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Full Length Research Paper

Distribution, diversity and abundance of copepod zooplankton of Wular Lake, Kashmir Himalaya

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Wular Lake, the largest freshwater lake of India, plays a significant role in the hydrography of the Kashmir valley by acting as a huge absorption basin for floodwaters. Although rich in biodiversity, no published report is available on Copepoda diversity, distribution and abundance in such an important Ramsar Site of Kashmir Himalaya. Copepod samples, collected over a period of 12 months from September 2010 to August 2011 at five sampling sites revealed the occurrence of about 16 species belonging to 3 families namely cyclopoids with 12 species, calanoids and harpacticoids being represented by two species each. The dominant species seen were *Cyclops bicolor, Eucyclops agilis, Bryocamptus nivalis* and *Diaptomus virginiensis.* Various diversity indices like Shannon-Weaver, Margalef and Fisher_alpha were used to assess the Copepoda diversity in the lake. Further, discernible differences were observed among the studied sites showing 15 species at site III, 13 each at sites IV and II, 9 at site V and 8 at site I.

Key words: Copepods, cyclopoids, composition, diversity, Ramsar Site.

INTRODUCTION

Copepods are claimed to be numerically the most abundant metazoans on earth and conservative estimations revealed that they likely outnumber the abundance of insects (Schminke, 2007; Chang et al., 2010, Hwang et al., 2004, 2010; Kâ and Hwang, 2011), representing one of the biggest sources of animal protein in the world and play a central role in the transfer of carbon from producers to higher trophic levels in most aquatic ecosystems (Jerling and Wooldridge, 1995). Copepoda species which are one of the most important elements of the food chain in the aquatic environments form the inevitable food for fishes and show wide dispersion in all kinds of aquatic ecosystems. Further, copepods are also known to consume large quantities of bacteria (Wroblewski, 1980) and phytoplankton (Calbet et al., 2000) and are the main prey items of larval and juvenile fishes that link pelagic food webs (Tseng et al., 2008; 2009; Vandromme et al., 2010; Wu et al., 2010).

Their abundance and distribution are known to be influenced by hydrographic conditions and they have been suggested as indicator species for waters of different qualities and origins (Bonnet and Frid, 2004; Hwang and Wong, 2005; Thor et al., 2005; Hwang et al., 2006, 2009, 2010).

MATERIALS AND METHODS

Study area

Wular lake, an ox-bow type lake located in the north-west of Kashmir about 55 km from Srinagar city, is situated at an altitude of 1,580 m (a.m.s.l), and lies between 34°16´-34°20´N and 74°33´-74°44´E geographical co-ordinates, being formed by the meandering of River Jhelum which is the main feeding channel besides other tributaries. The lake is drained in the north-east by the only single outlet in the form of River Jhelum. The catchment of the lake is comprised of slopping hills of the Zanaskar ranges of the western Himalaya on the north eastern side and arable land around being used for agricultural purposes (Figure 1). The lake has been declared as the wetland of national importance (1986) under wetland programme of Ministry of Environment and Forests (MoEF), Gov-

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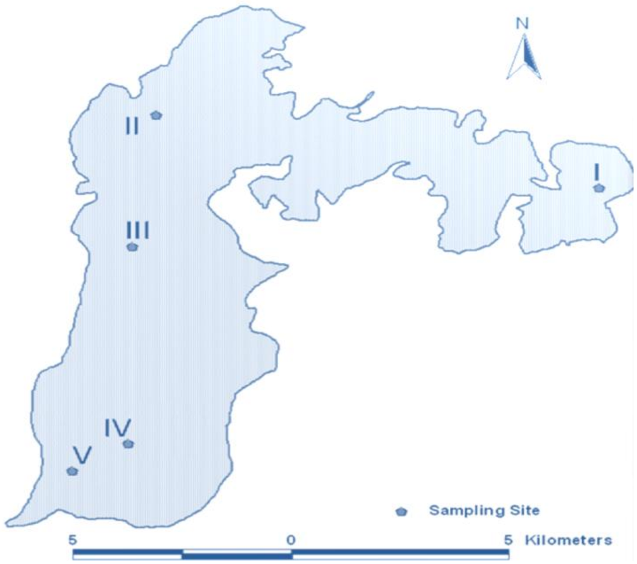

Figure 1. Map of Wular Lake with five sampling sites.

Table 1. Location of five study sites in Wular Lake.

Site	Latitude (N)	Longitude (E)	Distinguishing feature
I	34°21´ 51	74°39´42	Anthropogenic pressures
II	34°24´ 15	74°32 ´35	Good macrophytic growth
III	34°21´ 29	74°31´ 48	Profuse growth of macrophytes
IV	34°17´43	74°31´30	Centre of lake basin
V	34°17´ 16	74°30 ´25	Near outlet of the lake

Government of India and is designated as Ramsar Site (a Wetland of International Importance under Ramsar Convention, 1990).

Study sites

Five sampling sites were chosen to collect the copepods in Wular Lake (Table 1 and Figure 1).

Plankton samples were randomly collected between September 2010 to August 2011 from five sampling sites once in every month. At each site, samples were collected by filtering 100 L surface water through a Nylobolt plankton net (mesh size 52 µm). The plankton samples were fixed in 5% formalin added with 2 to 3 ml of glycerol which acts as a good preservative (Dussart and Defay, 1995). The qualitative and quantitative analyses were carried out in the laboratory with the help of binocular microscope and counting was done by a Sedgewick-Rafter counting cell. Identification of the specimens was carried with the help of standard woks of Pennak (1978), Edmondson (1992) and Battish (1992). Various diversity indices (Shannon-Weaver, Margalef and Fisher_alpha) were calculated by software PAST.

RESULTS AND DISCUSSION

A total of 16 species of copepods belonging to three families (Cyclopoida with 12 species, Calanoida and Harpacticoida with two species each) were identified (Table 2). Cyclopoids predominated over calanoids in the present study. This is quite expected as the wetland un-der study is weed infested. Rundle and Ormerod (1992) also found the abundance and richness of cyclopoids in wetlands with high weed infestation. Boxshall and Jaume (2000) opined that Cyclopoids are one of the most con-spicuous and diverse group of freshwater copepods and tend to have wide distributional patterns with many spe-cies being cosmopolitan in nature (Reid, 1998). Many studies suggest that species of the family Cyclopoida tend to increase stronger with eutrophication than spe-cies of Calanoida (Gliwicz, 1969; Patalas, 1972; Straile and Geller, 1998; Anneville et al. (2007). However, this pattern might not be consistent among lakes since Jeppesen et al. (2005) reported reduced numbers of cyclopoids under eutrophic conditions in eight Danish lakes.

The most abundant taxa in order of dominance were *Cyclops bicolor, Bryocamptus nivalis, Eucyclops agilis* and *Cyclops latipes* and other species observed were *Acanthocyclops bicuspidatus, C. bicolor, Cyclops bisetosus, Cyclops bicuspidatus, Cyclops panamensis, Cyclops scutifer, Cyclops vicinus, C. latipes, E. agilis, Bryocamptus minutus, B. nivalis, Diaptomus* sp. and *Diaptomus virginiensis*. Among the recorded copepods some species dominated in certain seasons while some disappeared in the other seasons (*Megacyclops viridis* and *Diaptomus* sp. were completely absent in winter and the latter was also absent in spring). Likewise *Cyclops scutifer* and *C. vicinus* were absent in summer and the latter was again absent in spring season) indicating the different growing patterns of the species, as a result, bimodal growth peaks were observed (Table 3). At sites I and II, dominant peaks of copepods were observed in autumn, while as sub-dominant, peaks were evinced in spring. In contrast to the above, sites III, IV and V exhibited the dominant peaks in spring; while the sub-dominant peaks were registered during autumn (for site III) and summer for the remaining sites (Figure 2). This changing behavioral patterns of the copepods (e.g. *Cyclops scutifer*- a typical cold water species, *C. vicinus* maintaining higher population in autumn and spring while *Megacyclops viridis* being more abundant in spring) can be attributed to the habitat preferences, environmental conditions or the dormancy period (Alekseev et al., 2007). The same diverse reasons have also been attributed to varying growth seasons of the copepods during the study period. Many species among the copepods are known to bridge seasonally unfavorable conditions with a dormancy or diapause period (Einsle, 1993). Diapause performance, however, also varies among populations of the same species (Santer, 1998).

This variability in diapause strategies has been observed in a variety of species and is suggested to be induced by environmental conditions, e.g., predation (Hairston, 1987) or food availability (Santer and Lampert, 1995). Copepod life cycle strategies differed in the

Table 2. Distribution of Copepoda at five study sites during September 2010 to August 2011.

Cyclopoida	**Site I**	**Site II**	**Site III**	**Site IV**	**Site V**
Acanthocyclops bicuspidatus	-	+	+ +	+	+ +
Cyclops bicolor	+ + +	+ +	+ + +	+	+
C. bisetosus	-	+	+	+	-
C. bicuspidatus	-	-	+ + +	-	-
C. scutifer	+	+	+	+	+
C. vicinus	+	+	+	+	+
C. latipes	-	+ + +	+ +	+ + +	-
C. panamensis	-	-	-	+	-
Eucyclops agilis	-	+ + +	+ + +	+	+ ++
Macrocyclops fuscus	+ +	-	+	-	-
Megacyclops viridis	+	+	+	-	-
Paracyclops affinis	-	+	+	+++	-
Calanoida					
Bryocamptus minutus	-	+ +	+ +	+ + +	++
Bryocamptus nivalis	+ +	+++	+	+ + +	++
Harpacticoida					
Diaptomus sp.	+	+	+	+ +	+
Diaptomus virginiensis	+ +	+ +	+	+	+
Grand total = 16	08	13	15	13	09

+++ = Most abundant; ++ = fairly present; + = present; - = absent.

Table 3. Seasonal variations in the population density* of copepods (ind./L.) at different sites from September 2010 to August 2011.

Site		**Autumn**	**Winter**	**Spring**	**Summer**
I					
01	*Bryocamptus nivalis*	44.0	21.3	45.7	37.0
02	*Cyclops bicolor*	63.0	68.3	23.7	51.7
03	*C. scutifer*	43.7	55.0	17.7	N.D
04	*C. vicinus*	66.3	16.3	N.D	N.D
05	*Diaptomus* sp.	46.7	N.D	N.D	46.7
06	*Diaptomus virginiensis*	34.0	25.3	64.7	41.3
07	*Macrocyclops fuscus*	30.0	20.3	60.7	37.0
08	*Megacyclops viridis*	17.3	N.D	47.7	32.5
II					
01	*Acanthocyclops bicuspidatus*	31.3	32.7	33.3	32.4
02	*Bryocamptus minutus*	55.3	32.7	43.3	43.8
03	*Bryocamptus nivalis*	43.0	34.3	67.3	48.2
04	*Cyclops bicolor*	47.7	62.0	25.3	45.0
05	*C. bisetosus*	50.0	12.3	37.0	33.1
06	*C. scutifer*	40.3	91.7	34.7	N.D
07	*C. vicinus*	70.3	33.3	N.D	N.D
08	*C. latipes*	60.3	33.7	53.3	49.1
09	*Diaptomus* sp.	32.7	N.D	N.D	32.7
10	*Diaptomus virginiensis*	38.3	27.7	68.7	44.9
11	*Eucyclops agilis*	51.3	43.7	70.0	55.0
12	*Megacyclops viridis*	21.7	0.0	60.0	27.2
13	*Paracyclops affinis*	26.0	24.0	46.7	32.2

Table 3. Contd.

III					
01	*Acanthocyclops bicuspidatus*	52.3	33.0	43.7	43.0
02	*Bryocamptus minutus*	49.0	26.0	43.0	39.3
03	*Bryocamptus nivalis*	49.3	40.3	83.7	57.8
04	*Cyclops bicolor*	24.0	68.7	19.7	37.4
05	*C. bisetosus*	37.3	17.0	48.7	34.3
06	*C. bicuspidatus*	56.0	27.7	62.3	48.7
07	*C. scutifer*	35.3	79.7	30.7	N.D
08	*C. vicinus*	59.0	29.0	N.D	N.D
09	*C. latipes*	67.7	21.0	37.3	42.0
10	*Diaptomus* sp.	35.0	N.D	N.D	35.0
11	*Diaptomus virginiensis*	30.3	20.7	57.0	36.0
12	*Eucyclops agilis*	53.3	30.7	55.3	46.4
13	*Macrocyclops fuscus*	20.0	10.3	55.0	28.4
14	*Megacyclops viridis*	14.3	N.D	37.0	17.1
15	*Paracyclops affinis*	22.3	29.3	55.7	35.8
IV					
01	*Acanthocyclops bicuspidatus*	44.0	32.3	44.0	40.1
02	*Bryocamptus minutus*	41.0	36.0	55.3	44.1
03	*Bryocamptus nivalis*	31.0	34.3	68.7	44.7
04	*Cyclops bicolor*	21.7	60.3	14.0	32.0
05	*C. bisetosus*	26.0	13.7	55.7	31.8
06	*C. panamensis*	29.0	46.0	45.0	40.0
07	*C. scutifer*	32.0	64.7	23.0	N.D
08	*C. vicinus*	44.0	31.7	N.D	N.D
09	*C. latipes*	51.0	19.7	53.7	41.4
10	*Diaptomus* sp.	30.7	N.D	N.D	30.7
11	*Diaptomus virginiensis*	34.0	18.7	61.3	38.0
12	*Eucyclops agilis*	18.0	22.3	63.3	34.6
13	*Paracyclops affinis*	31.3	29.3	85.0	48.6
V					
01	*Acanthocyclops bicuspidatus*	39.0	37.3	43.7	40.0
02	*Bryocamptus minutus*	29.0	39.0	55.3	41.1
03	*Bryocamptus nivalis*	25.7	29.3	70.7	41.9
04	*Cyclops bicolor*	23.0	72.7	32.3	42.7
05	*C. scutifer*	30.7	73.3	26.0	N.D
06	*C. vicinus*	30.0	43.3	N.D	N.D
07	*Diaptomus* sp.	45.7	N.D	N.D	45.7
08	*Diaptomus virginiensis*	17.0	24.3	75.0	38.8
09	*Eucyclops agilis*	85.3	13.0	61.0	53.1

N.D = Not detected; ***average results based on three analyses.

presence and timing of a seasonal diapause, that is, diapause in winter, autumn, or none at all, resulting in a distinct seasonality of community structure. Further, zooplankton use a variety of environmental parameters such as temperature (Marcus, 1982), photoperiod (Hairston and Kearns, 1995; Alekseev et al., 2007) and food quality to optimize the timing of diapause initiation and/or termination. Furthermore, maternal effects might also be important for the production of diapausing stages (LaMontagne and McCauley, 2001). However, high predation pressure during winter can be ultimate cause of lower population density at all biotopes.

Diversity indices are important tools for ecologists to understand community structure in terms of richness, evenness or total number of existing individuals underlying the basis of diversity indices (Wilhm and Dorris,

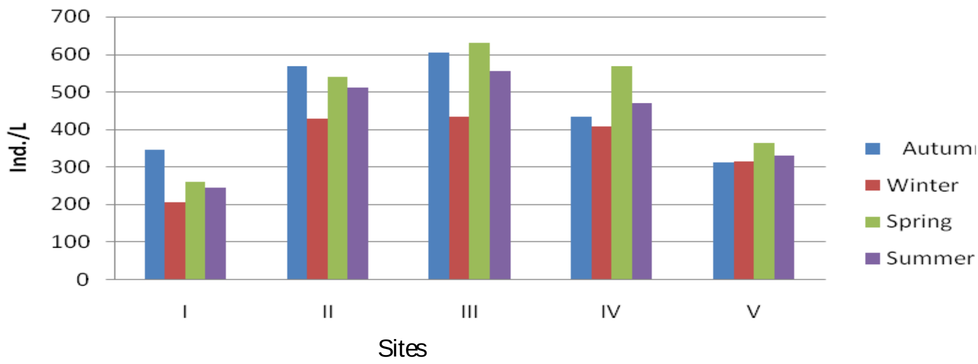

Figure 2. Seasonal variations in the population density of copepods at the different study sites.

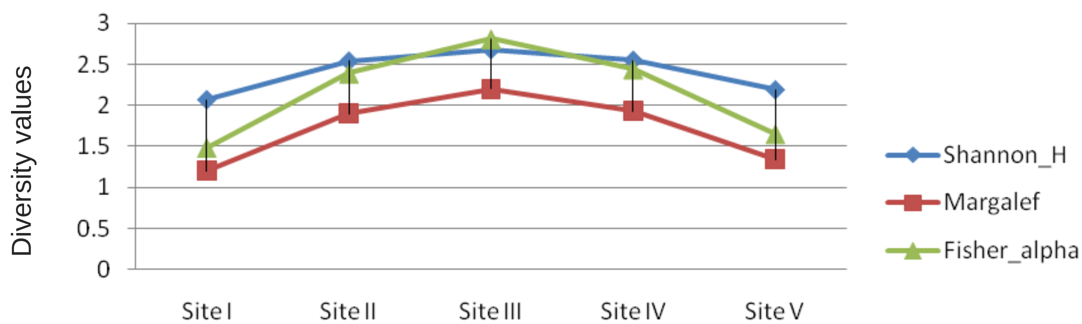

Figure 3. Diversity indices of copepods in Wular Lake during September 2010 to August 2011.

1968; Allan, 1975). Thus, any change in any of these three features will affect the whole population. So, the diversity indices depending upon these features are used effectively to determine the changes in a population (Mandaville, 2002; Dügel, 1995). During the study period, the Shannon index varies from 2.07 at site I to 2.67 at site III, Margalef diversity index ranged from the lowest, 1.20 at site I to the highest 2.20 at site III. Fisher_alpha index varied from 1.48 to 2.81 (Figure 3) reflecting the stress condition of site I which has higher anthropogenic activity. In contrast to the above, site III showed high diversity and number of different species characterized by undisturbed habitats.

During the study period, discernible differences among the species were observed at different studied sites, registering 15 species at site III, 13 species each at sites IV and II, 9 species at site V and 8 species at site I, respectively. Thus, copepods were found to be dominant at sites which were densely infested by macrophytes (site III). Accordingly, sites I and V, being least infested with macrophytes, maintained the lowest population of copepods. Similar conclusion was drawn by many workers in other studies (Blindow et al., 1993; Kuczyńska-Kippen, 2007). Gliwicz and Rybak (1976) further suggested that the more biologically and spatially complicated the habitat is, the more the available niches. It was also seen that most of the copepod species had a more or less positive associations among themselves. A positive association between two species is indicative of the similar requirement in environmental gradients, while a negative association is indicative of different environmental requirements or active competition between the species involved. Thus, it may be inferred that most of the copepod species in the present study perhaps have overlapping ecological niche to some extent. Moreover, food particle size and food quality appears to play a definite role in their niche separation (Maly and Maly, 1974). Lakes rich in organic matter support higher number of cyclopoids, thus suggesting their preponderance in higher trophic state of waterbody (Subbamma, 1992), a fact also revealed by Pejaver and Somani (2004) in Lake Masunda.

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