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Impact of Anthropogenic Activities on Macrobenthic Biodiversity of Kaliasote Dam of Bhopal, Madhya Pradesh, India

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Abstract

Present study was conducted to understand the impact of anthropogenic activities on macrobenthic biodiversity of the Kaliasote Dam which is one of the important multipurpose water bodies of Bhopal. The study reveals that the water quality of the Kaliasote Dam has shown the sign of deterioration at several places due to increasing anthropogenic pressure. Though average values of most of the parameters are within the permissible limit of CPCB however concentration of BOD (1.2 mg/l to 12 mg/l) and COD (8 mg/l to 31 mg/l) reveals moderate degree of organic pollution at some intervals. All the water samples collected during the period 2015-17 contain significant amount of nitrate and orthophosphate that facilitated growth and development of few indicator species of macrobenthic community. In general on the basis of physical, chemical and macro zoo benthic study, the Dam water can be classified as moderately polluted water body.

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Introduction

Water is a renewable resource but the reckless uses and improper management of water system have caused serious problems in availability and quality of water all over the world. Water may be contaminated by various means chemically or biologically and become unfit for drinking and other uses. Increase in industrialization, urbanization, agricultural and other human activities have caused enormous deterioration of the quality of various natural water bodies, particularly rivers and ground water in developing countries like India. The process of water quality deterioration caused by excessive nutrients as a result of growing anthropogenic activities is a serious problem confronting all lakes except the high altitude, Trans Himalayan glacial lakes. The inflow of large quantities of untreated sewage from human settlements and runoff from the agricultural field in the catchment usually results in the build up of nutrient supply, particularly nitrogen and phosphorus to the waterbody resulting in the formation of algal blooms or alteration in species composition of flora and fauna and finally water quality deterioration (Pani, 2017). With increasing pollution, change in water quality is expected to occur in the species composition, appearance of tolerant species, number of species and changes in abundance of species in all the water bodies especially in urban lakes, reservoirs and dams (Pani *et al.,* 2007). Monitoring of water quality therefore is very important, as majority of the water used in urban cities comes from surface water. It is the measure of how suitable the water is from a biological, chemical and physical perspective. Water quality can be impacted negatively by both natural and human causes.

Hence, understanding the status of water quality of the potable and other water resources through various physico-chemical and biological monitoring is essential for determining its best uses apart from preparing a Detailed Planning Report (DPR) for conservation and sustainable development of the water resources. Considering this, the water quality assessment of Kaliasote Dam of Bhopal was conducted during the period 2015-2017 to understand the impact of anthropogenic activities on macrobenthic biodiversity of the Dam.

Materials and methods

During present investigation total five sampling stations were selected for collection of water samples (Fig. 1).

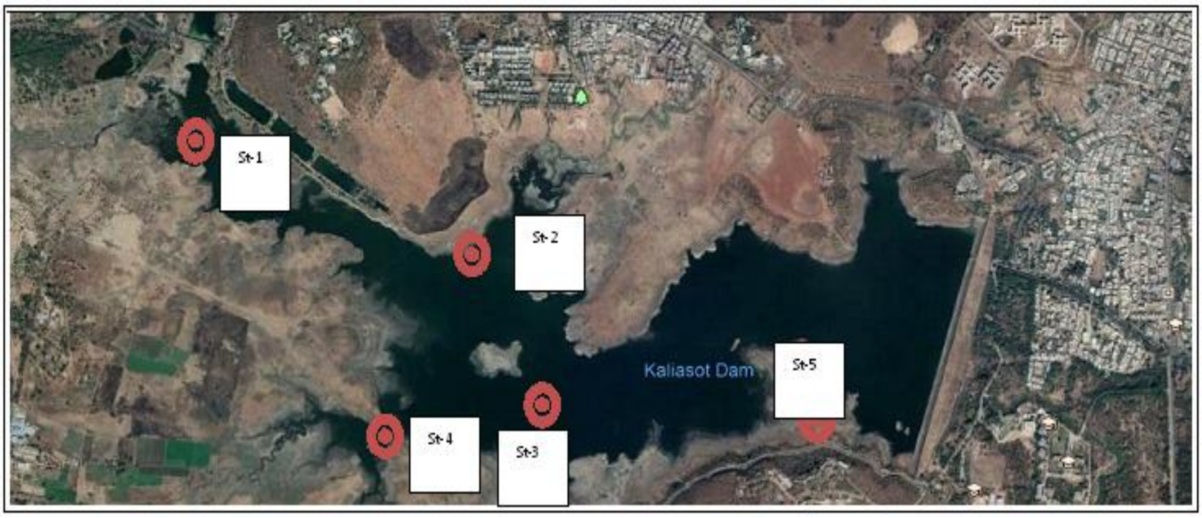

Fig. 1. Kaliasote Dam with sampling stations.

Station -1 near Bhadbhada Spill channel

Station -2 near Pandit Khusiram Aurvedic Hospital

Station -3 Centre (Near Shiv Temple)

Station -4 Near Southern waste weir

Station -5 Near Dam adjoining WALMI (Water & Land Management Institute).

Selection of sampling station was done considering the catchment structure, inflow and outflow channels, degree of pollution, and characteristics of the water in the Dam. For this one liter each water samples were collected from surface, middle and bottom layer by using Ruttner water sampler from each sampling station. An integrated sample was prepared by mixing the surface, middle and bottom samples so as to make a representation of water column of the particular sampling station. Macro-benthos samples were collected simultaneously from each sampling station using Peterson grab mud sampler. Collection, preservation and analysis of various physico-chemical and biological parameters were done following the standard methods described in APHA (2010).

Description of the study area

The Kaliasote Dam was constructed, as a storage Dam near the Water and Land Management Institute (WALMI), Bhopal and its tail end is the downstream of the Bhadbhada Spill gates of the Upper Lake. The name "Kaliasote" was derived from the name of Kalyan Strote, one of the ministers of Raja Bhoj, who had developed the spillway of Upper Lake.

The extra water of the Upper Lake is discharged through 11 radial gates installed for regulating water level of the Upper Lake. Thus situated in the downstream of Upper Lake the Kaliasote Dam was constructed to store the outgoing water of Upper Lake discharged through Bhadbhada gates for the purpose of irrigation and water supply.

The waste weir of the Kaliasote is draining water into River Betwa. The water from this Dam is being supplied for annual irrigation of 4588 ha land. The Dam is having a catchment area of 381.38 km² and the gross storage capacity is 35.387 Mcum. Kaliasote Dam is mainly suffering from siltation due to rapid change in land use pattern from agriculture to housing. The construction and development activities along the catchment not only accelerated the soil erosion rate in the Dam but also resulted in discharging untreated sewage in the Dam. In coming days the catchment area of the Dam will receive more pressure of habitation and that could lead to pollution stress on the Dam. Therefore it is imperative to start with preventive measures for the conservation of this Dam.

Results and discussion

The observations of analysis of various physico-chemical parameters of water samples collected from the Kaliasote Dam is depicted in Table -1 with the range values. Atmospheric temperature during the period of investigation ranged from 19.3 to – 38.7 oC.

Table 1. Range Values of various parameters in different seasons during 2015-2017.

S.no	Parameter	Min				Max				Mean
		Value	Station	Season	Year	Value	Station	Season	Year	
1	Air Temperature (°C)	19.3	2	Winter	2015	38.7	5	Summer	2015	28.64
2	Water Temperature (°C)	17.6	2, 4	Winter	2015,17	32.1	5	Summer	2015	25.25
3	pH	7.1	4	Winter	2017	8.6	5	Summer	2017	7.78
4	TDS (mg/l)	80.6	2	Winter	2017	237.9	1	Summer	2015	173.22
5	Conductivity (mS/Cm²)	0.14	3	Winter	2017	0.44	5	Monsoon	2017	0.29
6	DO (mg/l)	4.8	1	Monsoon	2016	9.2	5	Summer	2015	6.85
7	BOD (mg/l)	1.2	4	Summer	2015	12	5	Monsoon	2017	4.33
8	COD (mg/l)	8	2	Summer	2015	31	3	Monsoon	2017	18.93
9	Nitrate (mg/l)	1.01	4	Winter	2016	2.87	1	Summer	2016	1.34
10	Ortho-phospahte (mg/l)	0.67	2	Winter	2016	1.96	5	Monsoon	2015	1.28

The minimum value was recorded at station-2 during winter season, 2015 while the maximum value was observed at Station-5 during summer season, 2015 (Table-1). Water temperature on the other hand ranged from 17.6-32.1 °C. The minimum value was recorded at station-2 & 4 during winter, 2015 & 2017 while the maximum value was observed at Station-5 during summer season, 2015 as that of air temperature. Water temperature during the period of investigation, was found to have direct relation with atmospheric temperature; it increased or decreased with the changes in atmospheric temperature. Misra *et al.,* (2006) has also found the similar trend in temperature variations. Close relationship between atmospheric temperature and surface water temperature has also been reported by Bhatia *et al.,* (1970).

The variation in temperature during the period of investigation has affected the pH values of the Dam.

Table 2. Status of Kaliasote Dam at different stations on the basis of observation on Physic-chemical and Macro zoo benthic characteristics following the Biological Water Quality Criteria Developed by CPCB.

Stations	Range of Saprobic Score (BMWP)	Range of Diversity	Water Quality	Water Quality Class	Indicator colour
Station-2	7 and More	0.2-1	Clean	A	Blue
Station-4	6-7	0.5-1	Slight Pollution	B	Light Blue
Station-3 & 5	3-6	0.3-0.9	Moderate Pollution	C	Green
Station-1	2-5	0.4 & less	Heavy Pollution	D	Orange
	0-2	0-0.2	Severe Pollution	E	Red

The hydrogen ion concentration or pH is the most important and commonly studied property of natural water and wastewater. The measurement of pH is of great importance because chemical and biochemical reaction in an aquatic body takes place at a particular pH and plays an important role in productivity of waterbody. In Kaliasote Dam the pH values in most of the places were observed to be slightly alkaline. pH during the period of investigation ranged from 7.1 to 8.6.

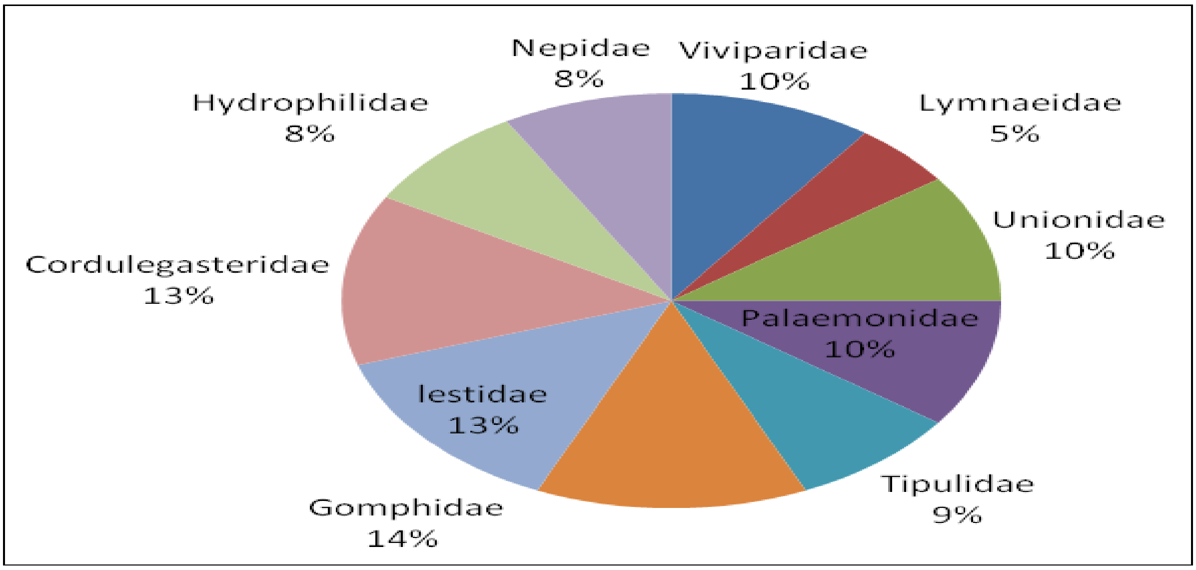

Fig. 2. Percent variation of macrobenthic communities at Station-1 during summer, 2015.

The minimum value was recorded at station-4 during winter, 2017 while the maximum value was observed at Station-5 during summer season, 2017. During the period of investigation a close look of the seasonal variation also depicted slightly higher values of pH during the summer months compared to monsoon and winter months. Misra *et al.,* (1994) also found similar results in case of Upper Lake which depicted slightly alkaline nature and pH varied from 7.1 to 9.5. In Kaliasote Dam the pH in general was slightly alkaline and shows comparatively better quality for sustainability of macro-benthic community in the Dam. Hydrogen ion values in Kaliasote Dam were also influenced by the changes in Total Dissolved

Solids (TDS). Total dissolved solids information is used to determine the overall ionic effect in a water source. Total dissolved solids in natural water mainly composed of a large variety of salts and inorganic minerals i.e., dissolved solids such as chlorides, carbonates, bicarbonates, nitrate, phosphate etc. which impart particular taste to water at higher concentration. TDS when present in excess in the water may create an imbalance for aquatic life (Bhateria and Jain, 2016). Certain physiological effects on plants and animals are often affected by the number of available ions in the water. Total Dissolved Solids during the period of investigation ranged from 80.6 to 237.9 mg/l.

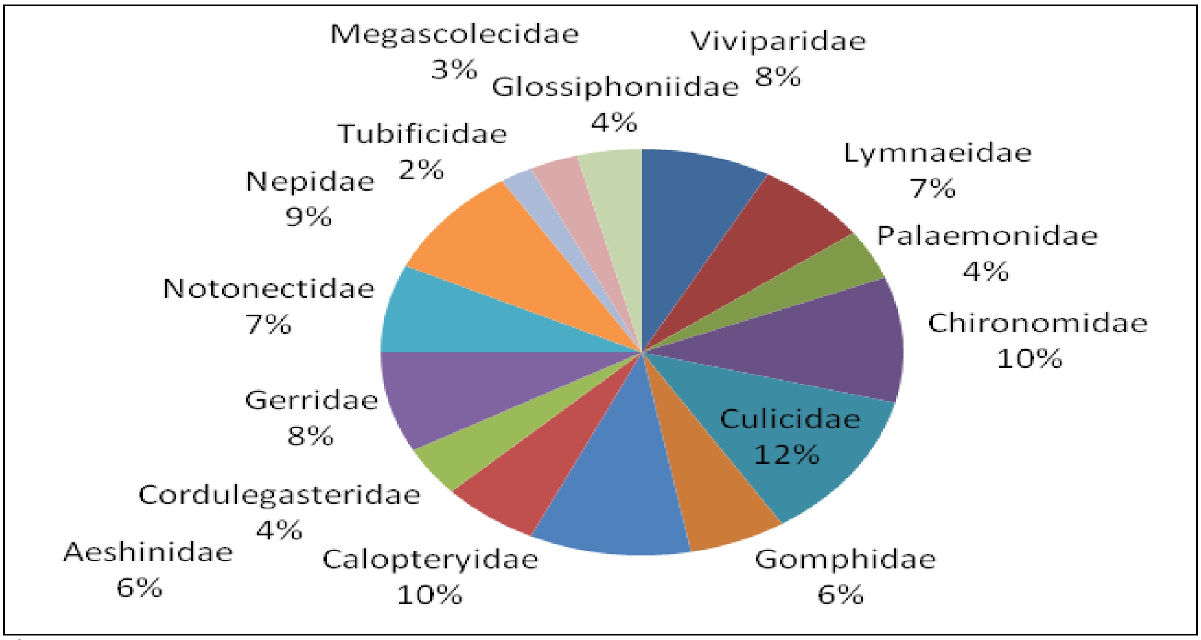

Fig. 3. Percent variation of macrobenthic communities at Station-2 during summer, 2015.

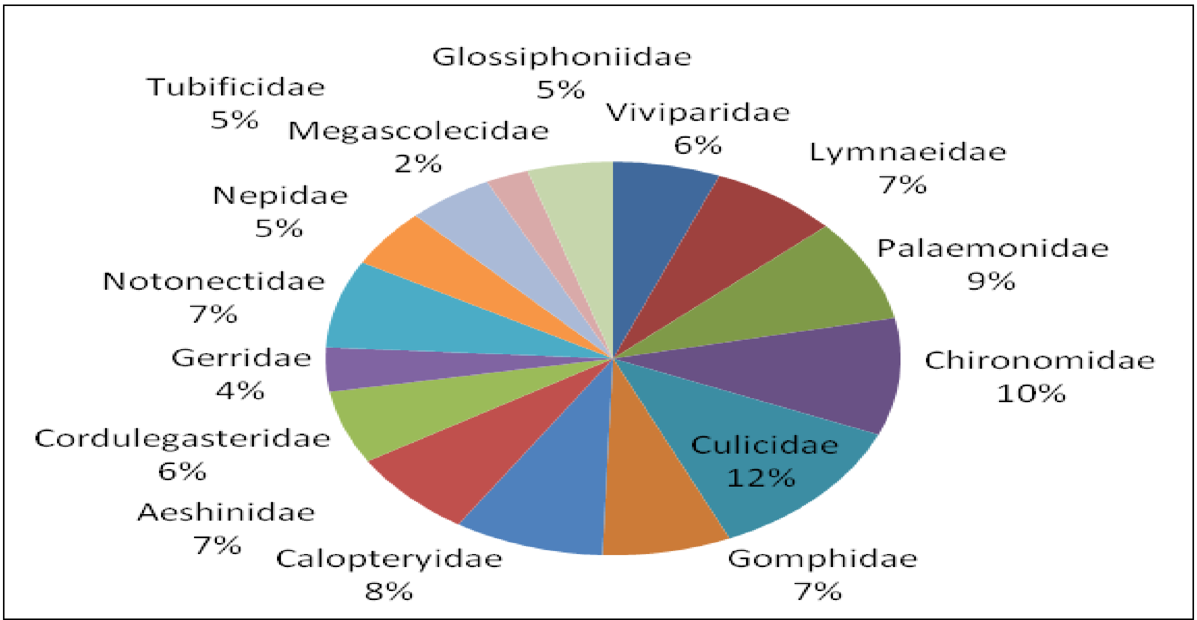

Fig. 4. Percent variation of macrobenthic communities at Station-3 during summer, 2015.

The minimum value was recorded at station-2 during winter, 2017 while the maximum value was observed at Station-1 during summer season, 2015. Values of TDS in turn influenced the conductivity of Kaliasote Dam. Conductivity values in the Dam during the period of investigation ranged from 0.14 too.44

mS/cm .The minimum value was recorded at station-3 during winter, 2017 while the maximum value was observed at Station-5 during monsoon season, 2017. Changes in the conductivity values during present investigations were observed inconformity with the changes in Total Dissolved Solids. Chemically pure water has low electrical conductivity while high values of electrical conductance show presence of ionic solids in water. In Kaliasote Dam moderate range of conductivity values were observed. Khtatavakar *et al.,* (1993) has also observed the similar seasonal pattern in their study of Shambhu Lake of Satera. Dissolved Oxygen (DO) is an important parameter to understand the trophic status of a water body. (DO) in the Dam during the period of investigation ranged from 4.8 to 9.2 mg/litre.

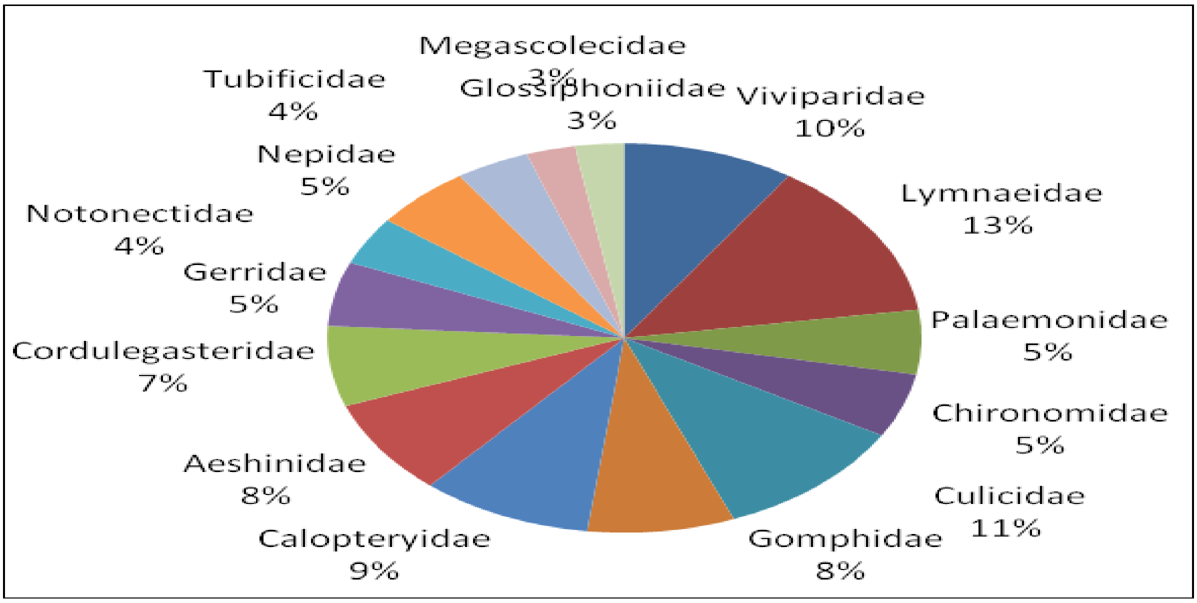

Fig. 5. Percent variation of macrobenthic communities at Station-4 during summer, 2015.

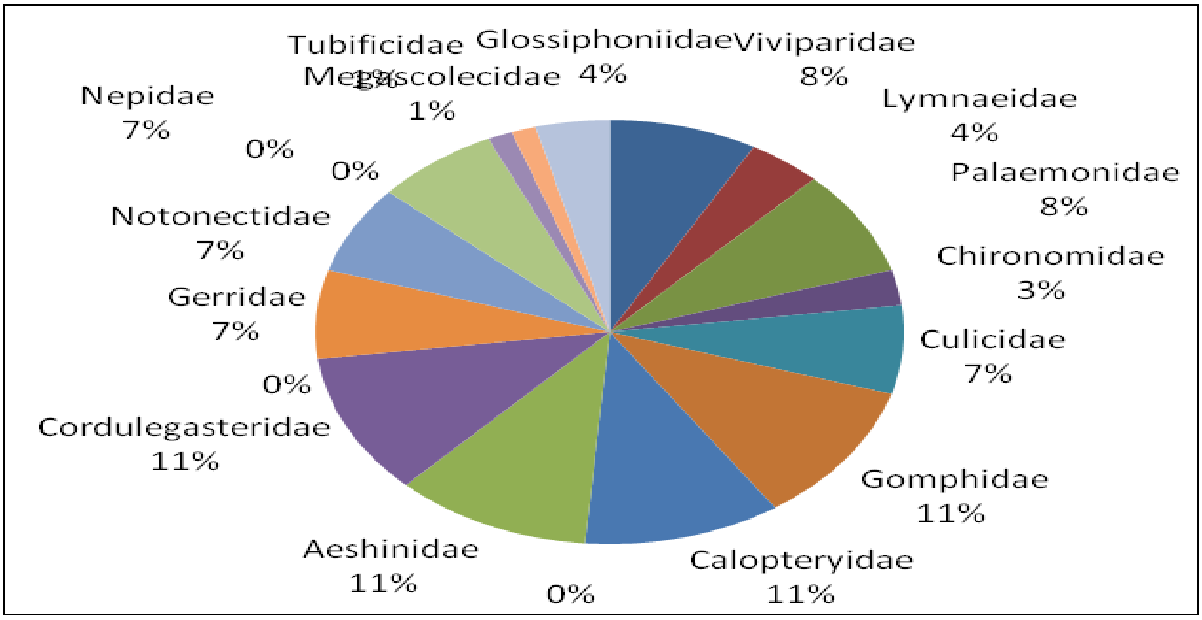

Fig. 6. Percent variation of macrobenthic communities at Station-5 during summer, 2015.

The minimum value was recorded at station-1 during monsoon, 2017, while the maximum value was observed at Station-5 during summer season, 2015. High dissolved oxygen concentration during summer months could be on account of high photosynthetic activity by the standing phytoplankton crop and the macrophytic vegetation in presence of optimum light. In Kaliasote Dam a moderate range of Dissolved Oxygen concentration was observed during most of the period of investigation.

Bio-chemical Oxygen Demand during the period of investigation ranged from 1.2 to 12 mg/l. The minimum value was recorded at station-4 during summer, 2015 while the maximum value was observed at Station-5 during monsoon season, 2017. Chemical oxygen demand (COD) determines the oxygen required for chemical oxidation of organic matter. COD values convey the amount of dissolved oxidisable organic matter including the non-biodegradable matters present in it (Choudhary and Rawtani, 2014). Chemical Oxygen Demand during the period of investigation ranged from 8 to 31 mg/l (Fig. 11).

The minimum value was recorded at station-2 during summer, 2015 while the maximum value was observed at Station-3 during monsoon season, 2017.

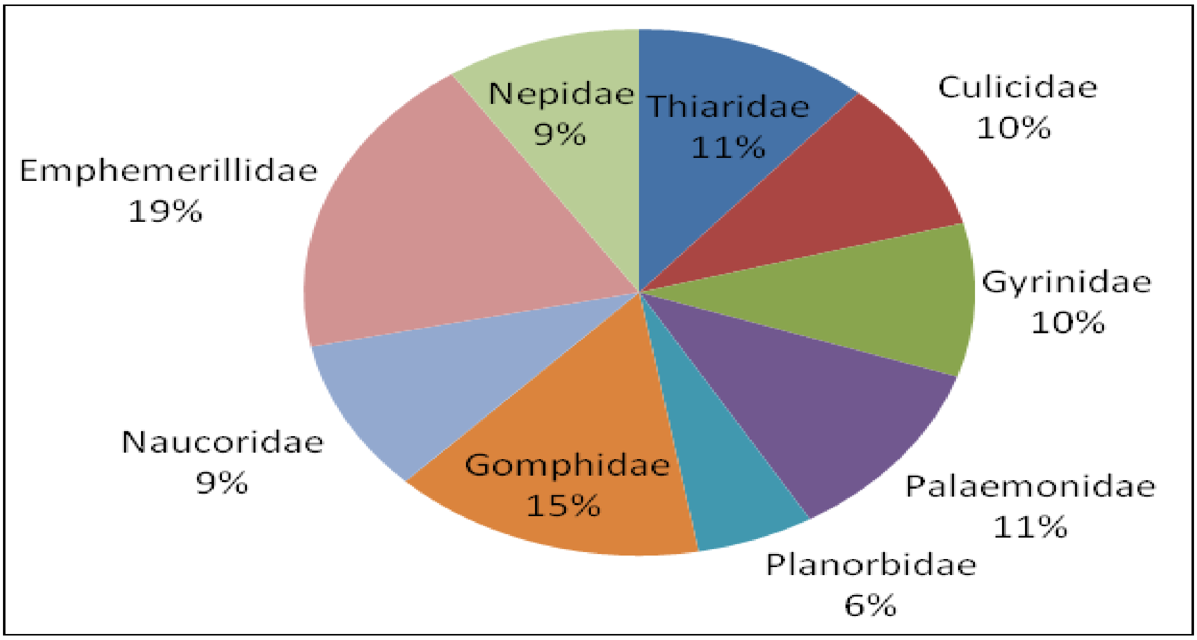

Fig. 7. Percent variation of macrobenthic communities at Station-1 during monsoon, 2015.

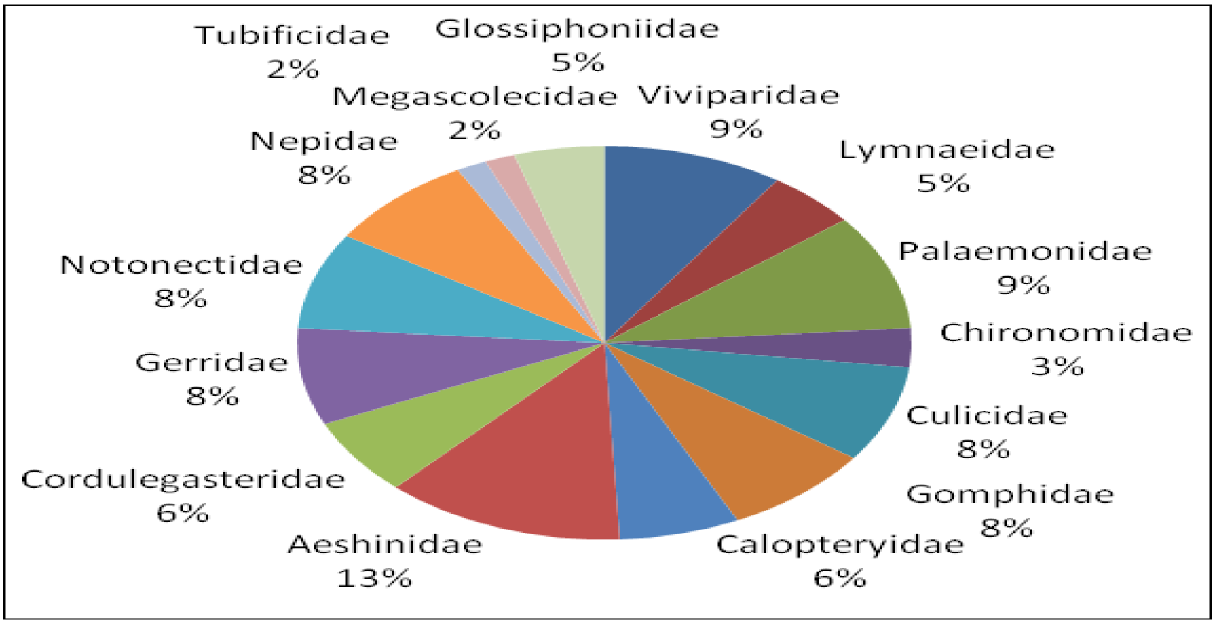

Fig. 8. Percent variation of macrobenthic communities at Station-2 during monsoon, 2015.

During present period of investigation major nutrients like Nitrate and Ortho-phosphate were analysed to understand the impact of both these nutrient on water trophic status as well as biodiversity of the Dam.

Nitrate in Kaliasote Dam mostly derived from agriculture sources. Introduction of large quantity of nutrients, mainly nitrogen and phosphorus to lake water has been reported to cause eutrophication problems (Kouimtzis *et al.,* 1994). Nutrient pollution because of not only with phosphorus but also with nitrogen coming from urban runoff and sanitary sewer systems can lead to eutrophication of the receiving water bodies (Stevens, 2003). Nitrate during the period of investigation ranged from 1.01 to 2.87 mg/l. Ortho-phosphate on the other hand ranged from 0.52 to 1.66 mg/l.

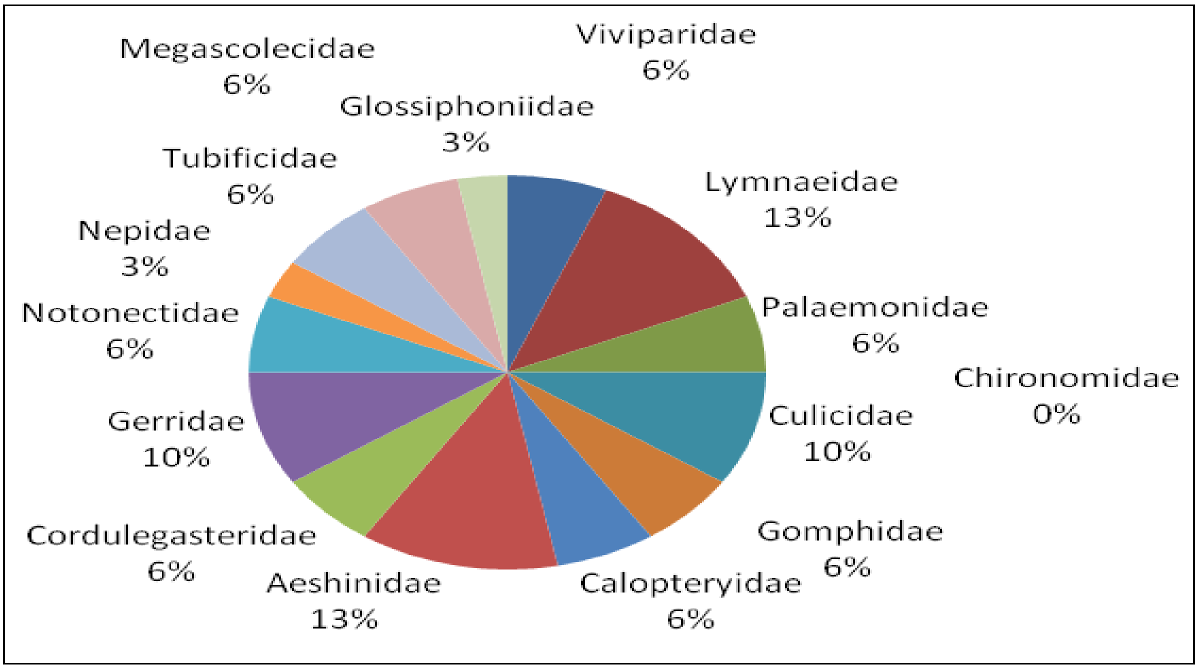

Fig. 9. Percent variation of macrobenthic communities at Station-3 during monsoon, 2015.

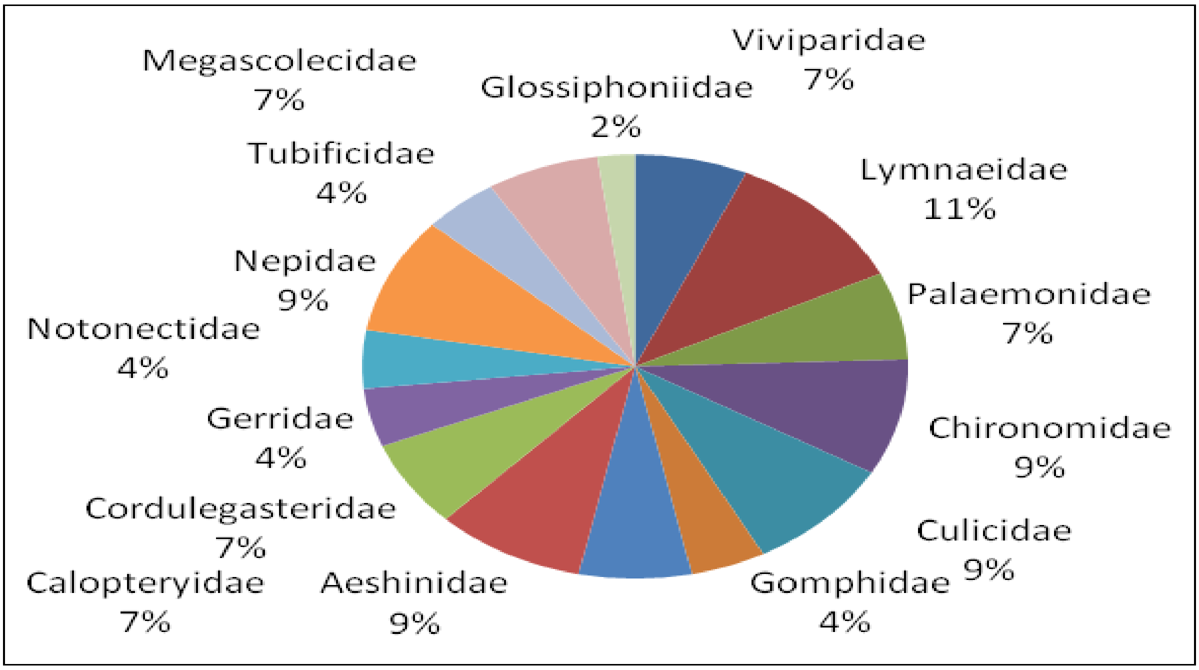

Fig. 10. Percent variation of macrobenthic communities at Station-4 during monsoon, 2015.

The minimum value was recorded at station-1 during winter, while the maximum value was observed at Station-2 during summer season. Phosphates enter waterways from human and animal wastes. The element phosphorus is necessary for plant and animal growth. Nearly all fertilizers contain phosphates (chemical compounds containing the element, phosphorous). When it rains, varying amounts of phosphates wash from farm soils into nearby waterways. Phosphates stimulate the growth of plankton and water plants that provide food for fish. This may increase the fish population and improve the waterway's quality of life.

If too much phosphate is present, algae and water weeds grow wildly, choke the waterway, and use up large amounts of oxygen, due to which many fish and aquatic organisms may die.

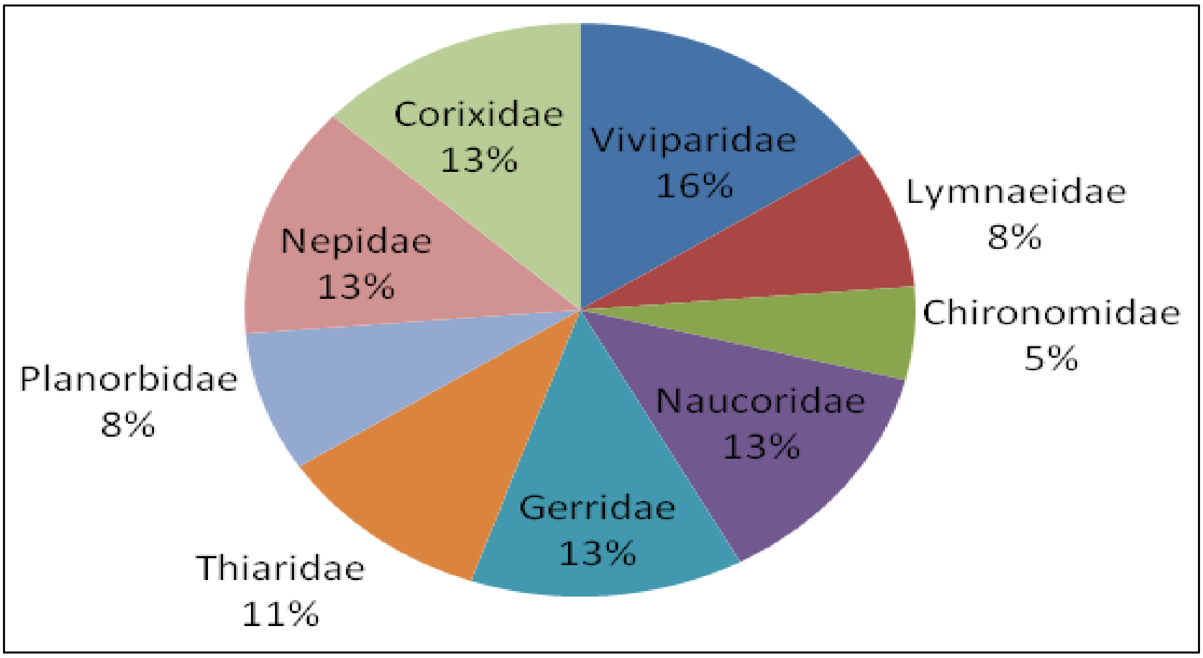

Fig. 11. Percent variation of macrobenthic communities at Station-5 during monsoon, 2015.

In recent times along with physico-chemical parameters bio-monitoring studies are also being undertaken to define the trophic status of a water body. Using macro benthos as a tool of Bio monitoring study cannot entirely replace the standard physico -chemical water quality methods which provide information on water quality at a particular spatial unit during the time of sampling however bio monitoring provide some historic insights into the water quality. Standard physico - chemical water quality methods therefore need to be carried out in conjunction with bio monitoring for comprehensive evaluation of health of a water body. Bio monitoring study is usually conducted with benthic macro-invertebrates, or more simply "benthos", which are larger than ½ millimetres and live on rocks, logs, sediment, and debris on river bed. The benthos includes crustaceans such as crayfish, molluscs such as clams and snails, aquatic worms and the immature forms of aquatic insects such as stonefly and mayfly nymphs. Benthos do not move around much and with long life cycle allow detection of past pollution events such as pesticide spills and illegal dumping thereby help in determining decline in aquatic environmental quality. Few benthos are generally intolerant of pollution and their large presence in stream indicates good water quality. Large presence of pollution tolerant benthos shows water is polluted. Benthos demonstrates an integrated effect of pollution and community response is sensitive to organic loading, thermal impacts, substrate alterations, toxic pollution etc. Considering this macrobenthic community of Kaliasote Dam was also analysed along with physico-chemical observations to obtain a realistic picture of water quality the Dam. Variations in different groups of macrobenthic community are shown in Fig. 2 to 15.

During summer, 2015 Macrobenthic community at station 1 in Kaliasote Dam was represented by 10 groups in which Gomphidae contributed 14% of total species followed by Cordulegasteridae & Lestidae both representing 13%, while Viviparidae & Unionidae represented (10%) each (Fig. 2). During summer, 2015, a change in species composition was observed at Station 2. Macrobenthic community at this station was represented by 15 groups in which both Chironomidae and Calopteryidae species contributed (10%) each followed by Culicidae 12% , Chironomidae 10% , Nepidae (9%) and Gerridae (8%) respectively (Fig. 3). During summer, 2015, the species composition observed at Station 3 was slightly different. Macrobenthic community at this station was also represented by 15 groups as observed at station-2 in which Culicidae represented 12%, while Chironomidae contributed (10%) species followed by Palaemonidae (9%) and Calopterydae (8%) (Fig. 4).

During this period a slight variation in species composition was observed at Station 4. Macrobenthic community at this station was also represented by 15 groups as observed at station-2&3. At this station Lymnaeidae contributed maximum species (13%) followed by Culicidae which contributed (11%) and Calopterydae contributing 9% (Fig. 5).

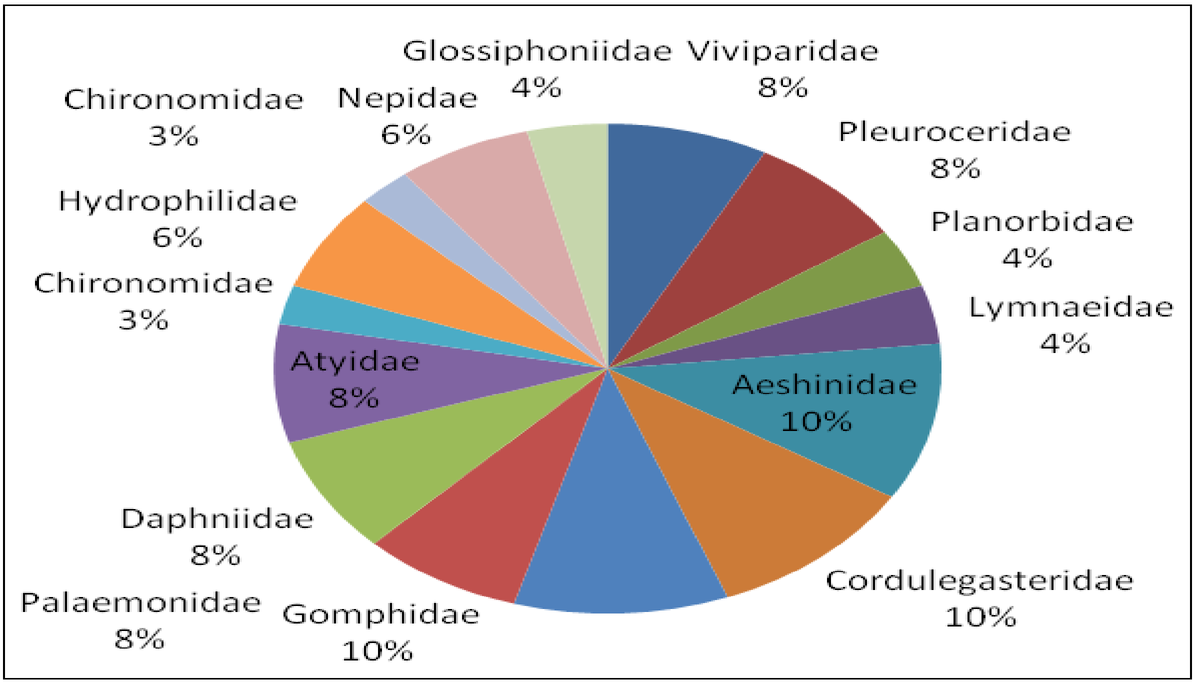

Fig. 12. Percent variation of macrobenthic communities at Station-1 during winter, 2016.

A slight variation in species composition was also observed at Station 4. Macrobenthic community at this station was also represented by 15 groups as observed at station-2,3&4. However four groups viz. Calopterydae, Cordulegasteridae, Aeshinidae and Gomphidae contributed maximum species (11%) (Fig. 6). During Monsoon, 2015 a reduction in total number of group was observed at Station 1. Macrobenthic community at this station was also represented by 9 groups. At this station Gomphidae contributed maximum species (15%) followed by Culicidae which contributed (11%) and Calopterydae contributing 9% (Fig. 7). During Monsoon ,2015 an increase in total number of group was observed at Station 2 as compared to station 1. Macrobenthic community at this station was represented by 15 groups. At this station Aeshinidae contributed maximum specie (13%) followed by Palaemonidae (9%) (Fig. 8). During Monsoon,2015 a slight decrease in total number of group was observed at Station 3 as compared to station 2. Macrobenthic community at this station was represented by 14 groups. At this station Aeshinidae again contributed maximum specie (13%) followed by Gerridae and Culicidae contributing 10% each (Fig. 9). During this period at Station 4 macrobenthic community was represented by 15 groups. Lymnaeidae contributed maximum specie (11%) followed by Aeshinidae, Nepidae & Chironomidae contributing 9% each (Fig. 10). During this period macrobenthic at Station 5 was represented by only 9 groups. Viviparidae contributed maximum species (16% followed by four groups viz. Corixidae, Nepidae, Gerridae, & Naucoridae contributing (13%) each (Fig. 11). During Winter , 2016 an increase in total number of group was observed at Station 1 as macrobenthic community at this station was again represented by 15 groups. At this station Aeshinidae, Gomphidae & Cordulegasteridae contributed maximum specie (10%) each (Fig. 12). During this season macrobenthic community at station 2 was again represented by 15 groups. At this station Aeshinidae, Gomphidae & Cordulegasteridae contributed maximum species (10%) each. Viviparidae represented the maximum species (15%) of the total (Fig. 13).

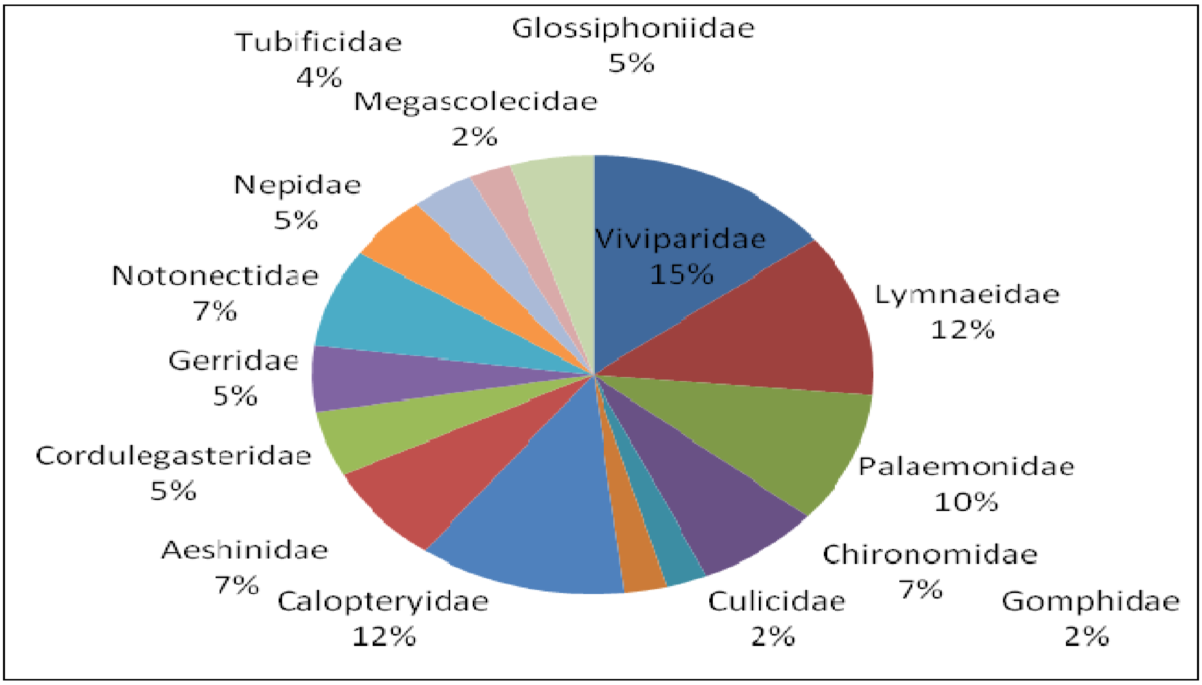

Fig. 13. Percent variation of macrobenthic communities at Station-2 during winter, 2016.

During this season macrobenthic community at station 3 was again represented by 15 groups. At this Viviparidae again represented the maximum species (14%) followed by Lymnaeidae (Fig. 14).

During Winter, 2016 at Station 4 macrobenthic community was again represented by 15 groups as observed at station-2&3. At this station Lymnaeidae contributed the maximum species (12%) followed by Viviparidae contributing 10%) and Calopterydae & Palaemonidae contributing 9% each (Fig. 15).

At Station 4 during winter, 2016 macrobenthic community was represented by 8 groups. At this station Viviparidae contributed the maximum species (15%) followed by Gomphidae, Thiardae & Pleuroceridae contributing 14% each (Fig. 16).

While observing the distribution of macrobenthic community during the period 2015-2017, a distict variation in terms of species composition with respect to seasonal and spatial variation was witnessed.

This may be due to variation in nutrient enrichment at different stations and avilability of water as the water balance of the Dam is highly variable due to its mulipurpous uses, irrigation being one of the major purpose.

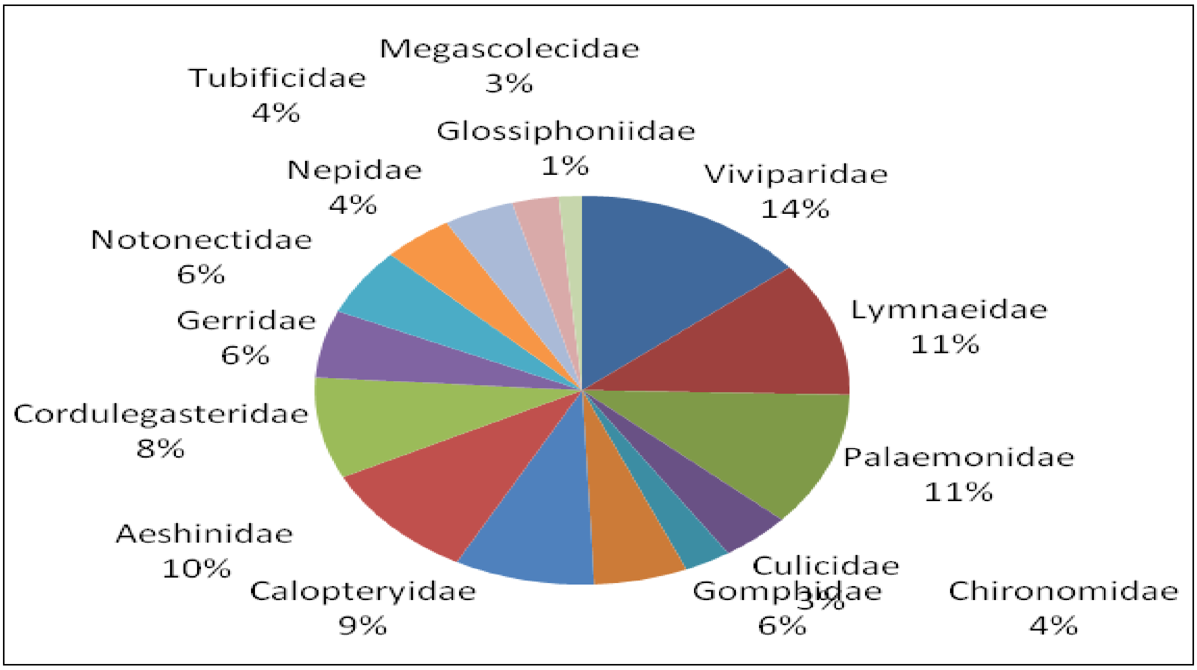

Fig. 14. Percent variation of macrobenthic communities at Station-3 during winter, 2016.

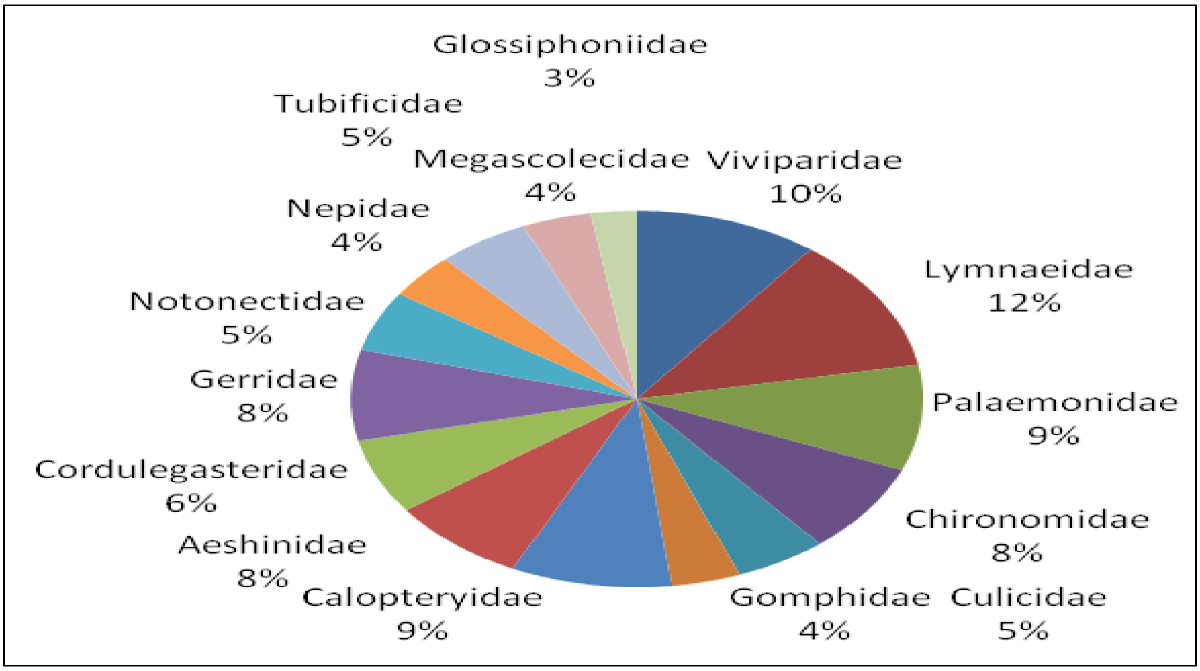

Fig. 15. Percent variation of macrobenthic communities at Station-4 during winter, 2016.

The catchment area of Kaliasote Dam where the present study was conducted is covered with natural vegetation on almost all sides of the Dam except at few places where few institutions have been established and new habitations have been established. The Dam receives most of its water as a discharge of Bhadbhada spill channel wherein excess water from Upper Lake flown into the reservoir during monsoon season. Other sources of water in this reservoir are from its catchment which is mostly consist of hillocks and undulating topography.

The micro and macro vegetation in the Dam are found mostly in patches and are more prominent in the south-western part and eastern part.This natural aquatic vegetation are mostly scattered at few places and also affected by the physico-chemical characteristic of the Dam (Table: 1).

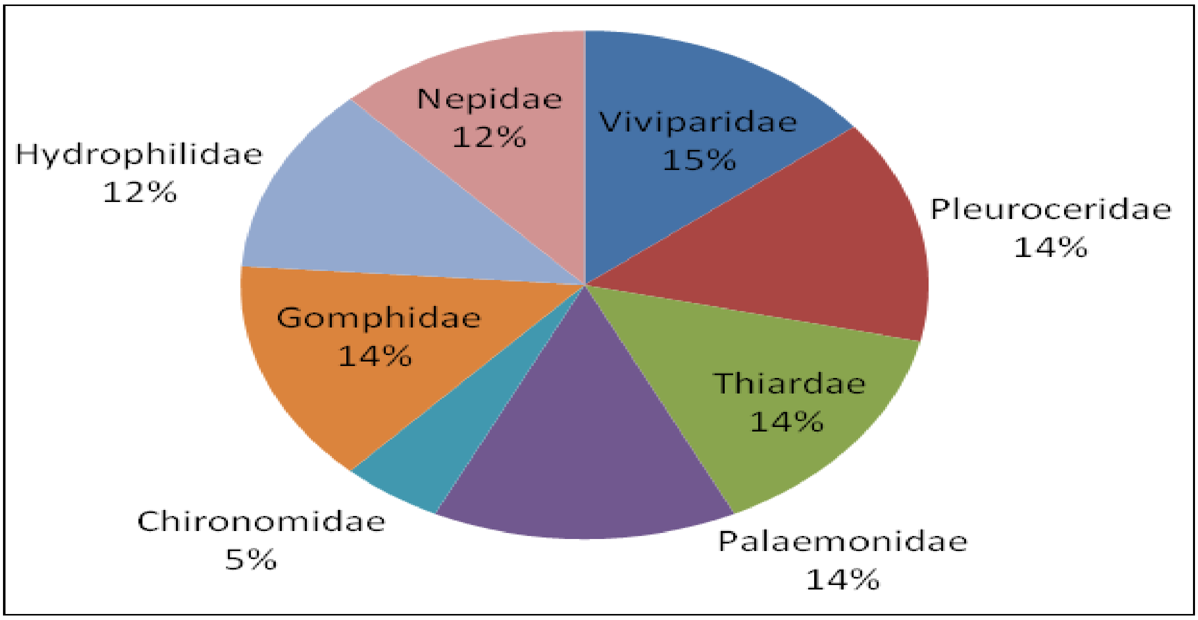

Fig. 16. Percent variation of macrobenthic communities at Station-5 during winter, 2016.

Due to accumulation of nutrients, at particular points the water quality of the dam has undergone considerable changes e.g. Station-1, Station-3 and Station-5. Further, addition of organic biomass due to religious activities like dumping of Idols, flowers from time to time resulted in decay of phytoplankton and zooplankton and other macro- vegetation which further resulted in the deterioration of water quality of the dam at these places. Observations recorded in the present studies revealed a strong interrelationship of the different physico-chemical and biological parameters. The physico-chemical characteristics of the dam regulated the changes in biological characteristics under the influence of various external (dumping of wastes, sewage inflow) and internal interventions (decomposition of autochthonous organic mass over the time). Thus the external factors have been observed to have direct influence ion physiochemical characteristics of the water and the impact of this has reflected on the ecosystem that showed remarkable changes in its macro zoo benthic communities (Bajpai *et al.,* 2001). In large water bodies these changes are usually recorded at sectoral places, which may not be uniform at all the places but its impact is visible in the water quality changes directly or indirectly. The conditional change due to external influence like the human intervention, inflow of sewage, agriculture waste inflow etc are the specific area concentrated problems which may be accounted as sewer impact on particular points and dissociated to affect the man water body in long run (Pani, 2017). This type of phenomenon has been reported in Kaliasote Dam in earlier studies (Choudhary and Rawtani. 2014). The accumulation of dead organic matter, its decomposition and dissociation of ions may be regulated with the mixing of water and subsided with the dilution factors. The impact of such activities may be observed when it is beyond the assimilative capacity of the water body and the concentration of one or the other parameters has upset the natural physiological activity of the ecosystem (Bhateria and Jain, 2016). However, in the Kaliasote Dam the selection of sampling points are based on the criterion to represent the observation recorded at different places related to the area specific activities and attempt has been made to compare different conditional changes at the selected sampling points and correlated these observations to know the status the water quality changes in seasonal, annual observations with the confirmation of observation from physico-chemical and biological parameters. During this period i.e. 2015-2017, on the basis of various physico-chemical and biological parameters, it can be concluded that the impacts observed on the Dam water are not an isolated incidence but is the characteristics of the water quality.

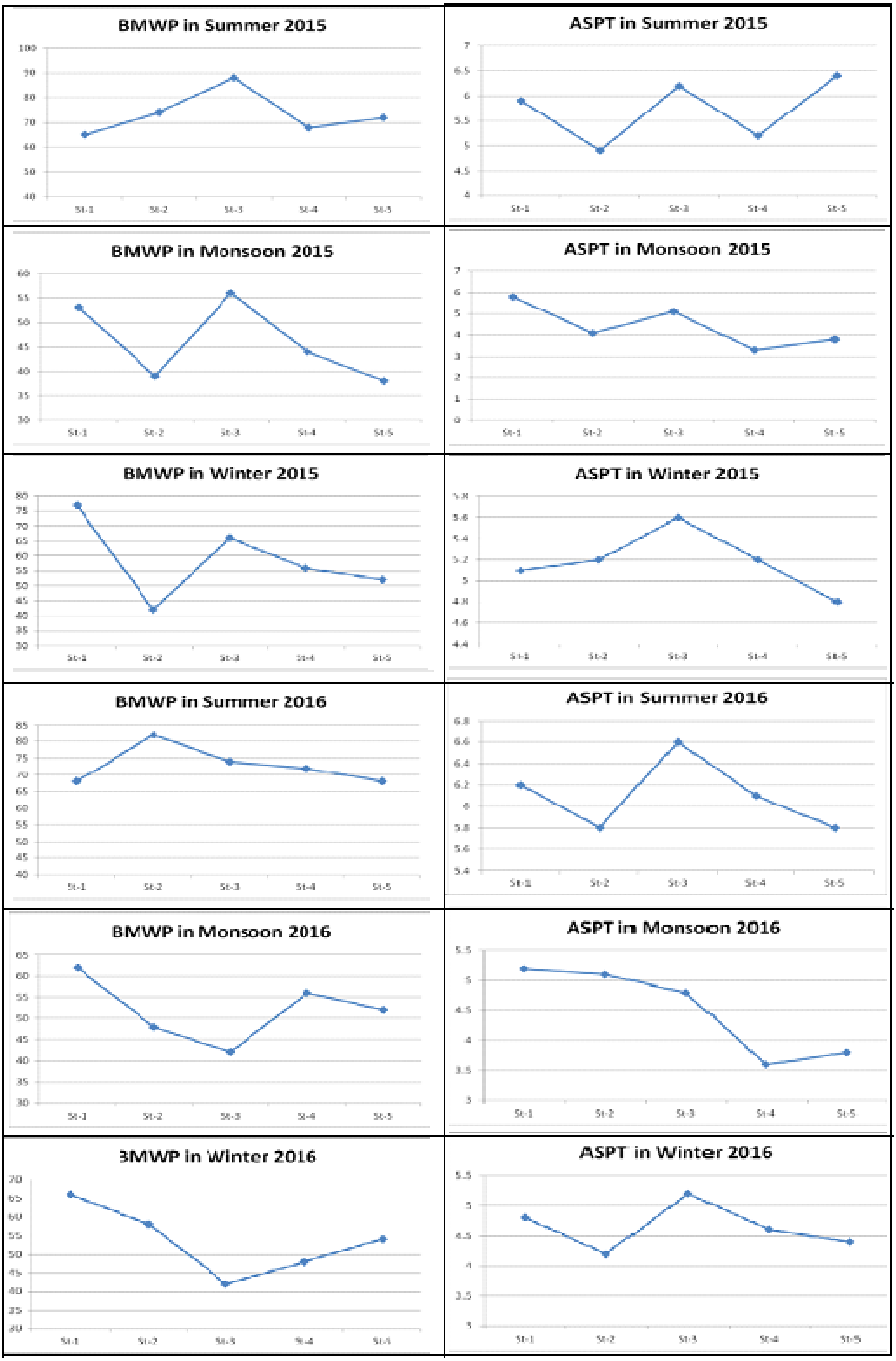

Fig. 17. Range of Saprobic Score (BMWP) & (ASPT) during different seasons of 2015-2017.

The compilation of data and its relevance with Dam ecosystem has been invariably confirmed with the available references of the different researchers also who have reported similar findings in their respective studies. During the period of investigation, apart from qualitative and quantitative analysis of macrobenthic community, the range of Saprobic Score (BMWP and ASPT) were also derived on the basis of seasonal data on macrobenthic parameters (Fig. 17) and values were compared with the index of Biological Water Quality Criteria Developed by Central Pollution Control Board (CPCB), GOI. Based on the observations Stations 1 to 5 have been categorized to define the water quality class of different regions of the Dam (Table-2). There has been a greater evidence of progressive deterioration of the water quality not only in India but also all over the world (Pani and Misra, 2005). While the natural factors like dust, storm, runoffs and weathering of minerals are slow process in causing eutrophication but modern civilization, industrialization and increase in pollution have lead to fast degradation of our fresh resources (Pandey *et al.,* 2010). With the increase in human population and their activities the self- purification power of water resources has diminished, leading to severe problems. In urban areas the situation is still worse where the water body is subject to much greater human pressure including direct discharge of sewage and industrial waste, which often contains heavy metals (Pani and Mishra, 2000).

Conclusions

The present investigation concludes that the water quality of the Kaliasote Dam is being deteriorated at several places due to various factors.

The concentration of BOD (1.2 mg/l to 12 mg/l) and COD (8 mg/l to 31 mg/l) reveals moderate degree of organic pollution at some intervals. All the water samples contain significant amount of nitrate and orthophosphate that provides nutrition for the growth and multiplication of microorganisms. In general on the basis of physical, chemical and macro zoo benthic study, study, the Dam water can be classified as moderately polluted water body (Table: 2).

Thus, by detailed analysis of data it can be concluded that the quality of water in general with respect to most of the parameters were observed to be well within permissible limits of class – C of Central Pollution Control Board (CPCB, New Delhi) under designated best uses of water for irrigation and drinking water after conventional treatment.

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