E-ISSN: 2347-5129
P-ISSN: 2394-0506
(ICV-Poland) Impact Value: 76.37
(GIF) Impact Factor: 0.549
IJFAS 2024; 12(6): 35-42

www.fisheriesjournal.com
Received: 03-09-2024
Accepted: 13-10-2024

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Fish diversity, relative abundance comparison between native and non-native fish species of Dal Lake, Kashmir Himalaya India

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DOI: https://doi.org/10.22271/fish.2024.v12.i6a.2992

Abstract
Diversity and species abundance assessments of any habitat often act as prime tools for its management and conservation. The goal of the current study is to learn more about the diversity and abundance of fish that exist today in Dal Lake, a significant urban lake of Kashmir Valley that has witnessed drastic changes over the last 40 years, from lower rung diversity, such as planktons, to higher rung diversity, such as fish. The study was conducted for a span of two years, between April 2019 and March 2021. With the aid of cast nets of varying mesh sizes, the fish were taken from five different sites within the lake. Over the course of the investigation, 4844 fish samples were gathered. The collected fish samples comprised of eight species with seven from the family Cyprinidae and one from the family Poeciliidae. Among the collected fish species from lake, *Cyprinus carpio communis* was highest in abundance followed by *Pethia conchonius*, while *Schizothorax esocinus* was least abundant. Shannon diversity index was highest (1.86) for site IV, while lowest (1.39) for site II. On a temporal scale it was highest (1.82) for the summer season and lowest (1.64) for the winter season.

Keywords: Significant, valley, temporal

Introduction
Fishes are one of the major groups of animal taxa present on earth and constitute 50% of high-quality protein consumption, providing sustenance to millions of people and supporting the national income of many countries [1]. India is a mega-diversity nation, taking into consideration number of fresh water fish species (more than 650). India ranks eighth in world and third in Asia in terms of fresh water fish diversity. Freshwater fishes are among the threatened taxa [2] due to their sensitivity to both quantitative as well as qualitative alteration of their habitats [3, 4]. Fish is a suitable tool for biological and ecological assessment owing to easy identification and higher economic value [5, 6]. These act as suitable biological indicator for environmental monitoring of the water bodies they inhabit [7, 8] as these are sensitive to minor environmental changes. In contrast to it, at the community level they show a wide range of tolerance.

Diversity is the prime facet of any biological system. Diversity of a habitat ranges from variability within the populations of a species to different species inhabiting the habitat [9]. The role of biodiversity varies from the ecological functioning of the habitat, response to various perturbations to the productivity of the ecosystem. Species composition is responsible for the aquatic ecosystem functioning and determining its ecological characteristics. In this way, ecological characteristics of one habitat having its own species composition are different from the other having different species composition [10]. The ability of the aquatic ecosystem to resist the external perturbations is dependent on its species composition and their relative abundance [11]. In the present times fish diversity conservation and the associated habitat management is an uphill task [12]. Conservation measures to mitigate the impact of the pressures have largely been slow and inadequate and as a result many of the species are declining rapidly [13]. Habitat alteration, climate change and introduction of exotic species is acting as a vicious tri-factor in the alteration of habitats and species erosion.

Climate change is now altering the fish species composition and abundance, causing loss of diversity, increase in abundance of invasive fishes [14] and habitat-range shifting of the species [15]. The introduction of exotic species is the second leading cause, after habitat degradation, of species extinction in freshwater systems [16]. The rapid loss of species, populations, communities and ecosystem as a result of habitat and water usage transformations highlight the importance of the species composition of an aquatic ecosystem. A fish doesn't act in isolation in the habitat. Rather it behaves as a part of integrated functioning of an aquatic ecosystem. So, it becomes important to examine the fish biodiversity of an aquatic ecosystem, in order to have better understanding of the functioning of the whole ecosystem. This will help to prevent the invasive threat of certain species.

Dal Lake has shown a tremendous change in the diversity and abundance of fish species, after the introduction of exotic *Cyprinus carpio* in it during 1950s. The fish composition of lake has shown the tremendous changes in terms of the relative abundance of fish from last four decades. The study will be helpful in the conservation of lake in general and sustainable fisheries visa vis native fish fauna conservation, in particular.

Materials and Methods

Sampling and collection

The sampling was done for a period of two years, from April 2019 to March 2021. The fishes were collected with the help of cast nets of different mesh sizes (2.5x 3.5 cm and 3.2 x 4.5 cm). For smaller size species dip net was used with a mesh size of 1.5 x 2.2 cm. The fishes were collected monthly from all the five sites of lake. The five sites are Site I (Hazratbal), Site II (Dalgate), Site III (Nishat), Site IV (Telbal) and Site V (Centre) (Figure 1). The collected samples were brought to laboratory for identification and species characterization. The fishes were identified based on taxonomic keys given by Talwar and Jhingran [17] and Kullander *et al.* [18].

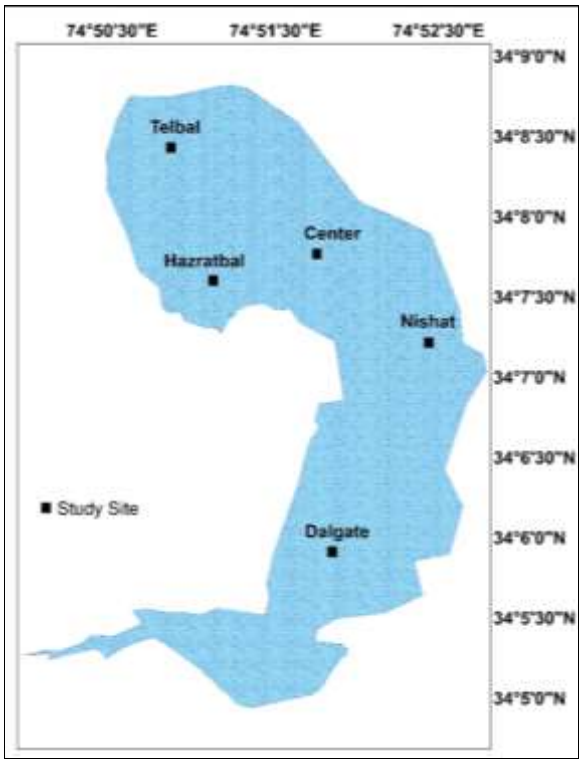

Fig 1: Map of Dal Lake depicting study sites

Diversity Indices

The fish diversity and abundance was assessed with the help of various diversity indices. The diversity indices used during the study are as:

Shannon Diversity Index (H): This diversity index was given by Shannon and Weaver [19]. The formula is as:

$$H = -\Sigma Pi \ln Pi$$

Where Pi, is the proportion of the individuals of a species in a sample.

Simpson's Index of Dominance (D): It is given by Simpson [20]. The formula for its calculation is as under:

$$D = \Sigma \frac{ni\ (ni-1)}{N\ (N-1)}$$

Where, ni is the proportion of individuals of a species of the total number of individuals and N is the total number of individuals of all species.

Simpsons Index of Heterogeneity (1-D): It is given by Lande [21]. It is calculated by subtracting the value of D from 1.

Margalef's Index: The formula given by Clifford and Stephenson [22] is as:

$$d = \frac{(S-1)}{\ln N}$$

Results

The reports on the fish diversity of Dal Lake from 1977 to 2019 were compiled and findings were then compared with the species composition and abundance of the current study, to know about the changes in species dynamics of the lake from past to present.

Overall fish fauna of Dal Lake

The earlier studies reported that the lake fishery was dominated by Schizothoracids till mid twentieth century. After that the population of local Schizothoracids showed a decline from the catch [23, 24]. Sehgal [25] reported a total of nine species (*Cyprinus carpio* var. *communis*, *Cyprinus carpio* var. *specularis*, *Schizothorax niger*, *Schizothorax curvifrons*, *Pethia conchonius*, *Botia birdi*, *Labeo dero*, *Schizothorax micropogon* and *Schizothorax esocinus*) from the lake. Shafi *et al.* [26] worked on the catch composition of Dal Lake, reporting eight (*Cyprinus carpio* var. *communis*, *Cyprinus carpio* var. *specularis*, *Schizothorax niger*, *Schizothorax curvifrons*, *Pethia conchonius*, *Carassius carassius*, *Crossocheilus diplochilus* and *Schizothorax esocinus*) species from the lake. Ahmed *et al.* [27] worked on current status of fish fauna of Dal Lake and reported nine (*Cyprinus carpio* var. *communis*, *Cyprinus carpio* var. *specularis*, *Schizothorax niger*, *Schizothorax curvifrons*, *Pethia conchonius*, *Carassius carassius*, *Crossocheilus diplochilus*, *Gambusia holbrooki* and *Botia birdi*) species from the lake. Other reports on the ichthyofauna of Dal lake include the work of Silas [28], Das and Subla [23], Saxena and Koul [29], Kullander *et al.* [18] etc.

The overall fish fauna of Dal Lake comprised 8 species belonging to 2 families, Cyprinidae and Poeciliidae,

dominated by the family Cyprinidae of which 7 species were found: *Cyprinus carpio* (*C. carpio* var. *communis* and *C. carpio* var. *specularis*), *Schizothorax niger*, *S. curvifrons*, *S. esocinus*, *Carassius carassius*, *Crossocheilus diplochilus* and *Pethia conchonius* whereas, only one species was reported from the family Poeciliidae, i.e., G*ambusia holbrooki* (Table 1). During the study period, 8 identified species of fishes were comprised of food fishes, forage fishes and one ornamental fish. The overall abundance of the fish fauna of the Dal Lake (Figure 2) followed the order: *C. carpio* var. *communis* (27%) > *P. conchonius* (14%) = *G. holbrooki* (14%) > *C. diplochilus* (13%) > *C. carassius* (11%) > *S. niger* (10%) > *C. carpio var. specularis* (7%) *S. curvifrons* (4%) > *S. esocinus* (0.3%).

Table 1: Overall fish fauna of Dal Lake

Fish species	Variety	Family	Local Name	Remarks
Cyprinus carpio	*communis*	Cyprinidae	Punjabe gad	Non-native food fish
	specularis			
Schizothorax niger	-	Cyprinidae	Ale gad	Native food fish
Schizothorax curvifrons	-	Cyprinidae	Satter gad	Native food fish
Schizothorax esocinus	-	Cyprinidae	Chirru	Native food fish
Carassius carassius	-	Cyprinidae	Gang Gad	Non-native forage fish
Crossocheilus diplochilus	-	Cyprinidae	Tethur	Native forage fish
Pethia conchonius	-	Cyprinidae	Bloz	Non-native forage and ornamental fish
Gambusia holbrooki	-	Poeciliidae	Mahi gad	Non-native forage fish

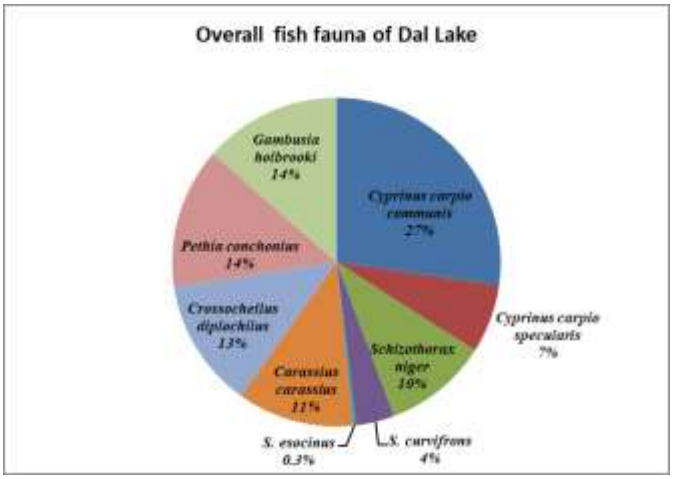

Fig 2: Overall abundance of fish fauna of Dal Lake

3.2 Relative abundance of fish

The relative spatial abundance of the ichthyofauna of the Dal Lake is depicted in the Table 2 which revealed that *C. c. communis* mostly dominates the Site-II (40.2%) and Site-III (25.4%) whereas, local *S. niger* (20%) and *S. curvifrons* (8.7%) mostly dominate the Site-IV. *S. esocinus* was found to be least (1.4%) abundant among all the fish fauna at every site whereas, *Pethia conchonius* and *Gambusia holbrooki* were found abundant at Site-I (22%) and Site-V (25.5%) respectively (Table 2). The spatial variation in abundance of non-native *Cyprinus carpio* and native *Schizothorax* spp. is depicted in Figure 3.

The relative temporal abundance of the fish fauna, depicted in table 3, revealed that during the spring, summer and winter seasons *Cyprinus carpio communis* was most abundant whereas *Gambusia holbrooki* was found most abundant during autumn. *S. esocinus* was found to be least abundant during spring, summer and autumn seasons whereas, *Gambusia holbrooki* was found least abundant during winter. The temporal variation in abundance of non-native *Cyprinus carpio* and native *Schizothorax* spp. is depicted in Figure 4. The invasive *Cyprinus carpio* was found abundant in the overall catch as compared to local *Schizothorax* species (Table 2 & 3).

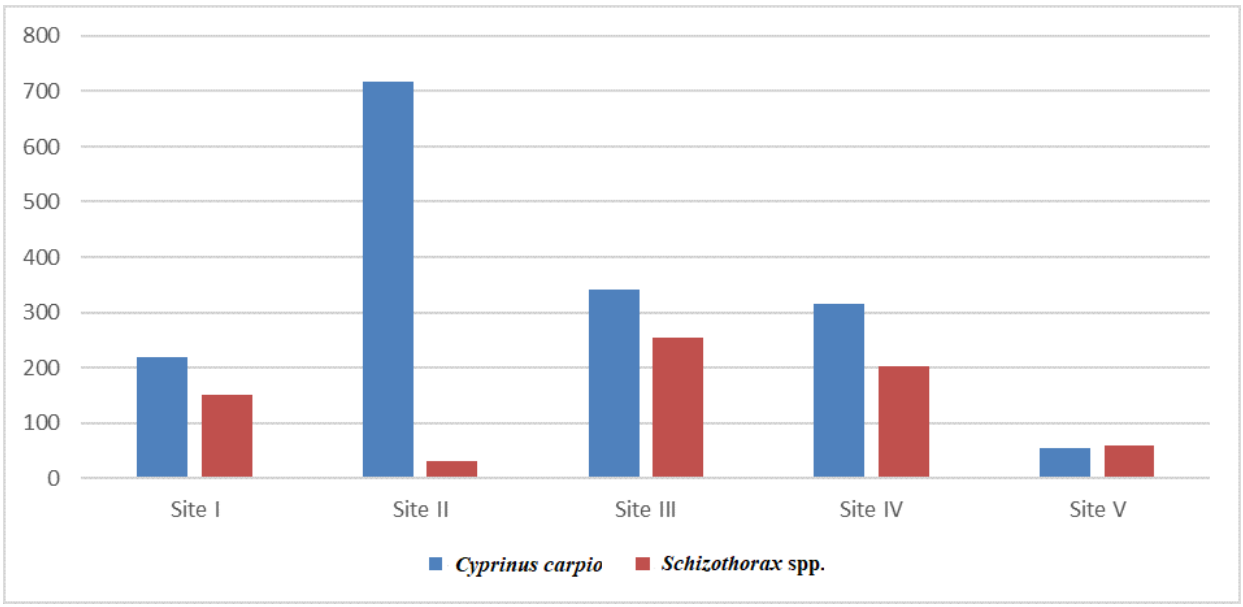

Fig 3: Comparison of spatial variation in abundance of non-native *Cyprinus carpio* and native *Schizothorax* spp.

Table 2: Spatial variation in relative fish abundance of Dal Lake

Fish species	Variety	Site-I	Site-II	Site-III	Site-IV	Site-V
Cyprinus carpio	*communis*	14.5	40.2	25.4	17.3	9.3
	specularis	6.8	11.0	5.2	4.4	3.2
Schizothorax niger		10.4	1.9	16.5	20.0	9.3
S. curvifrons		4.3	0.3	4.9	8.7	4.1
S. esocinus		0.0	0.0	1.4	0.0	0.0
Carassius carassius		8.8	20.7	8.2	5.3	10.9
Crossocheilus diplochilus		20.8	6.4	8.2	16.3	24.4
Pethia conchonius		22.0	9.9	11.9	16.8	13.2
Gambusia holbrooki		12.4	9.7	18.1	11.2	25.5

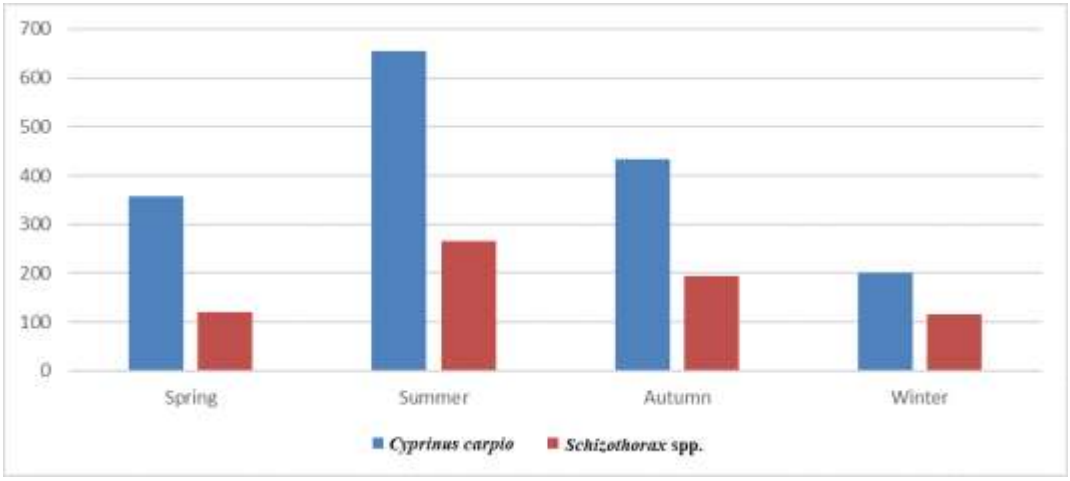

Fig 4: Comparison of temporal variation in abundance of non-native *Cyprinus carpio* and native *Schizothorax* spp.

Table 3: Temporal variation in relative fish abundance of Dal Lake

Fish species	Variety	Spring	Summer	Autumn	Winter
Cyprinus carpio	*communis*	32.7	23.6	20.3	31.7
	specularis	9.2	7.8	5.3	4.9
Schizothorax niger	-	11.1	9.5	9.2	21.1
S. curvifrons	-	4.1	3.1	3.6	8.8
S. esocinus	-	0.3	0.4	0.3	0.3
Carassius carassius	-	12.0	14.5	9.2	8.0
Crossocheilus diplochilus	-	17.6	13.1	10.1	16.0
Pethia conchonius	-	6.9	15.4	18.1	9.3
Gambusia holbrooki	-	6.1	12.5	23.9	0.0

Spatio-temporal variation of fish assemblage in Dal Lake

The spatiotemporal variation in diversity indices of fish species of Dal Lake is depicted in Table 4. The trend shown by the Shannon index (H′) depicts the maximum diversity at Site-IV (1.86), while it is seen minimum at Site-II (1.39). The dominance index (D) shows a trend of Site-II > Site-V = Site-III > Site-I = Site-IV, whereas the Margalef's diversity index or species richness index (d) was found maximum at Site-III (1.00) and minimum at Site-II (0.83).

As depicted in Table 4, the temporal variation in diversity indices revealed the maximum value for the Shannon index (H′) in summer (1.82) and the minimum in winter (1.64). The dominance index (D) showed the highest value during spring (0.24) and the lowest during autumn (0.18). The Margalef's diversity index or species richness index (d) were found to be high during spring (d = 1.05) and low during summer (d = 0.92).

Table 4: Spatiotemporal variation in diversity indices of fish fauna of Dal Lake

Spatial Diversity				
Site	**Taxa**	**Dominance D (Simpson's index of dominance)**	**Shannon diversity index (H′)**	**(Margalef's diversity index 'd')**
Site-I	7	0.17	1.83	0.87
Site-II	7	0.33	1.39	0.83
Site-III	8	0.18	1.84	1.00
Site-IV	7	0.17	1.86	0.92
Site-V	7	0.18	1.82	0.99
Seasonal Diversity				
Spring	8	0.24	1.67	1.05
Summer	8	0.19	1.82	0.92
Autumn	8	0.18	1.81	0.96
Winter	7	0.23	1.64	1.01

Comparison between abundance of exotic *Cyprinus carpio* and native *Schizothorax* spp.

The abundance data of *Schizothorax* spp. group containing three species was compared with *Cyprinus carpio*. On spatial scale, *Cyprinus carpio* is maximum at site II, while *Schizothorax* spp. is maximum at site III. At site V, *Cyprinus carpio* and *Schizothorax* spp. are in somewhat equal abundance. The site II, representing maximum abundance of *Cyprinus carpio* also represents minimum abundance of *Schizothorax* spp. which indicates that in a shared habitat between the two, *Cyprinus carpio* shows much abundance than *Schizothorax* spp. (Figure 3). On a temporal scale, it was found that, *Cyprinus carpio* and *Schizothorax* spp. were maximum in the summer season and minimum in winter season but all the seasons were dominated by *Cyprinus carpio* (Figure 4).

Cluster analysis of the fish fauna of the Dal Lake

The cluster analysis applied to the fish assemblage data set revealed the dendrogram with three well-defined clusters, Cluster-I, Cluster-II and Cluster-III, which showed the similarity and dissimilarity in the fish assemblage of Dal Lake at different sites (Figure 5). The Cluster-I is comprised of Site-II and Site-III depicting the uniqueness of the fish species present at these sites as compared to Site-I which is the component of cluster-II. Cluster-III comprised of Site-IV and Site-V depicting the similarities in fish assemblage at these sites.

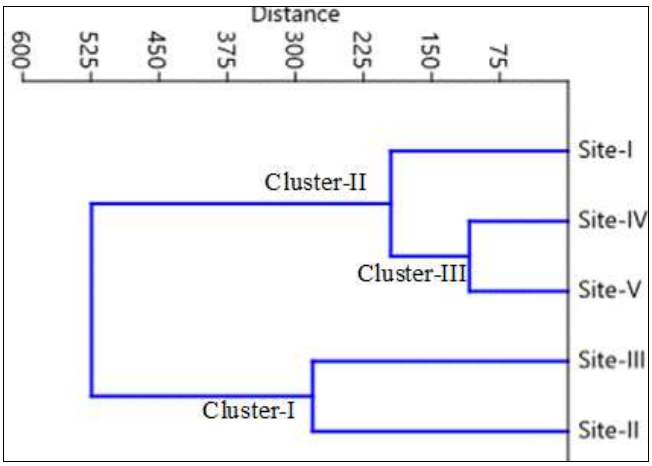

Fig 5: Cluster analysis of fish assemblage of Dal Lake

Discussion

Fishes of freshwater habitats are one among the most threatened taxonomic groups [2] due to high sensitivity of this taxonomic group to qualitative as well as quantitative changes of aquatic habitats [3]. In this scenario it becomes imperative to have knowledge of variety and variability of fishes in a habitat and their manifestations over spatial as well as temporal scales, so as to have holistic conservation and management of species along with their habitat. The study of temporal and spatial distribution of fish species provides information regarding breeding and feeding areas of fishes in a water body, which helps in the proper management and utilization of fishery resources [30].

A marked variation in the composition of fishes was observed on the basis of different sites chosen, both in terms of number of species got as well as number of individuals of a species. Spatial differences in fish catch are due to factors like temperature, depth and transparency of water [31, 32]. During the current study, clear variation was seen in the distribution of fish fauna of the Dal Lake with invasive *C. c. communis* mostly dominating the Site-II and Site-III whereas, local *S. niger* and *S. curvifrons* dominating the Site-IV. The temporal variation in fish fauna of the same habitat is supported by the study of Paley *et al.* [33] and the same may be attributed to differential food availability and habitat suitability [34]. More abundance of a fish at a particular site in a lake may be attributed to availability of food like algae and macrophytes, and suitability for predator avoidance [33, 35].

Fish catch of a water body is subject to variations in water and air temperature [36]. Fish catch in our study showed a marked variation across the different seasons of study period. Highest catch of fishes was found during summer season, while it was lowest during winter season. *Cyprinus carpio communis* dominated catch with highest catch during spring and winter season, while lowest during autumn. The high catch during spring and winter season may be attributed to low water level and more fishing activity compared to autumn season. This view is supported by Patrick [37], that fishing efficiency is low during low water temperature and high-water level. The temporal variation in fish abundance may be also attributed to changes in different abiotic components like temperature, depth, and variation in fish catching efforts during different seasons [38]. During the current study, invasive *Cyprinus carpio communis* was highly abundant as compared to local *Schizothorax* species that also is confirmed by previous studies [26, 27]. However, Ahmed *et al.* [27] reported *Botia birdi* during their study, but in the present study, it was not found in catch at any site.

Shannon-Weiner, Margalef's index, Evenness index and Simpson's index are the most commonly used indices [39, 40] in biodiversity assessments of any habitat. Shannon-Weiner Index is a combination of species diversity and species richness. In our study 'H' ranged from 1.39 to 1.86 indicating a good diversity of fish fauna in the Dal Lake. Limnological features have a profound effect on species richness of a lake than other factors [41]. Site-IV showed highest value of 'H' while lowest was found for Site-II. Similarly, Coulter [35] reported higher values for 'H' at some sites and lower for other sites of a same water body. This difference in 'H' across same water body at different sites is due to some sites providing hiding places for fishes to nest and breed [34].

Fish diversity was not uniform across all the seasons. In our study 'H' was highest (1.82) for summer season, while lowest (1.64) for winter season. Ideal range for 'H' is ≥ 3.5 [42]. Due to anthropogenic stress and fishing burden [43, 44] lower values of 'H' like in our study were reported by Ahamed *et al.* [45] during studies on biodiversity of Tilai river, Bangladesh. Higher value of 'H' in one season is due to more fishing hours compared to winter months and habitat suitability owing to feasible physico-chemical parameters like water temperature and air temperature [36]. Margalef's index has no fixed range and shows direct relationship of linearity with species richness i.e., higher the value, richer the community is in terms of diversity [46]. During the current study, Margalef's index showed less value for Site-II, while on temporal scale, less value of Margalef's index was obtained for summer season. A similar kind of trend was also reported in Dharla river by Alam *et al.* [47].

Cluster analysis analyzes the difference between the similar and dissimilar floral and faunal elements in an ecological community giving the results in the form of a dendrogram [48, 49]. During the present study, the cluster analysis showed

clearly the similarity of the fish fauna at five sites of the Dal Lake, with Site-II and Site-III closely related in fish species composition as compared to Site-I, Site-IV and Site-V. This difference could be due to the different habitat preferences of the fish fauna due to which they tend to accumulate and survive in different zones of a water body, thus avoiding competition and allowing better survival [38]. Several other workers also make the use of cluster analysis to get the similarity in fish fauna in their respective study areas [50, 51, 52]. The considerable impact of non-native invasive species on the native ones is a big challenge in the current scenario and numerous studies are being carried on the similar lines around the globe. The current study also revealed the dominance of non-native invasive fish species in the Dal Lake which is a matter of concern and steps should be taken for the conservation of the native fish diversity of the Dal Lake.

Conclusion

The current study of the fish diversity of Dal Lake, reveals that the overall catch from the lake is dominated by exotic *Cyprinus carpio*. The native Schizothoracids also called snow trout are showing the decline in abundance from this waterbody, with *Schizothorax esocinus* represented by 0.3% of total catch, restricted to only site iii (Nishat) of the lake. The overall catch is being dominated by exotic *Cyprinus carpio*, which is both reproductively and ecologically a hardy species compared to native *Schizothorax* spp. The present study was compared with earlier studies done on the lake and it reveals that, fishes like *Schizothorax micropogon*, *Labeo dero* and *Botia birdi* are totally absent from the catch of lake currently. Fishes like *Gambusia affinis* and *Carassius carassius* (both exotic) have appeared in the catch from the later studies done from start of twenty first century. In this scenario, the native species of the lake are facing a double edge sword with exotic common carp on one hand and increasing anthropogenic pressure on the other. The exotic carp fishery needs to be more exploited from the current rate and also a pollution mitigation policy of the lake is needed, in order to make the lake feasible for the overall fish fauna, which will be a step in the conservation of fisheries as well as whole lake ecosystem.

Acknowledgements

The authors are highly grateful to the Head, Department of Zoology, the University of Kashmir for providing all the necessary facilities during the present study.

Funding

The authors are highly grateful to the Science and Engineering Research Board, Department of Science and Technology, Ministry of Science and Technology, Government of India (File No. EMR/2017/003669) for providing financial assistance.

Conflicts of interest

The authors have no conflicts of interest to declare, that are relevant to the content of this article.

Availability of data and material

The data collected during the current study will be available from the corresponding author on reasonable request.

Ethics approval

Not Applicable

Consent for publication

All authors reviewed the manuscript and consented to its publication.

Authors Contribution

Yahya Bakhtiyar, Abrar Ahmad Bhat and Mohammad Yasir Arafat conceptualization and preparation of the main manuscript text. Abrar Ahmad Bhat, Sinan Nissar, Mohammad Yasir Arafat conducted the fieldwork. Abrar Ahmad Bhat, Sinan Nissar, Tabasum Yousuf and Mohammad Yasir Arafat were involved in the lab work.

Yahya Bakhtiyar, Abrar Ahmad Bhat conducted the statistical analysis of the data. Yahya Bakhtiyar, Abrar Ahmad Bhat, Tabasum Yousuf and Mohammad Yasir Arafat prepared the tables and figures.

Yahya Bakhtiyar, Abrar Ahmad Bhat, Sinan Nissar, Mohammad Yasir Arafat reviewed and scrutinized the manuscript.

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