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Macro benthic community structure of artificially aerated Lake Naukuchiatal, India

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Abstract
Physico-chemical parameters of water, soil and macro benthic community of artificially aerated Lake Naukuchiatal, situated at an altitude of 1220 m asl was studied for 8 months from October 2017 to May 2018. Three sites viz., S1 (near pump house), S_2 (near lake resort) and S_3 (Chanauti) were selected on the basis of anthropogenic activities and fortnightly sampling was done. The important physico-chemical parameters of water *viz.* temperature, transparency, total dissolved solids, electrical conductivity, free carbon dioxide, pH, DO, total alkalinity, nitrate and phosphate were analyzed which varied from 15.05-22.25°C, 166-260.5cm , 77.2-117 mg L^{-1}, 165-230.10 µS cm^{-1} , 0-3.5 mg L^{-1}, 7.25-9.03, 1.52-11.13 mg L^{-1}, 82.5-115.85 mg L^{-1}, 0.11- 0.25 mg L^{-1} and 0.01- 0.13 mg L^{-1}, respectively. The soil parameters viz., texture, conductivity, pH, organic matter and organic carbon were analyzed and varied as- sand 20.08%, silt 32.15%, clay 47.78%, conductivity 282.5-373.5 µScm^{-1}, soil pH 7.65-8.55, organic matter 0.79-1.09 % and organic carbon 0.5-0.66%, respectively. Recorded macro benthic fauna comprised of Arthropoda, Annelida and Mollusca consisting 7 taxa belonging to order Oligochaeta, Diptera, Decapoda and Gastropoda. The population density of these varied between 368.35 and 521.95 ind.m^{-2}. The study concluded that the ecosystem of the Lake Naukuchiatal is better for aquatic organisms and is more diverse during November. The findings of the investigation is discussed further in detail.

Keywords: Macro benthos, community, anthropogenic, sampling, population density

Introduction
Macro benthic communities live on or in the bottom of the water body, are extremely diverse and represented by most of the phyla from protozoan to vertebrates. They also provide food material for economically important fish in aquatic environment where they are major secondary producers [1]. The diversity and abundance of benthic fauna are used in biomonitoring studies as these provide a more accurate understanding of transition in the aquatic ecosystems [2, 3]. They play an important role in the ecological processes occurring within the ecosystem and help in maintaining the water quality. A great role is played by them in nutrients cycling and controlling their outflow from ecosystems. Also macro benthic communities play an important role as connecting link in the food web and in purifying the polluted water. The water and soil quality of the water bodies have a strong effect on the diversity and distribution of macro benthos [4]. The benthos help in transforming organic matter from sedimentary storage into dissolved nutrients which can be dissolved into overlying waters and used by primary producers to enhance primary productivity.
Benthic species perform many important functions in the aquatic food web. They provide essential ecosystem services by accelerating decomposition of organic matters [5, 6]. The decomposed organic matter is one of the main sources of energy for benthic species in s water habitats [7]. Most of the benthic organisms are detritivores in the benthic zone. Their distribution and abundance is directly related to various environmental factors such as availability of food items, types of sediment, substrate, and quality of water. They also show spatial variation with depth, across habitats [8]. The significance role of macro benthos as biomonitoring tool is widely recognized because of their long life cycles, their limited mobility and differential sensitivity to various types of pollution**.** Due to their burrowing and feeding activities they regulate the physical, chemical and biological environment of the aquatic ecosystem and link the sediment to aquatic food web [9, 10].
Lake and their catchment areas are unique assets and valuable ecosystems of society and nature, which have social, cultural, and aesthetic value [11]. Lakes in hilly terrain are

considered as an extreme environment because they are small and sensitive ecosystems with rapid run off rates [12]. The present work has been done in the Lake Naukuchiatal where artificial aeration is going on to improve the quality of water. The lake Naukuchiatal or 'lake of nine corners' situated in district Nainital, is a famous lake of Kumaon region which attracts a lot of tourists. It is surrounded by hills and receives water from springs and through canal and has a catchment area of 1.03 km^2 with an average annual rainfall of approximately 2424 mm. The lake has 950.9 m length and 691.8 m breadth and a maximum depth of about 40.8 m. It is situated at $29^0 25'$ N latitude, $79^0 20'$ E longitude and an altitude of 1220 m above mean sea level, with surface area of 30.6 ha [13].

Materials and methods

The present study was carried out in Lake Naukuchiatal for a period of 8 months from October, 2017 to May, 2018. This study was focused on study of macro benthic community structure of artificially aerated Lake Naukuchiatal where aeration is going on since May, 2015 by 39 aeration discs at bottom of the whole lake connected to three compressors (13 discs by each compressor). It lays in Nainital district of state Uttarakhand at $29^0 19'$ N latitude, $79^0 37'$ E longitude and an altitude of 1220 m above mean sea level, with surface area of 30.6 ha which experience temperate weather in winter and semitropical weather in summer seasons. Three sampling sites viz. S1 (near pump house, the site of minimum disturbance), S_2 (near lake resort, the site of maximum disturbance) and S_3 (Chanauti, the site of major anthropogenic influence) situated about a distance of 200 m from each other, were selected for the regular sampling in the lake on the basis of anthropogenic influences**.** Fortnightly sampling was carried out for physico-chemical parameters of water, soil quality parameters and qualitative and quantitative analysis of benthos. The entire analysis was carried out in two steps viz. onsite analysis and lab analysis. On site analysis constituted the first step, which includes estimation of water temperature, transparency, total dissolved solids, electrical conductivity, pH, dissolved oxygen and free CO_2 while the second step constituted the estimation of phosphate, nitrate, alkalinity, important soil quality parameters (soil texture, soil pH, electrical conductivity, organic carbon, organic matter), and analysis of benthos which was carried out at the laboratory of Department of Aquatic Environment Management, College of Fisheries, G.B.P.U.A.&T, Pantnagar. All the water and soil quality parameters were estimated following standard methods [14], using standard equipments and adopting primary formulae.

Benthic organisms along with soil samples were collected from selected sites in sampling containers using Ekman's dredge. The organisms were identified and their density was calculated adopting procedure described by Pennak [15] and Tonapi [16]. To know the status of diversity of collected benthic species, different diversity indices *viz.* Margalef's index [17], Simpson's diversity index [18] and Shannon Wiener diversity index [19] were calculated.

The observed data of water and soil quality parameters were subjected to statistical analysis using computer programmes i.e. Microsoft office excel 2007 and SPSS 16.0.

Results and Discussion

The observation of physico- chemical characteristics of water, soil and distributional pattern of macro benthos taken from artificially aerated Lake Naukuchiatal during the investigation period from October, 2017 to May, 2018 is presented here in detail.

The water temperature was recorded at the surface and 32 m depth of all the three sites i.e. S_1, S_2 and S_3. During the investigation period, temperature varied from 15.05 to 22.25 °C. The lowest temperature value (15.05 °C) was observed in November at 32 m of site S_2, while the highest value (22.25 °C) was observed in the month of May at surface of site S_1. Low values of water temperature were observed from October, 2017 to January, 2018 and rising trend was seen from February to May 2018. Temperature is one of the important ecological factors, causing many direct and indirect effects that play a main role in its abiotic and biological behaviour [20].

Transparency is a characteristic of water that varies with the combined effect of colour and turbidity and measures the light penetration through the aquatic body. Wetzel [21] observed secchi depth range from a few centimeters in very turbid lakes to over 40 meters in the clearest known lakes. Transparency of Lake Naukuchiatal ranged between 152.5 to 266.0 cm during the study period. The maximum value (266.0 cm) of transparency was recorded in April at site S_2 while the minimum value was recorded in May at site S_1.

The concentration of total dissolved solids ranged from 77.20 to 117 mg L^{-1}. The highest value (117 mg L^{-1}) of TDS was recorded in month of May at site S_3 from the surface while lowest value (77.20 mg L^{-1}) was observed in month of October at 32 m depth of site S_2. The variation in the total dissolved solids is mainly due to the fluctuations in the ionic composition of water [22].

Electrical conductivity is a measurement of capability of water to transmit electric current in aquatic bodies. Most of salts in water are found in the ionic forms and capable of conduct electric current [23]. The mean value of electrical conductivity ranged from 165.11 to 230.10 µS cm^{-1}. The minimum value (165.11 µS cm^{-1}) of conductivity was recorded in May at site S_2 while the maximum value (230.10 µS cm^{-1}) was observed in October at site S_1 .The possible reason of higher value of EC at site S_1 may be due to increase in concentration of dissolved inorganic compounds which contributes to formation of ions [24]. Sinha *et al.* [25] investigated that the high values of electric conductivity indicate the presence of higher concentration of dissolved salts in the water.

In chemical parameters, the free CO_2 ranged between 0 to 3.5 mg L^{-1}. The highest value of free carbon dioxide was recorded during December at site S_2 from 32 m depth while it was absent in the months of February at site S_3, April and May at all three sites from surface. Dwivedi and Pandey [20] stated that the main source of CO_2 in water is decomposition of organic matter and respiration of animals which may influence the free CO_2 concentration.

The variation in water pH is governed by the amount of free carbon dioxide, carbonates and bicarbonates. These variations are accompanied by the changes in other physicochemical aspects that influence quality of water. pH of natural water usually lies in the range of 4.4 to 8.5 [26]. During the present investigation, pH varied from 7.25 to 9.03 with highest value (9.03) in May at site S_2 from the surface while lowest value in December at site S_2 from the surface. Fluctuations in pH affect metabolic and other physiological activities of aquatic fauna [27].

During the study period, the dissolved oxygen content of the lake in surface water varied from 1.52 to 11.13 mg L^{-1}. Wide

variation in dissolved oxygen content of water in lake might be due to dense growth of aquatic vegetation, high water depth and anthropogenic activities [28]. Jhingran [29] and Sharma [30] have observed that water temperature affects oxygen concentration in most of the water bodies.

Total alkalinity of natural water is due to the presence of salts of carbonates, bicarbonates, silicates, borates and phosphorus along with hydroxyl ions in free form. During the study period, alkalinity of Lake Naukuchiatal ranged from 82.5 to 115.85 mg L^{-1} with the highest value (115.85 mg L^{-1}) during May at site S_3 from 32 m depth while the lowest value (82.5mg L^{-1}) was observed during October at site S_2 from the surface. Alkalinity acts as a buffer against rapid pH change. Alkalinity is a measure of productivity of water and primary importance in the ecology of environment [31]. Alkalinity greater than 300 mg L^{-1} may be unproductive because of inadequate amount of carbon dioxide will be present at such high level [32].

Nitrate is contributed to fresh water through discharge of sewage, industrial wastes and runoff from the agricultural fields. In the present study, nitrate value ranged between 0.11 to 0.25 mg L^{-1} with maximum value (0.25 mg L^{-1}) during April at site S_3 from the surface while the minimum value (0.11 mg L^{-1}) during October and November at sites S_1, S_2 and S_3 from 32 m depth. Agricultural fertilizers, human and animal wastes are major sources of nitrates in lakes and reservoirs [33, 34].

Phosphorus is important to the growth of organisms and limits the primary productivity of water. The concentration of Phosphate-phosphorus in the Lake Naukuchiatal ranged between 0.01 and 0.13 mg L^{-1} during the study period with higher value (0.13 mg L^{-1}) during April at site S_3 from the surface while minimum value (0.01 mg L^{-1}) was observed during the month of November at site S_2 from 32m depth. The lower value of phosphate at 32 m depth may be due to enhanced oxidation and its consumption by primary producers.

Nature and properties of the parent material forming soil determine soil texture. Clay % in soil varied from 47.2 to 48 %. Silt varied between 32 and 32.6 %. Sand percent in soil recorded from 20 to 20.1 %. The textural class of soil was observed as clay silty loam under the selected sites of lake. Texture of soil influence the soil quality and unsuitable particle size may affect the physical and chemical properties of soil adversely required for producers' growth [35].

The value of electrical conductivity of soil ranged from 280 to 375 µS cm^{-1}. The highest value of electrical conductivity was recorded during March at site S_1 (375 µS cm^{-1}) while the lowest value was recorded in the month of October at site S_1 (280 µS cm^{-1}).

The soil pH of Lake Naukuchiatal showed marked variations from one site to another. During the present study, pH ranged from 7.5 to 8.5. The minimum value of pH (7.5) was observed in November at site S_1 while the maximum value (8.5) was observed during January, February and May. Chaudhari *et al.* [36] also found the soil pH varied from 6.33 to 8.34. The range of pH is comparable with the reports of Saravanakumar *et al.* [37] who have observed soil pH of mangroves of Kachchh between 6.9 to 8.45.

The organic matter of the aquatic soil ranged between 0.79-1.17%. The lowest value of organic matter was recorded in the month of November at site S1 (0.79 %) while the highest value (1.17%) was observed during January at site S2. The results of the present investigation differs from the earlier study of Agah *et al.* [38], who found the organic matter content of sediment of Strait of Hormoz in the range of 4.4 to 10%. The organic carbon of the aquatic soil ranged between 0.44 and 0.65 %. The lowest value of organic carbon was observed in the month of November at site S1 (0.44 %) while the highest value (0.65 %) was observed during February at site S_2 and S_3, respectively. According to Jhingran [39] the aquatic soils having low level of organic carbon (< 0.5 %) results into low productivity.

A total of 7 taxa of macrobenthic invertebrate comprising of Oligochaeta, Diptera, Decapoda, Mollusca were recorded from the lake during the eight month of study period. The population density of macro benthic invertebrates in Lake Naukuchiatal ranged between 368.35 ± 123.94 ind.m^{-2} and 521.95 ± 132.65 ind.m^{-2} (Table 1 and figure 1) during the study period. The observed values shows that the maximum population density of Oligochaeta (621.9 ind.m^{-2}) was found during the month of October while lowest (288.7 ind.m^{-2}) density was recorded in month of November. The maximum population density of Diptera, Decapoda and Mollusca was recorded as 688.6, 444.3, 584.9 ind.m^{-2} in the months of January, April and November. The minimum population density of these groups was 177.6, 133.3 and 288.6 ind.m^{-2} in the months of October and December. The disparity in the abundance of individuals indicates that temperature has a pronounced influence on their life cycle. The statistical analysis (One-way ANOVA) showed significant difference (p<0.05) in macro benthic invertebrate between groups.

Group wise percent composition of macrobenthic invertebrate

The observations on the group wise percent composition of macro benthic invertebrate fauna are illustrated in figure 2. Accordingly, the mean contribution by the Oligochaeta, Diptera, Decapoda and Mollusca to the total faunal composition was 26.65 %, 28.68 %, 16.15 % and 28.50 %, respectively. The density of macro benthic invertebrate community was lower during rainy condition in comparison to that of either summer or winter.

Biological indices

The macro benthic invertebrate fauna was analyzed for species diversity; species richness and evenness which showed great variations (table 2). The value of Simpson index (D) ranged between 0.133 to 0.171. The highest species diversity in terms of Simpson index was recorded during November & January while lowest species diversity was recorded during February. A lower value of D indicates higher biodiversity. The value of Shannon-Weiner index (H') ranged between 1.71 to 1.87. The value of Shannon-Weiner index was highest in November and minimum in February. Mishra [40] has found that Shanon and Simpson diversity indices of macro benthos in reservoirs were found lowest during summer and highest during the months of monsoon while in present study, the value of these indices were found highest during November & January and minimum during February. Species richness in terms of Margalef richness index ranged between 1.43 to 1.67. The Sheldon evenness index was ranged between 0.11 to 0.92. The value of Sheldon evenness index was maximum in the month of November and minimum in the month of October. Sheldon evenness index shows that Lake has more richness and evenness value in terms of macrobenthic fauna recorded during the present experiment. Ranson and Dorris [41] observed that there is high

correlation between macrobenthic diversity and conductivity. Similar observation was also recorded in the present study. Baattrup- Pederson Riis [42] recorded that decrease of benthic diversity in streams lead to decrease macrophytes diversity. The study of Varshney *et al.* [43] showed that there is less benthic diversity due to deprived quality of water sediment.

The present study reveals the current status of water quality and macrobenthos structure of artificially aerated lake Naukuchiatal. On the basis of examination of various observations on physico-chemical parameters of water and variation of macrobenthic community, it can be said that ecosystem of Lake Naukuchiatal is adequate for macrobenthos and other aquatic fauna.

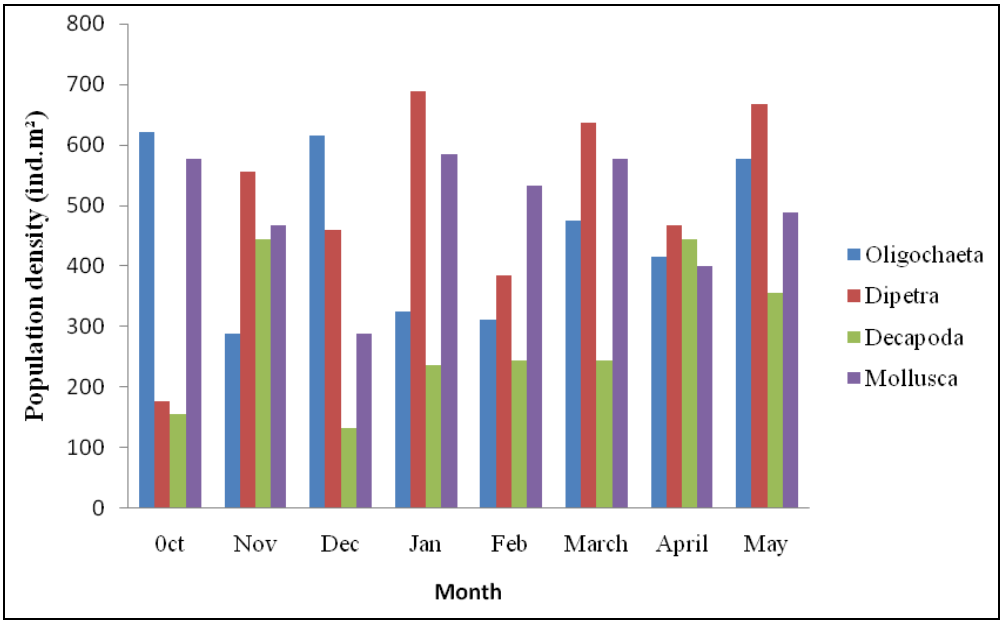
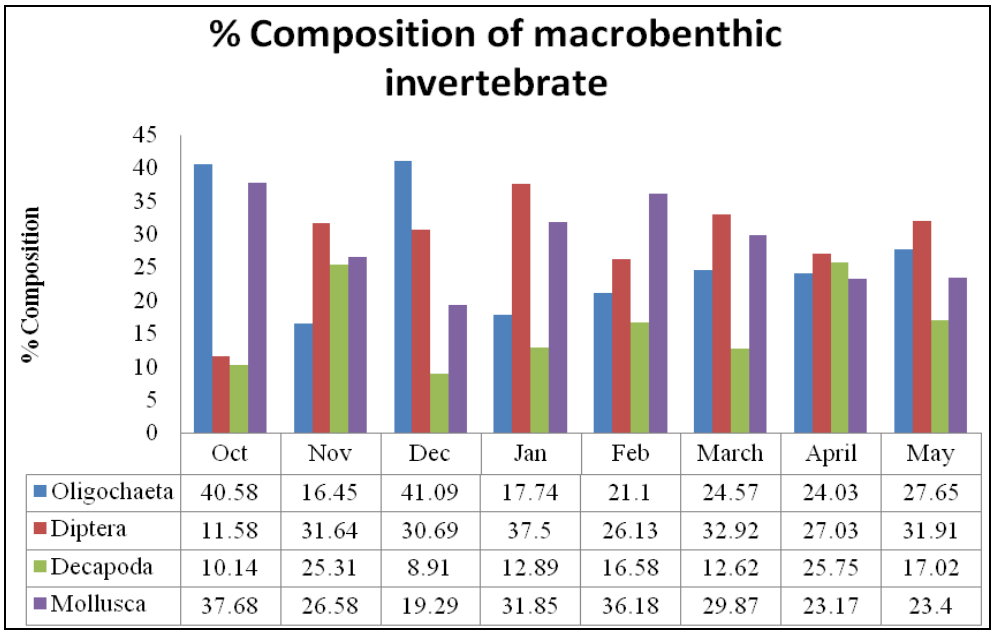


Fig 1: Population density of various group of macrobenthic invertebrate in Lake Naukuchiatal



	Oct	Nov	Dec	Jan	Feb	March	April	May
Oligochaeta	40.58	16.45	41.09	17.74	21.1	24.57	24.03	27.65
Diptera	11.58	31.64	30.69	37.5	26.13	32.92	27.03	31.91
Decapoda	10.14	25.31	8.91	12.89	16.58	12.62	25.75	17.02
Mollusca	37.68	26.58	19.29	31.85	36.18	29.87	23.17	23.4

Fig 2: % Composition of macrobenthic invertebrate in Lake Naukuchiatal

Table 1: Population density (Individuals / m^2) of various macrobenthic groups

Month	Oligochaeta	Diptera	Decapoda	Mollusca	Mean± sd
October	621.90	177.60	155.40	577.50	383.10± 250.93
November	288.70	555.40	444.30	466.50	438.73± 110.94
December	614.55	458.95	133.30	288.60	373.85± 208.41
January	325.75	688.60	236.85	584.90	459.03± 212.66
February	310.90	3850	244.40	533.10	368.35± 123.94
March	475.20	636.70	244.10	577.60	483.40± 172.92
April	414.60	466.40	444.30	399.80	431.28± 29.84
May	577.40	666.40	355.40	488.60	521.95± 132.65
Mean±sd	453.63±139.10	504.38±171.06	282.26±120.18	489.58±103.82	

Table 2: Values of diversity indices showing species diversity, richness at different months during the period of study

Month	Simpson diversity index	Shannon index	Sheldon evenness index	Margalef richness index
October	0.144	1.77	0.11	1.67
November	0.133	1.87	0.92	1.53
December	0.136	1.82	0.88	1.57
January	0.133	1.86	0.91	1.43
February	0.171	1.71	0.78	1.57
March	0.145	1.77	0.83	1.45
April	0.141	1.83	0.89	1.47
May	0.148	1.85	0.90	1.55

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