghan, Swat and Chitral and the number of anglers is steadily increasing.. Consequently the local residents directly benefit and their income is increasing (Table 5).

Table 4
Typical formula for trout feed (Naveed, 1994)

Ingredients	Percentage
Fish meal	45
Wheat flour	20
Corn gluten meal	10
Brewers yeast (dried)	5
Meat meal	10
Vitamin premixed (animal)	0.4
Vitamin stress (animal)	0.075
Vitamin C	0.075
Dry skimmed milk (non fat)	5
Bone meal	1.45
Soybean oil	3

Table 5
Revenue from trout (in Pakistan Rupies) (Brief on Fisheries, NWFP)

	1998-99	1999-2000
Sale of fish seed	59 500	100 976
Sale of fish	406 294	405 150
Licences	133 100	126 769
Comp. fee	8 260	20 925

5. TROUT IN QUETTA

Trout was introduced to Quetta from Kaghan in 1953. Since then the nearby Karez reservoir and other waters have been regularly stocked with fry and fingerling obtained from the local hatchery at Urruk. It has been suggested to introduce trout culture in Ziarat Valley.

6. RECOMMENDATIONS

Based upon the observation made at the Madyan Trout Hatchery, Swat, rainbow trout have a better potential than brown trout. It is better growing, tolerates crowding and water temperature fluctuations well.

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Section 4: Associated topics

FISHERIES IN TRANS-HIMALAYAN REGION: PROSPECTS FOR FISH CULTURE IN HILL DISTRICTS OF BANGLADESH

by

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ABSTRACT

The hills of Bangladesh contain a number of rivers and streams, and also a large reservoir called Kaptai lake. Kaptai lake fish stocks have been overexploited and require serious management effort through stocking and introduction of aquaculture in cages and pens in order to fully utilize the lake fishery potential. Nevertheless, the presence of Kaptai lake has resulted in an increase in per caput fish consumption by the hill people, although much of the fish catch is still delivered to distant markets. Further potential for increasing fish production is offered by streams and rivers where cage culture could be introduced. In the mid-1990s a project “Fish Culture Development (in hills) and Extension” created 11.5 ha of nursery ponds and 92 ha of other water bodies by modifications of creek flows and construction of small dams, and these were brought under fish culture. Training of farmers in aquaculture and fish farmer refresher courses were given special attention under this project. The only cold water fish species now present in Bangladesh is mahseer (*Tor putitora*) which has been introduced from Nepal.

1. INTRODUCTION

While geographically Bangladesh lies at the foot of the Himalayas, most of her territory belongs to floodplains formed by silt carried down by the Himalayan rivers. Bangladesh is the biggest delta of the world. Her geology, climate, flora and fauna are greatly influenced by the Himalayas. The great mountains shield the country from northern cold and winds, help monsoon precipitation and provide snow-melt flow in her rivers during dry season. Yet, Bangladesh indeed is very different from the Trans-Himalayan region geologically, geographically, climatically and in biodiversity. More than 90% of her territory consists of floodplains which are elevated only a few meters above the sea level. It is feared that due to the greenhouse effect leading to melting of ice at the poles and peaks of high mountains such as Himalayas, a large part of Bangladesh may become submerged by sea water. Due to the shortage of hills and absence of high mountains, Bangladesh has no true cold waters. During the coldest period of time the temperature seldom drops below 15°C. Only very few fish species such as mahseer can be considered to have affinity to cold waters. Bangladesh imported mahseer from Nepal several years ago and they are doing fine under Bangladesh conditions both for seed production in hatcheries and grow-out as food fish in farms.

Bangladesh is a rice and fish eating nation. The main source of her animal protein comes from aquatic sources, mainly from fish and crustaceans. With the expansion of population and the increasing needs for more cereal-based foods, high yielding varieties of rice production have been promoted since the 1960s. This has successfully raised food grain production and made Bangladesh self-sufficient in carbohydrate based foods but at the same time it has led to a serious decline in wild fish production from open inland waters due to irrigation use of water, pesticides and fertilizers.

2. FISH AND FISHERIES

Biodiversity of aquatic animals including fish in open inland water bodies is threatened and several indigenous fish species are either extinct or are on the verge of extinction. A list of the threatened riverine and floodplain species of fish in Bangladesh is given in Table 1.

Table 1
List of threatened riverine and floodplain species of fish in Bangladesh

Species group	Species	Local name
Carp	*Labeo gonius*	Ghainna, Kurchi
	Labeo nandina	Nandina, Nandil
	Cirrhinus reba	Bhangna, Bata
	Puntius sarana	Sarpunti
	Tor tor	Mohashol,
	Tor putitora	Mohashol,
Catfish	*Pangasius pangasius*	Pangash
	Mystus cavasius	Golsha tengra
	Batasio tengara	Tengra
	Ompok pabda	Madhu pabda
	Ompok bimaculatus	Boali pabda
	Ailia colla	Baspata
	Ailichthys punctata	Kajuli
	Pseudeutropius atherinoides	Batushi
Loach	*Botia dario*	Rani
	Lepidocephalus gontea	Gutum
Spiny eel	*Macrognathus aculeatus*	Tara baim
	Mastacambelus pancalus	Chirka
Whiting	*Nandus nandus*	Meni, Bheda
	Badis badis	Napit
Gurami	*Colisha faciatus*	Khalisha
	Colisha lalius	Lal khalisha
Glass perch	*Chanda nama*	Nama chanda
	Chanda ranga	Lal chanda
Mullet	*Rhinomugil corsula*	Khalla

To increase fish production through aquaculture and to improve livelihood of the rural population several exotic fish species have been imported to Bangladesh since the 1950s. Among them tilapia was not initially appreciated but is now gaining popularity as a culture species among the rural people. Exotic fish species introduced to Bangladesh for the last five decades are listed in Table 2.

Table 2
Freshwater fish introduced to Bangladesh during 1950-2000

Species group	Common name	Species	From where introduced and when
Carp	Common carp	*Cyprinus carpio* var. communis	China (1960) Vietnam (1995)
	Grass carp	*Ctenopharyngodon idella*	Hongkong (1966) Nepal (1974), Japan(1970)
	Silver carp	*Hypophthalmichthys molitrix*	Hongkong (1969)
	Bighead carp	*Aristichthys nobilis*	Nepal (1981)
	Mirror carp	*C. carpio* var. specularis	Nepal (1974) Hungary (1996)
	Black carp	*Mylopharyngodon piceus*	China (1983)
	Gold fish	*Cyprinus carpio* *Tor putitora*	Hongkong (1966) Nepal (1991)
	Silver barb	*Barbodes gonionotus*	Thailand (1987)
Gurami	Gurami	*Trichogaster pectoralis*	Thailand (1995)
Catfish	African catfish Pangash	*Clarias gariepinus* *Pangasius sutchi*	Thailand (1988) Thailand (1985)
Tilapia (cichlids)	Tilapia	*Oreochromis mossambicus*	Thailand (1954)
	Nilotica	*O. niloticus*	Thailand (1974,1986)
	Red strain of tilapia	Mutant of O.*niloticus x O. mossambicus*	Thailand (1988)
	GIFT	Genetically Improved Farmed Tilapia	Philippines (1994)

Some of the imported fish species are well adapted ecologically under local conditions and can be seen in fish markets. Among those common carp, pangash, tilapia, silver carp, grass carp, silver barb, mirror carp and bighead carp are an important component of marketed fish. However, it is still open to discussion whether all those exotic species were actually needed. Some of the imported species have been replacing some of the indigenous species from their natural habitats. It was found that polyculture of silver carp with Indian major carps seriously hampers the normal growth of catla (C*atla catla*), although catla is known as a very fast growing fish in Bangladesh and fetches a relatively high market price.

Traditionally a big segment of freshwater fish catch in Bangladesh used to come from open freshwaters. However, destruction of natural fish habitat, overfishing, environmental degradation, lack of proper management have led to a decline in catches. To some extent the loss is being compensated by the production from the growing aquaculture. This requires supplemental feeding and fertilization, and fish culture with low-cost carbohydrate-based supplemental feeding is gaining popularity in the country. The only exceptions are the Thai and African catfish which need animal protein rich diets. Due to the fast growth and high market price of the the Thai catfish, its culture is booming in rural areas. African catfish introduced to Bangladesh during 1987-88 has already earned a bad name and thus is banned, but it has already entered the ecosystem and will be difficult to eradicate as the species can breed naturally in closed and open water bodies. While aquaculture in plains of Bangladesh is expanding, the three hill districts and some parts of the northern and north-eastern hilly areas have not yet developed culture-based fisheries.

The three districts of Bangladesh lie in the south-eastern part of the country adjacent to the Indian hilly states and Myanmar. This area is inhabited by ethnic minorities. The northern tip of this area starts from the Indian state of Tripura and extends southward to the Bay of Bengal. Four rivers, i.e. Feni, Karnaphuli, Shangu and Matamuhori, and their tributaries carry water from hills to the Bay of Bengal. These rivers also created four valleys. Hill dwellers of Bangladesh produce part of their own food through shifting agriculture. They have not yet started fish culture. The biggest man-made closed water body in Bangladesh, Kaptai lake (reservoir), is situated in Rangamati, one of the hill districts. In 1961 a hydroelectric dam was constructed which created Kaptai lake which covers 68 000 ha during monsoon, and 58 000 ha during the dry season. The annual catch amounts to approximately 5-6 thousand tons. But the fish captured from this reservoir are not consumed locally, as most of it goes to big cities. Before the construction of the reservoir the *per caput* fish consumption in the area was far less compared to the present situation. Still, the *per caput* fish consumption in the hill districts is lower than in the rest of the country. Kaptai lake fishery is managed by the Bangladesh Fisheries Development Corporation (BFDC). The reservoir suffers from overfishing, and stocking the lake by BFDC has not resulted in an increase in fish production due to the lack of enforcement of fishing regulations.

Fish culture in Kaptai lake as well as in other waters of the three hill districts has good prospects. There are many creeks, where with little modification in their natural flow pen and cage culture could be introduced. In the valleys there are many small ponds and impoundments which could be used for aquaculture. During the mid 1990s the Government of Bangladesh encouraged aquaculture in creeks, ponds and lakes of the hill districts. Under the project named “Fish Culture Development (in hills) and Extension” 11.5 ha of nursery ponds and 92 ha of other water bodies were created by modifications of creek flows and construction of small dams, and these were brought under fish culture. Training of farmers in aquaculture and fish farmers refresher courses were given special attention under this project.

The Department of Fisheries of Bangladesh is trying to modernize fish culture activities in hill districts and provides extension. The Bangladesh Fisheries Research Institute is trying to develop cage and pen culture in Kaptai lake and hilly creeks. Low-cost feed development for cage culture is also an aim of the Institute. The Bangladesh Fisheries Development Corporation is trying to improve overall production of fish from Kaptai lake by selective stocking of Indian major carps. However, community participation is needed for the success of the stocking programme. Integrated farming of fish-cum-poultry, fish-cattle-poultry or fish-livestock-agriculture has good prospects in hill districts. Self-employment of hill people through integrated farming will not only improve economic conditions of hill dwellers but will also improve their nutrition

Table 3
List of indigenous fish and shrimps present in hill districts, including Kaptai Lake, Bangladesh

Group	Species
Synbranchidae	*Monopterus cuchia*
Tetradontidae	*Tetradon cutcutia*
Belonidae	*Xenentodon cancila*
Hemirhamphidae	*Dermogensis pussilus*
Cyprinodontidae	*Aplocheilus punchax*
Channidae	*Channa striatus, C. punctatus, C. marulius, C. orientalis*
Cyprinidae	*Salmostoma phulo, S. bacaila, Esomus danricus, Amblypharyngodon mola, Rohtee cotio, Labeo calbasu, L. rohita, L. gonius, L. bata, L. angra, Cirrhinus mrigala, C. reba, Puntius sophore, P. ticto, Aspidoparia jaya, A. morar, Danio sondhii, Crossocheilus latius, Puntius jelus, P. chola, P. conchonius*
Cobitidae	*Lepidocephalus guntea, Nemacheilus zonanternas*
Clariidae	*Clarias batrachus*
Siluridae	*Wallago attu, Ompok bimaculatus*
Heteropneustidae	*Heteropneustes fossilis*
Schilbeidae	*Ailia coilia, Pseudeutropius atherinoides, Eutropiichthys vacha*
Bagridae	*Mystus aor, M. cavasius, M. bleekeri, M. vittatus, Batasio tengana*
Sisoridae	*Gagata youssoufi*
Notopteridae	*Notopterus chitala, N. notopterus*
Engraulidae	*Setipinna phasa*
Clupeidae	*Gudusia chapra, Corica soborna, Gonialosa manminna*
Mastacembelidae	*Macrognathus aculeatus, Mastacembelus armatus, M. pancalus*
Mugilidae	*Rhinomugil corsula*
Anabantidae	*Colisa lalius, C. fasciatus, Anabas testudineus*
Gobidae	*Glossogobius giuris*
Nandidae	*Nandus nandus*
Pristolepidae	*Badis badis*
Sciaenidae	*Johnius coitor*
Centropomidae	*Chanda ranga, C. nama, C. baculis, C. lala*
Shrimps	*Macrobrachium rosenbergii* *M. lamarri*

A list of indigenous fish for the hill districts, and especially for the Kaptai lake (Table 3), includes 66 indigenous species of fish and two species of shrimps. Besides these indigenous species some of the exotic fish species introduced to Bangladesh entered the hill districts. These are common carp, Thai silver barb, grass carp, Thai catfish, African catfish, tilapia and GIFT.

Not all fish and shrimp species listed in Table 3 are commercially exploitable, nor does each one have a good aquaculture prospect. Based on the present status and past performance, some culturable fish/shrimp in hilly areas are listed in Table 4.

Table 4
Culturable fish and shrimp in hill districts

Fish group/shrimp	Culture potential		
	Pond	Cage	Pen
Indian major carps	✓	-	✓
Exotic carps	✓	-	✓
Silver barb	✓	-	✓
Thai catfish	✓	✓	✓
Tilapia	✓	✓	✓
African catfish	-	✓	✓
GIFT	✓	✓	✓
Freshwater giant shrimp	✓	✓	✓

Integrated natural resource management is a prerequisite for improving the quality of human life both on plains and in hills. The Chittagong Hill Tracts Region Development plan, submitted for ADB financing, is a right step towards the said goal. The project has components to improve the nutritional standard of hill people through increased fish production by open water management, pen and cage culture. The rivers and creeks of hill tracts of Bangladesh are good sites for aquatic biodiversity and natural spawning ground for some important commercial aquatic species. Selected fast growing species with low-cost diet may dramatically increase production of fish from Kaptai lake through pen and cage culture. Supplemental feed used in cages will indirectly help increase fertility of lake water. Pen culture and cage aquaculture can be extended to other hilly rivers and creeks of hill tracts. Cage and pen material production using local resources may be encouraged to lower the cost. Recreational sport fishing in Kaptai lake related to expanding tourism industry may be encouraged to develop facilities which will generate income for local people.

AQUACULTURE IN BANGLADESH: PROSPECT OF HIGH DENSITY MIXED CULTURE OF FISH WITH LOW COST DIETS

by

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ABSTRACT

To find out the maximum production potential of pond based aquaculture using low-cost diets on mono and mixed culture of three selected species experiments were conducted for a period of 18 months. Nine miniponds were used for monoculture of catfish (*Pangasius sutchi*), silver barb, (*Barbodes gonionotus*) and Genetically Improved Farmed Tilapia (GIFT), with three replications. Three other miniponds were used for mixed culture of the three above-mentioned fish. Initially, specific numbers of fish were stocked in miniponds and daily a mixture of low-cost supplemental feeds were applied to each group of ponds. Production of natural food in the investigated ponds was promoted to minimize supplemental feeding. Partial harvests of both stocked fish and newly produced ones were done periodically. Low-cost feed included pellets, mustard oil cake, wheat bran and rice bran with the same proportions (25%) for each trial. For the whole period of culture 1.5 m depth and deep green water colour were maintained by occasional intake or discharge of water and periodic fertilization. Two groups of fish, silver barb and GIFT, produced numerous new individuals both in mono and mixed culture. Cumulative total fish biomass production in each trial varied from 16.1 to 31.6 tons/ha with a feed conversion rate of 20.1 to 24.4% within the investigated period of 18 months. However, the projected feed conversion rate for a 12-month period was 31.0 to 50.4%. A huge cumulative amount of supplementary feed utilization (57.1 - 134.4 tons/ha/18 months) and high level of both plankton and fish biomass occasionally lowered the dissolved oxygen level to 0.7 mg/L but caused no fish mortality. So-called black soil formation at pond bottom was also minimal. The high level of fish biomass production resulted from the round-the-year equal water depth, presence of copious green algae, no fish mortality, negligible deoxygenation of the sediment resulting from the continuous stirring up of sediments by fish, and the ability of all three fish species to gulp air at the surface when the dissolved oxygen concentration declined.

1. INTRODUCTION

Tilapia (*Oreochromis mossambicus*) was introduced to Bangladesh from Thailand in 1954 (Rahman, 1985). It was expected at that time that tilapia would act as a miracle fish in aquaculture. While tilapias breed several times a year and depend mostly on vegetative food, their distribution and culture among rural farmers has not been as popular as expected. Gradually, nilotica (*O. niloticus) and* red tilapia (a mutant of *O. niloticus* x *O. mossambicus)* were imported to Bangladesh from Thailand (Gupta *et al*., 1992). Genetically Improved Farmed Tilapia strain known as GIFT (Eknath *et al*., 1993) was introduced to Bangladesh by ICLARM and BFRI during 1994. GIFT has now become a popular fish among farmers. Likewise, Thai silver barb (*Barbodes gonionotus*) and catfish (*Pangasius sutchi*) entered Bangladesh during 1985 and 1988, respectively, and soon became popular aquaculture species.

Seed production of these three species is easy. GIFT and silver barb naturally breed in closed water bodies. Seasonal water fluctuation in culture ponds due to seepage, and evaporation and turbidity during culture time is a problem in pond-based aquaculture. In view of the 21st century perspective, a minipond complex was constructed at the Marine Fisheries and Technology Station (MFTS), Cox's Bazar on sandy soils using concrete walls and polythene bottom laying (Hossain *et al*., 1994). The structural design made it possible to maintain water depth to a desirable level the year round and effectively stopped seepage and turbidity problems. Once water level and turbidity level stabilized natural productivity of the ponds dramatically improved and it is now possible to maintain rich phytoplankton for a long time with little initial fertilization.

Experimentally, mass production of both tilapia and GIFT as live food for sea bass showed very high rate of biomass production in miniponds with low-cost diets. Similarly, silver barb and Thai catfish production in those miniponds also showed a fairly high rate of biomass production (Hossain *et al*., 1999).

Next, an attempt was made to find out maximum production of these species individually and collectively using low-cost diets under pond-based aquaculture. Attention was focused on maximum utilization of natural productivity, and a low level of supplemental feeds was applied. The experiment was conducted for a period of 18 months and arrangements were made to discard or add water when necessary.

Twelve miniponds, each having identical size (200 m^2), depth (1.6 m) and standard bottom conditions (30 cm sand layer on polythene) were used. Three fish species were reared on a monoculture basis in different groups and a mixed culture using all three species in another group. To simplify management, a certain amount of daily supplemental feeds was allotted for each group for a 2-month period. Cummulative harvesting followed and at the end of the experiment, ponds were drained and harvested.

2. MATERIAL AND METHODS

Miniponds

12 miniponds out of 42 at MFTS were used. As mentioned earlier these ponds were identical in size, and constructed on totally sandy soil. Pond bottoms were level, underlaid by polythene. On polythene, a 30 cm layer of sand was deposited. Length, width and height of the miniponds were 25.0, 8.0 and 1.6 m, respectively. Water holding capacity of each minipond was roughly 320 tons. Each minipond was exactly $1/50^{th}$ of a hectare. The 12 ponds were divided into 4 groups of 3 ponds each.

Pond preparation

Before starting the experiment all ponds were drained, the bottom dried and sand agitated. Calcium carbonate at a rate of 5 kg/pond (250 kg/ha) was mixed with bottom soil. Then the ponds were filled with ground water, and the water was fertilized with urea, TSP and potash at a rate of 1.0, 1.5 and 0.5 kg/pond, respectively (50, 75 and 25 kg/ha). Initially, some green water was pumped from the nearby ponds to each of the experimental ponds with the help of a submergible pump. When water turned deep green, fish were stocked.

Fish

Three species were used. GIFT juveniles were produced at the Freshwater Station of the BFRI with joint collaboration of ICLARM, who delivered them to the MFTS in 1996. Several successive generations were produced at MFTS. Adult fish of 80-100 g were used in the experiment. Each of three ponds were stocked with 100 GIFT. Silver barb juveniles raised to adult stage at MFTS were also used. 100 silver barb with a body weight range of 100-150g were stocked in each pond of a group. Similarly, catfish raised to 350-400 g using high density culture, were used in another group at a rate of 100 fish/pond. The remaining of 3 ponds were each stocked with a mixture of the 3 species (a total of 100 fish in each pond). All fish were stocked at the beginning of April, 1999. Stocking particulars are shown in Table 1.

Table 1
Details on stocking each pond of a group

	Monoculture			**Mixed culture**		
	Silver barb	**GIFT**	**Catfish**	**Silver barb**	**GIFT**	**Catfish**
No. of fish	100	100	100	100	100	100
Av. wt. of fish (g)	119.5	91.2	368.0	115.2	85.3	361.0
Male/female ratio	40:60	50:50	-	40:60	50:50	-
Water transparency (cm)	21	22	21	20	22	23
Total fish biomass (kg)	11.95	9.12	36.8	11.52	8.53	36.1

Feed

Four types of feeds were mixed together for each pond. The mixture consisted of commercial pellets (Saudi-Bangla Fish Feed Ltd.), mustard oil cake, rice bran and wheat bran. The feeds were mixed together for a couple of days, and divided into 12 parts and stored in medium plastic containers for each pond. In the container the feeds were dry, but before application to ponds a portion of water was mixed to give it a semi-solid form. Fish in ponds were fed twice daily.

Feed ration

To minimize the use of supplemental feeding and to encourage fish to depend on natural foods produced in the ponds, a strict feed ration was followed as shown in Table 2. The feed ration was modified for each two-month period and the daily ration was strictly maintained to avoid management problems.

Rearing

The culture continued for an 18-month period. Care was taken to maintain identical water level in each pond through inspections. This was ensured by pumping ground water through a pipeline network when the water level went down. During rains, excess water was automatically discarded through piped outlets connected to a drain. Outlets were guarded by nets to prevent fish from escaping. After stocking of fish, a current was occasionally produced in the ponds having silver barb to induce them to breed in captivity. For this purpose water was pumped and a part of it was then discarded from the ponds through outlets. Twice a day, a fixed amount of supplemental feed was provided to each group as shown in Table 2. Identical amount of feed was supplied in each pond of a group. Water quality parameters, such as temperature, transparency, pH, and dissolved oxygen levels in ponds, were recorded from time to time. Whenever transparency of water rose above 25 cm, water was fertilized by urea and TSP (50% of the initial dose given during the pond preparation).

Table 2
Feed ration given to each pond of a group (kg/day)

Period in months	Monoculture			Mixed culture
	Silver barb	GIFT	Catfish	
0-2	0.5	0.5	1.0	2.0
2-4	1.0	1.0	1.5	3.0
4-6	1.0	2.0	2.0	4.0
6-8	1.5	3.0	2.5	4.5
8-10	2.0	3.5	3.0	5.0
10-12	2.5	4.0	3.5	5.5
12-14	3.0	4.5	4.0	6.0
14-16	3.5	5.0	4.5	7.0
16-18	4.0	6.0	5.0	7.5
0-18 Total (kg)	1 142.0	1 773.0	1 624.0	2 688.0

Water quality analysis

Temperature was recorded by ordinary thermometer, pH by digital pH meter, water transparency by Secchi disc and DO by Hach kit. After 10-11 months of rearing, when the biomass of fish increased rapidly, DO was measured more frequently in the early mornings.

Non-target fish

Ponds designated for silver barb or catfish were invaded by GIFT, which were periodically harvested using seine net. Total weight of non-target fish harvested from each pond was recorded separately. Harvested fingerlings were weighed and their numbers were estimated. To get rid of non-target fish from ponds, dry feed particles were scattered to lure the fish to the surface and the fish were harvested into a fine mesh seine net.

Harvesting

Cumulative harvesting was done in 3 groups of ponds where numerous fry were found. Fingerlings and fry, specially those of GIFT and silver barb, were harvested 3-12 months after stocking. After 12 months there was no selective harvesting. The final harvest was done at the end of the 18-month period. Catfish were partially harvested at the end of 12 months both in mono and mixed culture groups. In mixed culture groups 25% of catfish were harvested before the final harvest. At the end of the experiment, all ponds were drained and all fish harvested. Fish harvested from each pond during the culture period or at the end of the experiment were recorded separately after weighing. To estimate the projected fish biomass in each pond of a group within a 12-month period, fish harvested from July 1999 to March 2000 were recorded and no further harvest during 13-18 months was done (Table 3). The projected figure includes actual harvest till the 12^{th} month and an estimated quantity of fish remaining in each pond thereafter. Projected production/year is presented in Table 6.

Table 3
Cumulative harvest of fish from each pond of a group (average)

	Monoculture			Mixed culture		
	Silver barb	**GIFT**	**Catfish**	**Silver barb**	**GIFT**	**Catfish**
Selective harvest a. No of f ry	27500	58000	-	8900	31500	-
b. Wt. of fry (kg)	12.4	29.0	-	4.6	15.8	-
c. Wt. of juveniles (kg)	78.5*	118.7	62.7*	38.7	71.2	-
d. Wt. of adult fish (kg)	58.0*	91.2	77.5*	35.0	52.3	48.7
Final harvest (kg)	139.1* (7.0)	203.4 (10.2)	234.5* (11.7)	75. 8 (3.8)	117.5 (5.9)	172.8 (8.6)
Av. total fish biomass pond (kg)	288.0	442.3	374.7		632.4	
Av. production t/ha	14.4	22.1	18.7		31.6	

* Included significant number of non-targeted species, mostly GIFT.
Figure in parenthesis indicates final harvest, t/ha

Apparent conversion
Conversion rate based on supplemental feed applied to each pond was calculated on basis of net weight gained by fish at the end of experiment and the total amount of feed utilized. Conversion rate of feed was calculated from the ratio of total feed supplied and net weight gained by fish as percentage. Projected conversion rate for a 12-month period was also calculated.

3. RESULTS

3.1 Natural fish food production in ponds

Liming of bottom soil with calcium carbonate ($CaCO_3$) and initial fertilization of water by urea (TSP) and potash created a plankton boom within 15 days in all ponds. As shown in Table 1, during stocking of ponds with fish, transparency levels were 20-23 cm only. On the other hand, when ponds were filled with ground water, the bottom of each pond was almost visible. During the whole period of culture, the colour of pond water remained deep green. During the initial 2-4 months, ponds were occasionally fertilized, especially when the water transparency exceeded 25 cm. After 4 months no fertilization was needed. The color of water indicated a high level of phytoplankton in all ponds during the whole period of investigations.

During partial harvesting and when bottom soil was examined to find out whether any so-called black soil formed at the bottom, surprisingly, no black soil was detected. Black soil formation at the end of the 18-month period was negligible in all ponds except those used for catfish monoculture, where a small amount of black soil was visible after the final harvest. A cumulative high level of supplemental feeds 1142 - 2688 kg/pond (57.1-134.4 tons/ha) as shown in Table 4, and absence of black soil indicated the energy budget in the pond ecosystem was also enriched with detritus-based food. Feed conversion rate or feed efficiency shown in Table 4 does not include natural food produced in the pond and ultimately consumed by fish.

Table 4
Gross and net production of fish biomass and feed efficiency

	Monoculture			Mixed culture
	Silver barb	**GIFT**	**Catfish**	**3 species together**
Gross production (kg)	288.0	442.3	374.7	632.0
Stocking biomass (kg)	11.95	9.12	36.80	56.12
Net production (kg)	276.05	433.18	337.9	575.88
Feed consumed wet wt. basis (kg)	1 142 (57.1)	1 773 (88.7)	1 624 (81.2)	2 688 (134.4)
Apparent feed efficiency (%)	24.2	24.4	20.8	21.4

Figure in parentheses shows amount of feed used, t/ha

3.2 Fish production in ponds

The average gross production of fish biomass in the 4 groups ranged from 288.0 - 632.4 kg/pond (Table 3). Highest average production of 632.4 kg/pond was recorded in the mixed culture group which corresponds to 31.6 tons/ha. Out of the total fish biomass produced in the mixed group silver barb, GIFT and catfish represented 24.4, 40.6 and 35.0 %, respectively. In this group no fish were listed as non-target species (Table 5) as both GIFT and silver barb were stocked in this group, whereas GIFT found in the silver barb group and vice-versa were listed as non-target species. The biomass of non-target species found in ponds was also included in the respective groups as they grew and took nutrition from those ponds. Size variations of GIFT and silver barb were remarkable, some GIFT were more than a kilogram in weight, some were tiny. The largest silver barb was 1369 g. Size variation in catfish was not so much although some individuals were more than 3 kg and some were slightly over 1 kg in body weight. The second highest production of fish biomass was recorded in monoculture of GIFT. An average 442.3 kg/pond (22.1 tons/ha) were harvested from this group within the 18-month period (Table 3). Final harvest for this group was 203.4 kg/pond, which represented GIFT of various sizes, some fish as big as 1125g and some smaller than 5g. The ponds designated for monoculture of catfish or silver-barb were heavily invaded by GIFT (Table 5), but presence of non-target species in GIFT ponds was minimal. Only an average of 10.6 kg of silver barb were present per pond, out of an average biomass production of 442.3 kg/pond during the 18-month period (Table 5). Monoculture of catfish yielded a cumulative biomass production of 374.7 kg/pond (18.74 tons/ha). However, some non-target species, especially GIFT, were found in the group which occupied 23.3% of the total biomass production. Biomass production from catfish alone was 287.4 kg/pond (14.4 tons/ha) as shown in Table 5.

Table 5
Fish biomass production based on target and non-target species (kg)

	Monoculture			Mixed culture
	Silver barb	GIFT	Catfish	
Total production (kg)	288.0 (14.40)	442.3 (22.12)	374.7 (18.74)	632.4 (31.62)
Target species (kg)	234.3 (11.72)	431.7 (21.59)	287.4 (14.37)	-
Non-target species (kg)	53.7 (2.69)	10.6 (0.53)	87.3 (4.67)	-

Figure in parenthesis shows calculated production, t/ha

The lowest biomass of fish among the 4 groups was obtained in monoculture of the silver barb group. Gross production of the fish biomass was 288.0 kg/pond (14.4 t/ha). As already mentioned GIFT somehow entered all ponds of this group and average biomass from GIFT was recorded as 53.7 kg/pond. Therefore, production of silver barb alone was 11.72 tons/ha (2 34.3 kg/pond).

3.3 Feed efficiency

A cumulative total of 2 688 kg of feed was used in each pond of the mixed species group (Table 4). The average production of fish was 632.0 kg/pond (gross weight). The initial stocking biomass of all 3 species in this group was 56.12 kg on average. Therefore, net biomass production stood at 575.88 kg/pond/18 month. The resultant feed efficiency was 21.4%, which means 4.7 kg of supplemental feeding were necessary to raise 1 kg of fish in this group. Feed efficiency was 20.8% for catfish, 24.4% for GIFT and 24.2% for silver barb. The apparent feed efficiency may be considered low when natural food production in ponds is taken in consideration. Here, it may be mentioned that initial stocking weight, especially that of catfish, was high (350 g or more), and the stocked biomass was also high, which reduced the apparent feed efficiency.

Projected production of fish and feed efficiencies 12 months from the beginning of experiment are summarized in Table 6. Projected feed efficiency varied from 31.0 to 50.4% when net fish biomass produced and the feed consumed during that period are considered. This feed efficiency is also apparent as natural foods produced in ponds were also utilized by fish.

3.4 Water quality parameters

Temperature throughout the investigation period ranged between 18.0 and 32.5°C (higher than in the nearby earthen ponds), pH was 7.9-9.0, dissolved oxygen (DO) level varied from 0.7 to 8.0 mg/L. Transparency in pond water varied from 25-45 cm throughout the investigation, after stocking fish.

Table 6
Projected production of fish and feed efficiency after 12 months

	Monoculture			Mixed culture		
	Silver barb	**GIFT**	**Catfish**	**Silver barb**	**GIFT**	**Catfish**
Biomass (kg) Actual harvest Estimate of fish in pond	148.9 120.0	238.9 150.0	140.2 150.0	78.3 40,0	139.3 50.0	48.7 146.1
Gross total (kg)	268.9	388.9	290.2	118.3	184.3	194.8
					502.4	
Stocking biomass (kg)	11.95	9.12	36.80		56.12	
Net total (kg)	256.95	379.78	253.4		446.28	
Feed consumed (kg)	510,0	840.0	810.0	-	1440.0	
Feed efficiency (%)	50.4	45.2	31.2	-	31.0	

3.5 Seed production in pond

Initial stocking numbers of GIFT and silver barb were deliberately kept low (5 000 fish/ha) in mixed and monoculture as these species breed in confined water. Initially little flow of water in ponds stocked with silver barb in mono or mixed culture induced silver barb to produce numerous fry. GIFT reproduced throughout the rearing period. Even an accidental entry of GIFT in the pond with monoculture of silver barb and catfish resulted in a high number of fry of GIFT. The fry of GIFT and silver barb were routinely harvested using fine meshed nets. Total biomass of fry and juveniles and their estimated numbers were recorded whenever those were harvested. This is shown in Table 3. The total number of fry harvested from monoculture of silver barb and GIFT were 27 500 and 58 000 on average, respectively. 40 400 fry of silver barb and GIFT were collected from the mixed group.

3.6 Behavior of fish during culture

Throughout the investigation period of 18 months no fish were fed to satiation except during the initial 2 months when it was difficult to determine the satiation level as fish seldom surfaced to take feed. After 2-3 months of rearing fish in all ponds were observed to come to the surface whenever supplemental feed was administered. Even catfish used to take feed from hand after 12-13 months of regular feeding. Broadcasting of dried feed on the surface of a pond always lured fish, especially fry and juveniles, to the surface, which helped selective harvesting. No feed remained uneaten when occasionally the daily ration of feed was placed on a feed tray made of mosquito net and steel frame, and placed on the pond bottom. Experimentally, feed was mixed with sand and placed on a feed tray, and it was found that fish plough the sand to find feed particles when the tray is placed at the bottom of the pond. When DO went below 1.5 mg/L level, all species were seen to gulp at the surface. Gulping of GIFT and silver barb was frequent. Catfish, unlike the other two species, used to come to the surface and soon dived after a quick gulp.

4. DISCUSSION

The experiment was conducted for a long period to find maximum production of fish under pond-based aquaculture utilizing low cost feed. In this respect, the trial was highly successful. Over 30 tons/ha/18months was recorded using low-cost supplemental feeds with 3 popular culture species together when a cumulative harvesting process was followed. In the investigation standing crop in a given time was not that high. At the end of investigation the highest standing crop in mixed culture was 366.1 kg (18.3 tons/ha) as shown in Table 3 (mixed: 75.8 + 117.5 + 172.8 kg, yield from final harvest). Besides, catfish and GIFT individually registered 234.5 kg/pond (11.73 tons/ha) and 203 kg/pond (10.2 tons/ha) on a monoculture basis when final harvest was made at the end of the experiment. The results indicate 10-12 ton of GIFT or catfish may be produced per year using low cost diets if species are cultured separately. When fed rice bran as supplemental feeding with 5-6% of estimated biomass, GIFT yielded an average gross production of 4 411 kg/ha/6 months. Culture of catfish (*P. sutchi*) with a stocking density of 12 500/ha fed on 100% pellets (same brand as used in this investigation) gave 11.4 tons/ha/10 months which also included 9.8% of non-target fish mostly tilapia, in an abandoned coastal farm initially used for semi-intensive cultivation of tiger shrimps (AFL, personal communication, 1999). Mixed culture of silver barb, GIFT and catfish may yield 18 tons/ha/year as was found in this investigation based on final harvest as standing crop (Table 3) or more than 25.1 tons/ha (502.4 kg/pond) based on projected production per year (Table 6). As for silver barb, final harvest gave 139.1 kg/pond (7.0 tons/ha) which also included some GIFT. Hussain *et al.* (1989) registered a production of 1952 kg/ha/5 months of silver barb feeding on rice bran with a stocking density of 1 600/ha, where no fry was produced during the culture time.

Projected production within a year shows much higher rate of yield (Table 6). This is because a selective harvesting process was followed while rearing was in progress, and fish, especially silver barb and GIFT, renewed both their number and loss in biomass. Natarajan (1985) reported on the production of tilapia (*O. niloticus*) stocked at high density (70 000; 140 000; and 210 000/ha) in tanks manured with poultry manure. He found that total fish production (including fry) was highest at the lowest density. The maximum production was 39.3 kg/ha/day and minimum of 32.1kg/ha/day. Sariz and Arieli (1980) reported highest 25.0 tons/ha/200 days production of tilapia when oil-coated pellets were fed, with a stocking density of 100 000/ha. In case of standing crop the final harvest figure (Table 3) may be the limit under low-cost supplemental feeding in pond-based aquaculture.

The feed used in this investigation was a commercial pellet (Bangladesh Taka 19.00 - 20.00/kg), mustarded oil cake (Tk. 8.00 - 9.00/kg), rice bran (Tk. 4.00 - 5.00/kg) and wheat bran (Tk. 5.00 - 6.00/kg). Therefore, average cost of feed per kg was Tk. 9.00 - 10.00. The apparent conversion rate was 20.8 - 24.2%, which means roughly 4.1 to 4.8 kg of low-cost feed is necessary to raise one kilogram of fish. For a high density culture this cost may be viable if we consider the high price of the marketed fish. But if the culture period is shortened, feed efficiency will increase. This experiment was conducted to maximize the production to find out the potential of high biomass production under semi-controlled conditions. If projected production found in mixed culture within 12 months is considered, both feed efficiency and production rate tend to increase. Production rate of fish initially was very high compared to that of a later stage in terms of supplemental feed supplied. At the later stage of culture most of the feeds were utilized to sustain the standing biomass, not for its increase. Continued selective harvesting could have led to a better fish production during 12 - 18 months.

Most interesting in this experiment was that no reared fish died when the level of dissolved oxygen was low (0.7 mg/L) and that there was almost no accumulation of organic debris at the bottom of ponds in spite of the exceptionally high amount of cumulative supplemental feeding (134 t/ha/18 months) given during the 18 months of mixed culture. As all the test animals used in this experiment had gulping abilities, no mortality was observed. All three species used in this experiment had a habit of stirring up the bottom deposit.

The level of daily supplemental feeding in this experiment was kept deliberately low, which probably encouraged fish to continuously stir the bottom in search of food, thus agitating the bottom soil. This process helped to mineralize the accumulated organic material and encouraged plankton growth. That there was no need for fertilization to enhance plankton growth after 2-3 months of fish stocking was probably due to the fertility being recycled. The continuously high level of plankton in culture, which was indicated by richly green water during the investigation period, was due to the presence of the green alga *Chlorella*. *Chlorella* cannot be eaten by any fish employed in this investigation due to its size.

It may be concluded that the high fish biomass production in this investigation was possible due to the stability of the system, including undisturbed water volume, a continuously high level of natural food production, rational supplemental feeding, gulping and stirring abilities of the fish species used in this study.

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MANAGEMENT AND PRESERVATION OF THE GIANT FISH SPECIES OF THE MEKONG

by

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ABSTRACT

Some 1 200 fish species are recorded from the Mekong and among them there are several that grow to a very large size. This paper focuses on large fishes in the Mekong, particularly the Mekong giant catfish (*Pangasianodon gigas*), the giant carp (*Catlocarpio siamensis*) and the Jullien's golden carp or seven-striped barb (*Probarbus jullieni*). They deserve special attention in the context of conservation. *C. siamensis* (giant barb) is not on the Red List, but is becoming increasingly rare in the Mekong. In general, large-bodied fish tend to be more susceptible to fishing, partly because of their relative mobility, which increases the likelihood of encountering fishing gears. The situation for the *Probarbus* spp is further aggravated in that fishers target them at the spawning grounds. A number of recommendations are put forward for the preservation of these species. These will have to be translated into agreements and management plans implemented by the riparian countries of the Mekong River. It is assumed that the agreed basin-wide management objective is to restore and maintain viable wild populations of the species considered here, as well as preserving the ecosystem as a whole

1. INTRODUCTION

The Mekong River is the largest river in Southeast Asia and one of the great rivers of the world. The main channel of the Mekong, from its origin to its mouth in the South China Sea, supports a variety of different fish assemblages, based on differences in physical characteristics as well as differences in historic configuration. Some 1 200 fish species are recorded from the Mekong (Rainboth, 1996), but recent work indicates that the total number of species is about 1 700 (Rainboth, pers. comm. 2001). This number will undoubtedly increase as additional taxonomic studies and fish surveys are completed. Among the 1 200 fish species, there are several that grow to a very large size.

This paper focuses on large fishes in the Mekong, particularly the Mekong giant catfish (*Pangasianodon gigas*), the giant carp (*Catlocarpio siamensis*) and the Jullien's golden carp or seven-striped barb (*Probarbus jullieni*), as they are potential "flagship species" in the context of conservation. As such they deserve special attention since they are potential focal points for awareness raising and education on issues relating to the preservation of Mekong biodiversity and fish production. However, the focus on individual species, which is a common feature of conservation projects, is unlikely in itself to ensure preservation of the ecosystem. Even though preservation of biodiversity in a wider sense is necessary for safeguarding ecosystem stability and functions, it is not sufficient, since many other factors also influence the ecosystem.

This paper discusses some issues relating to rarity and the development of policies for management.

2. THE STATUS OF MEKONG GIANT FISH

P. (Pangasius) gigas (giant catfish) and *P. jullieni* (Jullien's golden carp or seven-striped barb) are classified as 'endangered' on the 2000 IUCN Red List, while *Probarbus labeamajor* and *Probarbus labeaminor* are listed but classified as 'data deficient' (Table 1). It appears that the population sizes of the three species have decreased substantially over the last decades. *C. siamensis* (giant barb) is not on the Red List, but is becoming increasingly rare in the Mekong, and Rainboth (1996) maintains that it is overfished and suggests that the catch should be strictly regulated by size.

Table 1
Mekong finfish listed in the 2000 IUCN Red List of threatened species

Species	Common name	Red List*	Size (cm)
Aaptosyax grypus	--	DD	100
Botia sidthimunki	Dwarf botia	CR A1c	5.5
Chela caeruleostigmata	Leaping barb	CR A1c	7
Chitala blanci	Royal featherback	LR/nt	90
Epalzeorhynchos bicolor	--	EW	12
Oreoglanis siamensis	--	VU D2	14
Pangasianodon gigas	Giant catfish	EN C2b	300
Pangasius sanitwongsei	Pla thepa	DD	250
Probarbus jullieni	Jullien's golden carp Seven-striped barb	EN A1ac	100
Probarbus labeamajor	Thicklip barb	DD	150
Probarbus labeaminor	Thinlip barb	DD	70
Scleropages formosus	Asian bonytongue (E)	EN A1cd+2cd	90
Tenualosa thibaudeaui	Laotian shad	EN A1a	30

*, CR: Critically Endangered, DD: Data Deficient, EN: Endangered, LR: Lower Risk, VU: Vulnerable, EW: Extinct in the wild (for a full description of the classification, see http://www.redlist.org/categories_criteria.html)

3. ON RARITY AND SIZE

It is relevant here to consider the meaning of the term 'rare' in the context of biodiversity. While it may be rightly assumed that many fish species are threatened due to human activities, such as overfishing or alterations to the environment (dams etc.), species may also be rare for other reasons. Some taxa are rare because they are evolving, and others may be relics of very old groups. On an evolutionary time scale, new taxa have always evolved and others disappeared. In fact, from this point of view most of the species that ever existed on Earth are extinct. The implication is that even in natural environments (with no perceptible influence from human activities) rare species will be found. Therefore, attempting to preserve all species that are rare or appear to be threatened is perhaps misplaced effort. However, as distinct from this natural process, the rate at which species are now disappearing has accelerated greatly due to man's activities. It is accepted that evolution cannot produce new species at the same rate. Hence global attention is now being given to maintenance of biodiversity, most notably through the Convention on Biological Diversity (http://www.biodiv.org/).

Based on the limited information available, it appears that the population sizes of the three species have decreased substantially over the last decades. They have in common that they grow to large, even colossal, sizes. Froese and Torres (1999) conclude, from data in FishBase, that the proportion of threatened fishes increases substantially for maximum sizes exceeding 100 cm, and that most fish species that grow to this size are threatened. In addition, the available evidence indicate that non-guarding species (applies to all three taxa) appear to be more at risk of being threatened than live bearers and nest/egg guarders (classification by Balon, 1990).

On the assumption that large species in general have lower population densities than small-bodied species, and also that there is a minimum population size that is required to avoid genetic problems (see below), it may be argued that larger species require larger areas. This is another possible cause for the decline of the large species, in that increasing disruption of migration corridors, from construction of dams and weirs, means fragmentation of existing habitats and isolation of sub-populations.

Typically, fisheries tend to first deplete the largest species, and subsequently gradually change the exploitation pattern towards smaller sized fish (Pauly *et al.,* 1998). In general, large bodied fish tend to be more susceptible to fishing, partly because of their relative mobility, which increases the likelihood of encountering fishing gears. Add to this the preference of most fishers for large, valuable fish, and the fishery itself appears as a plausible cause of their decline. The situation for the *Probarbus* spp is further aggravated in that fishers target them at the spawning grounds.

4. PROPOSED MANAGEMENT TECHNIQUES

Any management action aimed at improving the situation of threatened species or reintroduction of extinct species must start by identification of the possible reasons for rarity. Failing this, efforts aimed at improving or re-establishing populations are likely to fall short. Notably, this implies that stocking aimed at supplementation or re-introduction of a threatened or extinct species should only be considered after the factors that cause rarity or extinction have been alleviated.

It is unlikely that it will be possible to address the factors that cause rarity of the Giant Mekong species in isolation from the rest of the ecosystem. Management policies for their preservation will have to be developed together with the other sectors and users that influence the system. It is suggested that the approach most likely to attain the objective is adaptive (or experimental) management, which implies integration of experiences and scientific information from multiple disciplines into models that attempt to make predictions about alternative policies (see e.g. Walters, 1997). Successful experimental management and application of its results will require a high degree of coordination between those involved, and this may best be achieved through the Mekong River Commission[1]'s Basin Development Plan (BDP) initiative.

The following recommendations are written in terms of outcomes to be achieved. These will have to be translated into agreements and management plans implemented by the riparian countries of the Mekong River. It is assumed that the agreed basin-wide management objective is to restore and maintain viable wild populations of the species considered here, as well as preserving the ecosystem as a whole (the recommendations would be somewhat different for other objectives).

- Studies and workshops have identified the main reason(s) for rarity and actions have been taken to alleviate these:
    - based on available data and knowledge, one or more models have been created (these may range from simple, verbal models to complex, computerized models);
    - hypotheses have been formulated and screened to eliminate those that are unlikely to have given rise to the observed data;
    - experiments have been designed and implemented to test the hypotheses (the experiments may range from small to large, ecosystem scale; the time factor is an issue: large-scale ecosystem experiments may give more reliable results but take a long time, whereas small-scale experiments usually give quicker results);
    - the results of the experiment(s) have been analyzed and the main reason(s) for rarity identified;
    - the results of the experiments have been used to further refine the management system(s) towards alleviation of the factors that cause rarity;
    - at all stages in the process, gaps in data and knowledge will be identified and prioritized, and sufficient resources assigned to fill the high priority gaps.

- The major sub-populations and their breeding grounds are known, both in terms of ecology and population genetics.
- A basin wide monitoring programme is in place, covering ecology, genetics, life history requirements.
- Relevant data and meta data are stored and made available to scientists and the public.
- A breeding and stocking programme is in place
    - broodstock is maintained in sufficient numbers and with appropriate genetic profile(s) (the life cycle is closed on station);
    - genetically and otherwise appropriate seed fish are stocked if/when considered relevant.
- Aquaculture (which has different objectives) is developed in parallel, recognizing that captive populations can contribute to understanding the biology of wild organisms, either through simple observation or specifically designed experiments.
- Participatory management of the breeding grounds is in place, possibly involving compensation for lost income to fishers.

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[1] The Mekong River Commission is an organization established to promote sustainable development of the Mekong River Basin. It operates under an agreement (with the status of international law) signed by the four downstream riparian countries, namely Thailand, Lao PDR, Cambodia and Viet Nam. The two other upstream riparian countries, China and Myanmar, are not signatories.

5. CONCLUSIONS

It seems likely that the giant Mekong fish considered here are threatened due to human activities, and a set of recommended outcomes, including experimental management, are detailed which may help to identify the factors that need to be managed in order to secure the future of these species. Management aimed at preserving self-sustaining natural populations of the giant Mekong fish species populations will most likely be a subset of management of the aquatic resources of the basin. It is unlikely that efforts to save the wild populations of the giant species will be successful unless an ecosystem approach is used. To accomplish this on a basin-wide scale will require collaboration with other sectors, and this may best be carried out through the MRC's Basin Development Plan. It is in this context that the special characteristics of the giant species become apparent; they are very obvious and suitable for catching the imagination and interest of non-specialists among the public as well as policy makers.

Failing the ecosystem approach, preservationists will have to resort to keeping the threatened organisms in captivity, for possible future re-introduction to the wild. However, unless simultaneous efforts are made to also preserve the stability and function of the ecosystem, this amounts to little more than a cosmetic approach that addresses symptoms and not causes.

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BREEDING AND NURSING OF ASIATIC SHOVELNOSE CATFISH (*Aorichthys seenghala* (Sykes, 1841)

by

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ABSTRACT

Shovelnose catfish (*Aorichthys seenghala*) is an endemic species found in the Salveen River and its tributaries. The Salveen River originates in the eastern Himalayas. This popular fish is easy to catch and hence to overfish. In 1996 the Thailand Department of Fisheries initiated a programme of breeding this species in captivity. The programme has succeeded to spawn the fish in earthen and concrete tanks, and to grow them to a size of up to 250 g in 20 months.

ASIAN SHOVELNOSE CATFISH (*Aorichthys seenghala*)

Asiatic shovelnose catfish is an endemic species found in the Salween River and its tributaries. The Salween River originates in the Tibetan range of the eastern Himalayas and passes the Thai - Myanmar border and runs off to the Andaman Sea. In Thailand, the main stream has three large west draining tributaries, the Pai River at Mae Hong Son and the Moei River at Tak (both in the northern region), and the Suriya – Maekasat River in the Thungyai Wildlife Sanctuary, Kanchanaburi, in the western region. The status of this species is more or less “endangered” due to the poor knowledge of its biology, but also due to the declining stocks of this fish in natural waters. The large size and a long period of 4 to 5 years required to reach maturation contribute to this decline. It has been one of the popular species to capture due to the tasty flesh, high price when marketed, easy to catch and therefore overfish. In 1996 the Thailand Department of Fisheries set up a programme of breeding this fish at the Maehongson Inland Fisheries Station.

General biology

Asiatic shovelnose catfish or “Pla Kot Hua Seum” is one of the catfish in the family Bagridae. The species is easily recognized by its very broad, flat and long head with smooth upper surface, and the grayish or green back and sides. The largest fish captured was 100 cm long, with a body weight of 5 kg. In the Pai River, Maehongson Province, this species spawns during the cold season from January to April. It spawns at the edge of the shore at about 1 – 2 m below the surface. It excavates a sand-gravel hole near a rock, about 1 m in diameter and 30 cm deep, in which the female lays eggs and take care of the fry.

Collection and feeding of broodfish

The fish is captured in the Pai River, Maehongson Province, Thailand using hook-and-line, cast nets, gill nets and seines, and is then transported to the Maehongson Inland Fisheries Station. The captured fish are released in 2 400 m^2 earthen ponds. Males and females are separated, each in different ponds. Broodfish do not adapt to formulated feed because they are extremely predatory. Fingerlings of carps and rohu are fed at 0.5 – 2.0% body weight once a day. Sex can be distinguished by the shape of the genital papilla. In the male, the genital papilla is pointed and the fish has a slender body. The female papilla is oval and a mature fish has a big belly full of eggs. Its abdomen becomes distended at spawning time. The cloaca is reddish and prominent. Males should be at least 60-80 cm in total length and 2.0 – 2.5 kg in body weight, while females should be 80-100 cm in total length and 3.0 – 4.5 kg in body weight.

Natural spawning methods

Spawning ponds can be either earthen or concrete. In an earthen pond, the size should be around 800 m^2 with a water depth of 1–1.5 meters. The pond should have a deeper section at the outlet to assist in fry harvesting. Ponds were prepared by liming with calcium hydroxide at the rate of 1 kg per 25 m^2 and water was filled to a depth of 1 m at the time of stocking. During January to April, broodfish were stocked at the rate of 5 pairs per pond. The pond was drained 4 months after stocking and 5 depressions with diameters of 57-98 cm and 8-23 cm deep were found in the bottom. 1 834 fingerlings with 5 different sizes from 3 to 11 cm total length and 1 to 10 g body weight were collected. Males were found to lose their skin mucus and the color of body changed from grayish back and whitish sides to reddish.

A concrete pond with the a of 50 m^2 with a minimum 50–70 cm water depth can also be used for spawning of the Asiatic shovelnose catfish. The pond's bottom must be carefully covered with sand and gravel to approximately 10-30 cm thickness and filled with aquatic plants as in natural habitats. There should be continuous flow of water through the pond at a rate of 10 L per minute. Broodfish are stocked at a rate of 5 pairs per pond during January to April. The pond was drained 4 months after stocking and 563 fingerlings of 2-3 cm total length and 1-3 g body weight were found in 90 cm diameter and 8-23 cm deep holes in the bottom at the corner of the pond. Only one male showed sign of losing its skin mucus and changing the color of its body from grayish back and whitish sides to reddish.

Following spawning, males protected their nest and fed their young with their own skin mucus until the fry reached fingerling stage. At this stage the fingerlings became predatory and cannibalistic. Spawning of broodfish stocked in earthen and concrete ponds during May to August and September to December is unreliable.

Hormonal induced spawning methods

Artificial spawning of the Asiatic shovelnose catfish by using synthetic luteinizing releasing hormone in combination with dopamine antagonists has not been successful.

Nursing and rearing of fingerlings

Fingerling, at a stocking rate of 50 fish per m^2, can be nursed in 20 m^2 concrete ponds supplied with a continuous 10 L per minute water through-flow. Fish were fed twice daily to satiation with 35-40% protein complete feed. After 30, 60 and 90 days, the total length of fingerlings was 5-7, 7-10 and 10-15 cm, and body weight was 1-3, 3-7 and 7-15 g, respectively. The survival rate was about 70-90%.

The Asiatic shovelnose catfish can also be nursed in cages at the rate of 100 fish per m^3 and fed to satiation with 30-35% protein complete feed twice daily. After 8 and 20 months, the total length of fingerlings was 25-30 and 33-35 cm, and body weight 70-100 and 200-250 g, respectively. The survival rate was 80-95%.

These results are only preliminary and have showed that the Asiatic shovelnose catfish can adapt from its natural habitat to a captive environment and can spawn in captivity.

OPPORTUNITIES AND CONSTRAINTS RELATED TO THE DEVELOPMENT OF AQUACULTURE SYSTEMS BASED ON INDIGENOUS MEKONG FISH SPECIES

by

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ABSTRACT

The Mekong River is one of the world's largest rivers, with possibly the largest inland fishery. Aquaculture contributes around 10% of the total fish production in the four countries of the Mekong River basin. Exotic species dominate in aquaculture, especially the Indian and Chinese carps, tilapia and the African catfish. At present, exotic species can be found in natural water bodies, including Tonle Sap Great Lake and the Mekong River. These species have been intentionally and accidentally released, and may cause genetic pollution, feeding competition and introduction of diseases. The main cause of inbreeding is lack of broodstock, especially in small scale hatcheries (in Cambodia), where space constraints may limit the number of broodstock that can be kept. The introduction of indigenous species in aquaculture in some riparian countries is constrained by lack of domesticated broodstock, risks of genetic pollution caused by release or escape of domesticated fish, disease dissemination, high production cost and lack of human resource with expertise on research into breeding and raising technologies. Aquaculture of Indigenous Mekong Fish Species (AIMS) Component has been created in order to carry out research on economically feasible and attractive aquaculture systems using indigenous Mekong fish species that may complement or replace the use of exotic species for culture purpose in the Mekong basin. Networking is actively supported in order to facilitate exchange of ideas and experiences relating to indigenous Mekong fish species. A total of 19 indigenous Mekong fish species has been selected and 11 research stations from four countries have been assigned by governments to conduct the research. One protocol of AIMS will be to avoid transfer of live aquatic animals between countries. The component is collaborating with other agencies (including AIT, FAO, and NACA), in order to share experience and provide training to AIMS staff.

1. INTRODUCTION

At more than 4 400 kilometers in length, the Mekong is one of the world's largest rivers. The total basin population is approximately 73 million (MRC, 2000), and the Lower Mekong Basin is home to some 60 million people, three-quarters of whom earn their living from agriculture and fishing, which account for 50 percent of the Lower Basin's GDP. Typically, land holdings are 1-2 ha. In Cambodia, Lao PDR and Viet Nam the estimated annual per capita income among subsistence farmers is US$ 150 – 200 (higher in Thailand).

Fish production in the Mekong Basin is quite substantial, with a total production of not less than 1 000 000 tons. Much of this production comes from family-based subsistence fisheries and about 10 percent is contributed by aquaculture.

The aquatic resources of the Mekong Basin represent an enormous biodiversity with more than 1 200 fish species as well as numerous other aquatic animals and plants. In recent years, some species are increasingly rare due to impacts on the physical environment as well as overexploitation, including the use of destructive fishing techniques.

Capture fisheries provide most of the fish required in the Mekong region, but in recent years aquaculture is an increasingly important contributor to fish production in the region. At present, exotic species dominate the aquaculture industry; especially tilapia and Chinese carps, including silver carp. Indigenous species that are being cultured include silver barb (*Barbodes gonionotus*), *Clarias batrachus, Pangasius hypophthalmus* and *Channa micropeltes* (Nandeesha, 1994).

The widely cultured, well-known exotics have been the primary target for past aquaculture development initiatives. Over a short time perspective, these species provided better chances of increasing and improving aquaculture, and were therefore the organisms of choice. Coupled with lack of attention to development of aquaculture techniques for indigenous species, this resulted in the dominance of exotics. The introduction of exotic species, intentionally or accidentally, to a system as diverse as the Mekong Basin, can be considered undesirable, when there is so much local potential that could be developed. The impact of introductions of exotic fish species is unpredictable, and has resulted in negative impacts in some cases.

The MRC Programme for Fisheries Management and Development Cooperation has been created in order to ensure the coordinated and sustainable management, use and development of the economic and nutritional potential of the inland living aquatic resources in the Mekong River Basin. The Component of Aquaculture of Indigenous Mekong Fish Species (AIMS) is a part of the MRC Programme for Fisheries Management, with the goal to safeguard the indigenous fish resources quantitatively, as well as in terms of biodiversity, from negative side effects of continued spreading of exotic fish species in the aquatic environment.

2. OPPORTUNITIES AND CONSTRAINTS RELATED TO THE DEVELOPMENT OF AQUACULTURE SYSTEMS BASED ON INDIGENOUS MEKONG FISH SPECIES

2.1. Genetic effect that occurs in using exotic species (effect on local stock by intentional or accidental release of exotic species)

Presently, several exotic species are already established in the basin, but the impacts of exotic fish farms (carp farms) on the environment are poorly documented.

At present, inland aquaculture and enhanced reservoir fisheries in the Mekong basin are almost exclusively based on exotic species, especially Indian and Chinese carps, tilapia and African catfish. Due to the annual flooding, particularly in Cambodia, some fish invariably escape from the fish ponds into the river and lakes. The problem of fish escape is also great in cage and enclosure culture system. Fish held in cages and pens frequently escape through holes in netting or mesh caused by predators, floating objects or rough weather. In addition to the fish released by accident, in some regions exotic species are intentionally released in rivers or lakes. These releases may cause changes in predation, competition for food, introduction of diseases, genetic pollution and co-introduction of nuisance species.

Beside the potential environmental problems caused by exotic species, exotic fish species (e.g. tilapia) are not very easy to market, and generally fetch a low price.

2.2. Opportunities and constraints for development of aquaculture systems based on indigenous species

A change in the development trend away from exotic species and towards a more environmentally friendly development of aquaculture is preconditioned by the development of economically feasible new techniques. Given such techniques, indigenous fish may complement or replace the culture of exotic fish species.

FAO (1997, p.21) emphasises that aquaculture stocks or stocks for culture-based fisheries can be managed within the culture facility:

1. to avoid inbreeding,
2. maintain stock integrity by hybridizing different stocks, strains, or species,
3. by minimizing transfer of genetically different stocks, and
4. by periodic assessment of their genetic diversity (i.e. laboratory genetic analysis).

2.2.1 Introduction and selection of indigenous fish species

Indigenous species are often promoted as alternatives to introduction of exotic species for aquaculture development. They may be preferred locally, may have less chance of introducing disease, may grow better under local conditions, may contribute to preservation of biodiversity, and help maintain integrity of aquatic communities and ecosystems by appropriate management (FAO, 1997). Among the more than 1 200 fish species in the Mekong Basin, it may not be difficult to select and develop some species for aquaculture development. Species should be selected based on the performance of the fish in culture, the desired breeding programme, the genetic profile of the broodstock, and last but not least economic and environmental considerations.

2.2.2 Breeding and genetic improvement

The development of aquaculture of indigenous species may aim to conserve genetic resources. However, introduction of domesticated indigenous stocks also poses a potential threat to biodiversity. The FAO Technical Guidelines for Responsible Fisheries, Aquaculture Development (FAO 1997, p.22) state the following on the use of indigenous (native) species:

"*Native species are often promoted as alternative to introducing exotic species for aquaculture development ... However, native species taken from the wild and domesticated or subjected to other genetic modifications may also pose a risk to the remaining wild stocks, both from genetic and disease standpoints.*"

Brood fish collected from the wild need to be domesticated in order to tolerate the hatchery conditions. The domestication process imposes specific selection pressures, which are different from those in the wild, and the genetic profile of the cultured organisms will invariably change. The culture of non-reproductive fish (e.g. sterile, triploid or mono-sex populations) will reduce the chance of released or escaped organisms breeding in the wild.

2.2.3 Inbreeding and genetic drift

Decreasing hatchability, fertility and survival, and increasing prevalence of deformities and diseases, may be signs of inbreeding and loss of genetic diversity. Many hatcheries are small, and consequently only capable of maintaining limited numbers of broodstock, which can rapidly give rise to inbreeding. This situation occurs in the Mekong Basin, e.g. in Cambodia (Funge-Smith, 2001). In general, small-scale farms may have only one or two ponds for maintaining or conditioning broodstock. One or two pairs of broodstock are bred and then kept for the next breeding season. The larger fingerlings from those pairs are selected as new brood fish and kept together with the parents. This may rapidly lead to inbreeding.

Large state hatcheries could provide a pivotal role in maintenance of genetic quality of broodstock, due to their ability to maintain large stocks and control breeding. Currently, controlled breeding is rarely practiced and management of fish is limited to selection and breeding of fast growing fish. This is principally due to lack of awareness of how to manage stocks and the inherent risks of inbreeding.

Inbreeding may be reduced or prevented by improved broodstock management, including periodic introduction of new broodstock from the wild. Funge-Smith (2001) mentions several methods for reducing the risk of inbreeding:

- Selective stripping of eggs and milt so that the breeding of individuals can be controlled. This would usually be accompanied by tagging of the fish so that records of breeding could be kept.
- Broodstock pairs are used only once and the fingerlings from that batch form a percentage of new broodstock.
- Stretching of generations of broodstock. If the same broodstock are spawned over two years instead of one, then a smaller effective breeding number can be used.

There is considerable expertise on the breeding of indigenous fish species in some of the riparian countries. The selection of species for artificial breeding experiments has been determined by various factors such as availability of breeders, by the wish to restock newly formed reservoirs or water bodies cut off from natural recruitment by dams, or by spot-wise checking of the suitability of certain species for aquaculture.

Technical problems may be encountered in finding good quality broodstock in nature, and in obtaining broodstock maturity in time. Broodstock caught in the wild may carry diseases.

Compared to the established exotic species, breeding of some indigenous Mekong fish may not be profitable. For example, to rear *Pangasius hypophthalmus* to reach maturity takes at least 4-5 years and the maintenance costs of the broodstock alone represent approximately 50% of the production cost of the fingerlings sold (Funge-Smith, 2001).

Developing indigenous Mekong fish species for aquaculture is relatively much more demanding, since a lot of basic research needs to be carried out, and training is required for government officers taking part in this effort.

3. COMPONENT STRATEGIES

As part of an attempt to reduce the spread/impact of the aquaculture of exotic fish in the Mekong basin, the immediate objective of the component of Aquaculture of Indigenous Mekong Fish Species is:

"*Economically feasible aquaculture systems developed using indigenous Mekong fish species, which may complement or replace the exotic species for culture purpose in the Mekong*".

The Component Description refers to the establishment of a Network in order to exchange ideas and experiences relating to indigenous Mekong species. There are networking needs at different levels, from farmer level, via component level (research institutes) to the wider public, including development/research organizations elsewhere. The AIMS component also collaborates with NACA on this, and the MRC web site.

A total of 19 priority species have been promoted for further research by AIMS (2000), including *Anabas testudineus*, *Barbodes altus*, *Barbodes gonionotus*, *Cirrhinus microlepis, Cirrhinus molitorella, Clarias macrocephalus, Henicorhynchus siamensis, Leptobarbus hoeveni, Macrobrachium lanchesteri, Morulius chrysophekadion, Mystus wyckioides, Notopterus notopterus, Osphronemus gourami, Osteochilus melanopleurus, Pangasius hypophthalmus, Pangasius larnaudiei, Pangasius bocourti, Puntioplites falcifer* and *Trichogaster pectoralis.* Some fish species overlap between countries, and Cambodia, Lao PDR, Thailand and Vietnam have agreed to carry out studies on 6, 6, 7, and 6 species, respectively. The criteria used for selecting the fish species included potential for low input aquaculture, market demand, potential for farmer-based (simple) hatchery production, etc. A total of 11 research stations have been selected for collaboration with the AIMS component, with two in Cambodia, three in Lao PDR, five in Thailand and one in Vietnam.

In all four countries, broodstock have been captured and/or selected from exiting stocks. In order to avoid inbreeding, at least 100 fish of each species have been collected. The brood fish that has been collected from the wild have to be acclimated to the captive pond environment. Simple breeding and hatching technologies, larvae culture, water control and management will be applied in order to evaluate the economy of the culture systems.

Research into non-reproductive fish such as sterile, triploid or mono-sex populations of organisms will not be priority. AIMS is not in a position to conduct extensive genetic examination of stocks, but might be able to facilitate and partly fund such research through its four-country network, should such an opportunity arise. AIMS may also facilitate awareness raising within the four countries by providing some simplified guidelines regarding genetic management of hatchery broodstock. AIMS will not support the uncritical movement of live fish between countries or sub-catchments.

The development of farming systems is also a goal of AIMS. Species successfully bred and raised as part of on-station research and with good economic potential will be subjected to full-scale tests on-station and on-farm in cooperation with the national fisheries extension services, NGOs, international organizations involved in fish culture development and with selected farmers. Promising technologies and extension approaches and species will be extended to other areas, and gradually replace the exotic species. The Component has identified the following areas for short-course training, which to some extent may differ between countries:

- Broodstock management, including genetic considerations and movement of live fish
- Species identification
- Feed and feeding
- Participatory monitoring and evaluation approaches
- Health management/disease prevention
- Project management, monitoring and reporting
- Introduction to experimental design and analysis
- Information management and networking.

The training will be carried out at local, national and regional level, in collaboration with local and regional training institutions as well as universities.

4. CONCLUSIONS

- Several exotic fish species are already established in the basin, although so far there are few reports of problems related to these species.
- Low numbers of broodstock in many hatcheries cause inbreeding.
- Responsible development of indigenous species: aquaculture can reduce or minimize the risks associated with exotic species.
- Development of indigenous species: aquaculture is faced with some constraints:
    - in relation to availability of domesticated broodstock,
    - genetic side effects due to domestication,
    - human resources in terms of expertise in breeding and raising technologies.
- AIMS's goal is to develop a total of 5-8 indigenous species, which are expected to provide profitable alternatives to culture of exotics.
- AIMS has a strong environmental focus, and will pay special attention to:
    - genetics and broodstock management
    - transboundary movement of live fish
    - environmental management of indigenous fish farming systems
    - economics of indigenous fish aquaculture and genetic diversity.

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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 from 10 to 13 July 2001 in Kathmandu, Nepal, was attended by 70 participants from 10 countries. Comprising 32 presentations, the symposium reviewed information, experiences, ideas and findings related to fish and fisheries in the region. Special attention was given to fish species distribution, fishing intensity, socio-economic conditions and livelihoods of fisher communities, as well as to the impacts of environment degradation, conservation measures and aquaculture technologies on indigenous and exotic cold water fish. The symposium highlighted the role of fisheries 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. A number of priority issues were indentified, 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.

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