*Zoodiversity*, **58**(2):137–150, 2024
DOI 10.15407/zoo2024.02.137

*Ecology*

UDC 597.2/.5(235.243)

# ICHTHYOFAUNAL DIVERSITY OF A RAMSAR SITE IN KASHMIR HIMALAYAS — WULAR LAKE

**S. T. Mushtaq*, M. H. Balkhi, F. A. Bhat & S. A. Mushtaq**

*Faculty of Fisheries, Sher-e-Kashmir University of Agricultural Sciences and Technology Kashmir, Rangil, Ganderbal-190006, India*
**Corresponding author*
*E-mail: syedtalia2020@gmail.com*

S. T. Mushtaq (https://orcid.org/0000-0002-2287-6690
M. H. Balkhi (https://orcid.org/0000-0002-8075-5889)
F. A. Bhat (https://orcid.org/0000-0002-8741-5334)

urn:lsid:zoobank.org:pub:5F94DC20-5475-4C48-88CB-999CB6FD34EB

**Ichthyofaunal Diversity of a Ramsar Site in Kashmir Himalayas — Wular Lake. Mushtaq, S. T., Balkhi, M. H., Bhat, F. A. & Mushtaq, S. A.** — The present study was undertaken in order to assess the current status of ichthyofaunal diversity of one of Asia's largest freshwater lakes — Wular, India. In this study the sampling was carried out every month at 5 different sites of Wular Lake which were selected on the basis of different ecological niches. A total of 738 fish species were collected during the entire study. The ichthyofaunal biodiversity observed in this study belonged to 2 orders, 2 families, 4 sub families and 6 genera. The carps viz. *Cyprinus carpio* (var. *communis)*, *Cyprinus carpio* (var. *specularis)* and *Carassius carassius* contributed more than 82.52 % to the total catch by biomass and 50.79 % to the total catch by number. Shannon-Wiener diversity index showed maximum value (1.476) during summer and minimum value (1.195) during autumn. Similarly, Pielou's Evenness index and Simpson's dominance index also showed maximum values (0.856 and 0.645) in summer and minimum values (0.738 and 0.438) in autumn respectively. The study revealed that there was a drastic decline in the native *Schizothorax* due to encroachment, pollution and other anthropogenic disturbances. Many fish species that had been reported in the lake in the earlier studies were not reported in this study, indicating their disappearance from the lake. Keeping in view the progressively worse situation, there is an urgent need to take remedial steps to conserve the endangered native fish fauna of the lake in order to preserve its biodiversity from further degradation.

Key words: anthropogenic, Himalayas, Wular Lake, endangered, biodiversity, ichthyofauna.

**Introduction**

The aquatic ecosystems around the world in general, and in the vulnerable areas such as Himalayas in particular, are facing an ever increasing threat from anthropogenic activities which necessitate a better understanding of the freshwater biodiversity for its conservation. The conservation of biodiversity is related to environmental changes that occur on a global scale which include climate change, change of land use and land cover etc (Gude et al., 2007; Liu et al., 2011). Unfortunately over the last decade, there has been a rapid change in ecosystems than ever before, due to which the biodiversity had decreased rapidly (Balmford et al., 2003). This loss is followed by the loss of knowledge of biodiversity which is more obvious among people who totally depend on the natural ecosystems for their survival and sustenance. India is one of the mega biodiversity hotspots in the world and occupies 9$^{th}$ position in terms of freshwater biodiversity (Mittermeier & Mittermeier, 1997). The country has numerous water bodies ranging from coldwater/hill streams, brackish waters, estuaries, wetlands and marine waters. These water bodies are home to a wide variety of fishes. Among all the different kinds of water bodies, wetlands occupy an important position as they are critical habitats for waterfowl, fish and other wildlife. These may be defined as unique land areas with fluctuating water levels which have critical ecological significance and which support a large variety of plant and animal populations. Once such wetland which also happens to be among Asia's largest freshwater lakes is Wular. Wular Lake, a Ramsar site is an oxbow type lake of fluviatile origin, located in District Bandipora in the Union territory of Jammu and Kashmir. It acts as a huge absorption basin for annual flood waters and accounts for 60 % of the total fish production in the state. However, due to encroachments, increase in silt content, use of fertilizers and pesticides and other solid wastes which find their way in the lake through runoffs, the lake is under tremendous pressure.

The Wular lake is one of Asia's largest freshwater lakes located in north Kashmir between geographical coordinates of 34°17'–34.25' N and 74°30'–74.40' E. The lake is known for its diverse fish fauna as it is home to a number of fish species dominated by cyprinids, with the most common species being *Cyprinus carpio* var. *communis*, *Schizothorax esocinus*, *Schizothorax curvifrons* and *Schizothorax niger*.

The forces which change the abundance and distribution of wetlands have an affect on the diversity and persistence of the flora and fauna of the wetland as well. Unfortunately, as a result of increased human intervention coupled with increased fishing pressure, the endemic fish populations have declined dramatically over the years providing alarming signals of accelerated loss of biodiversity. Efforts are being made to protect and conserve the fish fauna of Wular Lake, including the establishment of protected areas and the regulation of fishing practices. However, the lake faces a number of threats, including pollution, habitat loss, and overfishing, which can have significant impacts on fish populations and their habitats. In order to assess the current status of fish species availability including species richness and evenness, the study was undertaken with an aim to frame recommendations to prevent degradation of the wetland.

**Materials and Methods**

Study area

Wular Lake is the largest water body of South Asia. Its open water area at present is 16 km$^2$ and is spread in two districts of Kashmir valley viz. Bandipora and Baramulla. During the present study five sites were selected for sampling (fig. 1) on the basis of factors like feasibility, accessibility, availability of fishers, off shore and inshore sites and different ecological niches.

Study sites

1. Ningli 34°17'–15.8' N and 74°30'–24.9' E
2. Central Site 34°17'–74.31' N and 74°31'–29.8' E
3. Watlab Ghat 34°21'–29.4' N and 74°31'–42.8' E
4. Ashtung 34°24'–14.8' N and 74°32'–34.9' E
5. Vintage Park 34°21'–51.5' N and 74°39'–42.0' E

Collection and preservation of fish

The present study was carried out from December, 2014 to November, 2015 for a period of one year. Fishes were collected on a monthly basis with the help of local fishermen operating cast nets for catching fish in the morning hours. The total catch (number and weight) was recorded on each site with help of a digital balance. The representative samples were brought to the laboratory at Faculty of Fisheries, Rangil, Ganderbal and preserved in 10 % formalin in separate jars according to the size (Misra, 1962; Munro, 2000).

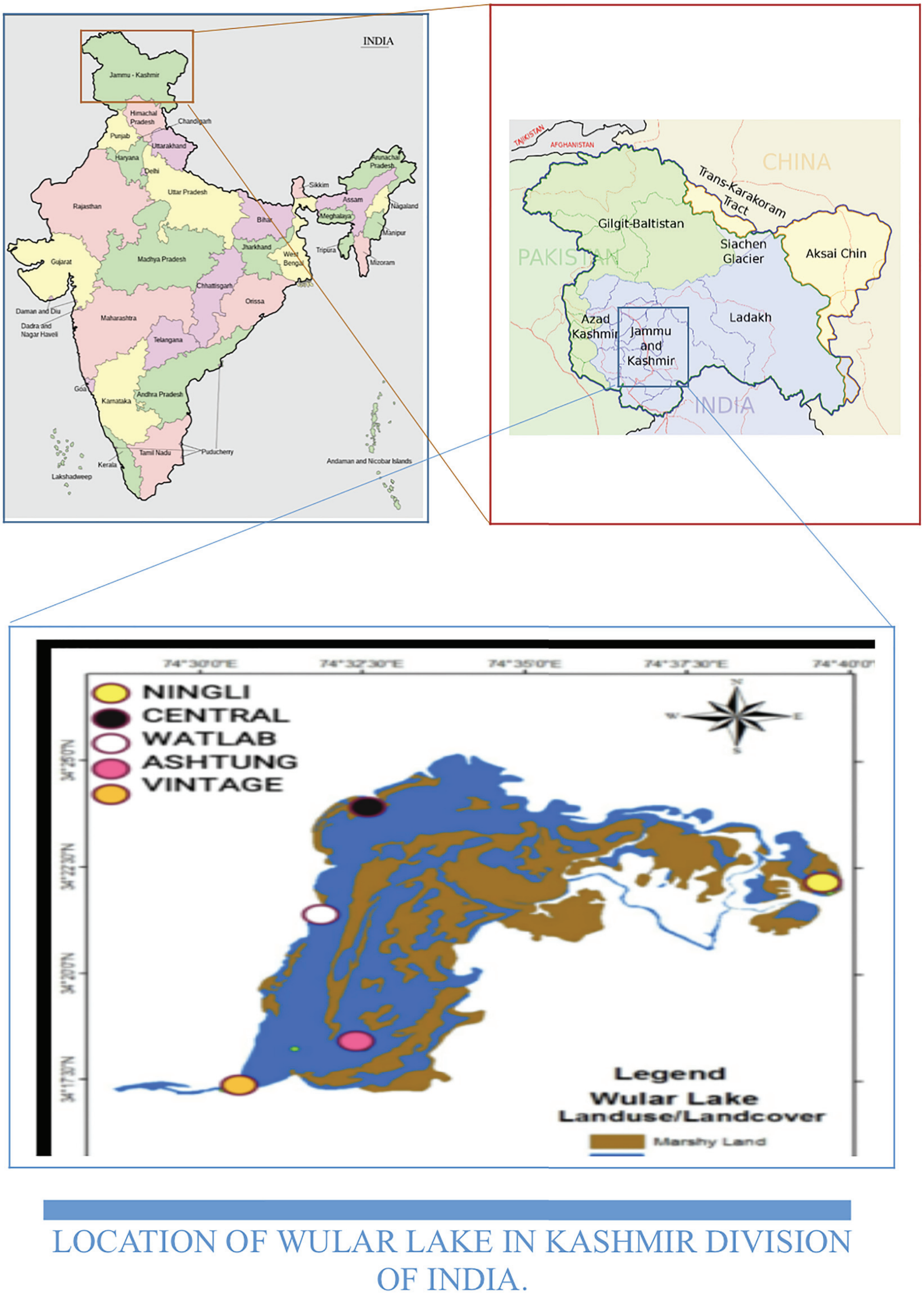


Fig. 1. Location of study sites in the Lake Wular.

Identification of fish

Identification of fish samples was done by using standard taxonomical works of Day (1877) and Kullander et al. (1999).

Biodiversity Studies

A. Shannon's Diversity Index

The Shannon Diversity Index was computed with the help of the following formula (Shannon and Weiner, 1949)

$$H' = -\sum_{i=1}^{S} p_i \ln p_i ,$$

where $p_i$ = probability of each species ($n_i/N$).
$N$ = total number of individuals in '$S$' species.
$n_i$ = number of individuals in ith species.

B. Index of Dominance

The index of dominance was computed using the following formula (E. W. Simpson, 1949):

$$I_D = \sum \left(n_i / N\right)^2 ,$$

where $N$ = total number of individuals.
$n_i$ = number of individuals in each species.

C. Evenness Index

The evenness index was computed with the following formula (E. C. Pielou, 1966):

$$J' = H'/\log_2 S ,$$

where $H'$ = species diversity index.
$S$ = total number of species.

Statistical analysis

The results obtained for biodiversity indices were interpreted with the help of statistical methods using Microsoft excel, SPSS (Statistical Package for the Social Sciences) for Windows and PAST (Paleontological Statistics) software respectively.

## Results and Discussion

Any fishing operation's catch composition indicates the variety of fish present in the area, which in turn aids in a better knowledge of the water body's biodiversity. Numerous scientists have investigated the fish flora in the water bodies that dot the Kashmir valley. However, Heckel made the first attempt to describe the fish species of Kashmir in 1838, naming sixteen species from this area. This was followed by Silas in 1960, who reported 28 fish species, Das and Subla in 1963, who reported 36 species, Nath in 1986, who reported 42 species, and so on. Additionally, Saxena and Koul (1966) classified 39 species from the area based on a literature review, whereas Yousuf (1996) only identified 37 species.

Fish have been regarded as an effective biological indicator of environmental quality and anthropogenic stress in aquatic ecosystems (Simon & Lyons, 1995; Bhat, 2003; Jayalekshmy and Sanalkumar, 2012) not only because of their iconic value, but also because of sensitivity to subtle environmental changes. They represent a wide range of tolerance at community level. Today the fish diversity and associated habitats management is a great challenge (Dudgeon et al., 2006). During the present investigation, a total of 8 species of fish belonging to two orders (Cypriniformes and Siluriformes), two families (Cyprinidae and Cobitidae), and four sub-families (Cyprininae, Schizothoracinae, Garrinae and Nemachilinae) were recorded at five different sites of Wular Lake (fig. 2). These included *Cyprinus* *carpio* (var. *communis)*, *Cyprinus carpio* (var. s*pecularis)* (Lacepede, 1803), *Carassius carassius* (Linnaeus, 1758), *Schizothorax niger*, *Schizothorax esocinus*, *Schizothorax curvifrons*, *Crossochelius diplochilus* (Heckel, 1838), *Triplophysa marmorata* (Heckel, 1838) and *Puntius conchonius* (Hamilton, 1822). The commercially important species were *Cyprinus carpio* (var. *Communis)*, *Cyprinus carpio* (var. S*pecularis)*, *Carassius carassius*, *Schizothorax niger*, *Schizothorax esocinus* and *Schizothorax curvifrons.* However, in a survey carried out during 1990–1997 covering the Jhelum River from Sopore to Uri and the three valley lakes, viz., Wular, Manasbal and Dal, Kullander et al. (1999) described 18 fish species, out of which 14 were native and 4 introduced. Bhat et al. (2020) reported 120 species in a variety of aquatic systems in J & K, 105 species were documented from Jammu region 23 from Kashmir valley and 15 from the Ladakh region. Recent surveys carried out by NIAE and JKLWWDA (2000) indicate occurrence of 13 fish species from Jhelum and associated lakes including Wular. Ahmed et al. (2017) reported 14 species of fish species from Jhelum and Dal lake and found *S. plagiostomus* to be abundant. It is evident from a comparison of the survey's findings with earlier research that the number of fish species has decreased over time. Several authors have also claimed that over the past few decades, India's fish biodiversity has rapidly decreased as a result of environmental degradation and human activities like damming, water abstraction, and pollution. These activities have put natural water bodies, specifically lakes and rivers, under extreme stress, which has had a catastrophic impact on fish diversity (Pandey & Das, 2006; Lakra & Pandey, 2009). Balkhi (2004) noted that there is a decline in fish species with respect to environmental degradation and supported the diminishing number of fish species as revealed in the current study. Qadri et al. (2018) discovered 8 species from Wular Lake and was found to be dominated by *Cyprinus carpio (*var. c*ommunis).* Leveque (2008) also reported that overexploitation, flow modification, destruction of habitats, and invasion by exotic species, pollution and eutrophication are major threats to fish biodiversity. Sultan and Kant (2016) reported 9 species of fish and their study indicated that there is the reduction in diversity in river Jhelum. That may be because of the degrading water quality conditions which is in agreement with Pastorino et al. (2021) who reported that harsh environment condition limits the biodiversity of the ecosystem.

The analysis of fish catch during the study period showed that both varieties of Common carp viz. *Cyprinus carpio* (var. c*ommunis)* and *Cyprinus carpio* (var. *specularis)* have gained dominance over the indigenous snow trouts (table 1). *Cyprinus carpio* var. *communis* contributed 45.73 % by biomass and 32.8 % by number followed by *Cyprinus carpio* var. s*pecularis* contributing 35.08 % by biomass and 19.06 % by number. However, *Carassius carassius* recorded a significantly lesser catch and contributed 1.71 % by biomass and 8.93 % by number. Overall, the carps contributed 82.52 % by biomass and 60.79 % by number to the total catch (figs 3 and 4). The dominance of Cyprinids at all sites as seen during the present study is also in accordance with the observations of Dutta et al. (2002); Dutta, (2003); Dutta and Kour (2005); Kaur (2006); Johnson and Arunachalam (2010); Kantaraj et al. (2011); Johnson et al. (2012); Murugan and Prabaharan (2012); Mishra (2013) who attributed it to their high adaptive variability to occupy all possible habitats. Due to their high fertility, common carp have an adaptive advantage over other species in how they use lake resources for growth (Das & Subla, 1963). Additional elements that contribute to the common carp's dominance over other fish species include its long spawning season, access to water resources, high fecundity, and prolific breeding habits. The months of June and July had the highest catches of both common carp strains, *Cyprinus carpio var. communis* and *Cyprinus carpio* var. *specularis*, in terms of biomass and quantity. This might be explained by summer's higher temperatures and increased food supply. Besides, Common carp is known to spawn during May to July and the planktonic peaks from March to April and July to August concur with the spawning activity of summer and autumn spawners, thus contributing to the high catch rates during summer months.

*Schizothorax niger*, *Schizothirax esocinus,* and *Schizothrax curvifrons*, were the three Schizothoracid species that made up the majority of the catch (Heckel, 1838). *Schizothorax niger*, which contributed 8.33 % by biomass and 10.6 % by number, had the highest catch based on biomass, followed by *Schizothorax esocinus*, which contributed 5.09 % by biomass and 6.26 % by number, and *Schizothorax curvifrons*, which contributed 2.14 % by biomass and 2.26 % by number. Schizothoracids made up 19.12 % of the total biomass and 15.56 % of the total population (fig. 5). The highest capture was made by *Schizothorax niger*, while the lowest was made by *Schizothorax curvifrons*. Other Schizothorax species, including *Schizothorax plagiostomus* (Heckel), *Schizothorax micropogon*, and others were studied in the past by the Department of Wildlife Protection, Government of J & K. According to Balkhi (2004), the fall in the native Schizothoracine population was brought on by the expansion of shallow peripheral lake areas and the variable water levels in some lakes and streams' tributaries. Additionally, the contribution of Schizothoracids to the captures has gradually decreased as a result of human interference in the aquatic ecosystems of the valley (Yousuf, 1996; Bhat et al., 2010; Mir & Channa, 2010). Since the introduction of common carp in 1956, the number of Schizothracine fishes in Wular Lake has significantly declined (Fotedar & Qadri 1974; Vass et al., 1984). Fish species like *Schizothorax richardsonii* (Gray) and *Bangana diplostoma,* which were formerly common and even widely captured commercially. The highest catch on the basis of biomass and number was seen in the months of June and July for *Schizothorax niger,* and *Schizothorax esocinus* while as the maximum catch of *Schizothorax curvifrons* was witnessed in the month of January. The Schizothoracids except *Schizothorax niger* show breeding migration with the onset of March/April even up to June (Jyoti & Malhotra, 1975). This also seems to be one of the reasons for higher catch of fishes during the months. Sunder et al., 1978; Yousuf, 1996; Shafi et al., 2005 and Bhat et al., 2010 reported similar observations in their study.

According to Balkhi (2004), the fall in the native Schizothoracine population was brought on by the expansion of shallow peripheral lake areas and the variable water levels in some lakes and streams' tributaries. The other smaller fish species, including *Triplophysa marmorata, Crossocheilus diplochilus* and *Puntius conchonius* formed a very low percentage of the catch (1.86 % by biomass and 19.99 % by number), with each species contributing 1.40 % by biomass and 9.73 % by number, 0.28 % by biomass and 4.66 % by number, and 0.18 % by biomass, respectively. *Triplophysa marmorata* (Heckel, 1838), *Crossocheilus diplochilus* (Heckel1, 1838), and *Puntius conchonius* were the three smallest fish species with the highest reported catches. This may be explained by their adaptability to many ecosystems, inability to serve as food to locals due to their small size, hardy nature, and tolerance for high pollution levels. In the course of the investigation, it was found that Wular Lake has gradually shrunk, as evidenced by the low water depths of 1.7 m in the winter and 3.06 m in the summer, which contrasted with the maximum average depth of 5.8 m as recorded by Pandit, 2002. The shallow lake waters, which offer these fishes a good environment, may be the cause of the abundance of a wide variety of smaller fishes. This fact is further supported by Othman et al. (2001), who said that the existence of smaller fish species like *Puntius conchonius* from shallow and much polluted locations indicated their hardiness, maintaining the species as a common one in different water bodies. In his study on stream fishes in the Western Ghats, Arunachalam (2000) noted that non-cyprinids like balitorids are primarily found at pool borders and shallow waters. Bhat et al., 2013 obtained similar results and reported that *Triplophysa kashmirensis* and *Crossocheilus diplochilus* were restricted primarily to those areas of Lidder stream which had shallow depth and slow water current velocity.

The term"biodiversity" refers to the numerous types of living species that live in terrestrial, marine, and freshwater habitats and is expressed at all levels of biological organisation, from the cell to the ecosystem. Depending on the context and scale, ichthyofaunal diversity can refer to different fish species, alleles or genotypes within life forms within a fish community, or species or life forms throughout aquatic regimes. To investigate the variables impacting the structure of the fish community, studies of geographical and temporal patterns of diversity, distribution, and species composition of freshwater fishes are helpful. The diversity and health of fish species are also significant indicators of the ecological well-being of water bodies.

The term"biodiversity" refers to a vast array of different types of living things in all levels of the biosphere, from the cellular to the ecosystem.Two things make up "Species diversity": the quantity or richness of species and the distribution of individuals among species. Numerous studies examining a wide range of ecosystems and creatures reveal that habitat heterogeneity and ecosystem productivity have a substantial positive correlation with species richness. The fish fauna of Jammu and Kashmir has been the subject of extensive research. Chalkoo et al. (2006), Arjumand (2006), and Mushtaq et al. (2018) are a few notable examples of recent efforts.

The Shannon-Weiner diversity ($H'$) index takes into account both the number of species and how individuals are distributed among them. This index considers both the total number of people and taxa. Wilhm and Dorris (1966) determined that a Shannon-Weiner diversity ($H'$) value > 3 indicated clean water, 1.00 to 3.00 indicated moderately polluted water, and 1.00 indicated severely polluted water. This classification places the Wular wetland in the group of moderately contaminated waterways. While Osborne et al. (1976) and Godfrey (1978) observed values ranging from 0.14 to 2.69 and from 1.938 to 5.34, respectively, Mackey et al. (1973) reported that the Shannon index ranged from 1.3 to 2.5. When both the number of species and evenness, e increase, Shannon-Weiner diversity, ($H'$) values rise. The value of $H'$ is maximised for a given number of species when all species are equally prevalent. The value of $H'$ typically ranges from 1.5 to 3.5, and it hardly ever rises above 4.5. A number close to 4.6 would suggest that all species have an equal number of individuals (Bibi and Ali, 2013). However, the current study discovered that the value of H' was highest in the summer ($H' = 1.476$) and lowest in the fall ($H' = 1.195$), indicating a relatively low diversity (table 2). When the Shannon-Weiner diversity index varied from 3.0–4.5, Biligrami (1988) advised better water body condition for fish diversity. The non-available and less availability of some fish species indicates the alarming decline of the fish diversity in the study area. The present results are in agreement with Welcomme (1985), Bayley and Li (1994), Granado (2000), Slavik and Bartos (2001), Offem et al. (2011), Hina (2010) and Patra et al. (2010). The Shannon-Weaver index serves as a sensitive pollution indicator. It is a result of both the diversity of species and the uniformity of individual distribution across taxa (Klemm et al., 1990). The very low Shannon index indicates that Wular Lake's fish diversity is extremely low as a result of pollution and other unfavourable environmental factors. Growing human populations and economic growth are the primary causes of Wular's declining fish variety, according to the Simpson index and Evenness (Wu et al., 1999). Human activity has the potential to influence biological, chemical, and physical processes, changing the nature of the lakes in the process. The following factors have an impact on Wular Lake's ecology and biodiversity: (i) direct dumping of untreated sewage from densely populated areas The following factors have an impact on the ecology and biodiversity of Wular Lake: (i) direct discharge of untreated sewage from agriculture and highly populated village activities; (ii) watershed runoff; (iii) pressure from tourists; (iv) sand mining; channelization and impoundment; and (v) illicit fishing. As noted by Hynes (1960) in his study, the interaction of these danger variables has an impact on biodiversity and puts freshwater species in particular at risk.

Pielou's index (*J*) is an evenness measurement index that assesses how evenly individuals are distributed among the current taxa. During the study period, Site C had the highest Pielou's index (0.9609) and Site E had the lowest (0.3333); seasonally, the highest and lowest values were 0.856 in summer and 0.738 in autumn, respectively.

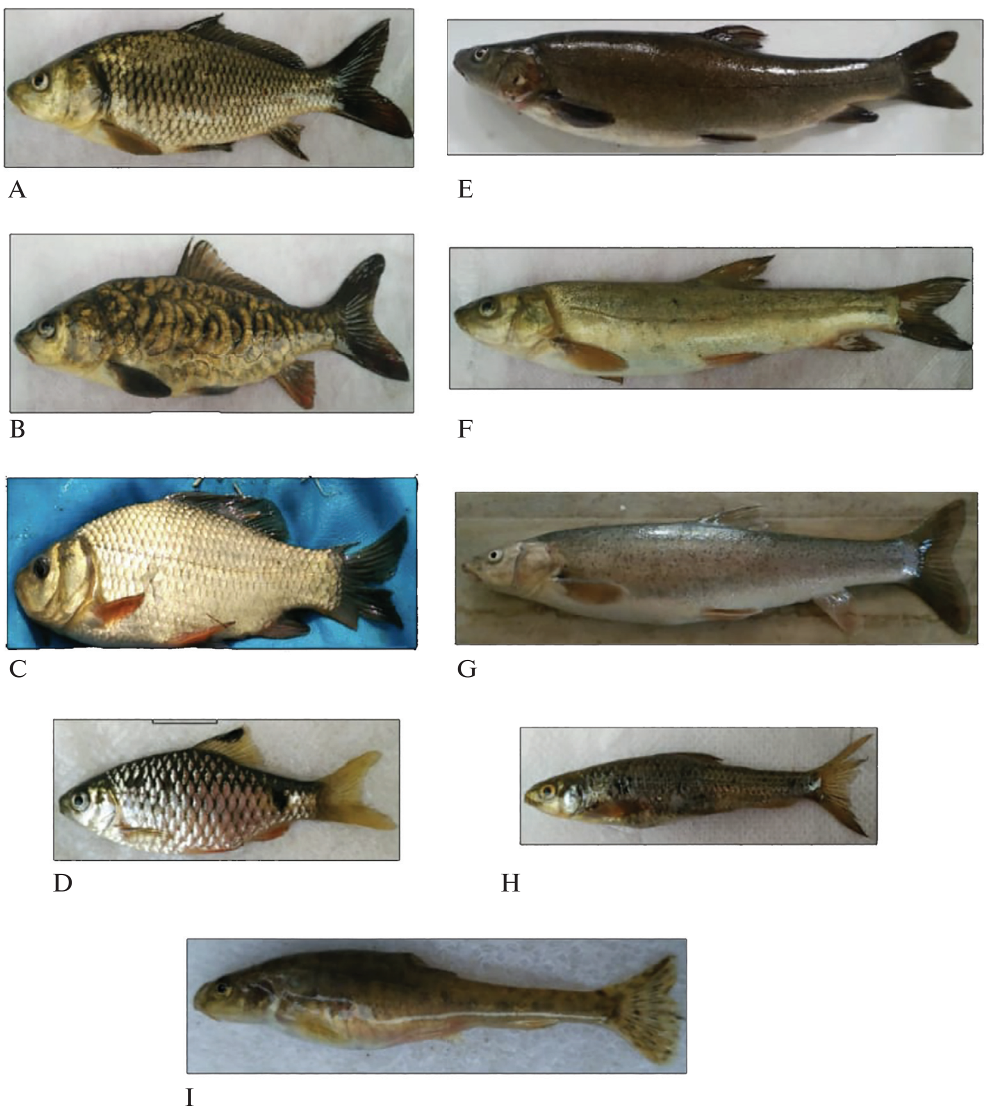


Fig. 2. Fishes caught during sampling: A — *Cyprinus carpio* var. *specularis;* B — *Cyprinus carpio* var. *specularis;* C — *Carassius carassius;* D — *Puntius conchonius;* E — *Schizothorax niger*; F — *Schizothorax curvifrons;* G — *Schizothorax esocinus;* H — *Crossocheilus diplochilus;* I — *Triplophysa marmorata.*

Since this index's value was close to 1, it is possible that the community's population of fish was more uniformly distributed (Emmanuel and Modupe, 2010). The maximum evenness value (0.99), according to Murugan and Prabharan (2012), was observed in the late monsoon, indicating a well-balanced and abundant fauna during the monsoon and post-monsoon.

When two people are randomly chosen from a sample, Simpson's dominance index ($I_D$) calculates the likelihood that they will be of the same species. The Simpson's index during the current inquiry was highest at Site A (0.7684) in the winter and lowest at Site E (0.1481) in the autumn. This index has a value between 0 and 1; the higher the number, the more diverse the sample. It may be deduced that Site A had the highest concentration of fish species while Site E had the lowest concentration. Seasonally, the values varied from 0.645 in the summer to 0.438 in the fall, indicating more species dominance in the summer and less dominance in the autumn (fig. 6).

The fish density in Kashmir's lentic and lotic water systems has been negatively impacted by the numerous anthropogenic stresses along the watershed area (Khan, 2004). A key issue for this wetland is the numerous anthropogenic hazards that have been seen during the course of the study, such as deforestation in catchment areas and non-point pollution from agricultural fields with insecticides, herbicides, weedicides, and chemical fertilisers. According to Khan (2004), anthropogenic pressure along catchments has negatively impacted the fish density in Kashmir's lentic and lotic waterways. Fish diversity is seriously threatened by unsustainable fishing practises and the discharge of sewage into the lake (Ahmad et al., 2012). According to Dudgeon et al., 2006 the major threat of the aquatic ecosystem in India is the intense human interventions resulting in the habitat loss and degradation and as a consequence of this many fresh water fish species have become endangered. It is noted that during the present study the wetland receives domestic sewage from adjoining villages and cities and the introduction of two exotic fish species have also been established well into this wetland posing a major threat to its native fish fauna. From the investigation, a number of factors, such as habitat loss, siltation, water pollution from household waste, pesticides, and agrochemicals, destruction of breeding and nursery grounds due to willow plantations, and conversion of lake area into agricultural lands, are to blame for the declining biodiversity of fishes in the Wular wetland. The feeding and spawning of fish were negatively impacted by the increasing silt load and altered temperature regime of the channel.

**Table 1. Contribution of different fish species to the total fish catch from Wular Lake**

| Site No. | Fish species caught | Biomass | | Number | |
|---|---|---|---|---|---|
| | | weight, kg | composition, % | number | composition, % |
| 1 | *Schizothorax niger* | 16.34 | 8.33 | 80 | 10.6 |
| 2 | *Schizothorax esocinus* | 9.98 | 5.09 | 47 | 6.26 |
| 3 | *Schizothorax curvifrons* | 4.21 | 2.14 | 17 | 2.26 |
| 4 a | *Cyprinus carpio* var. *communis* | 89.63 | 45.73 | 246 | 32.8 |
| 4 b | *Cyprinus carpio* var. *specularis* | 68.76 | 35.08 | 143 | 19.06 |
| 5 | *Carassius carassius* | 3.37 | 1.71 | 67 | 8.93 |
| 6 | *Triplophysa marmorata* | 2.76 | 1.40 | 73 | 9.73 |
| 7 | *Crossocheilus diplochilus* | 0.55 | 0.28 | 35 | 4.66 |
| 8 | *Puntius conchonius* | 0.37 | 0.18 | 42 | 5.6 |
| Total Catch | | 195.97 | 100 | 738 | 100 |

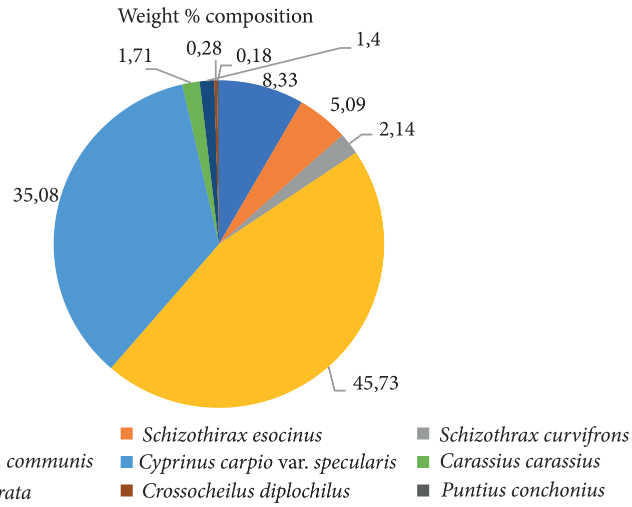


Fig. 3. Graphical representation of fishes caught by weight.

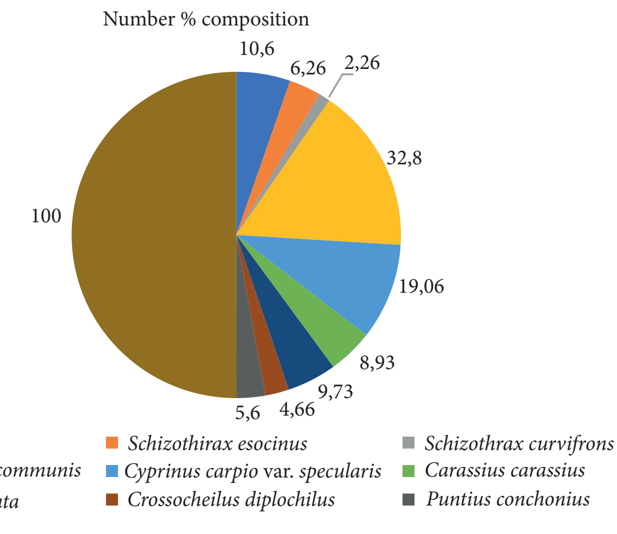


Fig. 4. Graphical representation of fishes caught by number.

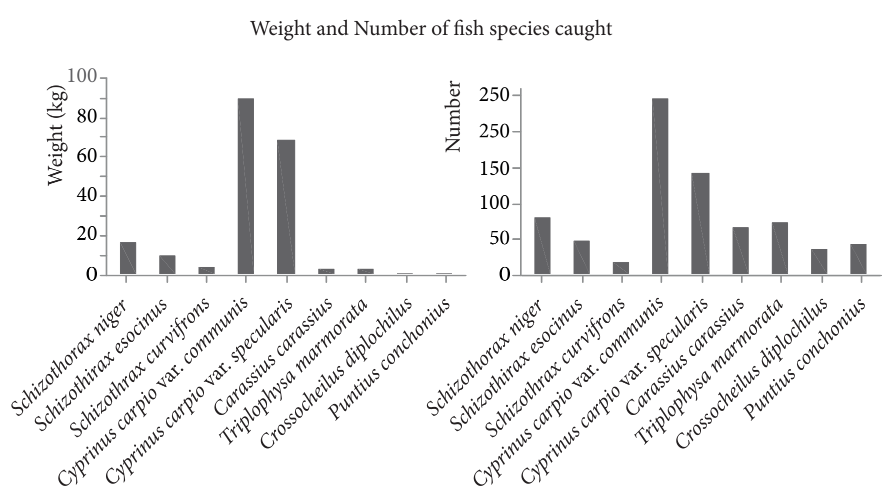


Fig. 5. Graphical representation of fishes caught by both weight and number.

**Table 2. Mean biodiversity indices for different fish species of Wular Lake, Kashmir**

| Month | Season | Shannon-Wiener Diversity Index | Pielou's Evenness Index | Simpson's Dominance Index |
|---|---|---|---|---|
| December | Winter | 1.336 | 0.7372 | 0.539 |
| January | | 1.549 | 0.9397 | 0.647 |
| February | | 1.317 | 0.7523 | 0.575 |
| Mean | | **1.400** | **0.809** | **0.587** |
| March | Spring | 1.437 | 0.888 | 0.632 |
| April | | 1.372 | 0.711 | 0.535 |
| May | | 1.338 | 0.895 | 0.683 |
| Mean | | 1.382 | 0.831 | 0.616 |
| June | Summer | 1.531 | 0.865 | 0.692 |
| July | | 1.465 | 0.876 | 0.694 |
| August | | 1.433 | 0.829 | 0.550 |
| Mean | | 1.476 | 0.856 | 0.645 |
| September | Autumn | 1.190 | 0.717 | 0.680 |
| October | | 1.326 | 0.748 | 0.390 |
| November | | 1.070 | 0.750 | 0.245 |
| Mean | | **1.195** | **0.738** | **0.438** |

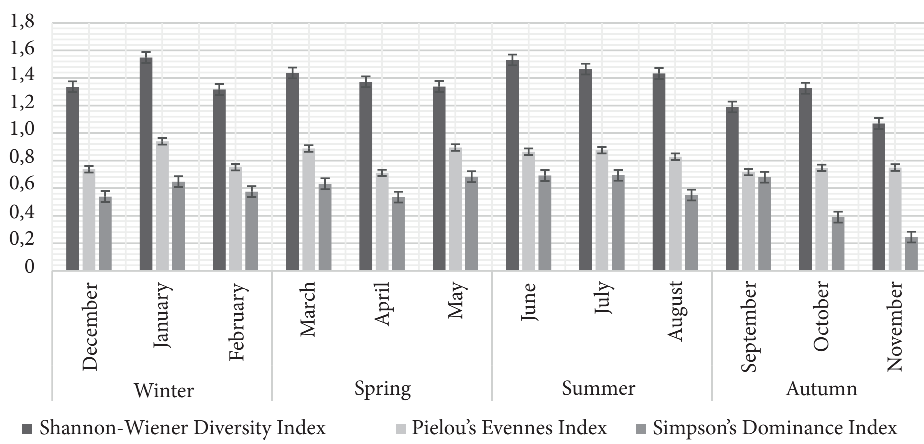


Fig. 6. Graphical representation of Diversity indices.

## Conclusion

The present study reveals that many factors are responsible for the decreasing biodiversity of fishes in the lake. These include habitat loss, siltation, water pollution caused by domestic wastes, pesticides and agrochemicals, destruction of breeding and nursery grounds due to willow plantation and conversion of lake areas into agricultural lands. Further the degrading water quality followed by increasing silt load along with changed temperature regime of channel has resulted in the prolific growth of aquatic vegetation, which has caused decline in fish populations by affecting the feeding and spawning.

**References**


Ahmad, S., Rahman, A. A. F. M., Mustafa, G. M. D., Hossain, M. B. & Nahar, N. 2012. Nutritional composition of indigenous and exotic fishes of Rainfed waterlogged paddy fields in Lakshmipur, Bangladesh, *World. Journal of Zoology* **7** (2), 135-140.

Ahmed, I., Ahmad, Z. & Ahmad, I. 2017. Current status of fish fauna of river Jhelum and Dal lake of Kashmir Valley. *Bulletin of Pure & Applied Sciences-Zoology*, **36** (2), 85-92.

Arjumand, S. 2006. *Preliminary survey on the status of aquatic biodiversity of river Jhelum in relation to certain biotic parameters, Srinagar, (Kashmir)*. PhD. Thesis, Barkatullah Univ., Bhopal, 1-86.

Balkhi, M. H. 2004. *Aquaculture management in Cold waters: Evaluation of Mahseer fishery potential and its farming feasibility for conservation in Himalayan region*. Final report, NATP (ICAR), 1-33.

Bayley, P. & Li, H. 1994. Riverine fisheries. *In*: Calow, P., Petts, G. E., eds. *The river handbook: hydrological and ecological principles*. Blackwell, Boston, 1994, 251-281.

Bhat, A. 2003. Diversity and composition of freshwater fishes in river systems of central Western Ghats, India. *Environmental Biology of Fishes*. 68, 25-38.

Bhat, F. A., Balkhi, M. H., Najar, A. M. & Yousuf, A. R. 2013. Distribution pattern, density and morphometric characteristics of Schizothoracines (Snow trouts) in Lidder River, Kashmir. *The Bioscan*, **8** (2), 363-369.

Bhat, F. A., Balkhi, M. H. & Yousuf, A. R. 2010. Fish biodiversity in the Kashmir Himalaya. *In*: *Biodiversity, development and Poverty elevation; International Day for Biological Biodiversity*. P. G. Department of Botany, University of Kashmir, 24-27.

Bhat, F. A., Yousuf, A. R. & Balkhi, M. H. 2020. Diversity of fishes in Jammu and Kashmir state. *Biodiversity of the Himalaya: Jammu and Kashmir State*, 859-887.

Bibi, F. & Ali, Z. 2013. Measurement of diversity indices of avian communities at Taunsa barrage wildlife sanctuary, Pakistan. *The J. Animal & Plant Sciences*, **23** (2), 469-474.

Biligrami, K. S. 1988. Biological monitoring of rivers, problems and prospect in India. *Aquatic Ecotoxicology*, 245-250.

Chalkoo, S. R., Qureshi, T. A., Dar, B. A., Kour, R. & Sodhi, A. S. 2006. Status Of Cold Water Fisheries OF Kashmir. *Fishing chimes*, **26** (10).

Day, F. 1877. *The fishes of India. A natural history of the fishes known to inhabit the seas and freshwaters of India, Burma and Ceylon* (Reprinted by Today and Tomorrow book agency, New Delhi), 1-778.

Dudgeon, D., Arthington, A. H., Gessner, M. O., Kawabata, Z. I., Knowler, D. J., Lévêque, C., ... & Sullivan, C. A. 2006. Freshwater biodiversity: importance, threats, status and conservation challenges. *Biological reviews*, **81** (2), 163-182.

Dutta, S. P. S. 2003. Fish fauna of Poonch district, Jammu region (J&K state). *Journal of Aquaculure Biology*, **4** (2), 241-246.

Dutta, S. P. S., Gupta, S. & Salaria, S. A. 2002. Ichthyofaunistic survey of Rajouri District (J & K State), *Aquacult.*, **3** (2), 201-205.

Dutta, S. P. S. & Kour, H. 2005. Ichthyofauna of Jammu district of Jammu region, Jammu and Kashmir State, India. *In*: Prof. Singh Koli, M. P., ed. *Fisheries and Aquaculture in Indus river region*. Society of Fisheries Professionals.

Emmanuel, L. O. & Modupe, O. O. 2010. Fish diversity in three tributaries of River Ore, South West, Nigeria. World *Journal of Fisheries and Marine Science*, **2** (6), 524-531.

Fotedar, D. N. & Qadri, M. Y. 1974. Fish and fisheries of Kashmir and the impact of carp, *Cyprinus carpio* on the endemic fishes, *Journal of Science*, 2, 79-89.

Godfrey, P. J. 1978. Diversity as a measure of benthic macro invertebrate community response to water pollution. *Hydrobiologia*, 57, 111-122.

Granado, C. 2000. *Ecologa de communidades el paradigma de lo pecces de agua dulce*. Universidad de Sevilla Secretariado de Publicaciones, Sevilla, 2000.

Heckel, J. J. 1839. *Fisches Kashmir's in Huegel, C.A.A. Von; Kashmir und Das Reich Der Sei*k. Bd. 4; abth 2, 351-392.

Hina, 2010. *Eco-biological studies of some freshwater ornamental fishes of Jammu*. Ph.D Thesis, University of Jammu, Jammu.

Hynes, H. B. N. 1960. *The biology of polluted waters*. Liverpool University Press, Liverpool, England, 1-202.

Jayalekshmy, V. & Sanalkumar, M. G. (2012). Bi-seasonal variation in the Piscian diversity in relation to physico-chemical parameters of Pallickal River-Kerala, India. *International Journal of Scientific and Research Publications*, **2** (11), 1-5.

Johnson, J. A. & Arunachalam, M. 2010. Relations of physicalhabitat to fish assemblages in streams of Western Ghats, India. *Applied Ecology and Environmental Research*, **8** (1), 1-10.

Johnson, J. A., Parmar, R., Ramesh, K., Sen, S. & Murthy, R. S. 2012. Fish diversity and assemblage structure in Kenriver of Panna Landscape, central India. *Journal of Threatened Taxa*, **4** (13), 3161- 3172.

Jyoti, M. K. & Malhotra, Y. R. 1975. Seasonal variations in feeding of *Nemacheilus kashmirensis.Matsya*, 1, 53-58.

Kantaraj, G. S, Thirumala, S. & Kiran, B. R. 2011. Fish diversity in relation to physico-chemical characteristics of Bhadra reservoir of Karnataka, India. *Advances in Applied Sciences Research*, **2** (5), 34-47.

Kaur, S. 2006. *Studies on the impact of tourism on streamBanganga and the indwelling macro and microorganisms*. Ph.D. Thesis, University of Jammu.

Khan, M. A. 2004. *Environment Appraisal of depleting fish diversity of Kashmir Valley. Fishery Management*. New Delhi, APH Publication Corporation, India.

Klemm, D. J., Philip, A. L., Florence & Lozoreckak. 1990. *Macro invertebrate fi eld and laboratory method for evaluating the biology integrity of surface water*. U.S. EPA, EPA/600/4- 90.030 Xii, 1-256.

Kullander, S. O., Fang. F., Delling, B. & Ahlander, E. 1999. The fishes of the Kashmir Valley. *In*: Nyman, L., ed. *River Jhelum, Kashmir Valley, Impact on the aquatic environment*.

Lakra, W. S. & Pandey, A. K. 2009. Fish germplasm resources of India with special emphasis on conservation and rehabilitation of threatened species. *In*: Goswami, U. C. & Kumar, D., eds. *Aquaculture Management.* Narendra Pub. House, New Delhi, 85-104.

Leveque, C. B. 2008. An assessment of animal species diversity in continental waters. *Hydrobiologia*, 542, 39-67.

Mackey, D. W., Sulsby, P. G. & Poodie, T. 1973. *The biological assessment of pollution in stream. Association of the river authorities.* Year Book and Directory, London, 189-197.

Mir, I. H. & Channa, A. 2010. A scanning electron microscopic examination of the intestinal tract of the snow trout, *Schizothorax curvifrons*. *Journal of Fisheries Aquatic Science*, 5, 386-393.

Mishra, R. N. 2013. Carp seed quality improvement program in Nepal. *Paper presented in seminar on Aquaculture in Nepal: Recent development and future prospects on 15 Mar, 2013, Kathmandu, Nepal*.

Misra, K. S. 1962. An aid to the identification of the common commercial fishes of India and Pakistan. *Records of the Indian Museum*, 57, 1-320.

Mittermeier, R. A. & Mittermeier, C. G. 1997. *Megadiversity. earth's biolocally wealthiest nation*. Cemex, Mexico City, Mexico,

Munro, I. S. R. 2000. *The Marine and Freshwater Fishes of Ceylon*. Biotech Books, Delhi.

Murugan, S. & Prabaharan, C. 2012. Fish diversity in relation to physico-chemical characteristics of Kamala Basin of Darbhanga, District Bihar, India. *International J. Pharmaceutical and Biological Archive*, **3** (1), 211-217.

Mushtaq, S. T., Mushtaq, S. A. & Balkhi, M. H. 2018. Ichthyofaunal diversity and CPUE (Catch Per Unit Effort) at Watlab Ghat, Wular Lake, Kashmir. *The Bioscan*, **13** (2), 683-687.

Nath, S. 1986. A checklist of fishes of Jammu and Kashmir State (India) with remarks on the ichthyogeography of the state, *Journal of the Zoological Society of India*, 38, 83-98.

Offem, B. O., Ayotunde, E. O., Ikpi, G. U., Ada, F. B. & Ochang, S. N. 2011. Plankton-based assessment of the trophic state of three tropical lakes. *Journal of Environmental Protection*, 2, 304-315.

Osborne, L. L., Davies, R. W. & Linton, K. L. 1976. Use of hierarchical diversity indices in lotic community analysis. *Journal of Applied Ecology*, 17, 567-580.

Othman, M. R., Samat, A. & Hoo, L. S. 2001. Effect of water quality to Fish abundance and Chlorophyll a (a selected aquatic organism) in Labu River-system, Malaysia. *Journal of Biological Sciences*, 1 (2), 1178-1182.

Pandey, A. K. & Das, P. 2006. Current status of fish germplasm resources of India and strategies for conservation of endangered species. *In*: Singh, H. S., Chaubey, A. K. & Bhardwaj, S. K., eds. *Proceedings of Recent Advances in Applied Zoology*, 1-39. Ch. Charan Singh University, Meerut.

Pastorino, P., Pizzul, E., Bertoli, M., Anselmi, S., Kušće, M., Menconi, V. & Renzi, M. 2021. First insights into plastic and microplastic occurrence in biotic and abiotic compartments, and snow from a high-mountain lake (Carnic Alps). *Chemosphere*, **265**, 129121.

Patra, A. P, Patra, J. K., Mahapatra, N. K., Das, S. & Swain, G. C. 2010. Seasonal variation in physico-chemical parameters of Chilka Lake after opening of New Mouth near Gabakunda, Orissa, India. *World Journal of Fish and Marine Sciences,* **2** (2), 109-117.

Pielou, E. C. 1966. Species diversity and pattern diversity in the study of ecological succession. *Journal of Theoretical Biology*, 13, 131-144.

Qadri, S., Bhat, F. A., Balkhi, M. H., Shah, T. H., Hussain, N., Bhat, B. A. & Aalia, S. 2018. Fish biodiversity, catch composition, distribution pattern of fishes in Wular Lake and their conservational measures for sustainable fish production. *Journal of Pharmacognosy and Phytochemistry*, **7** (6), 1883-1887.

Saxena, D. B. & Koul, D. N. 1966. Fish and fisheries of Jammu and Kashmir State, Part I. Fisheries resources and problems. *Ichthyologica*, 5, 45-52.

Shafi, S., Bhat, F. A., Parveen, M. & Yousuf, A. R. 2005. Catch composition of fishes from Dal Lake, Kashmir. *Journal of Research and Development*, Vol. 5.

Shannon, C. E. & Weaver, W. 1949. *The Mathematical Theory of Communication*. Urbana, IL: University of Illinois Press, 54.

Silas, E. G. 1960. Fishes from the Kashmir Valley. *Journal of the Bombay Natural History Society*, **57** (1), 67-77.

Simon, T. P. & Lyons, J. 1995. Application of the index of biotic integrity to evaluate water resource integrity in freshwater ecosystems. *Biological assessment and criteria: tools for water resource planning and decision making*, 245-262.

Simpson, E. W. 1949. Measurement of diversity. *Nature*, 163, 680.
Slavik, O. & Bartos, L. 2001. Spatial distribution and temporal variance of fish assemblages in the channelized and regulated Vltava River (Central Europe). *Environmental Biology of Fishes*, **61**, 47–55.
Sultan, S. & Kant, R. 2016. Survey and Study of fish fauna of River Jhelum (J & K). *International Journal of Multidisciplinary Research and Development*, **3** (1), 278–280.
Sunder, S., Bhagat, M. J., Joshi, C. B. & Ramakrishna, K. V. 1978. Fishing methods and fish catch composition of Dal Lake, Srinagar (Jammu and Kashmir) during 1969–1972. *J. Inland Fish. Soc*. India, 10, 9–18.
Vass, K. K., Raina, H. S., Sunder, S., Moza, U. & Langer, R. K. 1984. *Proc. Semn. Management Fish. Resources*, Jammu Uni., 31–32.
Welcomme, R. L. 1985. *River fisheries*. FAO Fisheries Technical Paper, 262, 1–318.
Wilhm, J. L. & Dorris, T. C. 1966. Species diversity of benthic macro-invertebrates in a stream receiving domestic and oil refinery effluents. *The American Midland Naturalist*, 76, 427–449.
Wu, C., Maurer, C., Wang, Y., Xue, S. & Davis, D. L. 1999.Water pollution and human health in China. *Environmental Health Perspectives*, 107, 251–256.
Yousuf, A. R. 1996. Fishery resources of Kashmir. *In*: Khan, A. H. & Pandit, A. K., eds. *Ecology, Environment and Energy*. University of Kashmir, 75–120.

Received 8 May 2023
Accepted 22 February 2024