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

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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 Saptaposhi in the eastern part, the Saptapandali (Narayan) 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; HMGN/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 (Ghus 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.

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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 hegamonlepis 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 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 | Mal, 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, 1986a |
| 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, 32 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 |
| Aandhri 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 |
| River                                | Orders | Families | Genera | Family | Genera      |
|--------------------------------------|--------|----------|--------|--------|-------------|
| Kathmandu River                      | 10     | 10       | 20     | Cyprinidae | (Khatri et al., 2019) |
| Bagmati River                        | 16     | 16       | 32     | Cyprinidae | (Shrestha, 1999) |
| Eastern Terai                         | 8      | 8        | 16     | Cyprinidae | (Kumar et al., 2011) |
| Morang District                      | 10     | 10       | 20     | Cyprinidae | (Subha et al., 2017) |
| Singhiya River                       | 14     | 14       | 28     | Cyprinidae | (Yadav, 2017) |
| Tawa Khola                           | 4      | 4        | 8      | Cyprinidae | (Jha et al., 2018) |
| Bakraha River                        | 2      | 2        | 4      | Cyprinidae | (Limbu et al., 2018a) |
| Dewmai Khola                         | 3      | 3        | 6      | Cyprinidae | (Limbu et al., 2018b) |
| Ratuwa River                         | 5      | 5        | 10     | Cyprinidae | (Limbu & Gupta, 2019) |
| Ratuwa River                         | 3      | 3        | 6      | Cyprinidae | (Limbu et al., 2019a) |
| Eastern Nepal                        | 10     | 10       | 20     | Cyprinidae | (Limbu et al., 2019b) |
| Manohara River                       | 3      | 3        | 6      | Cyprinidae | (Singh, 1992) |
| Tinau River                          | 4      | 4        | 8      | Cyprinidae | (Sharma, 1996) |
| Bagmati River                        | 1      | 1        | 2      | Nemacheilida | (Jha, 2006) |
| Tinau River                          | 4      | 4        | 8      | Cyprinidae | (Jha, 2006) |
| Mahottary District                   | 6      | 6        | 12     | Cyprinidae | (Jha, 1988) |
| Bagi River                           | 3      | 3        | 6      | Cyprinidae | (Jha, 2001) |
| Babai River                          | 6      | 6        | 12     | Cyprinidae | (Singh, 2002) |
| Rohini Khola                         | 4      | 4        | 8      | Cyprinidae | (Kunwar, 2002) |
| Daram Khola                          | 4      | 4        | 8      | Cyprinidae | (Malla, 2004) |
| Dano River                           | 4      | 4        | 8      | Cyprinidae | (Shrestha, 2005) |
| Harpan Khola                         | 5      | 5        | 10     | Cyprinidae | (Prajoo, 2007) |
| Meki River                           | 5      | 5        | 10     | Cyprinidae | (Pokhrel, 2008) |
| Dhanusha District                    | 6      | 6        | 12     | Cyprinidae | (Shilpi, 2010) |
| West Rapti                           | 4      | 4        | 8      | Cyprinidae | (Pokhrel, 2011) |
| Sharada River                        | 3      | 3        | 6      | Cyprinidae | (K.C., 2015) |
| Bagmati River                        | 6      | 6        | 12     | Cyprinidae | (Yadav, 2017) |
| Rapti River                          | 4      | 4        | 8      | Cyprinidae | (Oli, 2017) |
| Babai River and its tributaries      | 5      | 5        | 10     | Cyprinidae | (Khati et al., 2019) |
Table 3 Fish taxa in different Lentic systems.

| Lakes/reservoirs            | Total Fish Species | Fish Taxa | Dominant Taxa | Reference          |
|-----------------------------|--------------------|-----------|---------------|--------------------|
| Beeshazar and Associated    | 17                 | Cyprinidae| (WWF, 2006)   |
| Begnas Lake                 | 25                 | Cyprinidae| (Husen et al., 2019) |
| Begnas Lake                 | 19                 | Cyprinidae| (Gurung, 1997) |
| Begnas Lake                 | 22                 | Cyprinidae| (Husen et al., 2016) |
| Begnas Lake                 | 20                 | Cyprinidae| (Husen, 2014)  |
| Dipang Lake                 | 15                 | Cyprinidae| (Thapa, 2018)  |
| Ghodaghodi Lake             | 13                 | Cyprinidae| (Joshi & K.C., 2017) |
| Ghodaghodi Lake             | 18                 | Cyprinidae| (Lamsal et al., 2014) |
| Ghodaghodi Lake             | 29                 | Cyprinidae| (WWF, 2006)   |
| Jagadishpur Reservoir       | 25                 | Cyprinidae| (WWF, 2006)   |
| Jagadishpur Reservoir       | 42                 | Cyprinidae| (Gautam et al., 2010) |
| Phewa Lake                  | 21                 | Cyprinidae| (Devkota, 2011) |
| Phewa Lake                  | 19                 | Cyprinidae| (ELA, 2019)   |
| Phewa Lake                  | 25                 | Cyprinidae| (Gurung et al., 2005) |
| Phewa Lake                  | 15                 | Cyprinidae| (Nepal et al., 2015) |
| Phewa Lake                  | 23                 | Cyprinidae| (Husen et al., 2016) |
| Rara Lake                   | 3                  | Cyprinidae| (Terashina, 1984) |
| Rupa Lake                   | 23                 | Cyprinidae| (Gautam et al., 2016) |
| Rupa Lake                   | 21                 | Cyprinidae| (Husen et al., 2016) |
| Rupa Lake                   | 13                 | Cyprinidae| (Husen, 2014)  |
| Rampur Gol                  | 22                 | 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*) (Gubbhaju, 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      | Batrera edizi         | River Karnali                           | (Conway & Mayden, 2010)               |
| 2      | Batrion macronotus    | River Saptap Koshi                      | (Ng & Edds, 2004)                     |
| 3      | Erethistoides ascita  | River Mechi, River Kankai, River Trijuga, River Koshi | (Ng & Edds, 2005a) |
| 4      | Erethistoides crassianus | River Dhungra, River Rapit, River Narayani | (Ng & Edds, 2005a) |
| 5      | Myorghalis blythii    | Pharping- Kathmandu Valley              | (Jayaram, 1999)                      |
| 6      | Pseudoecheneis crassianus | Mewa Khola (Tributary of Tamor)        | (Ng & Edds, 2005b)                   |
| 7      | Pseudoecheneis edizi  | Mahesh Khola, River Trishuli            | (Ng, 2006)                            |
| 8      | Pseudoecheneis serracuda | River Seti, River Kali Gandaki, River Narayani, River Mahakali, | (Ng & Edds, 2005b) |
Psilorhynchus nepalensis River Rapti, Seti River, Narayani River (Conway & Mayden, 2008)
Psilorhynchus pseudochenies River Dudh Koshi (Menon & Datta, 1964)
Schizothorax macropthalmus Mahendra (Rara) Lake (Terashima, 1984)
Schizothorax nepalensis Mahendra (Rara) Lake (Terashima, 1984)
Schizothorax raraensis Mahendra (Rara) Lake (Terashima, 1984)
Neungvella nepalensis Narayani River, (Shrestha, 2008)
Turcinoemacheilius himalaya 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      | Barbonymus gonionotus | Silver barb       |
| 2      | Carassius carassius   | Goldfish          |
| 3      | Catla catla           | Bhakue            |
| 4      | Cirrhinus mrigala     | Naini             |
| 5      | Clarias garipinnus    | African maghur    |
| 6      | Ctenopharyngodon idella | Grass carp   |
| 7      | Cyprinus carpio       | Common carp       |
| 8      | Hypothalamichthys molitrix | Silver carp     |
| 9      | Hypothalamichthys nobilis | Bighead carp     |
| 10     | Labeo rohita          | Rohu              |
| 11     | Oncorhynchus mykiss   | Rainbow trout     |
| 12     | Oreochromis mossambicus | Tilapia         |
| 13     | Oreochromis niloticus | Tilapia           |
| 14     | Pangasianodon hypophthalmus | Pangasia    |
| 15     | Salmo trutta          | Brown trout       |

Table 6 IUCN Category of fish species in Nepal.

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

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 (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 pectinorai (Edds, 1986) in Chitwan National Park, Labeo gardi (Singh, 2002) in the Babai River, and Nemachelius 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.

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

| Order | Genus | Species |
|-------|-------|---------|
| 13 | Labor panguiia | Pangusia labo | Near Threatened |
| 14 | Neolissochilus becagonoldeps | Copper mahseer | Near Threatened |
| 15 | Schistura derer | Loach | Near Threatened |
| 16 | Systoma claratus | Steedman barb | Near Threatened |
| 17 | Chitala chitala | Clown knife fish | Near Threatened |
| 18 | Ctenophara nobilis | Frail gourami | Near Threatened |
| 19 | Oreochromis mossambicus | Mozambique tilapia | Near Threatened |
| 20 | Parambassis lala | Highfin glassy perchlet | Near Threatened |
| 21 | Ailia coila | Gangetic ailia | Near Threatened |
| 22 | Bagarius bagarius | Goonch | Near Threatened |
| 23 | Bagarius yarrelli | Goonch | Near Threatened |
| 24 | Ompok bimaculatus | Butter catfish | Near Threatened |
| 25 | Ompok pahda | Pabda catfish | Near Threatened |
| 26 | Ompok pabo | Pabo catfish | Near Threatened |
| 27 | Wallago attu | Wallago | Near Threatened |
| 28 | Cirrhinus cirrhosis | Mrigal carp | Vulnerable |
| 29 | Cyprinodon semiplatus | Assamese kingfish | Vulnerable |
| 30 | Nemachilus ingiisi | Loach | Vulnerable |
| 31 | Physoschistura elongate | Dwarf loach | Vulnerable |
| 32 | Schistura prashadi | Creek loach | Vulnerable |
| 33 | Schizothorax richardsonii | Snow trout | Vulnerable |
| 34 | Tor chelynotoides | Dark mahseer | Vulnerable |

Sources: ADB (2018) and Froese and Pauly (2020)
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 Palaearctic 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 these 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 (Amezuca 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 *Garra laneta*, *Pethia ticta*, *Nemacheilus* spp., *Chauna gachua*, *Glyptosternum* spp., *Coraglanis* spp., *Schizothorax richardsonii*   | (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.

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