

Review Article

Freshwater fish diversity and its conservation status in different water bodies of Nepal

Kumar Khatri^{1,2,*}, Bibhuti Ranjan Jha¹, Smriti Gurung¹, and Udhab Raj Khadka³

¹ Department of Environmental Sciences and Engineering, Kathmandu University, Dhulikhel, Nepal

² Mahendra Ratna Campus, Tribhuvan University, Kathmandu Nepal

³ Central Department of Environmental Science, Tribhuvan University, Kirtipur, Nepal

Abstract:

This review describes the current status of freshwater fish diversity, their IUCN categories and threats to fish fauna in Nepal. The freshwater systems of the country are known to harbor over 220 fish species, thereby indicating a rich ichthyofaunal diversity. However, this number varies from author to author. Cyprinidae is the most common and dominant taxon. A total of 15 endemic and 15 exotic fish species have been reported. A total of 34 fish species have been listed under the IUCN Red List threatened categories. Major threats to fish include damming and pollution. Fish diversity studies have mainly focused on inventories only. Studies focusing on river longitudinal aspects, the inclusion of spatio-temporal aspects, and rigorous taxonomic studies combined with genetic studies are crucial to develop strategic conservation measures of fish fauna in Nepal.

Keywords: Cyprinidae, fish diversity, lakes, Nepal, river

Introduction

Fishes are one of the most important and diverse groups of vertebrates, with an estimated 34,300 species (Froese & Pauly, 2020), and are directly related to human well-being (Leveque et al., 2008). An estimated 3000 species are found in Asia (Lundberg et al., 2000), with Carps (Cypriniformes) and Catfishes (Siluriformes) representing the major freshwater fish taxa from South Asia (Berra, 2007; Nelson et al. 2016). However, the knowledge of fish faunal diversity in tropical Asia, including Nepal, is still in its primal phase, where survey works are still fragmentary and sporadic, with many species yet to be discovered or to be described (Leveque et al., 2008).

Nepal is one of the richest countries in terms of freshwater resources with altitudinal variation ranging from 50 m elevation to the world's highest peaks exceeding 8000 meters. There are as many as 6000 rivers and rivulets in Nepal. About 70% of the country is drained by four major river systems, all originating from the higher Himalayas greater than 5000 m asl (meter above sea level), with some of their tributaries entering from Tibet as well (Bricker et al., 2014; Bhandari et al., 2018). These are the Sapta Koshi in the eastern part, the Sapta Gandaki (Narayani) in the central, the Karnali in the western part and the Mahakali in the far-western part of the country. Besides these, many medium and small-sized rivers originate from the Midhills (1200- 3000 m asl), Mahabharat range (3000 to 5000 m asl), and the Churia range (900-1200 m asl) (WECS, 2011; Bricker et al., 2014; Bhandari et al., 2018). Freshwater habitats - natural and

manmade- in the country covers an estimated area of about 826,818 ha (GoN/NPC, 2019; Table 1).

Along with freshwater resources (WECS, 2011), the country's geographical position linking the eastern and western Himalaya combined with varied topographical features with different climatic and ecological zones support rich fish diversity (Shrestha, 2000; HMG/N/MFSC, 2002). Despite being rich in water resources, the knowledge of fish diversity in Nepal is still very inadequate and unorganized. Most of the studies have focused on inventory only on selected stretches of rivers and tributaries; and some lentic systems such as lakes, ponds, and pools and irrigation canals in the country. There are even more limited studies on fishes from marshy lands (*Ghols* in Nepali) in Nepal (Jha & Shrestha, 2000). The lack of systematic studies and information on the ichthyofauna in the country is a big obstacle for exploring the fish variety and strategizing any means of conservation. In addition, the provision for deposition of voucher specimens and museum specimens are still lacking which further pose obstacle in conducting sound taxonomic studies. Genetic and molecular studies, which have been proven to be effective in resolving taxonomic resolution (Zhang & Hanner, 2012), are also lacking in the country. Therefore, the main objectives of this review are to generate comprehensive information on fish diversity, their present conservation status; threats; and to identify the knowledge gap in fish diversity studies in Nepal. This will contribute to strategizing effective methods for their conservation,

* Corresponding author: khatriku.kk@gmail.com

exploration, and exploitation in the future. Extensive literature review available from Nepal in the form of published (articles and books) and unpublished (reports and thesis) works from 1981 have been performed, and information has been compiled

and analyzed. The IUCN (International Union for Conservation of Nature and Natural Resources) conservation status of reported fish species was prepared.

Table 1 Freshwater types, respective surface area and percentage coverage in Nepal.

S.N.	Resources	Area (ha)	% coverage
1	Rivers	39500	47.77
2	Lakes	5000	0.6
3	Reservoirs	1500	1.38
4	Ponds	11396	1.4
5	Marginal swamps	12500	1.51
6	Irrigated paddy fields	398000	48.14
7	Irrigation canals	3160	0.38
8	Highway side ditches	262	0.03
Total		826818	100

Source: Directorate of Livestock and Fisheries Development (2073/74 B.S.)

Fish studies in Nepal from past to present: A brief account

Fish studies in Nepal started as early as 1800s (Hamilton, 1822), and a number of contributions have been made by scholars in the field of Ichthyology since then (Jha, 2006). However, most of these studies have focused on fish inventory (Edds, 1993; Shrestha et al., 2009; Jha et al., 2015; Shrestha, 2016). The first-ever report of fish of Nepal was recorded in the eighteenth century. Colonel Kirkpatrick is considered as the first person to report fish from Nepal in 1793 during his political mission (Rajbanshi, 2012). However, Hamilton (1822) is considered as the first person to provide authentic information on fishes of Nepal when he described 269 species of fish species in his work entitled, "An account of the fishes found in the River Ganges and its branches". Day (1878-1889) mentioned several freshwater fishes of Nepal in his work "Fishes of India, Burma and Ceylon". The early 1900s saw the works of Boulenger (1907) and Regan (1911), who reported 7 species and 5 species of fish, respectively from Nepal. Hora (1920-1940), in the series of the Journal of Bombay Natural History Society, reported 22 species from Nepal, including *Neolissochilus hexagonolepis* and *Tor putitora*. He also described the distribution of *Tor putitora* all along the Himalayas. Menon (1949-1962) reported a distributional list of 69 known species of fishes from the defined drainage system in the Himalayas and from Koshi drainage. Taft (1955) prepared a checklist of 94 species of fishes representing 13 Families from Kathmandu, Trisuli, Simara and Biratnagar during his fish survey. Swan in 1954 collected 25 fish species during the California Himalayan Expedition to Makalu. De Witt (1960) reported 102 fish species belonging to 21 Families.

It was only during the late 1960s, an article entitled "Freshwater fishes and Fisheries of Nepal" was published by Nepalese authors (Majupuria & Shrestha, 1968); and since the 1970s, information on the identification and systematics of freshwater fishes have been published sporadically. Jiwan Shrestha is considered as the native pioneer Ichthyologist with her first publication in 1981 of "Fishes of Nepal" with a description of 120 species of freshwater fishes belonging to 10 Orders, 26 Families, and 63 Genera. Other works on Ichthyology include those of Shrestha (2008) who reported 11 Orders, 35 Families, and 98 Genera, whereas Edds and Ng (2007) reported 10 species from different water bodies. Sharma (2008) reported 200 fish species belonging to 11 Orders, 36 Families and 114 Genera. Similarly, Rajbanshi (2012) reported 230 fish species belonging to 11 Orders, 32 Families and 99 Genera. These studies have mainly focused on generating an inventory of freshwater fishes. Moreover, these studies have not considered the seasonal variation in fish diversity. Temporal variation in fish diversity was studied by Jha (2006) in Aandhi, Arung, Bagmati, Jhikhu, Karra, East Rapti, Seti and Narayani rivers. Jha et al. (2015, 2018) also studied temporal variation in some glacial-fed and rain-fed tributaries of the Tamor River and the Kamala River, respectively, in eastern Nepal. The total number of fish species observed from different lotic and lentic systems, and the most dominant taxon observed based on these available literatures are given in Tables 2 and 3. The largest fish found in Nepal is *Bagarius yarrelli* (Sykes, 1839) measuring 2 m in length, weighing up to 250 kg, while the smallest is *Danio rerio* (Hamilton, 1822) measuring 26 mm in length, weighing just a few grams (Shrestha, 2002; Rajbanshi, 2002). Shrestha (1994) reported *Tor putitora* (Hamilton, 1822) as the largest fish weighing up to 45 kg.

Table 2 Different fish taxa in different river systems of Nepal.

Name of River	Total Species recorded	Fish Fish Taxa	Dominant Taxa	References
Koshi River System				
Koshi River	34	2 Orders, 6 Families, 21 Genera	Cyprinidae	(Shrestha, 1999)
Upper Sunkoshi River	29	4 Orders, 9 Families, 17 Genera	Cyprinidae	(Ranjit, 2002)
Tamor River	30	2 Orders, 6 Families, 15 Genera	Cyprinidae	(Shrestha et al., 2009)
Koshi Tappu Wildlife Reserve	63	6 Orders, 19 Families, 46 Genera	Cyprinidae	(Limbu & Subba, 2011)
Melamchi River	11	3 Orders, 6 Families, 10 Genera	Cyprinidae	(Mishra & Baniya, 2016)
Triyuga River	48	6 Orders, 18 Families, 37 Genera	Cyprinidae	(Shrestha, 2016)
Roshi Khola	5	2 Orders, 3 Families, 3 Genera	Cyprinidae	(Bhusal & Chitrakar, 2017)
Tamor River	13	2 Orders, 4 Families, 9 Genera	Cyprinidae	(Jha et al., 2018)
Sunkoshi River	27	4 Orders, 6 Families, 20 Genera	Cyprinidae	(Joshi, 1988)
Koshi River	69	9 Orders, 22 Families, 43 Genera	Cyprinidae	(Sapkota, 1992)
Indrawati River	26	5 Orders, 9 Families, 20 Genera	Cyprinidae	(Manandhar, 1994)
Bhotekoshi and Sunkoshi	16	2 Orders, 3 Families, 11 Genera	Cyprinidae	(Bajracharya, 2001)
Jhikhu Khola	12	3 Orders, 4 Families, 7 Genera	Cyprinidae	(Jha, 2006)
Sunkoshi River,	36	4 Orders, 10 Families, 27 Genera	Cyprinidae	(Mali, 2008)
Koshi River, KTWR	61	7 Orders, 23 Families, 43 Genera	Cyprinidae	(Saud, 2011)
Koshi River Basin	12	4 Orders, 8 Families, 10 Genera	Cyprinidae	(Singh, 2017)
Gandaki River system				
Kali-Gandaki/Narayani river	111	9 Orders, 26 Families, 69 Genera	Cyprinidae	(Edds, 1986b)
Chitwan National Park	113	9 Orders, 28 Families, 71 Genera	Cyprinidae	(Edds, 1986a)
Kali Gandaki	35	2 Orders, 7 Families, 23 Genera	Cyprinidae	(Shrestha, 1996)
Narayani River	131	10 Orders, 30 Families, 77 Genera	Cyprinidae	(Smith et al., 1996)
Narayani River	68	9 Orders, 23 Families, 52 Genera	Cyprinidae	(Dhital & Jha, 2002)
Marshyangdi River	26	5 Orders, 6 Families, 18 Genera	Cyprinidae	(Mandal & Jha, 2013)
Narayani River	108	10 Orders, 30 Families, 69 Genera	Cyprinidae	(Jha & Bhujel, 2014)
Chitwan National Park	54	6 Orders, 20 Families, 39 Genera	Cyprinidae	(Rayamajhi, 2017)
Seti Gandaki River Basin	30	5 Orders, 9 Families, 23 Genera	Cyprinidae	(Pokharel et al., 2018)
Chitwan District	111	10 Orders, 31 Families, 73 Genera	Cyprinidae	(Jha, 2018)
Trisuli River	28	3 Orders, 5 Families, 15 Genera	Cyprinidae	(Karna, 1993)
Tadi River	18	3 Orders, 4 Families, 14 Genera	Cyprinidae	(Mandal, 1995)
Mardi Khola	9	3 Orders, 4 Families, 8 Genera	Cyprinidae	(Adhikari, 2004)
Narayani River	32	4 Orders, 11 Families, 25 Genera	Cyprinidae	(Jha, 2006)
Aandhi River	18	4 Orders, 5 Families, 13 Genera	Cyprinidae	(Jha, 2006)
Arung River	27	4 Orders, 8 Families, 20 Genera	Cyprinidae	(Jha, 2006)
Karra River	25	5 Orders, 9 Families, 19 Genera	Cyprinidae	(Jha, 2006)
Seti River	18	3 Orders, 5 Families, 13 Genera	Cyprinidae	(Jha, 2006)
East Rapti River	30	4 Orders, 11 Families, 24 Genera	Cyprinidae	(Jha, 2006)
Rapti River	59	7 Orders, 20 Families, 42 Genera	Cyprinidae	(Paudel, 2006)
Reu River	26	7 Orders, 13 Families, 20 Genera	Cyprinidae	(Dhakal, 2015)
Narayani/Kali Gandaki River	66	5 Orders, 16 Families, 45 Genera	Cyprinidae	(Gillette et al., 2016)
Karnali River System				
Karnali river	118	9 Orders, 29 Families, 72 Genera	Cyprinidae	(Smith et al., 1996)

Karnali river	23	2 Orders, 4 Families, 15 Genera	Cyprinidae	(Shrestha, 1999)
Budhi Khola	67	9 Orders, 22 Families, 47 Genera	Cyprinidae	(Chaudhari, 1999)
Lower Karnali River	50	8 Orders, 17 Families, 32 Genera	Cyprinidae	(Karki, 2000)
Bheri River	19	4 Orders, 8 Families, 15 Genera	Cyprinidae	(Pandey, 2002)
Bheri River and its tributaries	16	3 Orders, 4 Families, 13 Genera	Cyprinidae	(Khatri et al., 2019)
Karnali River	36	5 Orders, 11 Families, 26 Genera	Cyprinidae	(Thapa, 2005)
Mahakali River				
Budiganga River	18	2 Orders, 5 Families, 11 Genera	Cyprinidae	(Shah, 2005)
Mahakali River	23	3 Orders, 5 Families, 15 Genera	Cyprinidae	(Poudel, 2008)
Mahakali River	21	4 Orders, 9 Families, 17 Genera	Cyprinidae	(Chataut, 2008)
Mahakali River	44	5 Orders, 14 Families, 35 Genera	Cyprinidae	(Khatri, 2010)
Mahakali and Chameliya River Junction	15	3 Orders, 4 Families, 11 Genera	Cyprinidae	(Bist, 2014)
Other Rivers				
Bagmati River	22	2 Orders, 4 Families, 16 Genera	Cyprinidae	(Shrestha, 1996)
Eastern Terai	60	8 Orders, 23 Families, 48 Genera	Cyprinidae	(Kumar et al., 2011)
Morang District	117	10 Orders, 31 Families, 69 Genera	Cyprinidae	(Subba et al., 2017)
Singhiya River	26	6 Orders, 15 Families, 22 Genera	Cyprinidae	(Yadav, 2017)
Tawa Khola	27	4 Orders, 10 Families, 21 Genera	Cyprinidae	(Jha et al., 2018)
Bakraha River	9	2 Orders, 3 Families, 7 Genera	Cyprinidae	(Limbu et al., 2018a)
Dewmai Khola	15	3 Orders, 6 Families, 10 Genera	Cyprinidae	(Limbu et al., 2018b)
Ratuwa River	27	5 Orders, 10 Families, 20 Genera	Cyprinidae	(Limbu & Gupta, 2019)
Ratuwa River	18	3 Orders, 7 Families, 14 Genera	Cyprinidae	(Limbu et al., 2019a)
Eastern Nepal	148	10 Orders, 33 Families, 77 Genera	Cyprinidae	(Limbu et al., 2019b)
Manohara River	11	3 Orders, 3 Families, 8 Genera	Cyprinidae	(Singh, 1992)
Tinau River	35	4 Orders, 14 Families, 27 Genera	Cyprinidae	(Sharma, 1996)
Bagmati River	3	1 Order, 2 Families, 2 Genera	Nemacheilidae	(Jha, 2006)
Tinau River	29	4 Orders, 9 Families, 21 Genera	Cyprinidae	(Jha, 2006)
Mahottary District	47	6 Orders, 19 Families, 35 Genera	Cyprinidae	(Jha, 1988)
Bagi River	11	3 Orders, 7 Families, 10 Genera	Cyprinidae	(Jha, 2001)
Babai River	40	6 Orders, 15 Families, 30 Genera	Cyprinidae	(Singh, 2002)
Rohini Khola	15	4 Orders, 8 Families, 14 Genera	Cyprinidae	(Kunwar, 2002)
Daram Khola	21	4 Orders, 9 Families, 17 Genera	Cyprinidae	(Malla, 2004)
Dano River	36	4 Orders, 12 Families, 28 Genera	Cyprinidae	(Shrestha, 2005)
Harpan Khola	22	5 Orders, 7 Families, 18 Genera	Cyprinidae	(Prajoo, 2007)
Mechi River	32	5 Orders, 15 Families, 26 Genera	Cyprinidae	(Pokheral, 2008)
Dhanusha District	33	6 Orders, 18 Families, 28 Genera	Cyprinidae	(Shilpi, 2010)
West Rapti	24	4 Orders, 8 Families, 19 Genera	Cyprinidae	(Pokhrel, 2011)
Sharada River	15	3 Orders, 6 Families, 11 Genera	Cyprinidae	(K.C., 2015)
Bagmati River	16	6 Orders, 9 Families, 12 Genera	Cyprinidae	(Yadav, 2017)
Rapti River	20	4 Orders, 7 Families, 15 Genera	Cyprinidae	(Oli, 2017)
Babai River and its tributaries	22	5 Orders, 11 Families, 20 Genera	Cyprinidae	(Khatri et al., 2019)

Table 3 Fish taxa in different Lentic systems.

Lakes/reservoirs	Total Fish Species	Fish Taxa	Dominant Taxa	Reference
Beeshazar and Associated lakes,	17		Cyprinidae	(WWF, 2006)
Begnas Lake	25	5 Orders, 9 Families, 18 Genera	Cyprinidae	(Husen et al., 2019)
Begnas Lake	19	5 Orders, 6 Families, 14 Genera	Cyprinidae	(Gurung, 1997)
Begnas Lake	22	5 Orders, 6 Families, 14 Genera	Cyprinidae	(Husen et al., 2016)
Begnas Lake	20	5 Orders, 5 Families, 14 Genera	Cyprinidae	(Husen, 2014)
Dipang Lake	15	5 Orders, 7 Families, 12 Genera	Cyprinidae	(Thapa, 2018)
Ghodaghodi Lake	13	5 Orders, 8 Families, 11 Genera	Cyprinidae	(Joshi & K.C., 2017)
Ghodaghodi Lake	18	6 Orders, 9 Families, 13 Genera	Cyprinidae	(Lamsal et al., 2014)
Ghodaghodi Lake	29		Cyprinidae	(WWF, 2006)
Jagadishpur Reservoir	25	7 Orders, 12 Families	Cyprinidae	(WWF, 2006)
Jagadishpur Reservoir	42	6 Orders, 18 Families, 34 Genera	Cyprinidae	(Gautam et al., 2010)
Phewa Lake	21	5 Orders, 6 Families, 16 Genera	Cyprinidae	(Devkota, 2011)
Phewa Lake	19	5 Orders, 6 Families, 19 Genera	Cyprinidae	(EIA, 2019)
Phewa Lake	25	5 Orders, 7 Families, 18 Genera	Cyprinidae	(Gurung et al., 2005)
Phewa Lake	15	4 Orders, 4 Families, 15 Genera	Cyprinidae	(Nepal et al., 2015)
Phewa Lake	23	5 Orders, 5 Families, 14 Genera	Cyprinidae	(Husen et al., 2016)
Rara Lake	3	1 Order, 1 Family, 1 Genus	Cyprinidae	(Terashina, 1984)
Rupa Lake	23	5 Orders, 6 Families, 18 Genera	Cyprinidae	(Gautam et al., 2016)
Rupa Lake	21	5 Orders, 6 Families, 15 Genera	Cyprinidae	(Husen et al., 2016)
Rupa Lake	13	3 Orders, 3 Families, 12 Genera	Cyprinidae	(Husen, 2014)
Rampur Gol	22	5 Orders, 13 Families, 15 Genera	Cyprinidae	(Oli et al., 2013)

Endemic fish species

The total number of endemic fish species in Nepal also differs with different authors. Shrestha reported eight endemic species in 1995 while in 1999 she reported only six endemic fish from Nepal. Rajbanshi (2002) reported seven endemic fish species from the mountainous cold waters of Nepal. However, 15 endemic fish species (Table 4) can be discerned from other literature sources (Ng & Edds, 2004, 2005; Ng, 2006; Conway & Mayden, 2008, 2010; GoN/MoFSC, 2014).

Exotic fish Species

In Nepalese freshwater bodies, several fish species have been introduced since 1956. The first exotic fish to be introduced in the country was the Common carp (*Cyprinus carpio*) (Gubhaju, 2008). Rajbanshi (1982) reported seven exotic fish species introduced for commercial uses; Shrestha (1995) reported ten exotic fish species; GoN/MoFSC (2014) reported 12 exotic fish species whereas GoN/NPC (2019) reported eight exotic species. Compilation and analyses of these different information suggest that as of now, there are 15 exotic fish species in Nepal (Table 5).

Table 4 List of endemic freshwater fish species from Nepal.

S. No.	Fish Species	River/Location	Reference(s)
1	<i>Balitora eddsi</i>	River Karnali	(Conway & Mayden, 2010)
2	<i>Batasio macronotus</i>	River Sapta Koshi	(Ng & Edds, 2004)
3	<i>Erethistoides ascita</i>	River Mechi, River Kankai, River Trijuga, River Koshi	(Ng & Edds, 2005a)
4	<i>Erethistoides cavatura</i> .	River Dhungra, River Rapti, River Narayani	(Ng & Edds, 2005a)
5	<i>Myersglanis blythii</i>	Pharping- Kathmandu Valley	(Jayaram, 1999)
6	<i>Pseudocheneis crassicaudata</i>	Mewa Khola (Tributary of Tamor)	(Ng & Edds, 2005b)
7	<i>Pseudocheneis eddsi</i>	Mahesh Khola, River Trishuli	(Ng, 2006)
8	<i>Pseudocheneis serracuda</i>	River Seti, River Kali Gandaki, River Narayani, River Mahakali,	(Ng & Edds, 2005b)

9	<i>Psilorhynchus nepalensis</i>	River Rapti, Seti River, Narayani River	(Conway & Mayden, 2008)
10	<i>Psilorhynchus pseudocheniensis</i>	River Dudh Koshi	(Menon & Datta, 1964)
11	<i>Schizothorax macrophthalmus</i>	Mahendra (Rara)Lake	(Terashima, 1984)
12	<i>Schizothorax nepalensis</i>	Mahendra (Rara)Lake	(Terashima, 1984)
13	<i>Schizothorax raraensis</i>	Mahendra (Rara)Lake	(Terashima, 1984)
14	<i>Neoanguilla nepalensis</i>	Narayani River,	(Shrestha, 2008)
15	<i>Turcinoemacheilus himalaya</i>	Indrawati, Koshi, Kali Gandaki and Narayani Rivers	(Conway et al., 2011)

Table 5 Exotic fish species reported in Nepal.

S. No.	Scientific Name	Common/Local Name
1	<i>Barbomys gonionotus</i>	Silver barb
2	<i>Carassius carassius</i>	Goldfish
3	<i>Catla catla</i>	Bhaku
4	<i>Cirrhinus mrigala</i>	Naini
5	<i>Clarias gariepinus</i>	African maghur
6	<i>Ctenopharyngodon idella</i>	Grass carp
7	<i>Cyprinus carpio</i>	Common carp
8	<i>Hypobalamicthys molitrix</i>	Silver carp
9	<i>Hypobalamicthys nobilis</i>	Bighead carp
10	<i>Labeo rohita</i>	Rohu
11	<i>Oncorhynchus mykiss</i>	Rainbow trout
12	<i>Oreochromis mossambicus</i>	Tilapia
13	<i>Oreochromis niloticus</i>	Tilapia
14	<i>Pangasianodon hypophthalmus</i>	Pangasia
15	<i>Salmo trutta</i>	Brown trout

Table 6 IUCN Category of fish species in Nepal.

S. No.	Fish Species	Common/Local Name	IUCN Red List Category
1	<i>Cyprinus carpio</i>	Common carp	Critically Endangered
2	<i>Schizothorax nepalensis</i>	Snow trout	Critically Endangered
3	<i>Schizothorax raraensis</i>	Rara snow	Critically Endangered
4	<i>Glyptothorax kashmirensis</i>	Catfish	Critically Endangered
5	<i>Hypselobarbus micropogon</i>	Korhi barb	Endangered
6	<i>Schismatorhynchus nukta</i>	Nukta	Endangered
7	<i>Tor putitora</i>	Golden mahseer	Endangered
8	<i>Pangasianodon hypophthalmus</i>	Striped catfish	Endangered
9	<i>Anguilla bengalensis</i>	Indian mottled eel	Near Threatened
10	<i>Balitora brucei</i>	Gray's stone loach	Near Threatened
11	<i>Garra rupecula</i>	Suker	Near Threatened
12	<i>Hypobalamicthys molitrix</i>	Silver carp	Near Threatened

13	<i>Labeo pangusia</i>	Pangusi labeo	Near Threatened
14	<i>Neolissochilus hexagonolepis</i>	Copper mahseer	Near Threatened
15	<i>Schistura devdani</i>	Loach	Near Threatened
16	<i>Systemus clavatus</i>	Stedman barb	Near Threatened
17	<i>Chitala chitala</i>	Clown knife fish	Near Threatened
18	<i>Ctenops nobilis</i>	Frail gourami	Near Threatened
19	<i>Oreochromis mossambicus</i>	Mozambique tilapia	Near Threatened
20	<i>Parambassis lala</i>	Highfin glassy perchlet	Near Threatened
21	<i>Ailia coila</i>	Gangetic ailia	Near Threatened
22	<i>Bagarius bagarius</i>	Goonch	Near Threatened
23	<i>Bagarius yarrelli</i>	Goonch	Near Threatened
24	<i>Ompok bimaculatus</i>	Butter catfish	Near Threatened
25	<i>Ompok pabda</i>	Pabdah catfish	Near Threatened
26	<i>Ompok pabo</i>	Pabo catfish	Near Threatened
27	<i>Wallago attu</i>	Wallago	Near Threatened
28	<i>Cirrhinus cirrhosis</i>	Mrigal carp	Vulnerable
29	<i>Cyprinion semiplotum</i>	Assamese kingfish	Vulnerable
30	<i>Nemacheilus inglisi</i>	Loach	Vulnerable
31	<i>Physoschistura elongate</i>	Dwarf loach	Vulnerable
32	<i>Schistura prashadi</i>	Creek loach	Vulnerable
33	<i>Schizothorax richardsonii</i>	Snow trout	Vulnerable
34	<i>Tor chelynoides</i>	Dark mahseer	Vulnerable

Sources: ADB (2018) and Froese and Pauly (2020)

Present conservation status of fishes of Nepal

Nepal has a legal framework for the protection of aquatic organisms in Aquatic Animal Protection Act BS 2017 (1960 AD) with an amendment in 2055 BS (1997 AD) (also known as Jalchar Samrachhyan Ain 2017 BS in Nepali), but FAO (1997) claims that the Act does not have adequate regulations to implement action to conserve fish. In general, more attention has been given to the protection of wild animals rather than fishes in Nepal by organizations like IUCN (Jnawali et al., 2011). However, Shrestha (1995) has recommended ten fish species as the most important with critical status and listed in the National Red Data Book of Nepal (Anonymous, 1995) for their legal protection. A recent report has mentioned 21 fish species in the IUCN Red List of threatened category out of 230 species (ADB, 2018), whereas Froese and Pauly (2020) has enlisted 34 species (Table 6).

Based on all the available literature cited in this review and Froese and Pauly (2020), the freshwater system of Nepal harbors a total of 255 fish species belonging to 12 Orders, 41 Families and 124 Genera including 15 endemic and 15 exotic fish species. The 12

Orders are as Cypriniformes (50.99%), Siluriformes (29.64%), Perciformes (9.88%), Synbranchiformes (2.37%), Anguilliformes, Clupeiformes and Salmoniformes (1.19% each), Beloniformes, Cyprinodontiformes, Mugiliformes and Osteoglossiformes (0.79% each); and Tetraodontiformes (0.40%). On the other hand, three species such as *Glyptothorax pectoralis* (Edds, 1986) in Chitwan National Park, *Labeo gardi* (Singh, 2002) in the Babai River, and *Nemacheilus gadda* (Pohkeral, 2008) in Mechi River reported during review are not listed in Froese and Pauly (2020) could be attributed to confusion with local names. The different IUCN categories of reported taxa in this review are shown in Fig. 1.

The lotic systems are known to harbor around 213 fish species belonging to 12 Genera, 37 Families and 105 Orders, including exotic species. These orders are Cypriniformes (with 111 species), Siluriformes (65 species), Perciformes (21 species), Synbranchiformes (5 species) Clupeiformes (3 species), Mugiliformes and Osteoglossiformes (2 species each), Anguilliformes, Beloniformes, Cyprinodontiformes, Salmoniformes and Tetraodontiformes (1 species each).

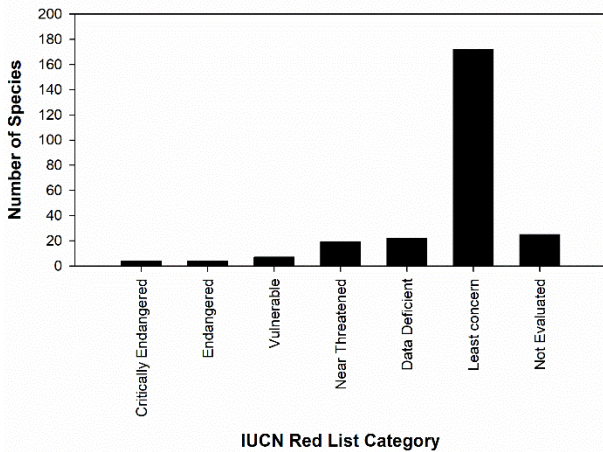


Figure 1 IUCN Red List categories of freshwater fishes in Nepal.

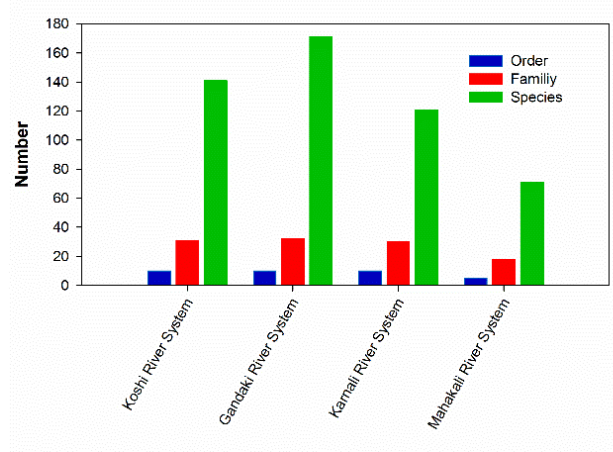


Figure 2 Fish taxa in four major river systems.

Of the four major river systems, the Gandaki system has been known to harbor the highest number of species (171) and Mahakali with the lowest number of species (71). In contrast, Nepalese lakes are known to harbor 79 fish species belonging to 51 Genera, 24 Families, and 7 Orders, including 11 exotic species. These orders are Cypriniformes (with 47 species), Perciformes (13 species), Siluriformes (12 species), Synbranchiformes (4 species), Beloniformes, Osteoglossiformes and Salmoniformes (1 species each). Fig. 2 shows the number of different fish taxa observed from these river systems.

Family Cyprinidae dominates freshwater fish habitats in Nepal. Fish species diversity shows distinct elevational distribution with decreased diversity with elevation gain (Bhatt et al., 2012; Swar, 2002). The Terai region shows the highest diversity (41%), followed by the Siwaliks (39%), middle mountains (4%) and high mountains (4%) (GoN/MoFSC, 2014). The Gandaki basin is the second largest river basin in the country, where the Oriental and Palearctic realms also interdigitate the basin. Furthermore, the Kali Gandaki drainage of the basin crosses four major mountain ranges and divides the basin into at least five ecoregions -trans-Himalaya, mountain, high hills, low hills, and mid land (Edds, 1993). These factors probably explain higher fish diversity in the Gandaki river system.

In general, freshwater fish diversity in Nepal shows a distinct altitudinal gradient in accordance with the River Continuum Concept (RCC) proposed by Vannote et al. (1980). The RCC states different physico-chemical parameters of a lotic system changes from the headwaters through the middle reaches to the mouth of a river, and lotic biotic assemblages reflect those changes. The upper reaches of glacier-fed and snow-fed rivers in the mountain regions characterized by fast-flowing water regimes and rich dissolved oxygen are dominated particularly by *Schizothorax* species. The mid-hills are mainly inhabited by a mixed group of fishes like *Tor* spp., *Labeo* spp. etc. In contrast, lower Terai is mainly inhabited by minnows, carps, knife fish,

perches, and eels (Shrestha, 2003), which are typical warm water taxa (Hoagstrom et al., 2011). A number of studies have reported the presence of *Schizothorax* spp. in the Himalayan streams from India as well (Sharma & Mehta, 2010; Bhat et al., 2010). However, the presence of fish beyond the tree line in Nepal has not been reported yet. High altitude lakes and rivers are known to be naturally fishless because the elevation acts as a natural physical barrier against fish migration and colonization (Ventura et al., 2017). In Nepal, only three endemic species of *Schizothorax* have been reported from Lake Rara -a high mountain lake in the western region of the country (Terashima, 1984; Table 3).

Threats to fish in Nepal

Both natural and anthropogenic threats are present. Natural threats include siltation of water bodies, hydrological regimes, geological weathering, temperature, surface runoff, groundwater flow and precipitation (Khadka & Khanal, 2008). Anthropogenic threats include a range of human activities and include damming, overharvesting, illegal fishing, waste dumping, and poisoning (Gurung, 2012). The two most important anthropogenic threats in Nepalese rivers are damming (ADB, 2018) and river pollution (HMGN/MFSC, 2002). With several dams existing in different rivers and many more hydroelectricity projects in the pipeline, river damming poses serious threats to many fish species (ADB, 2018). Damming and impoundments may result in loss of migratory species and decreased diversity through the loss of hydrological connectivity and alteration of flow regimes (Amezua et al., 2019; Benejam et al., 2010; White et al., 2011). Reduced fish diversity and abundance are attributed to the disruption of the reproductive cycles of fish species through the loss of their migratory routes, fish kill and injury by turbine blades, and increased susceptibility to parasitic infection (ADB, 2018). Climate change may further exacerbate the impacts. Fifty-nine fish species in Nepalese freshwater systems have been recognized as cold-water species (Swar, 2002). Climate change

induced altitudinal shift towards higher elevations may jeopardize several indigenous species such as *Tor* spp., *Neolissochilus hexagonolepis*, and *Schizothorax* spp. (Gurung, 2012;

Swar, 2002). A summary of different threats and their likely impacts on freshwater fishes in Nepal are shown in Table 7.

Table 7 Different threats and impacts on freshwater.

Threats	Impacts	References
Impoundment in Kulekhani Reservoir	Complete disappearance of <i>Garra lamta</i> , <i>Pethia ticto</i> , <i>Nemacheilus</i> spp., <i>Channa gachua</i> , <i>Glyptosternum</i> spp., <i>Coraglanis</i> spp., <i>Schizothorax richardsonii</i>	(Saund & Shrestha, 2007)
River pollution in Bagmati	Fish diversity reduced from 54 to 7 species	(HMGN/MFSC, 2002)
Destructive fish catch methods	Decline in fish diversity and abundance	(Gurung, 2012)
Introduction of fish	Loss of native species through competition	(Gurung, 2012)
Climate change	An altitudinal shift towards higher elevation may occur	(Gurung, 2012)

Source: Modified from Gurung (2012) and ADB (2018).

Conclusion

This review describes the status of freshwater fish diversity in Nepalese freshwater systems. The total fish species found in Nepal varies from 220 to 255, thus differs from author to author. However, most of the literature has consistently reported the total number between 186 to 232 while a recent literature suggests a total of 252. However, this study has recorded a total of 258 species indicating a rich ichthyofauna diversity. Cyprinidae is the most common as well as the dominant taxon. Gandaki basin harbors the largest number of fish diversity. A total of 34 fish species in Nepal have been listed under IUCN Red List threatened category. Major threats to fish fauna include damming and pollution of water bodies.

Many of the fish studies have been conducted at selective stretches of the rivers, which fail to reflect the gamma diversity as a river flows through different ecological zones with variable environmental parameters. Moreover, most of these studies are one-time study, which does not reflect the seasonal variation of fish abundance and diversity. Therefore, studies focusing on longitudinal aspects encompassing different seasons are crucial to capture spatio-temporal variations. Fish assemblages, like any other biotic assemblages, are affected by a range of abiotic variables. Therefore, fish diversity studies should also consider different environmental variables.

Natural and anthropogenic stressors such as siltation, flood, habitat alterations, illegal fishing, the introduction of new species and overexploitation are known to affect fish assemblages. Therefore, the assessments of impacts of such stressors also need to be understood. The provision for deposition of voucher specimens and museum specimens still lacks with poor taxonomic studies. Moreover, till now, morphology-based identification and taxonomy are widely followed in the Nepalese context. Genetic and molecular studies have been proven to be effective in resolving not only taxonomic resolution of many taxa; such studies are also important in assessing genetic diversity. For fish taxonomic resolution and diversity assessment, eDNA (environmental DNA) has been used frequently. Therefore, considering the importance of genetic diversity as the raw materials for

evolution, genetic and molecular studies should also be conducted.

The findings of this study will be useful to ichthyologists, aquatic biologists as well as managers/planners working in the field of fish diversity, freshwater conservation, and management.

References

- ADB. (2018). *Impact of dams on fish in the rivers of Nepal*. doi <http://dx.doi.org/10.22617/TCS189802>.
- Adhikari, B. (2004). *Fish diversity and fishery resources of Mardi Khola, Kaski, Nepal*. (Unpublished master thesis), Central Department of Zoology, Tribhuvan University, Nepal.
- Amezcuca, F., Rajnohova, J., Flores-de-Santiago, F., Flores-Verdugo, F., and Amezcua-Linares, F. (2019). The effect of hydrological connectivity on fish assemblages in a floodplain system from the South-East Gulf of California, Mexico. *Frontiers in Marine Science*, 6:240. doi 10.3389/fmars.2019.00240
- Anonymous. (1995). Nepal's Flora and Fauna in the Current CITES list, 1995. Published by IUCN, Nepal, 1995.
- Bajrachrya, B. (2001). *Fish and fishery resources of the Bhotekoshi and Sunkoshi River*. (Unpublished master thesis), Central Department of Zoology, Tribhuvan University, Nepal.
- Benejam, L., Angermeier, P.L., Munne, A., & Garci-Aberthou, E. (2010). Assessing effects of water abstraction on fish assemblages in Mediterranean streams. *Freshwater Biology*, 55, 628–642.
- Berra, T. (2007). *Freshwater fish distribution*. Academic press.
- Bhandari, D., Uprety, M., Ghimire, G., Kumal, B., Pokharel, L., & Khadka, P. (2018). Nepal flood 2017: Wake up call for effective preparedness and response, Rugby, U.K.: Practical Action.
- Bhat, F.A., Yousuf, A.R., Balkhi, M.H., Mahdi, M.D., & Shah, F.A. (2010). Length-weight relationship and morphometric characteristics of *Schizothorax* spp. in the River Lidder of Kashmir, *Indian Journal of Fisheries*, 57(2), 73-76.

- Bhatt, J.P., Manish, K., & Pandit, M.K. (2012). Elevational gradients in fish diversity in the Himalaya: water discharge is the key driver of distribution patterns. *PLoS ONE* 7(9), e46237. doi 10.1371/journal.pone.0046237.
- Bhusal, G., & Chitrakar, P. (2017). Taxonomic investigation and fish diversity study on some hill stream fishes available in Roshi Khola, Panauti of Nepal. *International Journal of Fisheries and Aquatic Studies*, 5(3), 213-217.
- Bist, T.B. (2014). *Fish diversity of Mahakali and Chameliya River junction area, far western Nepal*. (Unpublished master thesis), Central Department of Zoology, Tribhuvan University, Nepal.
- Boulenger, G.A. (1907). Reports on a collection of Batrachia, Reptiles and fish from Nepal and the western Himalayas. *Records of the Indian Museum.*, 1, 14-58.
- Bricker, S.H., Yadav, S.K., Macdonald, A.M., Satyal, Y., Dixit, A., & Bell, R. (2014). *Groundwater resilience Nepal: Preliminary findings from a case study in the Middle Hills*. British Geological Survey Open Report, OR/14/069, 67.
- Chataut, M.K. (2008). *Biodiversity of fish and fishery resources of Mahakali River*, (Unpublished master thesis), Central Department of Zoology, Tribhuvan University, Nepal.
- Chaudhari, B.R. (1999). *Fish bio-diversity and fishery resources of Budi Khola, a branch of the Karnali River*, (Unpublished master thesis), Central Department of Zoology, Tribhuvan University, Nepal.
- Conway, K.W., Edds, D.R., Shrestha, J., & Mayden, R.L. (2011). A new species of gravel-dwelling loach (Ostariophysi: Nemacheilidae) from the Nepalese Himalayan foothills. *Journal of Fish Biology*, 79, 1746-1759.
- Conway, K.W., & Mayden, R.L. (2008). Description of two new species of *Psilorhynchus* (Ostariophysi: Psilorhynchidae) and redescription of *P. balitora*. *Ichthyological Exploration of Freshwaters*, 19(3), 215-232.
- Conway, K.W. & Mayden, R.L. (2010). *Balitora eddsi*, a new species of hill stream loach from Nepal (Ostariophysi: Balitoridae). *Journal of Fish Biology*, 78, 1210-1216.
- Day, F. (1886). *The fishes of India - being a natural history of the fishes known to inhabit the seas and fresh water of India, Burma and Ceylon*. Reprinted by Today's and Tomorrow's Book Agency, New Delhi, Vols. I & II.
- Day, F. (1889). *The fauna of British India including Ceylon and Burma*. Vols. I & II. Taylor and Francis, London.
- De Witt, H.H. (1960). A contribution to the ichthyology of Nepal. *Stanford Ichthyology Bull*, 7(4), 63-68.
- Devkota, S. (2011). *Study on the impact fisheries on Jalari community of Phewa lake region Pokhara with a note on its ethnoichthyological Knowledge*. (Unpublished master thesis), Central Department of Zoology, Tribhuvan University, Nepal.
- Dhakal, D.P. (2015). *Species diversity and distribution of fish community of Renu River*. (Unpublished master thesis), Central Department of Zoology, Tribhuvan University, Nepal.
- Dhital, R.R., & Jha, D.K. (2002). Fish fauna of the Narayani River System and their impact on the fishermen community in Chitwan, Nepal. In Petr, T., & Swar, D.B. (eds.), *Cold water fisheries in the trans-Himalayan countries*. FAO. Fisheries Technical Paper. No. 431 Rome, FAO, pp. 116-125.
- Edds, D.R. (1993). Fish assemblage structure and environmental correlates in Nepal's Gandaki River. *Copeia*, (1), 48-60.
- Edds, D.R. (1986a). The fishes of Royal Chitwan National Park. *Journal of Natural History Museum*, 10(1), 1-12.
- Edds, D.R. (1986b). Fisheries of Kali Gandaki/Narayani Rivers. *Journal of Natural History Museum*, 10(1-4), 13-22.
- EIA. (2019). Environmental impact assessment (E.I.A.) of Phewa Lake Waste Water Management Project, Kaski District, Gandaki Province.
- FAO. (1997). Information of fisheries management of the kingdom of Nepal. Food and Agriculture Organization of the United Nations (F.A.O.).
- Froese, R., & Pauly, D. (2020). Fishbase. World Wide Web electronic publication. Retrieved October 12, 2020 from www.fishbase.se.
- Gautam, D., Saund, T.B., & Shrestha, J. (2010). Fish diversity of Jagadisapur Reservoir, Kapilbastu district, Nepal-a Ramsar Site. *Nepal Journal of Science and Technology*, 11, 229-234.
- Gautam, G., Jain, R., Poudel, L., & Shrestha, M. (2016). Fish faunal diversity and species richness of tectonic Lake Rupa in the mid-hill of central Nepal. *International Journal of Fisheries and Aquatic Studies*, 4(3), 690-694.
- Gillette, D.P., Edds, D.R., & Jha, B.R. (2016). *An assessment of climate change impacts on fishes in the Gandaki River basin, central Nepal*. Final Report submitted to Kathmandu University.
- GoN/MoFSC. (2014). *Nepal biodiversity strategy and action plan 2014-2020*. Government of Nepal, Ministry of Forests and Soil Conservation, Kathmandu, Nepal.
- GoN/NPC. (2019). *Environment statistics of Nepal 2019*. Government of Nepal, National Planning Commission, Central Bureau of Statistics, Thapathali, Kathmandu, Nepal.
- Gubhaju, S.R. (2008). Strategies for the conservation of fish in Nepal. In: *Indigenous fish stock and livelihood, workshop*. 5th June 2008, F.R.D./DoFD/NARC/NEFIS, 49-60.
- Gurung, M. (1997). *Study on Fish diversity and fishery resources of the Begnas Lake, Pokhara Valley*. (Unpublished master thesis), Central Department of Zoology, Tribhuvan University, Nepal.
- Gurung, T.B. (2012). Native fish conservation in Nepal: Challenges and opportunities. *Nepalese Journal of Biosciences*, 2, 71-79.
- Gurung, T.B., Wagle, S.W., Bista, J.D., Dhakal, R.P., Joshi, P.L., Batajoo, R., Adhikari, P., & Rai, A.K. (2005). Participatory fisheries management for livelihood improvement of fishers in Phewa Lake, Pokhara, Nepal. *Himalayan Journal of Sciences*, 3(5), 47-52.
- Hamilton, F. (1822). An account of the fishes found in the River Ganges and its branches. Edinburgh, pp. 405.
- HMG/N/MFSC. (2002). Nepal Biodiversity Strategy, pp. 170.
- Hoagstrom, C.W., Adams, G., Neumann, R.M., & Willis, D.W. (2011). *Guide to the fishes of South Dakota*. Forum Communications, pp. 70.
- Hora, S.L. (1940). The game fishes of India XL. The Boker of Assamese and Katli of the Nepalese *Barbus (Lissocheilus hexagonolepis)* McClelland. *Journal of the Bombay Natural History Society*, 42, 78-88.

- Husen, M.A. (2014). Impact of invasive alien fish, Nile tilapia (*Oreochromis niloticus*) on native fish catches of sub-tropical lakes (Phewa, Begnas and Rupa) of Pokhara valley, Nepal. In Thapa, G.J., Subedi, N., Pandey, M.R., Thapa, S.K., Chapagain, N.R., & Rana, A. (eds.), *Proceedings of the International Conference on Invasive Alien Species Management*, pp. 112-122.
- Husen, M.A., Gurung, T.B., Nepal, A.P., Rayamajhi, A., & Chand, S. (2019). First report of two fish species: *Chanda nama*, and *Hetropneustes fossilis* from Begnas Lake. *International Journal of Fauna and Biological Studies*, 6(4), 44-49.
- Husen, M.A., Sharma, S., Bista, J.D., Prasad, S., & Nepal, A. (2016). Capture fishery in relation to Nile tilapia management in the mountainous lakes of Pokhara valley, Nepal. In W.W. Taylor, D.M. Bartley, C.I. Goddard, N.J. Leonard, & R. Welcome (Eds), *Freshwater, fish and the future: Proceedings of the Global Cross-sectoral Conference* (pp. 239-250). Food and Agriculture Organization of the United Nations, Rome; Michigan State University, East Lansing; and American Fisheries Society, Bethesda, Maryland.
- Jayaram, K.C. (1999). The freshwater fishes of Indian region. Narendra Publishing House, Delhi, India.
- Jha, A. (2001). *Industrialization and its effects on fish diversity in Bighi River Janakpur, Zone (Nepal)*. (Unpublished master thesis), Central Department of Zoology, Tribhuvan University, Nepal
- Jha, B.R. (2006). *Fish ecological studies and its application in assessing ecological integrity of rivers in Nepal*. Doctoral dissertation, Kathmandu University, Dhulikhel, Nepal.
- Jha, B.R., Gurung, S., Khatri, K., Gurung, A., Thapa, A., K.C., M., Gurung, B., & Acharya, S. (2018). Patterns of diversity and conservation status of freshwater fishes in the glacial fed and rain fed rivers of eastern Nepal. *Environmental Biology of Fishes*, 101(8), 1295-1305.
- Jha, B.R., Gurung, S., Khatri, K., Gurung, B., Thapa, A., & Acharya, S. (2015). River ecological study: building the knowledge such as climate change in Nepal. *Journal of Mountain Area Research*, 1, 28–39.
- Jha, B.S. (1988). *Study on fish and fishery resources of Mahottary district, Janakpur Zone Nepal* (Unpublished master thesis), Central Department of Zoology, Tribhuvan University, Nepal.
- Jha, D.K. & Shrestha, M.K. (2000). *Fish biodiversity of the wetland at LAAS, Rampur, Chitwan. Phase-I and Phase-II*. IAAS Research Reports, pp. 79-91.
- Jha, D.K., & Bhujel, R.C. (2014). Fish diversity of Narayani River System in Nepal. *Nepalese Journal of Aquaculture and Fisheries*, 1, 94-108.
- Jha, D.K. (2018). Species diversity, distribution and status of fishes in Chitwan district and adjacent areas, Nepal. *Journal of Natural History Museum*, 30, 85-101.
- Jha, D.K., Shrestha, M.K., & Rai, S.C. (1989). Fish fauna of Narayani and Rapti systems in Chitwan, Nepal. *Journal of Institute of Agriculture & Animal Science*, 10, 97-107.
- Jnawali, S.R., Baral, H.S., Lee, S., Acharya, K.P., Upadhyay, G.P., Pandey, M., Shrestha, R., Joshi, D., Laminchhane, B.R., Griffiths, J., Khatiwada, A.P., Subedi, N., & Amin, R. (2011). The status of Nepal mammals: the national red list series, Department of National Parks and Wildlife Conservation Kathmandu, Nepal.
- Joshi, D., & K.C., B. (2017). Fish diversity of Ghodaghodi Lake in Kailali, Far-West Nepal. *Journal of Institute of Science and technology*, 22 (1), 120-126.
- Joshi, P.L. (1988). *Studies on fishery resources of Sunkoshi River with particular reference to dam and its impact on fishery*. (Unpublished master thesis), Tribhuvan University, Nepal.
- K.C., B. (2015). *Fish diversity of Sharada River in Salyan Mid-Western Nepal*. (Unpublished master thesis), Central Department of Zoology, Tribhuvan University, Nepal.
- Karki, S.K. (2000). *Fish bio-diversity and fishery resources of lower Karnali, Nepal with special reference to the Eastern Part*. (Unpublished master thesis), Central Department of Zoology Tribhuvan University, Nepal.
- Karna, B.K. (1993). *A study on the fishery ecology of the Trishuli River*. (Unpublished master thesis), Central Department of Zoology Tribhuvan University, Nepal.
- Khadka, R.B. & Khanal, A.B. (2008). Environmental management plan (E.M.P.) for Melamchi water supply project. *Environmental Monitoring and Assessment*, 146(1-3), 225-234.
- Khatri, K., Jha, B.R., Gurung, S., Khadka, U.R., Pokharel, S., Adhikari, A., & Shrestha, A.K. (2019). Fish diversity and distribution status in Bheri and Babai River, mid-western, Nepal. In Gurung, S., Sitaula, B.K., Bajracharya, R.M., Raut, N., & Dahal, B.M. (Eds.), *Proceedings of International Conference on Natural Resources, Agriculture and Society in Changing Climate*, pp. 206-217, Kathmandu, Nepal.
- Khatri, D.S. (2010). *Study on fishes of Mahakali River with reference to Hill-Stream fishes*. (Unpublished master thesis), Central Department of Zoology, Tribhuvan University, Nepal.
- Kumar, P., Barma, S.K., & Subba, B.R. (2011). A checklist of fishes of eastern Terai of Nepal *Nepalese Journal of Biosciences*, 1, 63-65.
- Kunwar, P.S. (2002). *Distributional patterns and community structure of fish and invertebrate in Rohini River, Nepal*. (Unpublished master thesis), Central Department of Zoology Tribhuvan University, Nepal.
- Lamsal, P., Pant, K.P., Kumar, L., & Atreya, K. (2014). Diversity, uses, and threats in the Ghodaghodi Lake complex, a Ramsar Site in western lowland Nepal. 680102, doi 10.1155/2014/680102.
- Lévêque, C., Oberdorff, T., Paugy, D., Stiassny M.L.J., & Tedesco, P.A. (2008). Global diversity of fish (Pisces) in freshwater. *Hydrobiologia*, 595(1), 545–567.
- Limbu, J.H., & Gupta, S.K. (2019). Fish diversity of Damak and lower Terai region of Ratuwa River of Jhapa district, Nepal. *International Journal of Fauna and Biological Studies*, 6(1), 01-04.
- Limbu, J.H., Prasad, A., & Baniya, C.B. (2019a). Spatio-temporal variation of fish assemblages in Ratuwa River, Ilam, Nepal. *Journal of Ecology & Natural Resources*, 3(3), 000168. doi 10.23880/jenr-16000168.
- Limbu, J.H., Acharya, G.S., & Shrestha, O.M. (2018b). A brief report on ichthyofaunal diversity of Dewmai Khola of Ilam district, Nepal. *Journal of Natural History Museum*, 30, 312-317.

- Limbu, J.H., Chapagain, N., Gupta, S.K., & Sunuwar, S. (2019a). Review on fish diversity of eastern Nepal. *International Journal of Fisheries and Aquatic Studies*, 7(3), 177-181.
- Limbu, K.P., & Subba, B.R. (2011). Status of key faunal species in Koshi Tappu Wildlife Reserve after Koshi flood disaster 2008. *Nepalese Journal of Biosciences* 1, 41-54.
- Limbu, J.H., Shrestha, O.M., & Prasad, A. (2018a). Ichthyofaunal diversity of Bakraha River of Morang district, Nepal. *International Journal of Fisheries and Aquatic Studies*, 6(5), 267-271.
- Lundberg, J.G., Kottelat, M., Smith, G.R., Melanie, L., Staissny, J., & Gill, A.C. (2000). So many fishes, so little time: an overview of recent ichthyological discovery in continental waters. *Annals of the Missouri Botanical Garden*, 87(1), 26-62.
- Majupuria, T.C., & Shrestha, J. (1968). Fresh water fishes and fisheries. *HMG/UNESCO Regional Seminar of the Ecology of Tropical Highlands*, Kathmandu, Nepal, 4-7.
- Mali, S.R. (2008). *Study on fish resources of Dolalghat region in reference to fishing techniques, conservation fish production and marketing*. (Unpublished master thesis), Central Department of Zoology, Tribhuvan University, Nepal.
- Malla, P.M. (2004). *Diversity, distributional patterns and frequency occurrence of fish and invertebrate species in Daram Khola, Baglung, Nepal*. (Unpublished master thesis), Central Department of Zoology, Tribhuvan University, Nepal.
- Manandhar, S. (1994). *A study on the effect of physico-chemical parameters on the fish fauna in the Indrawati River*. (Unpublished master thesis), Central Department of Zoology Tribhuvan University, Nepal.
- Mandal, R.B., & Jha, D.K. (2013). Impacts of damming on ichthyofaunal diversity of Marshyangdi River in Lamjung district, Nepal. *Our Nature*, 11(2), 168-176
- Mandal, R.B. (1995). *Studies on biodiversity of the fishes in relation to changing habitat of the Tadi River*. (Unpublished master thesis), Central Department of Zoology, Tribhuvan University, Nepal.
- Menon, A.G.K. (1949). Notes on fishes; XLIV - Fish from the Koshi Himalayas, Nepal. *Records of the Indian Museum.*, 47, 231-237.
- Menon, A.G.K. (1962). A distributional list of fishes of the Himalayas. *Journal of the Zoological Society of India*, 14(1&2), 23-32.
- Menon, A.G.K., & Datta, A.K. (1964). *Psilorhynchus pseudodeheneis*, a new Cyprinid fish from Nepal. *Records of the Indian Museum.*, 59, 253 -255.
- Mishra, A.R., & Baniya, C.B. (2016). Ichthyofaunal diversity and physico-chemical factors of Melamchi River, Sindhupalchok, Nepal. *Journal of Institute of Science and technology*, 21(1), 10-18.
- Nelson, J.S., Grande, T.C., & Wilson, M.V.H. (2016). *Fishes of the world*. Hoboken, New Jersey: John Wiley & Sons.
- Nepal, A.P., Sharma, S., & Gurung, T.B. (2015). Fish catch seasonal variation in Phewa Lake, Nepal. *Nepalese Journal of Aquaculture and Fisheries*, 2, 27-39.
- Ng, H.H., & Edds, D.R. (2004). *Batasio macronotus*, a new species of Bagrid catfish from Nepal (Teleostei: Bagridae). *Ichthyological Exploration of Freshwater*, 15 (4), 295-307.
- Ng, H.H., & Edds, D.R. (2005a). Two new species of Erethistoides (Teleostei: Erethistidae) from Nepal. *Ichthyological Exploration of Freshwater*, 16 (3), 239-248.
- Ng, H.H., & Edds, D.R. (2005b). Two new species of *Pseudechensis rheophilic*, catfish (Teleostei: Sisoridae) from Nepal. *Zootaxa*, 1047, 1-19.
- Ng, H.H. (2006). The identity of *Pseudechenis sulcata* (McClelland) with description of two new species of Rheophilic catfish (Teleostei: Sisoridae). *Zootaxa*, 1254, 45-68.
- Oli, B.B., Jha, D.K., Aryal, P.C., Shrestha, M.K., Dangol, D.R., & Gautam, B. (2013). Seasonal variation in water quality and fish diversity of Rampur Ghol, a wetland in Chitwan, Central Nepal. *Nepalese Journal of Biosciences*, 3, 9-17.
- Oli, T.B. (2017). *Fish diversity of west Rapti River, Dang, Nepal* (Unpublished master thesis), Central Department of Zoology, Tribhuvan University, Nepal.
- Pandey, C.B. (2002). *A study on the effect of Physico-chemical parameters on the Fish Fauna in the Bheri River* (Unpublished master thesis), Central Department of Zoology, Tribhuvan University, Nepal.
- Paudel, S. (2006). *Study on the fish and fishery resources of the Rapti River*. (Unpublished master thesis), Central Department of Zoology, Tribhuvan University, Nepal.
- Pokharel, K.K., Basnet, K.B., Majupuria, T.C., & Baniya, C.B. (2018). Correlations between fish assemblage structure and environmental variables of the Seti Gandaki River Basin, Nepal. *Journal of Freshwater Ecology*, 33(1), 31-43.
- Pokharel, B.R. (2008). *Study of water quality, fish and fishery of Mechi River*. (Unpublished master thesis), Central Department of Zoology, Tribhuvan University, Nepal.
- Pokharel, B.P. (2011). *Fish diversity of West Rapti River Mid – Western Nepal*. (Unpublished master thesis), Central Department of Zoology, Tribhuvan University, Nepal.
- Poudel, L. (2008). *Study on fish and fishery resources of Mahakali River at Dodhara Chandani VDC area, far western Nepal*. (Unpublished master thesis), Central Department of Zoology, Tribhuvan University, Nepal.
- Prajoo, N. (2007). *Study on fish diversity of Harpan Khola and socioeconomic of the Jalari women of Pheva Lake*. (Unpublished master thesis), Central Department of Zoology, Tribhuvan University, Nepal.
- Rajbanshi, K.G. (1982). *General bibliography of fish and fisheries of Nepal*. Royal Nepal Academy, Kathmandu, pp. 99.
- Rajbanshi, K.G. (2002). Zoogeographical distribution and the status of cold water fish of Nepal. In Peter, T., & Swar, D.B. (Eds), *Cold water fishes of Trans-Himalayan countries*. F.A.O. Fisheries Technical Paper No. 431, F.A.O., Rome, Italy, pp. 214-240.
- Rajbanshi, K.G. (2012). *Biodiversity and distribution of fresh water fishes of central Nepal Himalayan region*. Kathmandu: Nepal Fisheries Society, pp. 136.
- Ranjit, R. (2002). The current status of capture fishery in the Upper Sunkoshi River. In Petr, T., & Swar, D.B. (Eds.), *Cold water fisheries in the trans-Himalayan countries*. FAO. Fisheries Technical Paper. No. 431 Rome, FAO, pp. 240-249.
- Rayamajhi, A. (2017) Fish assemblage structure of Chitwan National Park, its buffer and adjacent zone, central Nepal

- with notes on macro habitat. *International Journal of Fisheries and Aquatic Studies*, 5(5), 408-416.
- Regan, C.T. (1907). Reports on a collection of Batrachia, reptiles and fish from Nepal and the western Himalayas. *Records of the Indian Museum*, 1, 157-158.
- Sapkota, K. (1992) *A study of the fishery ecology of the swamplands of Koshi River*. (Unpublished master thesis), Central Department of Zoology, Tribhuvan University, Nepal.
- Saud, S. (2011). *Fish diversity and fishery resources of the Koshi River at KTWR, Nepal*. (Unpublished master thesis), Central Department of Zoology, Tribhuvan University, Nepal.
- Saund, T.B., & Shrestha, J. (2007). Fish and benthic fauna in Kulekhani Reservoir, Makwanpur *Nepal Journal of Science and Technology*, 8, 63-68.
- Shah, R.B. (2005). *Fish diversity of Budbiganga River, far-western Nepal*. (Unpublished master thesis), Central Department of Zoology, Tribhuvan University, Nepal.
- Sharma, C.M. (1996). *Study on the fish biodiversity and fishery resources of the Tinau River* (Unpublished master thesis), Central Department of Zoology, Tribhuvan University, Nepal.
- Sharma, C.M. (2008). Freshwater fishes, fisheries, and habitat prospects of Nepal, *Aquatic Ecosystem Health & Management*, 11(3), 289-297.
- Sharma, I., & Mehta, H.S. (2010). Studies on snow trout *Schizothorax richardsonii* (Gray) in River Beas and its tributaries (Himachal Pradesh), India. *Records of the Zoological Survey of India, Occasional Paper*, 323, 1-69.
- Shilpi, S. (2010). *Study on the fish and fishery resources in Dhanusha District*. (Unpublished master thesis), Central Department of Zoology, Tribhuvan University, Nepal.
- Shrestha, J. (1981). *Fishes of Nepal*. C.D.C. Tribhuvan University, Kathmandu, Nepal.
- Shrestha, J. (1994). *Fishes, fishing implements and methods of Nepal*. Smt. M.D Gupta. Lalitpur Colony, Lashkar (Gwalior), India, pp. 150.
- Shrestha, J. (1995). *Enumeration of the fishes of Nepal*. Publication No.10. HMG/N & Govt. of Netherlands, 417/4308, 263.
- Shrestha, J. (1999). Cold water fish and fisheries in Nepal. *Fisheries Technical Paper*, 385, 13-40. FAO, Rome
- Shrestha, J. (2002). *Taxonomic revision of cold water fishes of Nepal*. Food and Agriculture Organization of the United Nations, Rome, Italy. F.A.O. Fisheries Technical Paper 431.
- Shrestha, J., Singh, D.M., & Saund, T.B. (2009). Fish diversity of Tamor River and its major tributaries of eastern Himalayan region of Nepal. *Nepal Journal of Science and Technology*, 10, 219-223.
- Shrestha, J.N. (2016). Fish diversity of Triyuga River, Udayapur district, Nepal. *Our Nature*, 14(1), 124-134.
- Shrestha, S. (2005). *Study on fish diversity and fishery resources of Dano River, Rupandehi district*. (Unpublished master thesis), Central Department of Zoology, Tribhuvan University, Nepal
- Shrestha, T.K. (2003). Conservation and management of fishes in the large Himalayan rivers of Nepal. *Second International Symposium on the Management of Large Rivers for Fisheries: Sustaining Livelihoods and Biodiversity in the New Millennium*. Phnom Penh, Cambodia, 2003 February 11-14. F.A.O. (of the United Nations).
- Shrestha, T.K. (2000). Cold water fisheries development in Nepal. In Petr, T., & Swar, D.B. (Eds.), *Cold water fisheries in trans-Himalayan countries*. FAO Fisheries Technical Paper, 431, 47-58.
- Shrestha, T.K. (2008). *Ichthyology of Nepal. A study of fishes of the Himalayan water*. Himalayan ecosphere. Kathmandu, Nepal.
- Singh, N.M. (1992). *Study on the physicochemical parameters in relation to fish fauna of Manohara River, Kathmandu valley*. (Unpublished master thesis), Central Department of Zoology, Tribhuvan University, Nepal.
- Singh, P.K. (2017). *Ichthyofauna and socio-economic status of Mallab Community in the Koshi River Basin, Bardaha VDC, Saptari, Nepal* (Unpublished master thesis), Tribhuvan University, Nepal.
- Singh, R. (2002). *Fish biodiversity and fishery resources of Babai River, Nepal*. (Unpublished master thesis), Central Department of Zoology, Tribhuvan University, Nepal.
- Smith, B.D, Bhandari, B., & Sapkota, K. (1996). Aquatic biodiversity in the Karnali and Narayani River basins- Nepal. IUCN Nepal, Kathmandu, pp. xii+59.
- Subba, B.R., Pokharel, N., & Pandey, M.R. (2017). Ichthyofaunal diversity of Morang district, Nepal. *Our Nature*, 15 (1-2), 55-67.
- Swar, D.B. (2002). The status of cold water fish and fisheries in Nepal and prospects of their utilization for poverty reduction. In Petr, T., & Swar, D.B. (Eds), *Cold water fisheries in the trans-Himalayan countries*. Fisheries Technical Papers No. 431, Published by FAO pp. 376
- Taft, A.C. (1955). *A Survey of the fisheries of Nepal, both present and potential*. Nepal American Agriculture Co-operation Service, Kathmandu, Nepal.
- Talwar, P.K., & Jhingran, A.G. (1991). *Inland Fishes of India and Adjacent Countries*. Vol. I & II. Oxford & I.B.H. Publishing Co., New Delhi, India
- Terashima, A. (1984). Three new species of the cyprinoids Genus *Schizothorax* from lake Rara, North Western Nepal. *Japanese Journal of Ichthyology*, 31(2), 122-135.
- Thapa, A.B. (2005). *An investigation of macro invertebrates and fish diversity in river dolphin habitat of the Karnali River*. (Unpublished master thesis), Central Department of Zoology, Tribhuvan University, Nepal.
- Thapa, B. (2018). *Fish diversity of Dipang lake in the Mid-hill of Kaski district, Nepal* (Unpublished master thesis), Central Department of Zoology, Tribhuvan University, Nepal.
- Vannote, R.L., Minshall, G.W., Cummins, K.W., Sedell, J.R., & Cushing, C.E. (1980). The river continuum concept. *Canadian Journal of Fisheries and Aquatic Sciences*, 37(1), 130-137.
- Ventura, M., Tiberti, R., Buchaca, T., Buñay, D., Sabás, I., & Miró, A. (2017). Why should we preserve fishless high mountain Lakes? In Catalan, J., Ninot, J.M., & Aniz, M.M. (Eds.), *High mountain conservation in a changing world*, pp. 181-205.
- Wagle, S.K., & Pradhan, N. (Eds.). (2011). *Proceedings of the consultative workshop on fish conservation in Nepal*. Fisheries Research Division (FRD), Godavari, Lalitpur, Nepal, pp. 229.

-
- WECS. (2011). Water and Energy Commission Secretariat. Water Resources of Nepal (GoN), pp. 67.
- White, S.M., Ondrac'kova', M., & Reichard, M. (2011). Hydrologic connectivity affects fish assemblage structure, diversity, and ecological traits in the unregulated Gambia River, West Africa. *Biotropica*, 44, 551-530.
- WWF. (2006). Wetlands of Nepal, Factsheet.
- Yadhav, N.S. (2017). *Fish diversity of Bagmati River, Sarlahi, Nepal*. (Unpublished master thesis), Tribhuvan University, Nepal.
- Yadhav, S.N. (2017). Studies on fish diversity and need for their conservation of Singhiya River, Morang district, eastern Nepal. *Agriculture, Forestry and Fisheries*, 6(3), 78-81.
- Zhang, J., & Hanner, R. (2012). Molecular approach to the identification of fish in the South China Sea. *PLoS ONE*, 7(2). doi 10.1371/journal.pone.0030621.