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Zooplankton as bioindicators of trophic status of two wetlands in Kashmir Himalaya

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ABSTRACT

Zooplankton are considered as bioindicator of eutrophication in aquatic environments because of their prompt response to changing environmental conditions and short life cycle. Zooplankton communities from Wular and Hokersar wetlands of Kashmir (India) were sampled for two years (Sep. 2012- Aug. 2014) in order to ascertain the trophic status of these freshwater bodies of Kashmir using plankton as indicators. As plankton communities are very much sensitive to changes in the environment, therefore, show prompt response in the abundance, density and diversity. The present study discusses Jarnefelts Plankton Quotient (Q) and Brachionus: Trichocerca ratio for the evaluation of the nature of the wetlands both recognized as Ramsar Sites of International Importance. A total of 89 taxa belonging to 33 rotifers, 30 cladocerans, 23 copepods and 03 ostracods in both the wetlands were encountered. Wular lake maintains highest number of 39 eutrophic taxa while in Hokersar wetland only 34 eutrophic species were recorded. Interestingly among the rotifers family Brachionidae was represented by Brachionus calyciflorus, B. bidentata, B. quadridentata and Brachionus sp. in both the wetlands suggesting that there is tremendous anthropogenic pressures on the freshwater bodies of Kashmir. Different species of plankters have wide as well as narrow range of tolerance towards the fluctuating environmental conditions. It can be inferred from the study that the Kashmir wetlands especially Wular and Hokersar are under the tremendous pressures of anthropogenic activities as was reflected by high E/O and B/T values.

Keywords: Zooplankton, bioindicators, trophic status, wetlands, Kashmir

1. INTRODUCTION

A bioindicator can be defined as ‘‘a species or group of species that readily reflects the abiotic or biotic state of an environment, represents the impact of environmental change on a habitat, community, or ecosystem, or is indicative of the diversity of a subset of taxa, or of the wholesale diversity, within an area’’ [1]. High nutrient inputs, principally nitrogen (N) and phosphorous (P) are draining at an alarming pace in the water bodies causing eutrophication [2,3, 4]. Thus eutrophication may have a cascading effect on different trophic levels and, especially, in zooplankton communities [5]. Zooplankton community is a considered as an important trophic level in the energy flow in aquatic ecosystems and in the maintenance and orientation of the aquatic trophic webs. Due to their short life cycles, they are highly predisposed to changing environmental conditions and have high degree of connectivity with the lower trophic levels in the aquatic ecosystems. All these characteristics make them as key elements for the understanding of the changes occurring in aquatic ecosystems due to eutrophication, particularly in understanding the potential for propagation of these disturbances along the food chains. Different zooplankton behaves differently in responses to eutrophication as changesin reproductive rates [6], filtering capacities [7] and specializations in acquiring food [8-9]. Therefore, it is imperative to study the zooplankton as bioindicator particularly with reference to Kashmir wetlands.

2. Material and Methods

The zooplankton, encountered in the present study, were classified into the indicators of eutrophy and oligotrophy as per the works of Jarnefelt [10-11], Jumpanen [12], Pandit [13,14] and others. Certain species, typical of Indian waters and particularly that of the region, were further classified according to the publications of Kaul *et al*. [15], Kaul and Pandit [16], Pandit [13], Khan and Rao [17], Mahajan [18] etc.Wheel animalcules were used as bioindicator organisms by Kolkwitz and Marsson [19 c.f. 20]. The exhaustive list of rotifers as indicators was given by Sladecek [20]. Following the classification of Sladecek, [20] Xenosaprobic and Oligosaprobic rotifers were considered as oligotrophic animalcules while as alpha-meso-saprobic were considered as eutrophic species.
Cladocera and Copepoda are used as model organisms for studying the health of an aquatic ecosystem [13, 21]. As per literature survey micro-crustaceans were categorized into eutrophic, eurytrophic and oligotrophic species [3, 9, 13, 14, 21-27etc.].
For the evaluation of the trophic status of both the wetlands under study, following two methods were employed:

(i) Jarnefelts Plankton Quotient System

Jarnefelts Plankton Quotient (Q) says that if the value E/O is more than 8, the waterbody is said to be eutrophic and if the value is less than 8 it is said to be the oligotrophic or mesotrophic [10-11].

$$\text{Plankton Quotient (Q)} = \frac{\text{Eutrophic + Eurytrophic species (E)}}{\text{Oligotrophic species (O)}}$$

(ii) *Brachionus: Trichocerca* ratio ($Q_{B/T}$)

Brachionus: Trichocerca ratio called as Sladecek's Q B/T quotient was also used in the present study to find out the trophic state of the wetlands. It is represented as:

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$$Q_{B/T} = \frac{\text{Number of species of } \textit{Brachionus}}{\text{Number of species of } \textit{Trichocerca}}$$

If the value of this quotient is less than 1.0 it means oligotrophic condition, values between 1.0 and 2.0 reflect mesotrophic and values over 2.0 indicate eutrophic conditions [20].

3. Study area

The present study was carried out from September 2012 to August 2014 in two typical wetlands of Kashmir- the Wular and the Hokersar. Wular lake is the largest freshwater lake in the Indian sub-continent located in the flood plains of River Jhelum with the geographical coordinates 34°16´-34°20´N latitudes and 74°33´-74°44´E longitudes (Fig.1). The lake is of ox-bow type (with a maximum length of 16 km and breadth of 7.6 km) is of fluviatile origin, formed by the meandering of river Jhelum, which brings huge quantities of alluvial deposits.The average maximum depth of the lake was reported to be 5.8m [14]. However, recently Shah and Pandit [28] maintained the average maximum depth of the lake to be 4.27 m only.

Hokersar, the Queen of wetlands in Kashmir Himalaya, is a natural perennial wetland (34º05`N- 34º06`N latitude and 74º8-74º12`E longitude) positioned 12 km to the west of Srinagar on Srinagar – Baramullah Highway in the northern most part of Doodhganga catchment (Fig.1.2) The wetland, situated at an altitude of 1,584 m (amsl), was once spread over an area of 19.5 km^2, and has presently got reduced to about 13.26 km^2 at present [29]. The famous wetland, designated as Ramsar Site on 08 November, 2005, is under control of Government since 1945 (Wildlife Protection Department of Jammu and Kashmir Government). It harbours 0.4-0.5 million overwintering migratory waterfowl (ducks, geese and rails) whichmigrate from Palaearctic region, extending from northern Europe to central Asian, to Kashmir wetland flying over great Himalayan massif [3,29]. The wetland is fed by two inlet streams, Doodhganga (from east) and Sukhnag Nalla (from west). The wetland achieves a maximum depth of 2.5 m in spring [30]while a minimum water depth of 0.7 m was recorded in autumn [31].

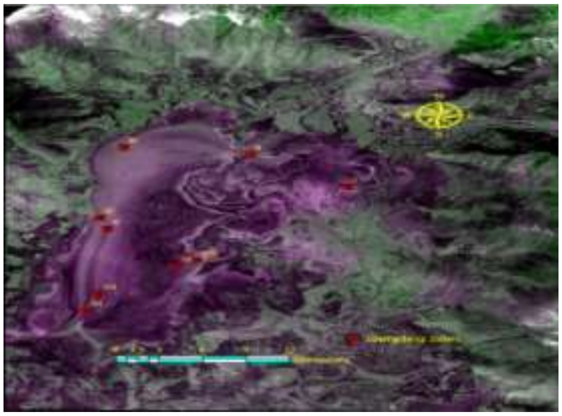

Fig.1 Map of Wular lake

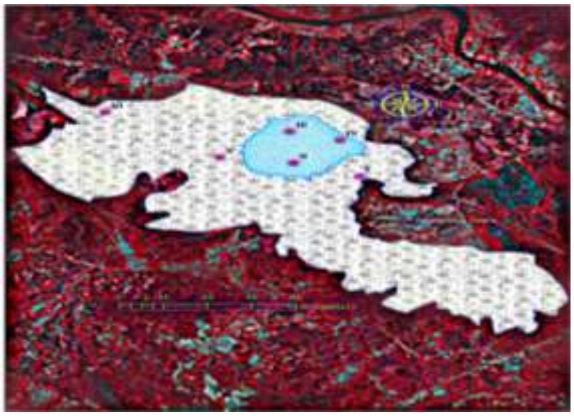

Fig.1.2 Map of Hokersar wetland

4. Results

Table 1.Classification of zooplankton on the basis of trophic status

and* are the species which are inhabitant of Wular and Hokersar wetlands respectively and the remaining species were common in both the biotopes.

Eutrophic taxa	Eurytrophic taxa	Oligotrophic taxa
	Rotifera (33)	
1. *Brachionus calyciflorus*	1. *Mytilina* sp. #	1. *Trichocerca* sp. and
2. *Brachionus bidentata*	2. *Paracolurella* sp. #	2. *Scardium longicaudum#*
3. *B. quadridentata*	3. *Monostyla* sp.	
4. *Brachionus* sp.	4. *M. depressa#*	
5. *Polyarthra vulgaris#*	5. *M. bulla#*	
6. *Platyias quadricornis*	6. *Keratella* sp. *	
7. *P. patulus*	7. *Keratella hiemalis*	
8. *Hexarthra mira*	8. *K. valga*	
9. *Keratella cochlearis*	9. *Cephalodella* sp.	
10. *Filinia* sp.	10. *C. megalocephala**	
11. *F. terminalis#*	11. *Colurella obtusa#* and	
12. *Euchlanis dilatata**	12. *Eothinia elongata**	
13. *Lecane flexilis**		
14. *Lecane* sp.		
15. *L. luna**		
16. *Lepadella patella#*		
17. *Asplanchna priodonta#*		
18. *Squatinella* sp. and		
19. *Anuraeopsis* sp.		
	Cladocera (30)	

1. *Alona affinis* 2. *A. guttata#* 3. *Bosmina longirostris* 4. *Chydorus ovalis* 5. *C. sphaericus* 6. *Ceriodaphnia dubia** 7. *C. reticulata** 8. *Daphnia ambigua#* 9. *D. laevis#* 10. *D. pulex* 11. *D. catawaba** 12. *Moina* sp. 13. *Macrothrix rosea#* 14. *Graptoleberis testudinaria#*and 15. *Leptodora kindtii#*	1. *Alona costata#* 2. *A. monacantha* 3. *A. quadrangularis* 4. *A. rectangula* 5. *A. dentifera#* 6. *Alonella exigua#* 7. *A. excisa#* 8. *A. globulosa#* 9. *Daphnia magna#* 10. *D. galeata#* 11. *Diaphanosoma brachyurum#* 12. *Simocephalus vetulus** and 13. *Polyphemus pediculus **	1. *Sida crystalline* and 2. *Simocephalus* sp.
	Copepoda (23)	
1. *Cyclops vernalis* 2. *C. bicuspidatus#* 3. *C. bisetosus#* 4. *C. vicinus* 5. *C. viridis* 6. *C. scutifer* 7. *C. strenuus* 8. *Eucyclops agilis#* 9. *E. macrurus** 10. *Eucyclops* sp.* 11. *Mesocyclops* sp.# and 12. *Mesocyclopsleuckarti#*	1. *C. bicolor* 2. *C. insignis#* 3. *C. nanus** 4. *C. latipes#* 5. *Macrocyclops fuscus#* 6. *Paracyclops affinis#* and 7. *Paracyclops* sp.	1. *Bryocamptus hiemalis* 2. *B. minutus* 3. *Canthocamptus* sp. and 4. *Diaptomus* sp.#
	Ostracoda (03)	
1. *Cypris* sp.	1. *Cyclocypris* sp. and 2. *Ilyocypris* sp#.	

In the present study the zooplankton community was represented by 89 taxa belonging to 33 rotifers, 30 cladocerans, 23 copepods and 03 ostracods in both the wetlands (Table 1). Among 89 taxa only 8 zooplankters viz., *Trichocerca* sp., *Scardium longicaudum, Sida crystallina, Simocephalus* sp., *Bryocamptus hiemalis, B. minutus, Canthocamptus* sp. and *Diaptomus* sp. indicate oligotrophy while the remaining taxa prefer eutrophic to eurytrophic conditions. The strongly eutrophic zooplankton namely *Brachionus calyciflorus, Bosmina longirostris, Chydorus sphaericus, Daphnia pulex, Cyclops vernalis* and *C. vicinus* can toleratesevere pollution and hence their abundance at the sites in both the wetlands which experience more anthropogenic pressures from the surrounding environment.

The wetlands also vary with regard to the sustenance of trophic indicators and as such Wular lake sustains highest number of 39 eutrophic taxa (16 Rotifera,12 Cladocera, 10 Copepoda and 01 Ostracoda), followed by 27 eurytrophic (08 Rotifera, 11 Cladocera, 06 Copepoda and 02 Ostracoda) and 08 oligotrophic taxa (02 Rotifera, 02 Cladocera and 04 Copepoda) while Hokersar wetland sustains 34 eutrophic (16 Rotifera,10 Cladocera, 07 Copepoda and 01 Ostracoda), 13 eurytrophic (05 Rotifera, 04 Cladocera,03 Copepoda and 01 Ostracoda) and 06 oligotrophic taxa (01 Rotifera, 02 Cladocera and 03 Copepoda) (Table 2). The fluctuations in the number of such species, however, are in general somewhat corroborating with the general eutrophic nature of the wetlands. A perusal of the data revealed that E/O quotient to the zooplankton community to Wular lake, value comes out to be 8.25. However, for Hokersar wetland the E/O quotient comes out to be 7.8.

Table 2. Distribution of zooplankton in two wetlands on the basis of trophic status

Zooplankton Groups	Eutrophic taxa	Eurytrophic taxa	Oligotrophic taxa	Q=E/O
Wular lake				
Rotifera	16	08	02	
Cladocera	12	11	02	
Copepoda	10	06	04	
Ostracoda	01	02	X	
Total	**39**	**27**	**08**	**Q=66/8=8.25**
Hokersar wetland				
Rotifera	16	05	01	
Cladocera	10	04	02	
Copepoda	07	03	03	

Ostracoda	01	01	X	
Total	**34**	**13**	**06**	**Q=47/6=7.8**

5. Discussion

Scrutinizing environmental changes caused by pollution has now become an important tool in the ecosystem investigation. The influx of increasing load of pollutants and toxicants into the aquatic ecosystems has been causing serious perturbations to the ability of flora and fauna in processing and cycling these materials. The changes caused by the allochthonous and autochthonous organic materials are reflected by the community architecture. Nature has provided different adaptability mechanisms for organisms in response to changing environmental conditions [28]. Aquatic communities especially planktonic ones are considered as biological indicators of an environment, as they are living under the direct influence of changing physical and chemical environment[32-34].

Zooplankton are considered as bioindicator of eutrophication in aquatic environments because of their prompt response to changing environmental conditions and short life cycle [20,36].Majority of the zooplankton show divergent response towards eutrophication in freshwater ecosystems [20,33-36]. As a result of eutrophication there is change in reproductive rates or even cycles [6,34], filtering rates [7] or some change their nutritive behavior in terms of food acquisition [8]. Eutrophication is the major cause for the replacement of large sized zooplankton with small bodied ones [3,9]. As a consequence of racing eutrophication, some of the observed species of zooplankton showed wide ecological amplitude, while some showed rapid variations to fluctuating environmental conditions thereby follow a definite succession in terms of mosaic and spatial distribution in both the wetlands under investigation.

Zooplankton community was represented by 89 taxa belonging to 33 rotifers, 30 cladocerans, 23 copepods and 03 ostracods in both the wetlands. Among 89 taxa only 8 zooplankters viz., *Trichocerca* sp., *Scardium longicaudum*, *Sida crystallina*, *Simocephalus* sp., *Bryocamptus hiemalis*, *B. minutus*, *Canthocamptus* sp. and *Diaptomus* sp. indicate oligotrophy while the remaining taxa prefer eutrophic to eurytrophic conditions. The strongly eutrophic zooplankton namely *Brachionus calyciflorus*, *Bosmina longirostris*, *Chydorus sphaericus*, *Daphnia pulex*, *Cyclops vernalis* and *C. vicinus* can toleratesevere pollution and hence their abundance at the sites in both the wetlands which have more anthropogenic pressures from the surrounding environment.

The wetlands also vary with regard to the sustenance of trophic indicators and as such Wular lake sustains highest number of 39 eutrophic taxa (16 Rotifera,12 Cladocera, 10 Copepoda and 01 Ostracoda), 27 eurytrophic (08 Rotifera, 11 Cladocera, 06 Copepoda and 02 Ostracoda) and 08 oligotrophic taxa (02 Rotifera, 02 Cladocera and 04 Copepoda) while Hokersar wetland sustains 34 eutrophic (16 Rotifera, 10 Cladocera, 07 Copepoda and 01 Ostracoda), 13 eurytrophic (05 Rotifera, 04 Cladocera, 03 Copepoda and 01 Ostracoda) and 06 oligotrophic taxa (01

Rotifera, 02 Cladocera and 03 Copepoda). The fluctuations in the number of such species, however, are in general somewhat corroborating with the general eutrophic nature of the wetlands.

On applying the E/O quotient to the zooplankton community to Wular lake, value comes out to be 8.25, reflecting that the lake is facing accelerated eutrophication and is still in its infancy stages [10c.f.14]. For Hokersar wetland the E/O quotient comes out to be 7.8, indicating that the wetland is heading towards eutrophication [10c.f. 14.].

Brachionus: Trichocerca Ratio ($Q_{B/T}$)

Brachionus: *Trichocerca* ratio was introduced by Sladecek in 1983. It is also called asSladecek's $Q_{B/T}$ quotient. As per Sladecek [20], the genus *Brachionus* are generally found in eutrophic waters (except two species i.e. *B. sericus* a typical acidophilic and *B. plicatilis* inhabitant of brackish waters) and the genus *Trichocerca* is purely oligotrophic in behavior. This ratio can be used for individual waterbody or even for the individual sample. Sladecek [20] also opined that this ratio is analog of the 5 phytoplankton quotients proposed by Thunmark [37] and Nygaard [38].

$$Q_{B/T}=\frac{\text{Number of species of } \mathit{Brachionus}}{\text{Number of species of } \mathit{Trichocerca}}$$

If the value of this quotient is less than 1.0 it means oligotrophic condition, values between 1.0 and 2.0 reflect mesotrophic and values over 2.0 indicate eutrophic conditions. During the present study, 04 taxa of *Brachionus* and only 1 taxa of *Trichocerca* were recorded in both the biotopes therefore; the ratio of the same quotient is 4:1 that reflects the eutrophic nature of both the wetlands as per Sladecek [20,39].

6. Conclusion

The present study clearly represent that the potential use of zooplankton to ascertain the nature of the wetlands by using them as indicators. As different species of plankters have wide as well as narrow range of tolerance towards the fluctuating environmental conditions. Further, it can be inferred from the study that the Kashmir wetlands are under the tremendous pressures of anthropogenic activities as was reflected by high E/O and B/T values.

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8. Competing interests

The authors declare that they have no competing interests.

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