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DIVERSITY AND RELATIVE ABUNDANCE OF ICHTHYOFAUNA IN MANASBAL LAKE OF THE KASHMIR HIMALAYAS, INDIA

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ABSTRACT

Diversity, abundance and distribution pattern of the fish fauna are important aspects that need to be considered in order to frame the conservation and management strategies in any water body. To assess the composition, diversity and relative abundance of the fish fauna in the Manasbal Lake of Kashmir, the present study was carried out for two years (March 2018 - February 2020). A total of 22522 fish specimens were netted out during the sampling period, and the relative abundance and various diversity indices were used to assess the overall diversity of the inhabiting fish fauna. A total of 7 species belonging to two families, Cyprinidae and Poeciliidae, were reported, of which the family Cyprinidae was dominant in the catch. The relative abundance and diversity of the fish fauna showed spatio-temporal variation wherein *Pethia conchonius* was most abundant during spring and winter, while *Gambusia holbrooki* was most abundant during summer and autumn. *Cyprinus carpio* was found to be abundant during all the seasons at Site II and Site III as compared to native cyprinids, *Schizothorax niger* and *S. curvifrons*. The current study also indicated a good fish diversity in the lake which varies on spatio-temporal scales, showing maximum diversity during winter (H' =1.498) and minimum diversity during summer (H' = 1.247), while Site II showed maximum diversity (H' =1.369) and Site I showed minimum diversity (H' =1.085). Overall lake possesses good fish diversity that could be a great source of income for the local populace provided the fish assemblages are sustainably managed.

Keywords:
Composition
Abundance
Cyprinidae
Fish assemblage
Native

How to Cite

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INTRODUCTION

For the stability of any ecological and biological community, proper interaction between different floral and faunal elements along with the abiotic factors is necessary (Pianka, 1994). Similar is the case for an aquatic ecosystem that has fish as the major component of all ecological interactions (Negi and Mamgain, 2013). Fish form the most diversified vertebrate taxa with a wide range of distribution according to habitat preferences (Bone and Marshall, 1982; De Silva et al., 2007). Fish are known to be the best source of animal protein and a boon to the economy of many countries all over the world (Tessema and Mohamed, 2016). Fish species composition, abundance and diversity are important indicators of an ecological community (Mwangi et al., 2012). The diversity of fish species relies on richness, abundance and phylogeny. Species richness comprises the number of species in the particular area of study, while species abundance involves the relative number of species (Gorman and Karr, 1978). Indeed, there arises a need to have an in-depth knowledge of species diversity, abundance and distribution in a water body to know the factors affecting the structure of a fish community as well as to develop management and conservation strategies in a given ecosystem (Hashemi et al., 2015; Solomon et al., 2017). The study of composition, abundance, distribution and diversity of fish species on the spatial and temporal grounds yields useful information regarding the factors affecting the overall community structure (Hugueny and Paugy, 1995; Silvano et al., 2000). These variables are closely related to other variables which are necessary for the successful establishment of a fish species like the range of microhabitat, food resource availability, the topography of the habitat and other physicochemical aspects of the water body (Harris, 1995; Belliard et al., 1997; Rahim et al., 2009). Manasbal Lake, the deepest lake in the valley, is a famous tourist destination and a source of income for the local population in terms of its floral and faunal yield. Though the studies on the ichthyofauna of different water bodies have previously been undertaken by some researchers (Brraich and Malik, 2016; Ahmed et al., 2017), the study of fish assemblage patterns and their spatio-temporal variation in diversity and abundance is scanty in general and particularly in Manasbal Lake. Thus, the present study was undertaken to get detailed information about the composition, abundance and diversity of the fish fauna in the deepest and warm monomictic lake of the Kashmir Himalayas, i.e. Manasbal Lake, to generate baseline data for future fish conservation and management strategies of the lake.

MATERIALS AND METHODS

Study area

Manasbal Lake, rightly called the ˝supreme gem of all Kashmir lakes˝, is the only warm monomictic lake of the Kashmir Himalayas, India which undergoes stratification once a year for a short period (Bhat et al., 2012; Magray and Jan, 2014). It is the deepest lake of the valley with an average depth of 12 m and is located about 30 km to the north of Srinagar in the Ganderbal district (Bhat et al., 2012). The lake is a semi-drainage type having only a permanent outlet source in the form of a Nallah through which its water drains into the River Jhelum. This lake is famous for its clean and clear water and for enchanting bloom of lotus (*Nelumbo nucifera*) flowers during the late autumn season (Jamila et al., 2014).

Collection of samples

The study area was divided into three sampling sites, viz. Site I, Site II and Site III (Fig. 1). The fish fauna of Manasbal Lake was assessed from the direct netting in the lake with the help of expert fishermen and also from the catches already obtained by the fishermen operational in the lake with the help of nets of different dimensions such as the cast net of mesh size from 1.3 to 3.0 cm, gill net of mesh size from 4.5 to 7.5 mm and bag net for smaller sizes fishes. Sampling sites were visited monthly for two years between March 2018 and February 2020, and the fish samples obtained were immediately identified using the taxonomic keys of Talwar and Jhingran (1991) and Kullander et al. (1999). Every month, on the sampling day the fish species caught were examined, identified and counted for proper data collection.

Estimation of abundance and diversity

The relative abundance of the fish was estimated using the formula as given by Negi and Mamgain (2013):

$$Relative\ abundance = \frac{Number\ of\ individuals\ of\ a\ paticular\ species}{Total\ number\ of\ individuals\ all\ species} \times 100$$

For the estimation of diversity, several indices were used, viz. Shannon diversity index, Simpson's index of dominance, Margalef's species richness index, equitability index and index of heterogeneity.

a) Shannon diversity index (H') was calculated using an equation put forth by Shannon and Weaver (1963):

$$\mathrm{H'} = -\sum \mathrm{Pi} \ln \mathrm{Pi}$$

where P is the number or proportion of individuals found in species i.

b) Simpson's index of dominance (D) was estimated from the equation (Simpson, 1949):

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

where ni is the number of individuals of species i and N is the total number of individuals for that site.

c) The complement of Simpson's index, i.e. the index

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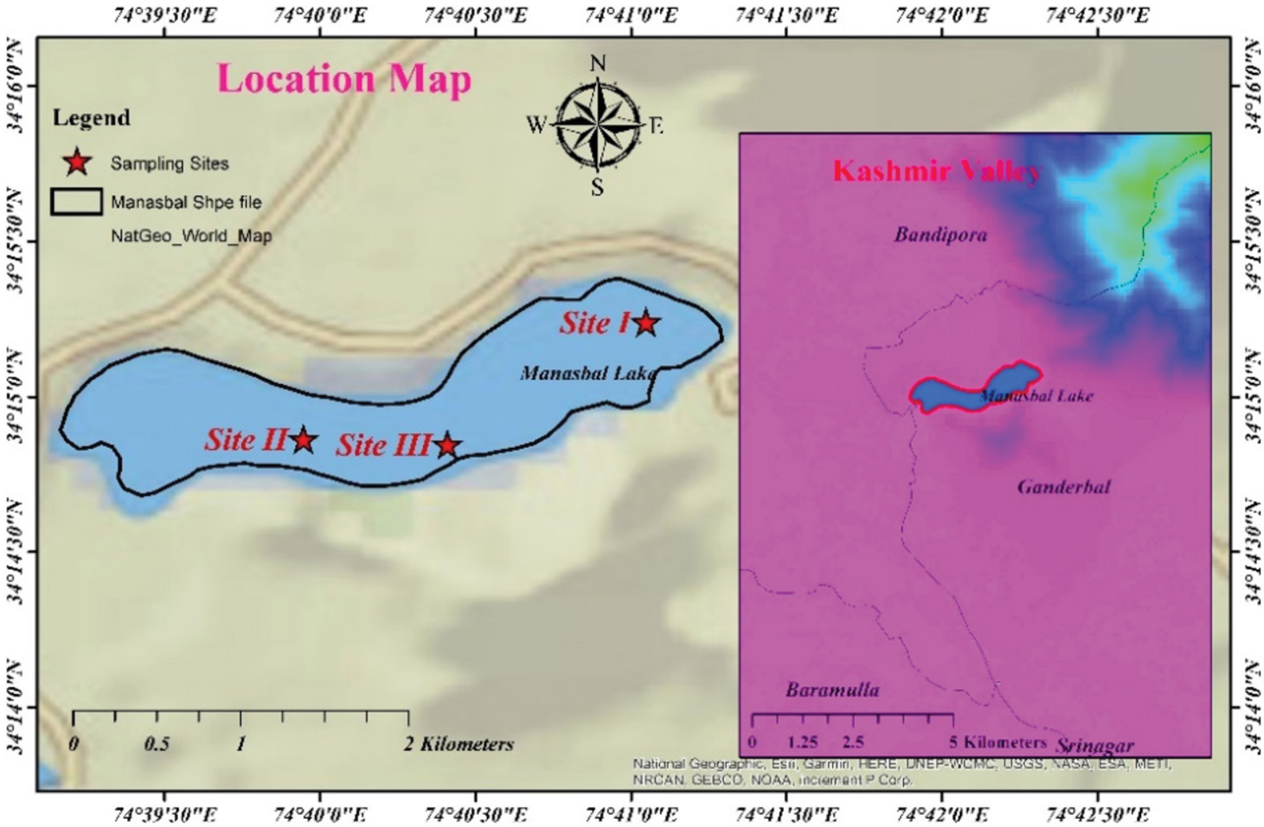

Fig 1. Map showing the study sites of Manasbal Lake

Site I – is the main point of disturbance due to tourist activities at the entry of the lake as it is the main harbor for boat and shikara ridings

Site II – was chosen as the open water zone of the lake with clean water and no visible pollution source

Site III – involves the direct involvement of people with the village called Kondbal settled on the bank. Here the anthropogenic pollution is evident with high macrophytic growth and more turbid water than at other sites

of heterogeneity (1-D), was estimated using Lande (1996).

d) Margalef's diversity index (d) was calculated from the equation of Clifford and Stephenson (1975):
where S is the number of species in a population and

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

N is the total number of individuals in species S.

e) Species equitability or evenness index (j) was estimated using Pielou (1966):
where H' is the Shannon diversity index and S is the

$$j = \frac{H'}{\ln S}$$

number of species in the catch.

Cluster analysis

Cluster analysis was done by hierarchical agglomerative clustering (HAC) which is based on Ward's method that uses Euclidean distances as a measure of similarity. This was done by using software PAST ver. 2.02.

RESULTS

The overall fish fauna of Manasbal Lake comprised 7 species belonging to 2 families, Cyprinidae and Poeciliidae, dominated by the family Cyprinidae of which 6 species were found: *Cyprinus carpio* (*C. carpio* var. *communis* and *C. carpio* var. *specularis*), *Schizothorax niger*, *S. curvifrons*, *Carassius carassius*, *Pethia conchonius* and *Crossocheilus diplochilus*. Only one specie was reported from the family Poeciliidae, i.e. *Gambusia holbrooki*. The percentage composition of the fish fauna of Manasbal Lake followed the order: *G. holbrooki* (36%) > *P. conchonius* (34%) > *C. diplochilus* (22%) > *C. carpio* var. *communis* (4%) > *S. niger* (1%) = *S. curvifrons* (1%) = *C. carassius* (1%) = *C. carpio* var. *specularis* (1%) (Fig. 2).

Relative abundance of fish

The temporal abundance of the fish fauna, depicted in Table 1, involves the mean values of the relative abundance of a fish species at different sites in a particular season. The table revealed that during the spring season *Pethia conchonius* was found to be most abundant, while the *C. carpio* var. *specularis* was the least abundant fish.

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Table 1. Temporal variation in the relative abundance of the fish fauna of Manasbal Lake

Seasons	Sampling Sites	Family Cyprinidae							Family Poeciliidae
		Crossocheilus diplochilus	*Pethia conchonius*	*Schizothorax niger*	*Carassius carassius*	*Cyprinus carpio* var. *communis*	*Cyprinus carpio* var. *specularis*	*Schizothorax curvifrons*	*Gambusia holbrooki*
Spring	Site-I	30.65	42.68	0.00	0.00	0.00	0.00	0.00	26.67
	Site-II	0.00	0.00	15.29	12.89	48.80	11.41	11.60	0.00
	Site-III	29.67	34.02	1.03	0.00	3.07	0.00	0.87	31.32
	Mean Total	20.11	25.57	5.44	4.30	17.29	3.80	4.16	19.33
Summer	Site-I	27.40	31.11	0.00	0.00	0.00	0.00	0.00	41.49
	Site-II	0.00	0.00	5.31	22.95	56.76	12.80	2.17	0.00
	Site-III	14.96	26.60	0.00	0.00	0.79	0.00	0.21	57.44
	Mean Total	14.12	19.24	1.77	7.65	19.18	4.27	0.89	32.97
Autumn	Site-I	14.98	37.33	0.00	0.00	0.00	0.00	0.00	47.70
	Site-II	0.00	0.00	20.70	7.96	54.14	9.24	7.96	0.00
	Site-III	15.27	34.86	1.20	0.00	0.93	0.00	0.60	47.14
	Mean Total	10.09	24.06	7.30	2.65	18.36	3.08	2.85	31.61
Winter	Site-I	19.58	79.02	0.00	0.00	0.00	0.00	0.00	1.40
	Site-III	0.00	0.00	22.06	9.11	44.36	7.43	17.03	0.00
	Site-III	24.30	53.27	5.42	0.00	9.16	0.00	4.11	3.74
	Mean Total	14.63	44.10	9.16	3.04	17.84	2.48	7.05	1.70

Note: The mean values include the average of the relative abundance values of a particular fish species

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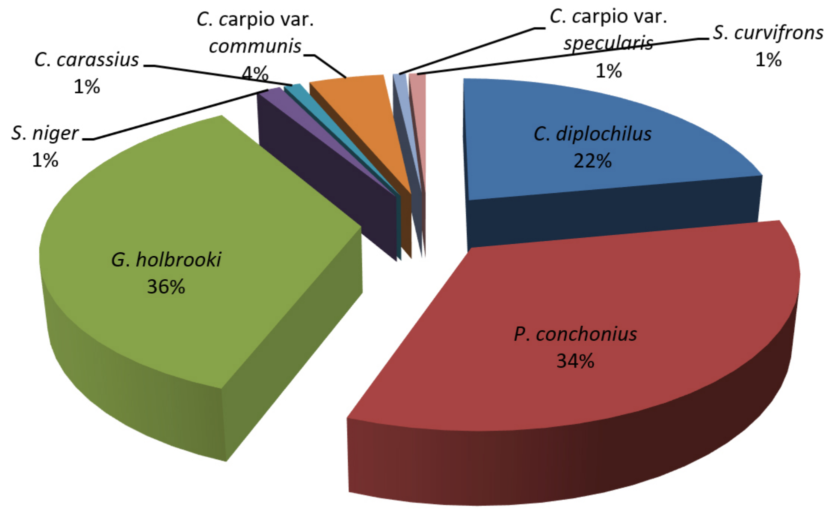

Fig 2. Percentage compositions of the fish fauna in Manasbal Lake

In the summer season, *Gambusia holbrooki* was found dominant in the catches, while *Schizothorax niger* and *S. curvifrons* were least abundant. During autumn again *Gambusia holbrooki* was abundantly found, while during winter *Pethia conchonius* was again found to dominate the catches in Manasbal Lake.

The spatial variation in the abundance of the fish fauna depicted in Table 2 showed the dominance of *Pethia conchonius* at Site I, *C. carpio* var. *communis* at Site II and *Gambusia holbrooki* at Site III. *C. diplochilus*, *P. conchonius* and *G. holbrooki* were not found in the catches at Site II.

The rank abundance curve of the fish fauna is given in Figure 3 which revealed that *G. holbrooki* was the most abundant fish followed by *P. conchonius*, whereas *C. carpio* var. *specularis* was the least abundant fish in the lake.

Table 2. Spatial variation in the relative abundance of the fish fauna of Manasbal Lake

Fish Species	Site-I	Site-II	Site-III
Crossocheilus diplochilus	26.00	0.00	20.69
Pethia conchonius	38.67	0.00	32.35
Gambusia holbrooki	35.33	0.00	43.18
Schizothorax niger	0.00	15.52	0.93
Carassius carassius	0.00	13.51	0.00
Cyprinus carpio var. *communis*	0.00	50.65	2.10
Cyprinus carpio var. *specularis*	0.00	10.37	0.00
Schizothorax curvifrons	0.00	9.95	0.75

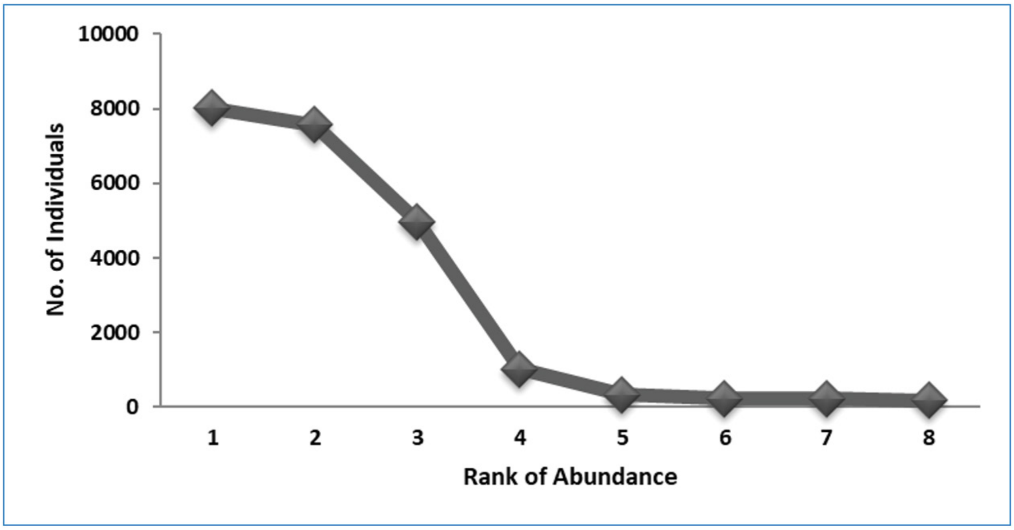

Fig 3. Rank abundance curve of the fish fauna of Manasbal Lake

Note: 1 = *Gambusia holbrooki*, 2 = *Pethia conchonius*, 3 = *Crossocheilus diplochilus*, 4 = *Cyprinus carpio* var. *communis*, 5 = *Schizothorax niger*, 6 = *Carassius carassius*, 7 = *Schizothorax curvifrons*, 8 = *Carpio carpio* var. *specularis*

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Diversity of the fish assemblage in Manasbal Lake

The spatial variation in diversity indices of fish species of Manasbal Lake is depicted in Table 3. The trend shown by the Shannon index (H') depicts the maximum diversity at Site II (1.369), while it is seen as a minimum at Site I (1.085). The dominance index (D) shows a trend of Site I > Site III > Site II, whereas species heterogeneity (1-D) ranged from 0.658 at Site I to 0.68I at Site II. The species richness index (d) was found to be maximum at Site III (0.558), followed by Site II (0.538) and minimum at Site I (0.211). The equitability index (j) was highest at Site I (0.988) and lowest at Site III (0.676).

The temporal variation in diversity indices is depicted in Table 4, wherein the maximum value for the Shannon index (H') was seen in winter (1.498) and the minimum in summer (1.247). The dominance index (D) showed the highest value during summer (0.333) and the lowest during spring (0.285). For the species heterogeneity (1-D), the maximum value was found during spring (0.715) and the minimum during summer (0.667). The species richness index (d) as well as the equitability index (j) were found to be high during winter (d = 0.944 and j = 0.720) and low during summer (d = 0.764 and j = 0.600).

Cluster analysis

The cluster analysis applied to the fish assemblage data revealed the dendrogram with two well-defined clusters, cluster-I and cluster-II, which showed the similarity and dissimilarity in the fish assemblage of Manasbal Lake at different sites (Fig. 4). The cluster-I depicts the uniqueness of the fish species present at Site II and the cluster-II is the cluster showing the similarity in the fish fauna at Site I and III.

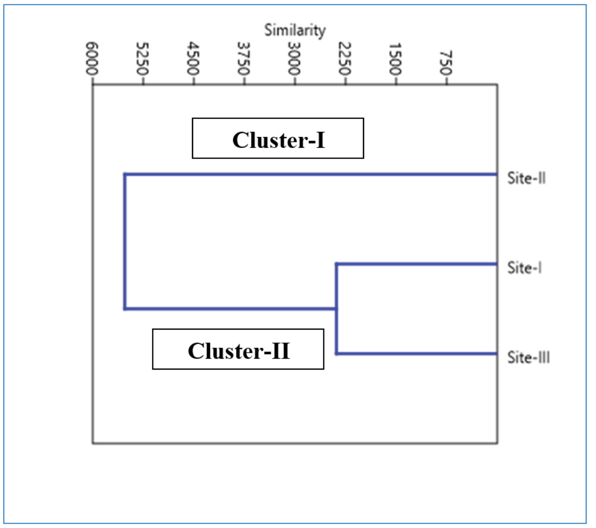

Fig 4. Dendrogram showing the similarities in the fish fauna at different sites in Manasbal Lake

DISCUSSION

Fish assemblages are an important component of an aquatic ecosystem, being the biological indicators screening the alterations of the habitat (Guo et al., 2018). During the present study on Manasbal Lake of the Kashmir Himalayas, India, the fish fauna reported included both native as well as non-native species. The native species included *Schizothorax niger*, *S. curvifrons* and *Crossocheilus diplochilus*, while the non-native fish species included *Cyprinus carpio* var. *communis*, *C. carpio* var. *specularis*, *Carassius carassius*, *Gambusia holbrooki* and *Pethia conchonius*.

Table 3. Spatial variation in diversity indices of fish species in Manasbal Lake

Sites	No. of Spp	No. of Individuals	Shannon Index (H')	Simpson's Index (D)	Species Heterogenity (1-D)	Species Richness Index (d)	Equitability Index (J)
Site-I	3	13075	1.085	0.342	0.658	0.211	0.988
Site-II	4	1688	1.369	0.320	0.681	0.538	0.850
Site-III	6	7759	1.212	0.337	0.664	0.558	0.676

Table 4. Temporal variation in diversity indices of fish species in Manabal Lake

Seasons	No. of Spp	No. of Individuals	Shannon Index (H')	Simpson's Index (D)	Species Heterogenity (1-D)	Species Richness Index (d)	Equitability Index (J)
Spring	7	7358	1.415	0.285	0.715	0.786	0.68
Summer	7	9507	1.247	0.333	0.667	0.764	0.60
Autumn	7	3990	1.333	0.325	0.675	0.844	0.641
Winter	7	1667	1.498	0.316	0.685	0.944	0.72

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The study of the relative abundance has an important role in determining the structure of an aquatic community because changes in the relative abundance of species in turn negatively impact other parameters like species richness, ecosystem biomass, the ecological structure of the food chain and food webs, and also some biological parameters of fish species (Rochet and Trenkel, 2003; Sarkar et al., 2008). During the current study, the relative abundance of the fish fauna in Manasbal Lake showed the overall dominance of the family Cyprinidae with 6 species and one species from the family Poeciliidae. The variation in spatial and temporal distribution and abundance of fish species is due to the difference in their habitat preferences, feed availability at different sites and abiotic factors like temperature, water depth, etc. *Gambusia holbrooki*, mosquito larvae eating fish, is seen in huge numbers during the late spring and summer seasons at Sites I and III owing to the low water depth at these littoral sites and the presence of calm water pools full of vegetation which is the best-suited habitat for this fish species. A similar kind of habitat preference has been observed by Casterlin and Reynolds (1977) and Hubbs (2000) for *G. affinis*, and by Pen and Potter (1991) for *G. holbrooki*. Further, these two sites have comparably more polluted water due to human interference, which leads to the breeding of mosquito larvae and thus abundant *G. holbrooki*. Similarly, *Pethia conchonius* and *Crossocheilus diplochilus* are also more abundant towards the littoral sides with deep pools of water within a large area of low water flow with more feeding options available and more secure habitat grounds in the form of macrophytic vegetation. Aurnachalam (2000) reported a similar kind of habitat preference for *Puntius* spp. (=*Pethia*) in Western Ghats, India, and Singh and Agarwal (2013) in the Laster stream. Other fish species involving *C. carpio* var. *communis*, *C. carpio* var. *specularis*, *S. niger*, *S. curvifrons* and *C. carassius* are found dominating the open water deep zones with less pollution and more clear waters having dense submerged vegetation as proper breeding grounds. Similar findings have been reported by Penne and Pierce (2008), Taylor et al. (2012) and Hou et al. (2019). The abundance of fish species changes temporally with the changes in different abiotic components like temperature, depth (which both decrease during the winter season due to which fishes tend to go deeper and deeper), and also due to variation in fish catching efforts during different seasons.

Diversity indices are the basic statistical parameters revealing the variety and richness of a biological community. These yield vital statistics regarding the rarity and commonness of species in a community (Akongyuure et al., 2017). Kerkhoff (2010) reported the typical range from 1.5 to 2.5 for the Shannon diversity index in an ecological community. A similar range is reported by Ataguba et al. (2014). In our study, the Shannon diversity index was greater than 1 in all the seasons and almost approaching 1.5 in the spring and winter seasons, which is an indication of good diversity of the fish fauna as well as their even distribution in Manasbal Lake. Solomon et al. (2017) reported the Shannon diversity index range from 0.217 to 1.597 in Kalgawi Lake, Nigeria, while Emmanuel and Modupe (2010) reported the range between 1.869 and 2.015 in three tributaries of the River Ore. The spatial range of the Shannon diversity index ranged from 1.085 to 1.369, which indicates an even distribution of the fish species as also reported by Galib et al. (2013), Ataguba et al. (2014) and Solomon et al. (2017). The Simpson's diversity index values were found to range from 0.320 to 0.342 for sites and 0.285 to 0.333 for seasons. These values indicate a good dominance of species according to their habitat preferences. This is in accordance with Lowe-Mc Connell (1999) and Siqueira-Souza and Freitas (2004). The species heterogeneity values for the fish fauna of Manasbal Lake were reported to be approaching 1 on both spatial and temporal grounds, which suggests a good diversity as well as better environmental conditions for the fish fauna. Similar results have been shown by Emmanuel and Modupe (2010), Yem et al. (2011) and Ataguba et al. (2014) in their respective studies. The species richness index values for the fish fauna of Manasbal Lake were reported to be less than 1, indicating less species richness compared to other water bodies, as reported by Ejikeme Odo et al. (2009) in the Anambra River, Galib et al. (2013) in Choto Jamuna and Ataguba et al. (2014) in Gubi dam, which may be attributed to different habitat preferences of the fish species as well as the number of species encountered at different sites during the sampling events. Species equitability index values were reported to be close to 1 suggesting even distribution of fish species. Our values are closely associated with those of Emmanuel and Modupe (2010), Ataguba et al. (2014) and Solomon et al. (2017). Callaway et al. (2002) reported the patterns of fish diversity in the North Sea with respect to epibenthic invertebrates wherein they reported the dominance of small demersal fish fauna in the catches. Brucet et al. (2013) analysed the influence of geographical and anthropogenic factors on fish diversity in European lakes.

Cluster analysis helps to differentiate between the similar and dissimilar floral and faunal characteristics in an ecological community giving the results in the form of a dendrogram (McKenna, 2003; Singh et al., 2004). During the present study, the cluster analysis showed the similarity in the fish fauna at two sites of Manasbal Lake, i.e. Site I and Site III, while at Site II the fish fauna showed a difference in abundance and distribution compared to the other two sites. 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. A similar type of cluster analysis was used by Labropoulou and Papaconstantinou (2004) and Hossain et al. (2012) to get the similarity in fish assemblages with respect to their water bodies. Johannesen et al. (2012) reported six clusters in their study of demersal fish assemblages in the

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Arctic-Atlantic transition zone in the Barents Sea.
The impact of non-native and invasive species on the native ones is a big issue in the present-day world and studies are carried out to know the negative aspects of invasive fish species on the native ones around the globe. *C. carpio* is a worldwide known invasive species hampering the survival of native fish species wherever it establishes itself; the same purpose was kept in mind during the present study. Our study also revealed the dominance of non-native fish species over the native ones which is a matter of concern and steps need to be taken to help increase the population of native fish fauna equally.

CONCLUSION

The fish diversity at different sampling sites and seasons was studied in the deepest lake of Kashmir, keeping in view its importance as a famous tourist destination and economic asset in terms of its fish fauna. The present study revealed a good diversity of fishes in Manasbal Lake indicating less stress on the lake in terms of human interference and organic pollution load, unlike other water bodies of the Kashmir Himalayas. Also, there seems to be less exploitation of its fishery resources because of traditional methods of gear used for fishing. Overall the lake is harboring a good diversity of fish, particularly the economically important Cyprinids which form a great food and economic source for the local population. Proper management aspects need to be framed to develop this lake for a better source of income generation at the commercial level.

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RAZNOLIKOST I RELATIVNA ZASTUPLJENOST IHTIOFAUNE U JEZERU MANASBAL U KAŠMIRSKOJ HIMALAJI, INDIJA

SAŽETAK

Raznolikost, zastupljenost i distribucija ihtijofaune važni su aspekti koje je potrebno uzeti u obzir kako bi se provele strategije očuvanja i upravljanja u bilo kojem vodnom tijelu. Ovo istraživanje provedeno je u razdoblju od dvije godine (od ožujka 2018. do veljače 2020.) radi procjene sastava, raznolikosti i relativne abundancije ihtiofaune u jezeru Manasbal u Kašmiru, Ukupno je 22522 riblje jedinke ulovljeno tijekom razdoblja uzorkovanja, a relativna brojnost i različiti indeksi raznolikosti korišteni su za procjenu ukupne raznolikosti postojeće riblje faune. Utvrđeno je ukupno 7 vrsta koje pripadaju u dvije porodice, Cyprinidae i Poeciliidae, od kojih je u ulovu dominirala obitelj Cyprinidae. Relativna brojnost i raznolikost riblje faune pokazala je prostorno-vremenske varijacije gdje je *Pethia conchonius* bila najzastupljenija vrsta tijekom proljeća i zime, dok je *Gambusia holbrooki* bila najbrojnija tijekom ljeta i jeseni. Utvrđeno je da je *Cyprinus carpio* prisutan tijekom svih godišnjih doba na lokalitetu II i lokalitetu III u usporedbi s domaćim ciprinidima, *Schizothorax niger* i *S. curvifrons*. Ova studija također je ukazala na dobru raznolikost riba u jezeru koja varira na prostorno-vremenskim ljestvicama, pokazujući maksimalnu raznolikost tijekom zime (H’ = 1,498) i minimalnu raznolikost tijekom ljeta (H’ = 1,247), dok je lokacija II pokazala maksimalnu raznolikost (H’ = 1,369), a lokacija I pokazala je minimalnu raznolikost (H’ = 1,085). Sveukupno ovo jezero posjeduje dobru riblju raznolikost koja bi mogla biti izvrstan izvor gospodarstva za lokalno stanovništvo pod uvjetom da se ribljim zajednicama upravlja održivo.

Ključne riječi: sastav, zastupljenost, Cyprinidae, riblja zajednica, zavičajne vrste

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