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Macro-Invertebrates (Annelida; Oligochaeta) As Bio-Indicator of Water Quality under Temperate Climatic Conditions

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ABSTRACT

The present research work deals with the distribution of benthic macro-invertebrates (Annelida; Oligochaeta) in relation to water quality of Anchar lake. The qualitative and quantitative analysis of benthic macro-invertebrates showed the presence of three species viz. Limnodrilus hoffmeister, Erpobdella octoculata and Glassophonia complanata in the lake. Among the three species Limnodrilus hoffmeister belonged to class Oligochaeta whereas Erpobdella octoculata and Glassophonia complanata belonged to class Hirudinea. The occurrence of these species in higher number is due to the presence of organic rich waters and entry of sewage, which favours growth of these worms. The distribution of these organisms is generally influenced by Nitrogen (NO_3 and NH_4) along with phosphorus. The distribution of Limnodrilus sp showed positive correlation with NO_3-N and NH_4.-N ($p \leq 0.05$, $r = 0.429$) and ($p \leq 0.05$, $r = 0.324$) respectively. This indicates that both N & P are important factor for abundance and presence of Limnodrilus hoffmeister, Erpobdella octoculata and Glassophonia complanata. Dissolved Oxygen and free CO_2 are also found to be an influential factor in affecting the distribution of Annelida especially Limnodrilus sp. Which showed strong negative correlation with dissolved oxygen ($p \leq 0.01$, $r = -0.770$) and strong positive correlation with free CO_2 ($p \leq 0.01$, $r = 0.741$). The study reveals that macro-invertebrates especially Oligochaetes can be used as indicator of water quality because they are found in lake with contaminated water quality.

Key words: *Anchar Lake, Macro-Invertebrate, Oligochaeta, Water Quality.*

INTRODUCTION

Aquatic habitats are known to support an extraordinary array of species, which is one of the most characteristic of the aquatic ecosystem for maintaining its stability and resilience. In an aquatic ecosystem, aquatic biota is closely dependent on the physical, chemical, and biological characteristic of water that directly act as a controlling factor[58]. Among them, benthic communities (macro-invertebrates) form an integral part of an aquatic ecosystem, as they form a major portion of the total biota in both lentic and lotic systems.

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They carry many functions by acting as grazers, collectors, shredders or predators[40].

What are benthic macro-invertebrates?

The benthic macro-invertebrates are associated with bottom that are retained by a sieve or mesh with pore size 0.2-0.5 mm which includes heterogeneous assemblages of organisms belonging to various phyla. In general, phylum annelids are elongated, bilaterally symmetrical and highly organised animals, in which the organs have grouped into definite system. Appearance of metamerism represents their greatest advancement, so they are called segmented worms. Mostly they are aquatic, some terrestrial, borrowing or tubicolous and some commensal and parasitic. Annelida are dived into four main classes Polychaeta (bristle worms), Oligochaeta (earthworms and relatives), Archiannelida (Cray fish and ectosymbionts) and Hirudinea (leeches), primarily on the basis of the presence or absence of parapodia, setae, metameres, and other morphological features.

Among these, Polychaeta are marine and carnivores (example, *Nereis*, *Arenicola*, etc), Oligochaeta are freshwater and terrestrial (example, *Pheretima*, *Tubifix*, *Lumbricus* etc), Archiannellida are exclusively marine (example, *Polygordius*, *Nerilla*, *Protodrillus*, *Dinophilus*) and hirudinea are fresh water and few are marine (example, *Leech*)[22].

Use of macro-invertebrates as bio-indicators:

According to Markert *et al*[30,31,32] a bio-indicator is, "an organism (or part of an organism or a community of organisms) that contains information on the quality of the environment (or a part of the environment)". An 'ideal' indicator at least should have the characteristics as follows: (a) taxonomic soundness (easy to be recognised by non-specialist); (b) wide or cosmopolitan distribution; (c) low mobility (local indication); (d) well-known ecological characteristics; (e) Numerical abundance; (f) suitability for laboratory experiments; (g) high sensitivity to environmental stressor (s); (h) high ability for quantification and standardization[33,35,45].

Bio-indicators include biological processes, species or communities and are used to assess the quality of the environment (anthropogenic or natural stressors) and how it changes over time[34]. Bio-indicators need to not only indicate the long-term interaction of several environmental conditions, but also react to a sudden change of the important factor (s). There are several alternations for indicators of bio-monitoring, however, benthic macro-invertebrates, periphytons and fishes are the most frequently utilized[26].

The usage of bio-indicators in estimation of environmental quality is not new concept since it was created more than 150 years ago. There is even a data that Oligochaete were mentioned for the first time in the context of water pollution indication by Aristotle (384-322 BC)[51]. This concept of evaluation of water quality based on organisms, marked as bio-indicators was mentioned firstly in the works of Kolenati[21]. These authors noticed that the organisms which populate polluted waters differed from those in clean waters.

Among the various biological indicators (such as algae, Periphyton, macrophytes, benthic-invertebrates and fish), benthic macro-invertebrates are the most commonly used biotic assemblages across the world[43, 45].

Oligochaetes are used in biodiversity studies, pollution surveys, and environmental assessment and have also economic importance[36,57] . In the muddy bottoms of lakes, oligochaete is generally one of the dominant components of the macro benthos. Oligochaeta, especially the tubificidae, has its capacity of increase in number with increasing organic matter, replacing other benthic macro-invertebrates[47]. According to Jumppanen[20] the first signs of Eutrophication and pollution in a lake are reflected in the benthic flora and fauna as the suspended waste immediately sink to the bottom to decompose and thus cause a change in benthic abundance.

Description of the Lake and Study Sites:

The present study was carried on a high-altitude Himalayan temperate water body, Anchar Lake. The lake is a shallow basined with fluviatile origin, situated near Soura 14 km to the north-west of Srinagar city at an altitude of 1585 m asl and lies within the geographical coordinates of 34°-20′ to 34°-26′ N latitude and 74°-82′ to 74°-85′ E longitude. The lake covers an area of 680 hectares, of peripheral areas have now turned marsh (Fig. 1). The progressive increase in phosphorus and nitrogen content of Anchar lake through inflow of wastewaters and anthropogenic activity in the catchment and within the lake has been found to be the main culprit in changing the trophic status of this water body[3].

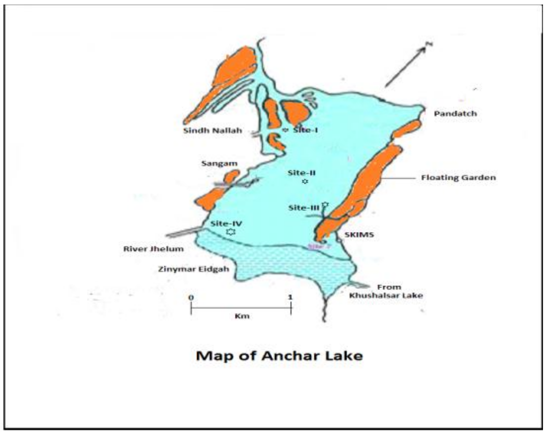

Fig. 1: Map showing Anchar Lake

Study Sites:

The brief descriptions of these sites are given below:

Site-1:- This site is situated on the western shore of the lake, where the Sind nallah enters into the lake. The site is located in the coordinates of 74.79° E Longitude and 34.2° N Latitude. The lake faces a heavy silt load from the inflowing Sindh Nallah. The siltation process has greatly affected the lake ecosystem, resulting in the formation of the extensive marsh land and shallowing which leads to the growth of diverse macrophytic vegetation which is dominated by *Phragmites australis, Typha angustata and Sparganium erectum*. The site has maximum water depth of 1.2 m.

Site-2:- This site is pelagic area situated almost in the centre of the lake. The site is located in the coordinates of 74.78° E Longitude and 34.149° N Latitude. The maximum water depth of the lake at this site is 2.2m which is maximum as compared to other sites. The site has occasional submerged vegetation growth.

Site-3:- This site is towards the north east region of the lake near SKIMS hospital. The site is located in the geographical coordinates of 74.795° E Longitude and 34.144° N Latitude. The site has maximum water depth of 0.9m and is occupied by emergent and submerged macrophytic vegetation like *Myriophyllum verticillatum*, *Potamogeton spp.* and small but stretched patches of Lotus (*Nelumbo nucifera*). At this site, the lake receives the effluents and sewage from the drainage system of the SKIMS and the adjacent areas.

Site-4:- This site lies near the outlet of the lake towards the Sangam village lying in the west. The site is located in the geographical coordinates of 74.801° E Longitude and 34.138° N Latitude. The site has maximum water depth of 1.2m. The water from this site finally flows into the river Jhelum.

Need for present study?

Lot of researches has been carried out on Anchar lake on water quality assessment, phytoplankton, zooplankton, fish and macro-benthos. However, after reviewing the literature it was observed that the distribution of benthic macro-invertebrate especially Annelida (oligochaeta) in relation to water quality is missing. Therefore, the present study was undertaken to know the distribution of Oligochaeta in Anchar lake, their relationship with water quality parameters and use of macro-invertebrates as indicator organisms.

MATERIAL AND METHODS

The sampling was done from December 2014 to November 2015. Water samples were collected in 1 litre plastic bottles from each sampling site. For dissolved oxygen, D.O bottles of 125 ml capacity were used and the fixation of samples was done in the field as per the Wrinkler's modified method. Air temperature, water temperature and pH were determined at the sampling spot and samples were immediately transported to the AEM laboratory, Faculty of Fisheries for further detailed analysis by using the standard methods as per A.P.H.A[6]and Adoni[4].

The benthic fauna encompassing annelids was collected from all four sites of the lake with an Ekman Dredge. The sediment samples collected were washed *in situ* and sieved through No. 40 (256 meshes/cm^2) for checking annelids. The macroscopic organisms were collected with the help of forceps and brushes and then preserved in 4% formalin. The samples were sorted under Stereo-microscope and preserved in 70% alcohol. The preserved annelids were identified by observing them under a stereo-microscope and identification was done with the help of standard taxonomical work of Adoni[4]. The abundance of these organisms was calculated as number per square meter by applying the following formula:

$$\text{Number of individuals/m}^2 = \frac{O \times 1000}{A \times S} \quad \text{(Welch, 1948)}$$

Where, O = No. of organisms counted.

A = Area of sampler in square meter (225 cm^2)

S = No. of samples taken at each station.

RESULTS AND DISCUSSION

Physico-chemical parameters

Air temperature:

During the present study, the overall mean air temperature was recorded 10±8.08 °C. The minimum air temperature of 3°C was recorded in winter and a maximum air temperature of 25.5°C in summer (Table 1). The lowest air temperature in winter season was due to short photoperiod, cold atmosphere while the highest air temperature during summer season was due to clear atmosphere and higher solar radiation. These results are in conformation with Sushil *et al*[50], Indresha and Patra[19] , Umer and Solanki[53] and Monisa and Balkhi[38] .

The air temperature has a significant positive correlation with water temperature ($p \leq 0.01$, r = 0.974) (Table 2). This is in confirmation with work of Chandrakiran *et al*[14], who also observed that the change in air temperature are closely proportional to the water temperature and hence, simultaneous measurement of both air and water temperature are important in determining the status of water body.

Table 1: The overall minimum, maximum and Mean and standard deviation of physico-chemical characteristics of water of Anchar Lake during the study period

S. No.	Parameter	Minimum	Maximum	Mean±SD
1	Air temperature (°C)	3	25.5	10.82±8.08
2	Water temperature (°C)	1.6	12.5	5.975±3.69
3	Maximum depth (m)	0.6	2.2	1.3±0.52
4	Transparency (m)	0.19	0.75	0.48±0.23
5	pH	6.9	8	7.51±0.31
6	Dissolved oxygen (mg/l)	4	8.5	6.69±1.48
7	Free CO_2 (mg/l)	6.5	21	12.76±3.79
8	Total alkalinity (mg/l)	98	197	151±26.28
9	Nitrate nitrogen (µg/l)	260	690	468.5±115.96
10	Ammonical nitrogen (µg/l)	100	292	171.04±54.28
11	Orthophosphate (µg/l)	110	285	166.21±60.94
12	Total phosphorus(µg/l)	301	655	416.5±137.89

Water temperature:

The present data showed fluctuations in the water temperature which are more are less concomitant with those of atmospheric temperature. Such a pattern of fluctuation has also been recorded by Yousuf[59]. The overall mean value of water temperature was found to be 5.97±3.69 °C. The maximum water temperature of 12.5°C was recorded during the summer season and the minimum water temperature of 1.6 °C during the winter season. (Table1). The highest water temperature in summer season was due to high solar radiations and clear atmosphere while as the lowest temperature was due to high water level, less solar radiation and low atmospheric temperature. These results are in conformation with Ahanger *et al*[5] who said that water temperature increase during warmer months and decrease during colder months and it plays an important role in governing the water quality.

The water temperature has a significant positive correlation with CO_2 ($p \leq 0.01$, r = 0.557), transparency ($p \leq 0.05$, r= 0.851) (Table 2).

Depth:

During the present study, the mean depth of lake was found to be 1.3±0.52 m. The minimum depth of 0.6 m was recorded at SKIMS (Site-III) which is due to erosion from nearby catchment resulting in accumulation of sediment and dumping waste material from the adjacent area. Maximum depth of 2.2 m was recorded at the centre which is least effected by sedimentation as it is not directly impacted by the inflowing water from Sindh nallah. Pandit[39] , Bhat *et al*[11] and Sushil *et al*[50], in their studies they have observed that the depth of water is dependent on the volume of water column, discharge rate of inflow and the amount of precipitation received in the form of rain and other anthropogenic activities.

During the present investigation, the depth has a significant positive correlation with Transparency ($p \leq 0.01$, r=0.757) (Table 2) which is in conformation with Monisa[38] who also recorded the positive correlation between depth and transparency at different basins of Dal lake.

Transparency:

Transparency is one of the important physical properties of water, indicative of the degree to which sunlight can penetrate through water. During the present study, the mean transparency was (0.48±0.23 m). The higher transparency value of 0.75 m was observed at the centre in winter, which may be due to low organic matter production with poor planktonic growth, while lowest transparency value of 0.20 m (Table 1) was observed at SKIMS (Site-III) in summer season, which may be due to the inflow of sewage. The results are in agreement with Ahangar *et al*[5], Bhat *et al*[11] and Sushil *et al*[50]. They observed that maximum transparency of the Anchar lake was due to the settlement of sand, silt and clay during winter while minimum transparency was due to bloom of planktonic algae.

In the present study transparency recorded significant positive correlation with dissolved oxygen ($p \leq 0.01$, r= 723) (Table 2). Bhat *et al*[10], also recorded the significant positive correlation between transparency and dissolved oxygen in Anchar lake.

pH:

pH is the measure of acidity or alkalinity of water; hence it is an important factor for water quality analysis. During the present study, the overall mean pH was found to be (7.51±0.31) (Table 1) depicting an alkaline nature of Anchar Lake. During the present investigation, the pH ranged from 6.9 to 8.0. Minimum pH was found during the summer season at the SKIMS (Site-III), while maximum pH was found during winter season at inlet (Site-I). The fluctuation in pH has been related to photosynthetic activities and also with dissolved oxygen by many workers[1,23,55].

The pH recorded a significant Negative correlation with CO_2 ($p \leq 0.01$, r= -0.797) and NH_4-N ($p \leq 0.01$, r= -0.634) while as significant positive correlation with dissolved oxygen ($p \leq 0.01$, r=0.850) (Table 2).

Table 2: The correlation between various physico-chemical parameters of Anchar lake

	1	2	3	4	5	6	7	8	9	10	11
2	0.974**										
3	-0.121	-0.095									
4	-0.42	0.000	0.757**								
5	-0.365	-0.365	0.420*	0.377							
6	-0.298	-0.311	0.502*	0.360	0.850**						
7	0.555**	0.557**	-0.298	-0.287	-0.797**	-0.701**					
8	-0.438*	0.497**	0.449*	-0.528**	-0.178	-0.442*	0.010				
9	-0.169	0.187	0.673**	-0.656**	-0.608**	-0.727**	0.363	0.727**			
10	-0.209	-0.190	0.408*	0.494*	-0.634**	-0.687**	0.473*	0.592**	0.871**		
11	0.083	0.064	0.508*	-0.620**	-0.791**	-0.807**	0.706**	0.578**	0.82**	0.871**	
12	-0.036	-0.072	0.537**	-0.689**	-0.723**	0.786**	0.583**	0.672**	0.855**	0.834	0.916**

** Correlation is significant at the 0.01 level

* Correlation is significant at 0.05 level

1=Air temperature, 2=Water temperature, 3=Depth, 4=Transparency, 5=pH, 6=Dissolved oxygen, 7=Free carbon dioxide, 8=Total alkalinity, 9=Nitrate nitrogen, 10=Ammonical nitrogen, 11= Orthophosphate, 12= Total phosphorus.

Dissolved oxygen:

Dissolved oxygen is one of the most important parameter is assessing the quality of water, which is essential to maintain biotic forms in water. During the present study, the overall mean dissolved oxygen was (6.69±1.48 mg/L). The range of dissolved oxygen was (4 mg/L to 8.5 mg/L) (Table 1). The lower value of dissolved oxygen, was recorded at SKIMS (Site-III), during summer season, was due to increased amount of organic matter and agricultural runoff. The organic matter gets decomposed at faster rate at higher temperature thereby reducing oxygen level of water. Higher dissolved oxygen was recorded in winter which is as a result of increased solubility of oxygen at lower temperature. Yousuf and Shah[60], Bhat *et al*[11] also opined that, the lowest value of dissolved oxygen during summer in Anchar lake due to increased amount of organic matter and sewage which consumes dissolved oxygen for decomposition.

Dissolved oxygen in the present study showed a significant negative correlation with free CO_2 ($p \leq 0.01$, r= -0.701) (Table 2), which means that with the increase in dissolved oxygen content CO_2 content decreases.

Free CO_2:

During the present study, the mean free CO_2 in was found to be (12.76±3.79 mg/L). The range of free CO_2 concentration was found to be (6.5mg/L to 12 mg/L) (Table 1). The minimum value of free CO_2 was recorded at the inlet may be due to decrease in temperature by entering the fresh water from Sindh nallah, which subsequently increase the oxygen holding capacity of water, while as the maximum free CO_2 was recorded at SKIMS site may be due to entry of sewage and also due to decomposition of organic waste which increase the free CO_2 concentration. These result are in conformation of Ahanghar *et al*[5], who also revealed that CO_2 liberated during respiration and decay of organic matter depends upon the water temperature, depth rate of respiration, decomposition of organic matter and chemical nature of bottom, which also holds true during the present investigation.

The free CO_2 recorded the significant negative correlation with pH (($p \leq 0.01$, r= -0.797) and dissolved oxygen ($p \leq 0.01$, r= -0.701) (Table 2). Similar results have been observed by Bhat *et al*[10], during his study.

Total alkalinity:

Alkalinity is a measure of buffering capacity of water and is important for aquatic life in a fresh water system. During the present study, overall, mean alkalinity was (151±26.28 mg/L) (Table 1). The range of alkalinity was found to be (98 mg/L to 197 mg/L). The lower value of alkalinity was found during Summer at the centre (Site-I), which may be attributed to the decrease in bicarbonate ions and dissolution of calcium carbonate ions in water column, while as the higher alkalinity was found at the SKIMS (Site-III) during the winter. Umer and Solanki[53], also observed the higher alkalinity during winter months and said that the accumulation of organic matters produced by decomposition of vegetation which in turn, added carbonate and bicarbonate in the lake.

Nitrate nitrogen (NO_3-N):

Nitrates are the essential nutrients for photosynthetic autotrophs and in some cases, have been identified as the growth limiting nutrient. During the present study, overall mean nitrate nitrogen was (468. ±115.96 µg/L). The range of nitrate nitrogen was found to be (260 µg/L to 690 µg/L) the minimum concentration was recorded at the centre, while as the maximum concentration was observed at the SKIMS site during the summer months which could be due to entry of large amount of domestic sewage and decaying of organic matter. Abubakr and Kundangar[2] also reported the progressive increase in nitrogen and phosphorus in lakes and attributed it to sewage contamination while studying the changing biodiversity of seven lakes of Kashmir. They also attributed the progressive increase of phosphorus and nitrogen in Anchar and Manasbal lake the main culprit in in changing the trophic status of lake.

Ammonical nitrogen (NH_4-N):

In the present study, the mean concentration of ammonical nitrogen was recorded as (17.04±54.28 µg/L) and the range of ammonical nitrogen was found to be (100 µg/L to 292µg/L) (Table 1). The highest value was recorded during the spring season near the SKIMS (Site-III) which might be due to the entry of domestic sewage, use of nitrogenous fertilizers in nearby agricultural fields, while lower value was recorded during winter. The result is agreement with Sushil *et al*[50]. who also reported the higher concentration of ammonia in Anchar lake and attributed it due to organic pollution and agricultural wastes. Wetzel[57] also attributed that high level of ammonia in the lakes may be its release from the sediments under low oxygen level at which nitrification of ammonia ceases and the absorptive capacity of the sediments is reduced.

Ammonical nitrogen recorded a significant positive correlation with free co_2 ($p \leq 0.05$, r = 0.473), while as significant negative correlation with dissolved oxygen ($p \leq 0.01$, r = - 0.687) and pH ($p \leq 0.05$, r = - 0.634) (Table 2)

Orthophosphate (PO_4-P):

Phosphorus is an essential element for fertility of lakes and is regarded as key nutrient in the productivity of waters. During the present study, the overall mean orthophosphate was (166.21±60.94 µg/L) and the range was found to be 110 to 285 µg/L (Table 1). The low orthophosphate content was found at the inlet site during the winter, it may be due to inflow of fresh water from Sindh nallah and higher dissolves oxygen and pH, while as the higher value was found in summer at the SKIMS site, which may be due to the influx of sewage, agricultural runoff probably contaminated with phosphate (applied as fertilizer). Herney *et al*[18]. (reported higher value of phosphate during warmer season due to rapid evaporation and mineralization of decomposed materials in water.

Total phosphorus (TP):

Presence of phosphorus in excess of 30 µg/L in water bodies is regarded as a major nutrient triggering eutrophication Welch[56]. During the present study, the mean total phosphorus was (416±137.89 µg/L) and the range was found to be (301 to 655µg/L) (Table 1). The minimum valve of total phosphorus was found during colder months at the outlet of the lake, while higher value was found in summer at the SKIMS site, which may be due to the influx of sewage, agricultural runoff probably contaminated with phosphate (applied as fertilizer) rapid evaporation and other effluents. The result is in complete agreement with Herney *et al*[18] and Abubakr and Kundangar[2] who related increase in nitrogen and to sewage contamination.

Total phosphorus has a significant positive correlation with free co_2 ($p \leq 0.01$, r=0.583) and orthophosphate ($p \leq 0.01$, r=0.916) (Table 19), while as significant negative correlation with dissolved oxygen ($p \leq 0.01$, r=0.786) and pH ($p \leq 0.01$, r=0.723) (Table 2).

Benthic macro-invertebrates (Annelida):

During the present study, a total of three species representing the phylum Annelida were recorded from Anchar lake. Three species are *Limnodrilus hoffmeister, Erpobdella octoculata and Glassophonia complanata.* One species (*Limnodrilus hoffmeister*) belonged to class Oligochaeta while two species (*Erpobdella octoculata* and *Glassophonia complanata*) belonged to class Hirudinea.

The percentage contribution of *Limnodrilus hoffmeister* was (47, 23, 18 and 12%) at Site-3, Site-4, Site-2, Site-1, respectively followed by *Erpobdella octoculata* (42, 19, 14 and 25%) at Site-3, Site-4, Site-2, Site-1, respectively and *Glassophonia complanata* (46, 17, 16 and 21%) at Site-3, Site-4, Site-2, Site-1, respectively (Fig. 1).

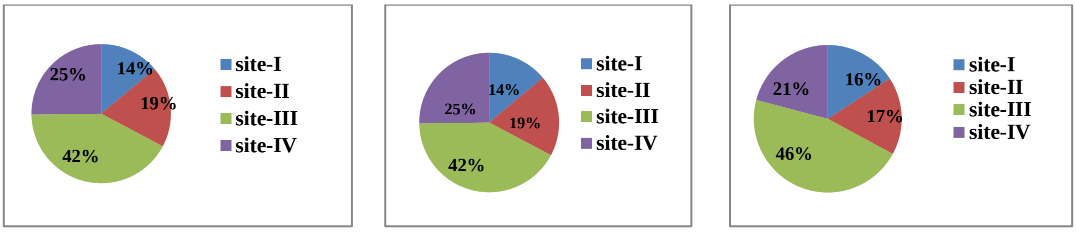

Fig. 1: Percentage composition of *Limnodrilus hoffmeister, Erpobdella octoculata* and *Glassophonia complanata* at four site of Anchar lake

The maximum percentage of *Limnodrilus hoffmeister* at all the study sites can be used as an index to verify the level of organic pollution. These results are in agreement with the work of Verdonschot[54] and Marchese and Ezcurru de Drago[29] .

The highest mean population density of *Limnodrilus hoffmeister, Erpobdella octoculata, Erpobdella octoculata* was 611.5± 308.27 Ind./m^2, 537.5± 289.36 Ind./m^2, 541.33± 223.52 Ind./m^2 respectively at the site 3 (SKIMS), while lowest population density of *Limnodrilus hoffmeister, Erpobdella octoculata, Erpobdella octoculata* was 163.33±117.38 Ind./m^2, 178.17±96.13 Ind./m^2, 185.67± 99.06 Ind./m^2 respectively at the site1 (inlet).

The higher density at site 3, is due to the organic enrichment of bottom sediments by direct discharge of domestic and agricultural sewage rich in nutrients. Moreover, presence of silt and detritus in the sediment favours the presence of these organisms in high number. Qadri and Yousuf[41] also reported the presence of Oligocheates in high number in Nigeen lake and concluded that organism prefer the lake areas with silty and sandy substrate. Stephan and Alves[49] concluded that the high densities of *Limnodrilus* suggest high amount of food availability (organic matter) together with rare opportunities for biotic interactions such as predation and competition. They are consequences of water pollution which may play an important role in the fitness of such genus.

Lowest density at inflow site (1) is due to the entry of water from Sindh Nallah which brings fresh and cold water from snowmelt glaciers having high dissolved oxygen and low organic matter and detritus.

The above statement/s is also confirmed statistically during the present study as *Limnodrilus, Erpobdella,* and *Glassophonia* recorded strong negative correlation with dissolved oxygen ($p \leq 0.01$, r= - 0.770, - 0.704, - 0.795) and positive correlation with NO_3-N ($p \leq 0.05$, r= 0.429, 0.406, 0.460), NH_4-N ($p \leq 0.05$, r= 0.324, 0.403, 0.403), PO_4-P ($p \leq 0.01$, r= 0.608, 0.586, 0.693) and TP ($p \leq 0.05$, r= 0.506, 0.456, 0.604) respectively (Table 3).

The positive correlation between these three species especially *Limnodrilus hoffmeister* with NO_3-N, NH_4-N, PO_4-P and TP indicate that these species can tolerate the increased concentration of organic substances. Hence, these species can be considered as indicators of water pollution / reduced water quality[17,24]. Yap et al[40] also reported positive correlation between *Limnodrilus* and NO_3-N, NH_4-N and temperature while negative correlation was recorded with pH and D.O. thereby, indicating that temperature along with nitrate and ammonia are the influential factors affecting positively the density and distribution of this species. The same hold true for the present work.

Table 3: Pearson's correlation coefficient of three species of Annelida and selected physico-chemical parameters of Anchar lake

S. No.	Parameters	Species		
		Limnodrilus	*Erpobdella*	*Glasophonia*
1	Air temperature	0.750**	0.675**	0.680**
2	Water temperature	0.715**	0.710**	0.664**
3	Depth	-0.412*	-0.413*	-0.387*
4	Transparency	-0.303	-0.232	-0.409
5	pH	-0.691**	-0.653**	-0.756**
6	Dissolved Oxygen	-0.770**	-0.704**	-0.795**
7	Free CO_2	0.741**	0.750**	0.764**
8	Total alkalinity	0.097	0.003	0.47
9	Nitrate nitrogen	0.429*	0.406*	0.460*
10	Ammonical nitrogen	0.324*	0.403*	0.403*
11	Ortho phosphate	0.608**	0.586**	0.693**
12	Total phosphorus	0.506*	0.456*	0.604**

**Correlation is significant at the 0.01 level and *. Correlation is significant at the 0.05 level.

During the present study *Limnodrilus hoffmeister* recorded highest density at most polluted site 3, while lowest density was recorded at relatively cleaner site 1, indicating the species as site specific preferring polluted site, as such being tolerant to the pollution. Our results are substantiated with the results of Verdonschot[54], who also reported *Limnodrilus hoffmeister* to be tolerant to pollution. Studies on oligochaete species in the Scandinavian lakes based on the degree of enrichment indicate that *Limnodrilus hoffmeister* belongs to species tolerating extreme enrichment of organic pollution[44]. According to Brinkhurst[13] and Chowdhary *et al*[15] oligochaetes are more encountered in grossly polluted and organically enriched water bodies with low dissolved oxygen, the same results have been found in our study.

Since members of the genus *Limnodrilus* are considered as one of the most tolerant oligochate among Annelids, especially to organic pollution[13,25,37] , its continuous presence in Anchar lake indicate existence of high degree of organic pollution. It should be noted that classification of some aquatic species like *Limnodrilus* from the St. Lawrence Great lakes has placed the lake in eutrophic level[44].

It can therefore be concluded, that the density and distribution of *Limnodrilus hoffmeister* in Anchar lake at all the sampling sites is directly related to the presence of biologically important nutrients (N & P) and organic load. The presence of oligochaete species *Limnodrilus hoffmeister* indicates that this species is tolerant to eutrophic / polluted conditions. Thus, *Limnodrilus hoffmeister* can be used as good bio-indicator of polluted ecosystem/s under temperate climatic conditions.

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