academicJournals

Vol. 10(5), pp. 141-149, May, 2016
DOI: 10.5897/AJEST2016.2096
Article Number: EB46F6B58529
ISSN 1996-0786

http://www.academicjournals.org/AJEST

African Journal of Environmental Science and Technology

Full Length Research Paper

Dredging induced changes in zooplankton community and water quality in Dal Lake, Kashmir, India

Musharaf Rehman[1], A. R. Yousuf[2], M. H. Balkhi[3], M. I. Rather[4]*, N. Shahi[1], M. Meraj[1] and K. Hassan[1]

[1]Centre of Research and Development, University of Kashmir, Srinagar-190006, India.
[2]National Green Tribunal, Copernicus Marg, New Delhi-110001, India.
[3]Faculty of Fisheries, SKAUST (K), Srinagar-190064, India.
[4]Department of Environmental Sciences, University of Kashmir, Srinagar-190006, India.

Received 3 March, 2016; Accepted 2 April, 2016

A study was conducted from July 2013 to June 2014 to assess the outcome of dredging activity on the water characteristics and zooplankton community structure in Dal Lake. An assessment was done with respect to alterations in physico-chemical parameters and zooplankton community changes in pre-dredged and post-dredging periods. The results showed a considerable reduction in Secchi transparency while water depth, conductivity, total dissolved solids, nitrate and total phosphorous concentrations increased noticeably in post dredging scenario. Variations in the values of dissolved oxygen, pH and temperature as a result of dredging were not statistically significant. The environmental changes as a result of dredging activity affected the structure and distribution of zooplankton community; the abundance of rotifers decreased, while the crustaceans increased. The prominent taxa were *Brachionus* sp., *Keratella cochlearis, Bosmina longirostris, Chydorus sphaericus* and *Diaptomus* sp.

Key words: Dredging, water quality, zooplankton, rotifer, crustacean.

INTRODUCTION

Eutrophication of lakes which leads to deterioration of aquatic ecosystems has been of a great concern around the globe (Ruban et al., 2001; Bennion et al., 2015). The major factors that pose environmental threats to water bodies include increasing anthropogenic pressure that may result in excessive input of nutrients and organic matter. Excessive loading of nutrients leads to increased algal growth, high nitrogen and phosphorus loads, toxicity, changes in community structure, loss of recreational amenity and reduction in water clarity in most lakes (Smith, 1998; Carpenter et al., 1999; Yin and Kong, 2015).

*Corresponding author. E-mail: irsheemohamad@gmail.com.

Dal Lake, a Himalayan urban lake which is one of the beautiful lakes known for its pristine beauty, has been a great concern for ecologists due to fast decline in its size and water quality. The main natural process responsible for the decrease of lake area is siltation, a process wherein the catchment inflows dump huge silt into the water body (Rashid and Naseem, 2007).

To combat this process of deterioration, restoration programmes have been initiated for reduction of excessive sedimentation and loading of nutrients in Dal Lake. A number of plans prepared by some national and international agencies were prepared to combat the process of deterioration of this water body, prominent ones being ENEX (1978), Riddle (1985), NLCP (1997), AHEC Roorkee (2000) and CSIR-NEERI (2013).

Sediment remediation is often required for improvements in the quality of water and other components of the aquatic ecosystem (Murphy et al., 1999; Hadnagy et al., 2015). Dredging is one of the lake restoration techniques that removes surface bottom layers rich in pollutants and control their release or nutrient bioavailability (Sondergaard et al., 2007). In many studies, dredging activity has been known to induce changes in the different components of the lake ecosystem. Many studies have been conducted to study sediment dredging and its environmental effects (Voie et al., 2002; Weston et al., 2002). There is substantial increase in nitrate, ammonical nitrogen, total phosphorus, conductivity and total alkalinity after dredging (Kundangar and Abubakar, 2001). Dredging is currently the most commonly selected option for remedying contaminated sediments (Gustavson et al., 2008). However, there is an on-going debate between the proponents of negative effects which include release of toxic chemicals, increased turbidity, mortality of benthic organisms, altered food webs and issues with disposal of the dredged material (Zhong and Fan, 2007); and on the other hand, the positive benefits like treatment of eutrophic lakes for improvement of water quality and permanent removal of contaminants from an aquatic system are also being supported (Je et al., 2007; Mackie et al., 2007; Zhang et al., 2010). In aquatic ecosystems, changes in species composition of small and rapidly reproducing organisms have been considered among the earliest and most sensitive ecosystem responses to anthropogenic stress (Schindler, 1987). Zooplankton can also be used to indicate disturbance or recovery of aquatic ecosystem (Havens, 2002). Only handful of information is available regarding the effects of dredging on zooplankton community (Li et al., 2007; Wu et al., 2008).

In this study various physicochemical and biological characteristics of Dal Lake were surveyed over a period of one year (July 2013 to June 2014). The effects of dredging on water quality and zooplankton community structure has been explained in this paper. Pre-dredging and post-dredging statistical analysis was also used to elucidate the association between zooplankton taxa composition and their environment.

MATERIALS AND METHODS

Study area description

The Dal lake is situated in the north-east of Srinagar city at an altitude of 1600 m above mAMSL and lies between 34° 4' and 34° 9' N latitude and 74° 48' and 74° 53' E longitude. The lake covers an area of 18 km^2 and is a part of natural wetland which covers a total of 25 km^2, composed of open water area, floating gardens (known as Radh in Kashmiri language), built up land masses with human settlements, house boats, etc. The lake has a shore length of 15.5 km^2 and roads run along the periphery. Two sites were chosen to study the variation in physico-chemical parameters of water and zooplankton population as a result of dredging (Figure 1). The sites were Lashkari Mohalla (dredging site) and Hazratbal open (reference site).

Water and biological analysis

Water samples were collected on monthly basis with the help of Ruttner water sampler for one complete year from July-2013 to Jun-2014 at dredging (Lashkari Mohalla) and reference site (Hazratbal open). Water was analysed for physico-chemical characteristics as per the standard methods (APHA, 2005). Various analytic methods used are summarized in the Table 1.

Plankton samples were procured by sieving 10 L of lake water through plankton net (140 T nylobolt) with a 63 µ mesh size. The plankton samples were immediately preserved in 4% formalin and sub-samples were examined under stereoscopic and compound microscopes for identification.

Enumeration of zooplankton was done by using 1 ml capacity Sedgwick-rafter (SR) cell with dimensions of 50 x 20 x 1 mm (APHA 2005). Zooplankton samples were counted with a dissecting microscope at 40× magnification. Individuals were represented in per cubic meter. They were identified to the genus/species level with the help of standard taxonomic works like Edmondson (1959), Smirnov (1974), Pennak (1978), Michael and Sharma (1998) and Sharma (1999). Shannon-Weiner index was calculated as per Equation 1:

$$H' = -\sum_{i=1}^{R} pi \ln pi \quad (1)$$

In the equation, R is richness and pi is often the proportion of individuals belonging to the ith species.

Data analysis

The range, mean and standard deviation were calculated for descriptive statistical analysis using Microsoft excel 2010. To evaluate the differences in physicochemical parameters in pre and post-dredging stages, independent t tests were used. ANNOVA was applied to density of zooplankton species between various sites.

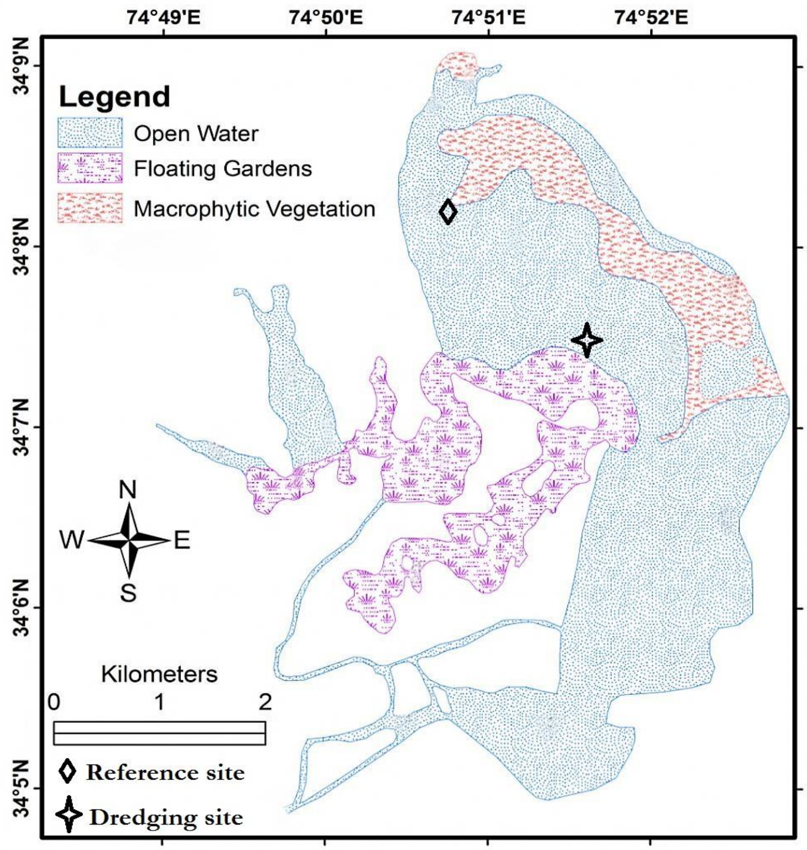

Figure 1. Location of the study sites of Dal Lake.

Table 1. Analytical methods for estimation of physico-chemical parameters of water.

S/N	Parameters	Units	Analytical methods
1	Temperature	°C	Instrumental method
2	pH	pH units	Potentiometric method
3	Transparency	m	Sechi disc method
4	Dissolved oxygen	mg/l	Winkler Azide -Modification method
5	Electrical conductivity	$\mu s\ cm^{-1}$	Conductivity cell potentiometric method
6	Free CO_2	mg/l	Titrimetric method
7	Total alkalinity	mg/l	Titrimetric (methyl orange) method
8	Total phosphorus	µg/l	Perchloric acid method
9	Ammonia nitrogen	µg/l	Phenate spectrophotometric method
10	Nitrate nitrogen	µg/l	Salicylate method
11	Total suspended solids	mg/l	Filtration and gravimetric

RESULTS AND DISCUSSION

Water quality changes

Pre and post dredging characteristics of water are summarised in Table 2. Significant differences ($P<0.05$) were detected with respect to chemical indices (nitrate-nitrogen and total phosphorus) and physical indices (electrical conductivity, transparency and depth). The concentration of nitrate-nitrogen, total phosphorus, electrical conductivity and depth increased significantly after dredging. Secchi transparency declined significantly

Table 2. Physico-chemical characteristics of water quality in Dal Lake.

Parameters	Pre dredging (n=6)	Post dredging (n=6)	Reference site (n=12)
	July 2013-December 2013	Jan 2014-June 2014	July 2013-June 2014
Water Temperature (°C)	17.18±6	15.48±8.94	15.8±7.30
Transparency (m)	1.43±0.15	0.633±0.28	1.45±0.46
Depth (m)	2.4±0.38	3.50±1.21	3.2±0.3
pH	8.32±0.44	8.15±0.39	8.36±0.35
Conductivity (µS/cm)	324.6±112.5	452.2±45.6	278.0±39.9
Dissolved Oxygen (mg/l)	8.08±0.67	7.63±0.99*	7.29±1.43
CO_2	7.06±0.05	5.1±1.5	7.5±4.7
Alkalinity (mg/l)	101±12.8	99.00±18.8	125.88±13.73
Ammonical Nitrogen (µg/l)	133.67±28.30	215.41±34.91*	143.67±27.38
Nitrate-Nitrogen (µg/l)	212.6±54.7	973±180.1*	118.02±118.02
Total Phosphate (µg/l)	1646±98.73	1710.8±103.7*	571.64±83.3
Total dissolved solids TDS (µg/l)	191.3±15.2	290.3±30.37*	236.5±27.0

Data are expressed as mean±standard deviation; *p<0.05.

after dredging while variation in water temperature, dissolved oxygen, free CO_2 and alkalinity was found insignificant (Figure 2a and b).

Concentration of soluble nitrogen and phosphorus is generally high in fine grain sediment (Fisher et al., 1982; Valiela, 1995). In post dredging scenario, the turbidity of water increased which may be attributed to the resuspension of sediment particles caused by the process of dredging. Dredging significantly increased the electrical conductivity of the lake water. An increase in the concentration of phosphorus was also observed after dredging, perhaps due to its potential release from bottom sediment on account of disturbance (Chunhua et al., 2000). Statistical analysis of the result shows that there was a significant variation in few water parameters of the lake water soon after dredging. Average value of nitrate-nitrogen, total phosphorous and electrical conductivity increased soon after dredging operation which could be due to resuspension of nutrients in the water column (Ryding, 1982). Ammonical nitrogen concentration showed an increasing trend after the commencement of dredging operation which can be attributed to potential release from sediments. The increase in TDS levels might be due to re-suspension of particulate matter (e.g., Ca, Mg, Na and their release from the sediments to the aqueous phase (Nayar et al., 2004). It was found that the effects of sediment dredging on surface water pH, dissolved oxygen and water temperature were negligible; this is in consonance with Lewis et al. (2001).

Zooplankton community structure

Trophic status of a water body determines the zooplankton community composition (Sládeček, 1983). Due to enhanced nutritional enrichment of lake ecosystems, there is considerable change in the zooplankton community structure (Conde-Porcuna et al., 2002; Hietala et al., 2004). A total of 53 taxa including 25 taxa for Rotifera, 17 taxa for Cladocera and 12 taxa for Copepoda were recorded in Dal Lake (Table 3). The rotifer community during pre-dredging phase were numerically dominated by *Asplanchna priodanta, Cephalodella gibba, Keratella cochlearis, Colurella obtusa* followed by *Brachionus* sp. and *Polyartha vulgaris.* The zooplankton community structure of Dal Lake responded rapidly to the environmental changes. On the initiation of dredging, the species composition as well as dominance pattern changed resulting in the decline in abundance of rotifers whereas the zooplankton crustaceans increased markedly. *Brachionus* sp. was found to be dominant followed by *Keratella cochlearis* in post dredging period.

The representative taxa of Rotifera which markedly decreased were *Asplanchna priodanta* and *Polyartha vulgaris,* implying these species could possibly be considered as target taxa for more intensive monitoring. High abundance of *Brachionus* sp. after dredging activity can be considered as a biological indicator of nutrient rich waters (Attayde and Bozelli, 1998).

The dominant cladocerans before the initiation of dredging were *Ceriodaphnia laticaudata* followed by *Chydorous ovalis, Daphnia similis* and *Bosmina longirostris*. The composition of this group also changed: *Chydorous sphaericus, Daphnia pulex* and *Bosmina longirostris* represented the bulk of the group after dredging process. The density of *C. sphaericus* increased significantly in post dredging stage. *Diaptomus* sp. and *Cyclops scutifer* were the abundant taxa among the

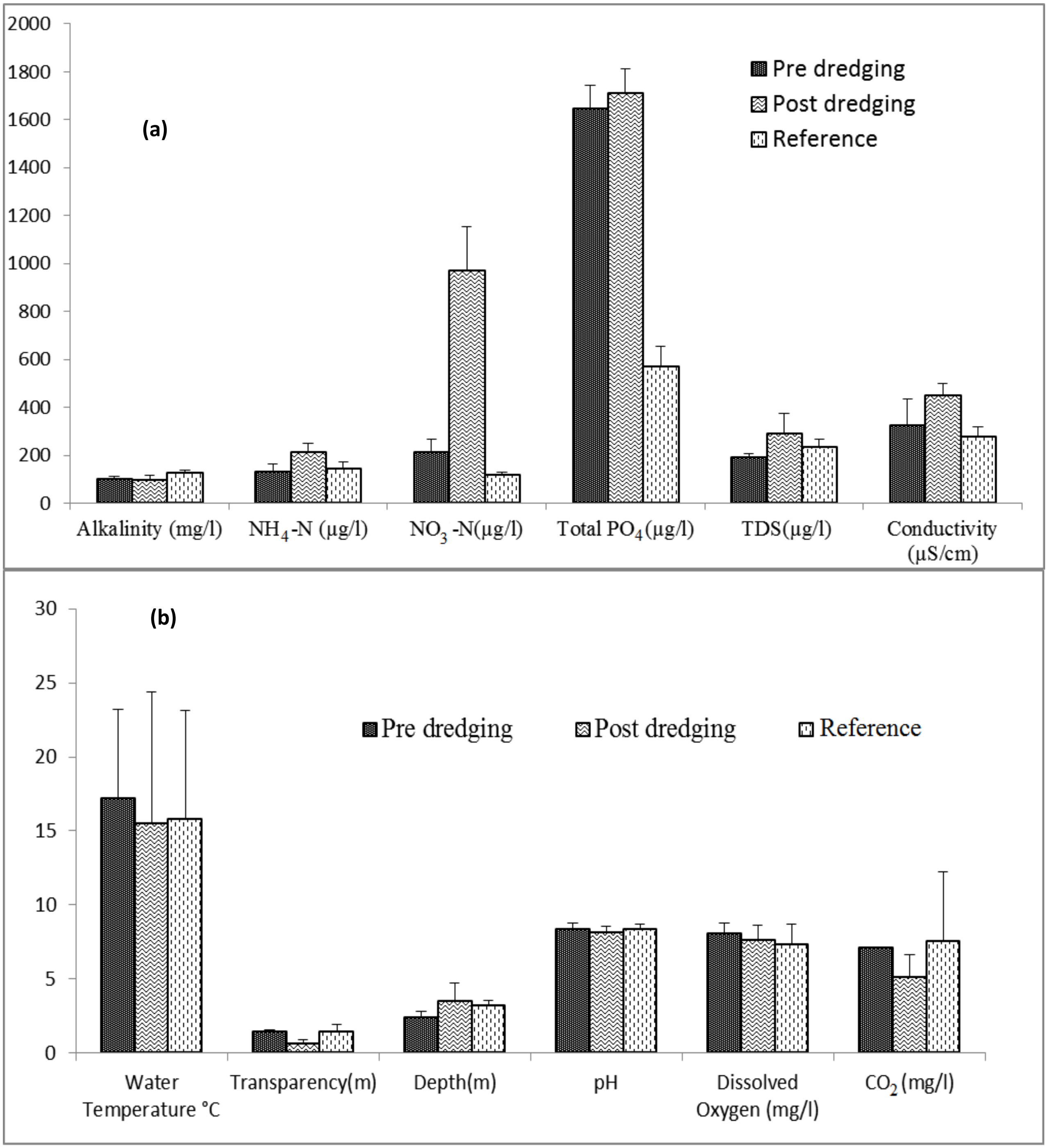

Figure 2. Mean (+/- SD) water quality parameters for pre-dredging (n=6), post dredging (n=6) and reference sites (n=12).

copepods after dredging. It could be concluded that rotifers were much influenced by nutrients while zooplanktonic crustaceans were influenced by physical conditions in the lake (Davies et al., 2009; Wanganeo, 2010). This is consistent with the results from previous studies that rotifers are more sensitive to changes in nutrients than crustaceans (Gannon and Stremberger, 1978). The distributional pattern of zooplankton species among reference and post dredging sites is shown in Table 3.

Shannon diversity index (Figure 3) of rotifers declined as the number of *Brachionus* sp., *Colurella* sp. and

Table 3. Distributional pattern of Zooplankton among reference and post-dredging sites.

Taxa	Reference site	Post-dredging site
Rotifera		
Ascomorphella	+	+
Asplanchna priodonta	+	+
Brachionus caudatus	+	R
Cephalodella giba	+	+
Colurella obtusa	+	R
Euchlanis dilatata	+	+
Filinia longiseta	+	-
Keratella cochlaeris	+	+
Lecane luna	+	-
Lecane sp	+	R
Lepadella	+	R
Monommata	+	-
Monostyla bulla	+	-
Monostyla quadrentia	+	-
Notholca acuminata	+	+
Notommata	+	-
Platiyas	+	-
Polyarthra vulgaris	+	-
Pompolyx sulcata	+	+
Squatinella mutica	+	-
Trichocerca cylindrica	+	+
Trichotria tetractis	+	-
Colourellria	+	-
Adriatica	+	R
Bdelloids	+	+
Cladocera		
Alona affinis	+	-
Bosmina coregoni	+	-
Bosmina longirostris	+	+
Ceriodaphnia lacaustris	+	-
Ceriodaphnia laticaudata	+	-
Ceriodaphnia reticulata	+	+
Chydorus gibbus	+	-
Chydorus ovalis	+	+
Chydorus sphaericus	+	+
Daphnia pulex	+	+
Daphnia rosea	+	+
Daphnia similis	+	+
Graptolebris testudinaria	+	+
Oxyurella	+	-
Pleuroxus striatus	+	+
Sida crystalina	+	+
Simocephalus vetulus	+	-
Copepoda		
Bryocamptus hiemalis	+	-

Table 3. Contd.

Cyclops bicolor	+	+
Cyclops insigins	+	-
Cyclops scutifer	+	+
Cyclops vicinus	+	-
Cyclops virdis	+	-
Diaptomus sp	+	+
Eucyciops prinophorous	+	-
Eucyclops agilis	+	-
Helicyclops	+	+
Paracyclops affinis	+	+

+ Present; R rare; - absent.

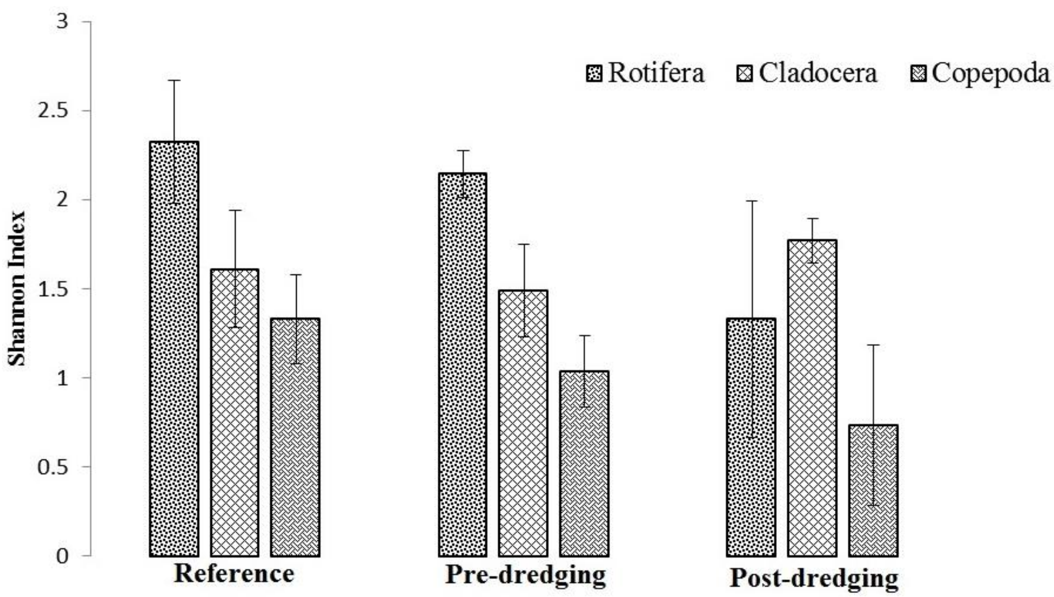

Figure 3. Shannon diversity index of reference, pre and post dredging sites.

Polyartha vulgaris significantly dropped after dredging.
The mean diversity value of Rotifera was 2.32 at reference site and pre and post dredging values were found to be 2.14 and 1.32, respectively. The Cladoceran diversity index increased (1.77) after dredging as compared to its reference value (1.60) and pre-dredging (1.48) scenario, while in case of Copepods, index decreased in post dredging settings.

The inorganic suspended matter released in the water column after the excavation is known to be a key factor in shaping zooplankton assemblages in particular cladocerans (Kirk and Gilbert, 1990). Progressive increase in the total density of cladocerans and a decrease of rotifer abundance group was marked noticeable. The presence of asynchronous trends between rotifers and cladocerans densities suggests that exploitative competition may be an important mechanism regulating filter feeder once the initial disturbance due to dredging is damped out. After the dredging phase, biotic interactions (predation and competition) appears be the main determinants in shaping zooplankton communities.

Conclusion

Pre and post dredging comparison of water quality revealed significant increase in the levels of phosphorus and nitrate nitrogen in the water column soon after dredging. The environmental changes as a result of dredging affected the structure and distribution of zooplankton community. Abundance of rotifers decreased, while the density of zoo-planktonic crustaceans increased noticeably. From this study, it can be concluded that dredging activity alters the physicochemical parameters of the water body and drastically changes the community composition of zooplankton. Predation and competition appears to be important determinants after dredging in building up the zooplankton community structure.

It is usually very difficult to predict and assess the lake condition using individual biotic community. So, extensive monitoring involving multiple biotic components will be necessary to assess post-dredging dynamics and guide management decisions. Zooplankton may be used in determining future lake health/trophic status of Dal Lake.

Dredging the lake sediments can only be effective after the influx of nutrients into the water body is controlled. Immediate measures required for further improvement are, controlling erosion in critical erosion zones of the catchment, arresting of suspended sediments in feeding nallah, reduction in permanent habitat in and around the lake and diversion of sewage to eliminate nitrogen and phosphorus entry. In-depth research in Dal Lake should help guide future dredging restoration project.

Conflict of Interests

The author has not declared any conflict of interests.

ACKNOWLEDGEMENTS

The authors express sincere gratitude to UGC, New Delhi, India for providing the first author financial support under FIP scheme and Director CORD University of Kashmir for providing the necessary laboratory facility for the research work.

REFERENCES

AHEC-Roorkee (2000). Detailed project report for conservation and management of Dal Lake, J&K Lakes and Waterways Development Authority.

APHA (2005). Standard methods for the examination of water and wastewaters, 21st edn., American Public Health Association, Washington.

Attayde JL, Bozelli RL (1998). Assessing the indicator properties of zooplankton assemblages to disturbance gradients by canonical correspondence analysis. Can. J. Fish. Aquat. Sci. 55:1789-1797.

Bennion H, Simpson GL, Goldsmith BJ (2015). Assessing degradation and recovery pathways in lakes impacted by eutrophication using the sediment record. Front. Ecol. Evol. pp. 3-94.

Carpenter SR, Ludwig D, Brock WA (1999). Management of eutrophication for lakes subject to potentially irreversible change. Ecol. Appl. 9:751-771.

Conde-Porcuna JM, Ramos-Rodrıguez E, Perez-Martınez C (2002). Correlations between nutrient concentrations and zooplankton populations in a mesotrophic reservoir. Freshwater Biol. 47:1463-1473.

Chunhua PU, Peimin WANG, Guoxiang HU, Weiping HU, Chengxin FAN (2000). Can We Control Lake Eutrophication by Dredging? J. Lake Sci. 3:011.

Davies OA, Abowei JFN and Otene BB (2009). Seasonal abundance and distribution of plankton of Minichinda stream, Niger Delta, Nigeria. Am. J. Sci. Res. 2:20-30.

ENEX (1978). Pollution of Dal Lake, ENEX of New-Zealand Inc.140

Fisher TR, Carlson PR, Barker RT (1982). Sediment nutrient regeneration in three North Carolina Estuaries, Estuarine, Coastal and Shelf Science. 14:101-116.

Gannon JE, Stemberger RS (1978). Zooplankton (especially crustaceans and rotifers) as indicators of water quality. Trans. Am. Microsc. Soc. 97:16-35.

Gustavson KE, Burton GA, Francingues NR, Reible DD, Vorhees DJ, Wolfe JR (2008). Evaluating the effectiveness of contaminated-sediment dredging. Environ. Sci. Technol. 42:5042-5047.

Havens KE (2002). Zooplankton structure and potential food web interactions in the plankton of a subtropical chain of lakes. Sci. World J. 2:926-942.

Hadnagy E, Gardner KH, Chesner WH, Justus H, Forgione M, Maxwell G (2015). Pilot-scale evaluation of an in situ amendment delivery and mixing device for contaminated sediment remediation applications. J. Soils Sediments 15:480-489.

Hietala J, Vakkilainen K, Kairesalo T (2004). Community resistance and change to nutrient enrichment and fish manipulation in a vegetated lake littoral. Freshwater Biol. 49(12):1525-1537.

Je CH, Hayes DF, Kim KS (2007). Simulation of resuspended sediments resulting from dredging operations by a numerical flocculent transport model. Chemosphere 70:187-195.

Kirk KL, Gilbert JJ (1990). Suspended clay and the population dynamics of planktonic rotifers and cladocerans. Ecology pp. 1741-1755.

Kundangar MRD, Abubaker A (2001). Post dredging changes and comparative limnology of Dal Lake Kashmir. Pollut. Res. 20:539-547.

Lewis MA, Weber DE, Stanley RS, Moore JC (2001). Dredging impact on an urbanized Florida bayou: effects on benthos and algal-periphyton. Environ. Pollut. 115(2):161-171.

Mackie JA, Natali S M, Levinton JS, Sanudo-Wilhelmy SA (2007). Declining metal levels at Foundry Cove (Hudson River, New York): Response to localized dredging of contaminated sediments. Environ. Pollut. 149:141-148.

Murphy TP, Lawson A, Kumagai M, Babin J (1999). Review of emerging issues in sediment treatment. Aquat. Ecosys. Health Manage. 2:419-434.

Nayar S, Goh BPL, Chou LM (2004). Environmental impact of heavy metals from dredged and resuspended sediments on phytoplankton and bacteria assessed in in situ mesocosms. Ecotoxicol. Environ. Saf. 59:349-369.

NLCP, National Lake Conservation Plan (1997). Conservation and Management of lakes: An Indian Perspective.

Rashid H, Naseem G (2007). Quantification of loss in spatial extent of lakes and wetlands in the suburbs of Srinagar City during last century using Geospatial approach. Proc. of Taal: The 12th World Lake Conference. pp. 653-658.

Ruban V, L´opez-S´anchez JF, Pardo P, Rauret G, Muntau H, Quevauv´ıller Ph (2001). Harmonized protocol and certified reference material for the determination of extractable contents of phosphorus in freshwater sediments-A synthesis of recent works. Fresenius J. Anal. Chem. 370:224-228.

Ryding SO (1982). Lake Trehörningen restoration project. Changes in water quality after sediment dredging. In Sediment/Freshwater Interaction. pp. 549-558.

Schindler DW (1987). Detecting ecosystem responses to anthropogenic stress. Can. J. Fish. Aquat. Sci. 44:6-25.

Sládeček V (1983). Rotifers as indicators of water quality. Hydrobiologia. 100:169-201.

Sondergaard M, Jeppesen E, Lauridsen TL, Skov C, Van Nes EH, Roijackers R (2007). Lake restoration: Successes, failures and long-term effects. J. Appl. Ecol. 44:1095-1105.

Valiela I (1995). Marine Ecological Processes (2nd ed.). Springer-Verlag, New York, USA.

Voie OA, Johnsen A, Rossland HK (2002). Why biota still accumulates high levels of PCB after removal of PCB contaminated sediments in a Norwegian fjord. Chemosphere 46:367-1 372.

Wanganeo A (2010). Manasbal Lake Kashmir-phytoplankton photosynthesis, nutrient dynamics and trophic status. Utpal Pub. 230.

Weston DP, Jarman WM, Cabana G, Bacon CE, Jacobson LA (2002). An evaluation of the success of dredging as remediation at a DDT-contaminated site in San Francisco Bay, California, USA. Environ. Toxicol. Chem. 21:216-224.

Yin H, Kong M (2015). Reduction of sediment internal P-loading from eutrophic lakes using thermally modified calcium-rich attapulgite-based thin-layer cap. J. Environ. Manage. 151:178-185.

Zhang S, Zhou Q, Xu D, Lin J, Cheng S, Wu Z (2010). Effects of sediment dredging on water quality and zooplankton community structure in a shallow of eutrophic lake. J. Environ. Sci. 22:218-224.