Distribution of Benthic Macro-invertebrates (Annelida; Oligochaeta) in Relation to Water Quality of Anchar Lake

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Thesis

Submitted to

Faculty of Fisheries

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in partial fulfilment of requirement for the award of the degree of

Master of Fisheries Science
(Fisheries Resource Management)

2017

Dedicated

To my

Parents

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Faculty of Fisheries, Rangil, Ganderbal

Certificate – I

This is to certify that the thesis entitled, **“Distribution of Benthic Macro-invertebrates (Annelida; Oligochaeta) in Relation to Water Quality of Anchar Lak”** submitted in partial fulfilment of the requirements for the award of the degree of **Master of Fisheries Science (Fisheries Resource Management)**, to the **Faculty of Fisheries, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir** is a record of bonafide research work carried out by **Mr. Altaf Ahmad Gojar (Regd. No. 2013-F-24-M)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that information received during the course of investigation has duly been acknowledged.

(Dr. Adnan Abubakr)
Chairman
Advisory Committee

Endorsed

Dean,
Faculty of Fisheries

Sher-e-Kashmir
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We, the members of the Advisory Committee of **Mr. Altaf Ahmad Gojar (Regd. No. 2013-F-24-M)**, a candidate for the degree of **Masters in Fisheries Resource Management** have gone through the manuscript of the thesis entitled, **"Distribution of Benthic Macro-invertebrates (Annelida; Oligochaeta) in Relation to Water Quality of Anchar Lake"** and recommend that it may be submitted by the student in partial fulfilment of the requirements for the award of the degree.

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Certificate – III

This is to certify that the thesis entitled, **"Distribution of Benthic Macro-invertebrates (Annelida; Oligochaeta) in Relation to Water Quality of Anchar Lake"** submitted by **Mr. Altaf Ahmad Gojar (Regd. No. 2013-F-24-M)** to the **Faculty of Fisheries, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir** in partial fulfilment of the requirements for the award of the degree of **Master of Fisheries Science (Fisheries Resource Management)** was examined and approved by the Advisory Committee and External Examiner on …………….

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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 also due to entry of sewage which favours growth of these worms. The worm distribution is generally influenced by NO_3 and NH_4. These two nutrients along with phosphorus seems important parameter for the distribution of Oligochaetes. 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. This is further validated by *Limnodrilus* sp. showing 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 Oligochaetes can be used as indicator of water quality because they are found in poor quality of lake.

Keywords: Anchar lake, Benthic Macro-Invertebrate; Annelida; Oligochaeta; Water quality.

Signature of Student　　　　　　　　Signature of Major Advisor

Dated____________　　　　　　　　Dated __________________

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INTRODUCTION

Water is one of the most common, yet the most precious, resource on earth. Due to tremendous development of industry and agriculture, the aquatic ecosystems have become perceptibly altered and as such they are exposed to all local disturbances regardless of where they occur (Ventakesan, 2007). The health of the lake ecosystems and their biological diversity are directly related to health of almost every component of the ecosystem (Ramesh *et al.*, 2007).

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. The macro-invertebrates have been found as the most common faunal assemblage for bio-assessment and provide most reliable information of long term ecological changes in the quality of aquatic ecosystems changing (Sing and Sharma, 2014). The macro-benthic community was found to be influenced by the type of substrate, the organic matter, the abundance of macrophytes as well as the concentration of calcium (Qadri and Yousuf, 2004). Macro-invertebrate distribution and community is strongly depend on the composition and structure of vegetation and are recognised as an essential food source for fish and amphibian in aquatic system (Tekhelmayun and Gupta, 2011). 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 (Rosenberg and Resh, 1993; Resh, 2008).

Benthic communities are integral part of an aquatic ecosystem as they form a major portion of the total biota in both lotic and lentic ecosystems. They carry on many functions by acting as grazers, collectors, shredders or predators within a stream **(**Wallace and Webster, 1996, Lobinske *et al.*, 1997 and Pearson, 2006). Benthic macro-invertebrates spend at least a part of their lifecycle at the bottom substrate in water bodies (Pamplin *et al*, 2006). The assemblage includes a wide range of organisms like polychaeta and oligochaeta (Annelida), bivalves and gastropods (Mollusca), and crustaceans and insect (Arthropoda), which form different levels of the food web in aquatic ecosystem (Tagliapietra and Marco, 2010). The distribution of macrozoobenthos is largely regulated by local habitat and regional variables in addition to the environmental factors (Johnson, 2003; Margaret *et al.*, 2005 and Zenker, 2009).

In an aquatic ecosystem the life of aquatic biota is closely dependent on the physical, chemical, and biological characteristic of water that directly act as a controlling factor (Yaqoob and Pandit, 2009). Thus as the abundance of benthic fauna mainly depends on the physical and chemical properties of the substratum, the benthic communities are known to respond to the changes in the quality of water.

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 a heterogeneous assemblages of organisms belonging to various phyla. The benthos occupies an important position in the lake ecosystem, serving as a link between primary producers, decomposers, and higher trophic levels (Pandit, 1980). The importance of macro-invertebrate as bio-assessment tool is widely recognised because of their limited mobility, comparatively long life cycle and differential sensitivity to pollution of various types. The benthic-invertebrates make ideal subject for biological assessment of water quality (Hynes, 1970).

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. They are dived into four main classes Polychaeta (bristleworms), 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. A total of 8700 known species are present in marine, fresh water and terrestrial environment. Among the four classes of Annelida, 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) (Kotpal, 2016).

Oligochaetes have a worldwide distribution, being frequently the most abundant benthic organism in fresh water ecosystem; many species are cosmopolitan (Brinkhurst and Jamieson, 1971). They are used in biodiversity studies, pollution surveys, and environmental assessment and have also economic importance (Mason, 1996; Wetzel *et al.,* 2000). In the muddy bottoms of lakes, oligochaete is generally one of the dominant components of the macro benthos, as is chironomid larvae. Oligochaeta, especially the tubificidae, has its capacity of increase in number with increasing organic matter, replacing other benthic macro-invertebrates (Schenkora and Helesic, 2006). According to Jumppanen (1996) 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 study area

The Anchar lake is a shallow basined lake with fluviatile origin, situated near Soura 14 km to the north-west of Srinagar city at an altitude of 1585 msl and lies within the geographical coordinates of 34^{o}-20′ to 34^{o}-26′ N latitude and 74^{o}-82′ to 74^{o}-85′ E longitude in a semi urban conditions (Angher *et al.,* 2012) The lake is sprawled over an area along east side of Srinagar to Gandarbal road. The Anchar lake is considered an example of ecologically sick lake, mostly infested with weeds. On the eastern bank major portion of peripheral areas has been encroached by the local population. They have filled a large area within the lake and changed into vegetable gardens. The lake is a single basined, open drainage type water body fed by Sind nallah and numerous small channels. Anchar lake also receives water from Dal Lake through a channel named Amir Khan via Khushalsar lake which in turn connected with the Nigeen lake. The lake is also fed by the springs in and along the periphery. Further a number of channels from agriculture fields, effluents from settlements and surface runoff from catchment area, directly drain into it throughout the year. The lake outfalls into river Jhelum at Sangam on its north east direction. The lake cover an area of 680 hectares half of which has now become marshland (Fig. 1).

The progressive increase in phosphorus and nitrogen content of Anchar lake through inflow of wastewaters and anthropogenic activity in the catchement and within the lake has been found to be the main culprit in changing the trophic status of this water body (Abubakr *et al.*, 2014).

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 and their relationship with water quality parameters.

The objectives of the present study were:

1. To study the water quality parameters of Anchar lake. The following physico-chemical parameters were assessed during the present study.
    - Air temperature
    - Water temperature
    - Depth
    - Transparency
    - pH

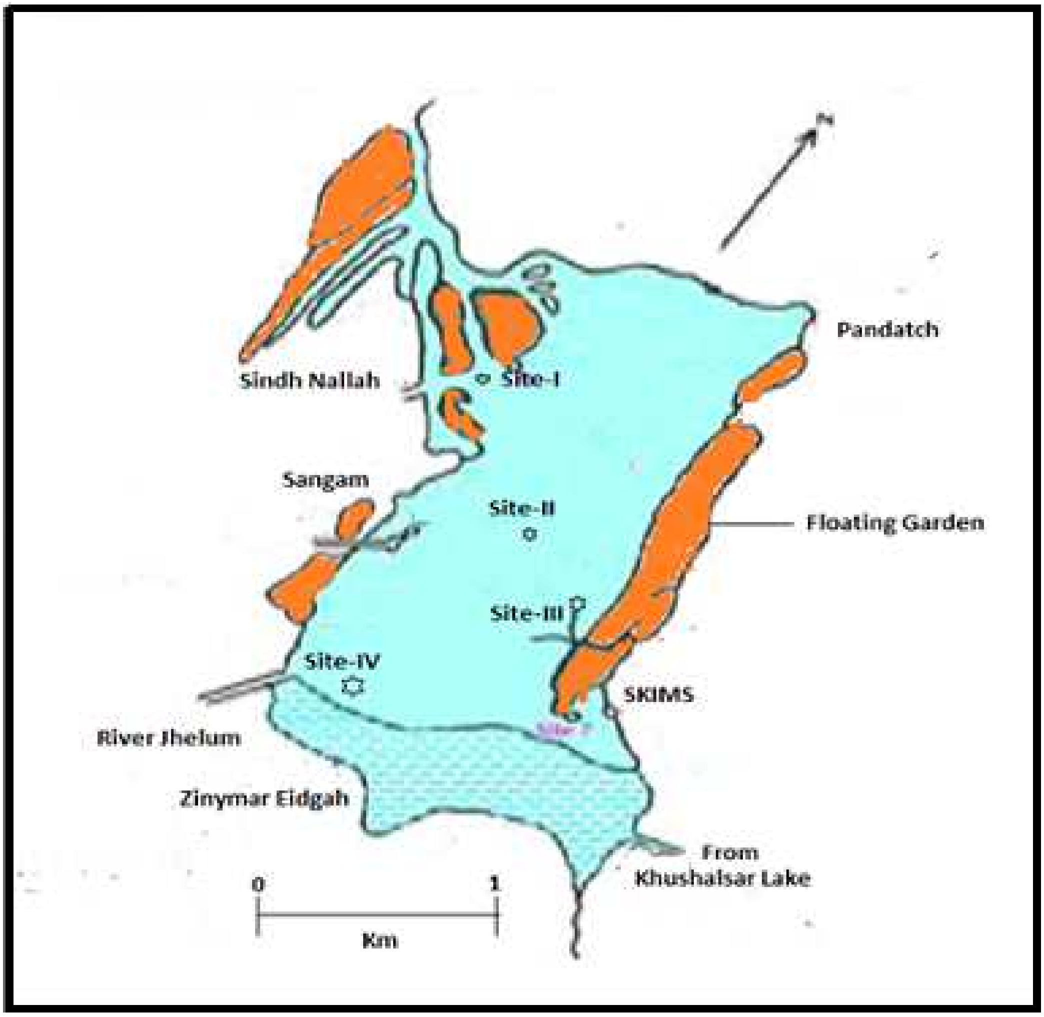


Fig. 1: Map showing Anchar lake

- Dissolved oxygen
- Free carbon dioxide
- Total alkalinity
- Nitrate nitrogen
- Ammonical nitrogen
- Orthophosphate, and
- Total phosphorus

2. To study the distribution of Annelida (oligochaeta)
3. To study the relationship between water quality and occurrence of Annelida (oligochata)

Chapter-2

REVIEW OF LITERATURE

2.1 Work done Abroad

Research has been carried on Annelids as early as by 1909 by Michaelsen. Some of the noteworthy contributors in this field are by Haydon (1922), Asahina (1943), Naidu (1964), Harman (1966), Brinkhurst (1971), Milbrink (1973), Milbrink (1980), Lang (1984), Says (1999), Sam (2000), Reddy (2001), Yap (2003), Othata (2006), Yap (2006), Arimoro (2007), Martins (2008), Elepet (2010), Tas (2011), Mereta (2013), Masood (2015), Nazarhaghighi (2015).

Sam (2000) studied earthworm Annelida (oligochaeta) of the Columbia river. He reported that the earthworms are the key component of many terrestrial ecosystems. According to the author, three main ecological types of earthworm found in the basin assessment area are epigeic, endo-geic. Each type has a different life history pattern, resource and ecological function requirement. He also showed the key ecological function of earthworm in relation to the ecological types and habitats.

Capraz and Arslan (2005) studied the Annelida (oligochaeta) fauna of Aksu stream. During the study 17 species of Oligochaeta were recorded consisting of 7 species from the family Tubificidae and 10 species from Nadidae. All of them were reported from the stream first time. The species with the widest distribution among Oligochaeta were *tubifix Tubifix, Limnodrilus Limnodrilus.*

Arslan (2006) studied the litoral fauna of Annelida (oligochaetes) of lake Egirdir (Isparta). He identified, 22 species belonged to 15 genera, consisting of 1 species from family haplotoxidae, 9 species from tubificidae and 11 species from family Nadidae. The litoral fauna of Oligochaeta in lake Egirdir was dominated by tubificid and naided taxa. The result of this study indicated that species richness and diversity of litoral fauna of oligochaetes were low but number of individuals high among the vegetation.

Yap *et al.* (2006) studied the influence of physico-chemical parameters on the distribution of oligochaeteas (*Limnodrilus* sp.) at the polluted downstream of Langat river, Malaysia. The result of this study indicated that the *limnodrilus* sp. was more tolerant to pollution, and therefore, they were good indicator of polluted ecosystem since they are found in the poor water quality of the river.

Kenny *et al.* (2009) studied that macro-invertebrate, as biological indicator of stream water quality. According to him macro-invertebrates can be utilized to identify impaired water, determine aquatic life stressors, set pollutant load reduction, and indicate improvement.

Elipet *et al.* (2010) while analysing the benthic macro-invertebrates in relation to environmental variables of lake Gala they found 49 zoobenthic taxa which were grouped as oligochaeta, chironomidae, and varia, comprised of 1628 Ind/m^2 on average were recognised in the sampling stations of the lake and found that chironomid comprising 54% followed by oligochaetes 34% and varia 9%. The result of the study showed that large number of pollution tolerant oligochaetes and chironomids are often indicator of poor water quality (characterised by low dissolved oxygen and high nutrient concentration).

Tas *et al.* (2011) studied the dynamics of oligochaete fauna in Sazlidre stream (Turkey) with relation to environmental factors. During the study a total of 14 species and immature tubificidae with hair setae were determined such as *Tubifex tubifex, Lemnodrilus hoffmeisteri, Chaetogaster diaphanas* etc. Among the 14 species *C. diaphanas, N. Barbata, N. bretscheri, O. Serpentine, S. Appendiculata, and P. longiseta,* were new records. It was also found that the number of oligochaeta were 9139 Ind/m^2 on an average and they also observed that oligochaeta species shows positive correlation with pH. Total hardness and organic matter.

Dalu *et al.* (2012) investigated macro-invertebrate communities to understand factors and processes structuring macro-invertebrate communities in a small reservoir. In total 42 macro-invertebrate families belonging to 10 orders were identified amongst macrophyte species and sediments, and showed that hydrological linked parameters such as conductivity, water level and macrophyte cover had the strongest influence on macro-invertebrate distribution.

Diomande *et al.* (2013) studied the spatial distribution and structure of benthic macro-invertebrates in Taabo lake, and recorded 29 taxa belonging to 17 families, 7 orders, and 3 classes. A total of 4028 individuals were collected, of which insect have highest percentage composition (53.21%), followed by Gastropoda (36.15%) and Oligochaeta (10.64%).

Hirabayashi *et al.* (2014) while studied bathymetric distribution of aquatic oligochaetes in mesotropic lake Kizaki, central Japan. They identified a total of 5 genera and 7 species belonging to three subfamilies: i.e. 1 (Naidinae), 2 (Rhyacodrilinae) and 4 (Tubificinae). Dominant species was *tubifex tubifex.* They also suggest that a decrease in dissolved oxygen concentration of bottom water was due to an increase in organic matter content of the sediment. As a result, *T. Tubifex* could expand their habitat in the profundal zone.

Nazarhaghighi *et al.* (2015) studied the first record of *Limnodrilus claparedeianus* from Anzali wetland Iran. The result showed that *Limnodrilus claparedeianus* among 13 stations in wetland revealed significant difference in west stations. He also showed that the correlation analysis did not exhibit any relation between abundance of *Limnodrilus claparedeianus* and total organic matter, abundance of species and percentage of silt in substrate sediment.

2.2 Work done in India

Research in India has been carried on Annelids as early as Gates (1951). Some of the noteworthy contributors in this field are by Day (1967), Patnaik (1971), Gupta (1976), Mishra (1985), Sundar (1986), Raveenthiranath (1990), Sinha (1993), Sunil (1995), Kumar (2001), Naseeman (2004), Kumar (2006) Pavithran (2009), Sing (2009), Patra (2010), Chowdhary (2013), Kumar (2013), Thilagavathi (2013), Prashantha (2014), Sharma (2014), Sing (2014), Antal (2015), Sharma (2015).

Nasemann *et al.* (2004) recorded 39 aquatic annelids (Polychaeta, Oligochaeta, Hirudinea) from Bihar streams, belonging to 10 families. They include 2 species of Polychaetes, 27 oligochaetes and 10 Leeches. 2 nadid species, *Nais bretscheri* and *Pristina acuminata*, are found for the first time from Indian subcontinent.

Sing *et al.* (2009) recorded fresh water oligochaetes, which records the presence of 102 species of freshwater oligochaetes belonging to 17 genera and 4 families. Besides this, a brief description of their global and Indian distribution has also been made along with their ecology, morphology of typical oligochaetes methods of their collection and preparation for taxonomic study has also been given.

Patra *et al.* (2012) worked on seasonal abundance and population fluctuation of the macro-invertebrate community related to macrophytes in the Santragachi lake, West Bengal. A total of 29 species of aquatic macrophytes were recorded and then categorized into 6 groups. Macro-invertebrate fauna associated with macrophytes revealed a total of 69 macro-invertebrate species represented in this lake. Crustaceans, Insects and Gastropods are the most dominant groups in the jheel in terms of abundance.

Chowdhary *et al.* (2013) studied macro-benthic invertebrates in the longitudinal profile of a river (Tawi), originating from Shivalik hills. They observed great variation in the distribution of macro-benthic invertebrate fauna in the upstream and downstream sections. Analytical study of river Tawi, revealed the presence of 52 taxa predominantly belonging to Phylum Annelida, Arthropoda and Mollusca. Amongst Phylum Arthropoda dominated both qualitative and quantitative dominance over the other two phyla. Upstream sections of the River were found to be pristine or nearly pristine in nature whereas downstream sections were observed to be highly polluted. Ephemeropterans, Plecopterans and Trichopterans which are commonly known as pollution sensitive species were found to be numerically abundant in the upstream sections and recorded to be totally absent in the downstream sections. On the other hand pollution tolerant species of order Coleoptera, Odonata, Diptera, and class Oligochaeta were present in greater number in the downstream sections. Numerical abundance of *Chironomous* sps. and *Tubifex* sps. throughout the experimental period reflected the anthropogenic stresses of the River in its downstream sections.

Kumar and Khan (2013) studied the distribution and diversity of benthic macro-invertebrate fauna in Pondicherry, India. 76 species of benthic macro-invertebrate fauna were identified. Macrofauna were mainly composed of deposit feeders, dominated numerically by molluscs and crustaceans. The pollution indicator organisms *Cassidula nucleus, Melampus ceylonicus, Sphaerassiminea minuta* were found and benthic macro-invertebrate fauna abundances were inversely related to salinity. It was found that benthic communities are highly affected by all the environmental parameters governing the distribution and diversity variation of the macro-faunal community.

Sharma *et al.* (2014) studied diversity of eartworms in transgenic habitat of Haryana and found 9 taxa of earthworms, such as *Metaphire posthuma*, *Drawidane palensis*, etc belonging to 6 genera and 3 families were recorded in the study area constituting 2.15% of total indian earthworm fauna. 156 species were recorded in esturarine ecosystem (102 polychaetes, 10 bivalves, 11 gastropods, 24 amphipods, 6 isopods and 3 crustacea), 252 species were recorded in riverine ecosystem (151 polychaetes, 12 bivalves, 16 gastropods, 53 amphipods, 16 isopods and 4 cumacea) and 163 species were recorded in island mangrove ecosystem (105 polychaetes, 10 bivalves, 16 gastropods, 21 amphipods, 9 isopods and 2 cumacea). Among the three ecosystems, a total of 292 benthic macrofauna consisting of 188 species of polychaetes, 12 species of bivalves, 17 species of gastropods, 55 species of amphipods, 16 species of isopods and 4 species of crustacea were recorded. However, there were obvious differences among the community structures in the three mangrove habitats. This result implied that the different mangrove ecosystem had different effects on the macrofauna communities and shed light on the macrofauna adaptation capability to specific habitats.

Sing *et al.* (2014), observed that the macroinvertebrates are the most common faunal assemblage for bioassessment and provide more reliable assessment of long term ecological change in the quality of aquatic system compared to its rapidly changing physico-chemical characteristics. This rview highlights very strong evedence that distribution of macro-invertebrates is governed by numerous physical, chemical, and biological factors which were taken in any study of macro-invertebrates and also found that the number, density, diversity, and activities of macro-invertebrates are depend on the substrate, temperature, disolved oxygen and water velocity.

Antal *et al.* (2015) studied the sediment characterization of a sub-tropical pond of Birpur, Jammu (J&K) in relation to its macro-benthic and bacterial fauna and analysed that macro-benthic invertebrates showed the presence of three species of phylum annelida belonging to the class Oligochaeta (*Tubifex tubifex, Branchiura* sp, *Dero digitata),* six species of phylum Arthropoda belonging to two orders, Diptera (*Chironomus chironomus*, Chironomous pupae, *Pentaneura* sp., *Culicodes* sp., *Tabanus* sp.) and Coleoptera (*Berosus* sp, *Paracymus* sp, *Hydroglyphus* sp. *And Canthydrus* sp.) and three species of phylum Mollusca belonging to three families Thiaridae (*Melanoides tuberculata*), Physidae (*Physa* sp.) and Planorbidae (*Gyralus* sp.). In the present study presence of some macro-benthic invertebrates such as *Chironomus chironomous*, *Tubifex tubifex* etc. interfers the water quality and water is getting polluted.

Sharma *et al.* (2015) studied the diversity of zooplankton and macro-benthic invertebrate of two perennial ponds in Jammu region. An ecological study was carried out so that to study diversity of zooplankton and macrobenthic invertebrates in two parrinial ponds (Jakh and Dilli ponds). In all 29 species of zooplankton were identified from Dilli pond and 24 species from Jakh pond. Among the macro-invertebrates 23 species were identified from dilli pond out of which 9 species belong to annelida, 12 species to arthropoda and 3 species to mollusca whereas, only 13 species, were recorded from Jakh pond out, of which 2 species belong to annelida, 8 species to arthropoda and 3 species to mollusca. Overall assessment indicates that during the investigaton class arthropoda was domonant among all.

2.3 Work done in Kashmir

In the state of jammu & kashmir contributers on this field are Sharma (1974), Pandit (1980), Balkhi (1987), Balkhi (1992), Habib (2012), Mir (2002), Mir (2003), Qadri (2004), Mahdi (2005), Yaqoob (2009), Sharma (2011), Yousuf (2006), Yaqoob (2007), Bhat (2011), Ahanger (2012), Jeelani (2012), Abida (2012), Mehraj (2013), Bhat (2014),Ganie (2014), Hassan (2014), Rafia (2014), Rashid (2014), Habib (2014), Rashid (2015).

Pandit (1980) studied biotic factor and food chain structure in some in some typical wetland of kashmir and found that the benthos occupies an important position in the lake eosystem, serving as a link between primary producers, decomposers and higher trophic levels.

Balkhi *et al.* (1987) studied the hydrobiology of Anchar Lake, Kashmir and reported a bimodal pattern in the seasonal fluctuation of zooplankton population, recording the primary peak in summer. Rotifera was the most dominant group both quantitatively and qualitatively. They opined that the dominance of Rotifera might be due to their smaller size as compared to crustacean plankters, thereby avoiding predation by fishes and other carnivores.

Balkhi and Yousuf (1992) while working on 100 water bodies belonging to nine different categories of Kashmir, observed higher values of species diversity for Rotifera as compared to that of Cladocera and Copepoda.

Mir and Yousuf (2002) recorded 13 taxa of macro-benthic organisms belonging to Annelida, Mollusca, and Arthropoda, during the yearlong study in Dal lake, Kashmir. A marked variation were found in the special distribution of various taxa, which was influenced by the texture of the sediment as well as by macrophytic community structure.

Qadri and Yousuf (2004) while studying that the ecology of macrozoobenthos in Nigeen lake, recorded that the macrozoobenthic community was found to be influenced by the type of substrate, the organic matter, the abundance of macrophytes as well as the concentration of calcium. Annelids formed the most dominant group including two oligochaetes i.e. *Tubifex tubifex* and *Branchiura sowerbyi*.

Dar *et al.* (2010) studied the Ecological distribution of Macrozoobenthos in Hokera wetland of Kashmir according to the author macro-invertebrate community respond to the environmental changes and are useful in assessing the impact of wastes on surface waters. Four types of environmental change, patterns of Macrozoobenthic community structure changes have been documented, these are, increased inorganic micronutrients, increased organic load, substrate alteration and toxic chemical pollution. Although a few species of Annelida were found to be dominant in terms of taxa and abundance of collection, Mollusca however, were poorly represented. Insecta, although represented by 1 texan namely *Chironomous* sp., was abundant throughout the study period.

Bhat *et al.* (2011) studied the ecological distribution of macro-invertebrate assemblage in river Sindh and its tributary including Baltal, Yashmarg, Sonamarg and Thajwas. A total of 33 taxa of macro-invertebrate were recorded belonging to Mollusca (3), Annelida (1) and Arthropoda (29). The study also revealed that the substrate composition dominated by gravel, pebble, and leaf litters are primary determinants of the invertebrate community structure recording maximum species diversity and abundance.

Ahangar *et al.* (2012) studied the crustacean community in Anchar lake under certain environmental factors The Crustacean fauna was represented by 11 species. The group showed maximum numerical surge during warm periods and minimum in colder periods. The species diversity was composed of *daphnidae* followed by *Bosminidae*, *Moinidae* and *Macrothricidae* in decreasing order. The population dynamics was mainly influenced by water level fluctuations and macrophytic density.

Bhat *et al.* (2012) studied the macro-invertebrate community association on three macrophytic species namely *Ceratophyllum demersum*, *Hydrilla verticillata* and *Potamogeton lucens* in Manasbal Lake. A total of 15 macro-invertebrate taxa were reported from these macrophytic species belonging to 3 phyla including Annelida, Mollusca and Arthropoda. Arthropoda was the dominant phyla comprising of class insecta, crustacea and arachinida. Annelida was the second dominant phyla represented by 2 classes hirudinea and oligochaeta. Mollusca were only represented by families, lymnaeidae and planorbidae.

Jeelani and Kaur (2012). Studied the ecologically of Anchar lake. They showed that the water temperature in general showing usual seasonal trend with maximum values in summer and minimum values in winter. The pH values indicate that the water is well buffered. Qualitative and quantitative analysis of zoobenthic invertebrate fauna revealed three groups viz. Annelida (5.5%), Crustacea (16.6%) and Insecta (77.0%). *Phylum annelida* was represented by a single taxon, *Placobdella* sp. (Hirudinea) while class crustacean included *Gammarus* sp (Amphipoda) and class Insecta was represented by 4 taxa namely *Stenonema* sp (Ephemeroptera), *Enallagma* sp. (Odonata), *Chironomus* sp. (Diptera) and *Micropsectra* sp. (Diptera) thereby showing the dominance of insect fauna.

Syed *et al.* (2012) studied the macrozoobenthic community as biological indicators of pollution in river Jhelum, Kashmir. A total of 21 species of macrozoobenthos were recorded during the period of present investigation. Arthropoda was the dominant group, comprising 15 species, followed by Annelids with 3 and Mollusca with 3 species. This study concluded that the presence of some pollution indicator species such as *Tubifex* sp., *Limnodrilus* sp., among Annelida, *Chironomous* sp. and *Gammarus pulex* among Arhropoda, *Lymnea* sp. and *Corbicula* sp. among Mollusca directly points to the shifting status of the river from non-polluted to polluted.

Habib and Yousuf (2012) studied the distribution of macro-invertebrate assemblages in two streams, Doodganga and Khanshah Manshah canal. During the period of investigation, 24 species of macrozoobenthos were recorded. Arthropoda was found to be the most dominant group, comprising of 23 species followed by Annelida with 1 species. The phylum Arthropoda was represented by class Insecta (5 orders) and Crustacea (1 orders). The diversity of benthic invertebrates was high in Doodhganga stream (21 taxa) as compared to Khanshah Manshah canal (18 taxa).It was observed that boulders and cobbles provided a stable habitat for macroinvertebrates dwelling in the stream. Greater diversity in the summers as against winters was recorded in both the streams. On the basis of the biotic indices, the Doodhganga stream is being adjudged pristine with no organic pollution, however slight organic pollution in Khanshah–Manshah canal was recorded.

Abida *et al.* (2013) studied the benthic macro-invertebrate assemblages of Verinag spring in Kashmir corresponding to different catchment and land uses acts as indicators of water quality. Physico-chemical parameters and population density of Annelids, Arthropoda and Mollusca individuals were determined. Diptera was dominating the study area instead of Annelida. The Oxygen concentration was high, which seems to be a function of good periphytic algal population. Macrozoobenthos represented one of the most important groups of animals particularly with respect to food of fishes and also played an important role in cycling of the organic material. Macrozoobenthos contributed a total of 19 taxa of which 12 belonged to Insecta, 1 to Crustacea, 3 to Annelida, and 3 to Mollusca.

Mehraj and Bhat (2013) studied the epigeal macro-invertebrate diversity in different microhabitats of the Sonamarg hill resort to assess and evaluate the distribution, diversity and occurrence of Sonamarg. A total of 34 species belonging to 11 different orders were reported during the study. Maximum diversity pertained to order Ceoleoptera (10 species) followed by Araneida (5 species) and Hymenoptera (5 species), Hemiptera (3 species), Dermoptera, Diptera, Oligochaeta and Scolopendramorpha (2 species each), Dictyoptera, Juliformia and Orthoptera (1 specie each). The evaluation of various relative parameters such as density, relative density, frequency, relative frequency, abundance, relative abundance and importance value index were also calculated. From the study it was concluded that the maximum abundance and diversity pertains to the habitat rich in organic matter followed by the forest area. The epigeal fauna exhibited fairly good degree of variation at different sites.

Bhat *et al.* (2014) studied the occurence of macrozoobenthos in trout stream (Lidder) and found that a progressive degredation in water quality and dicrease in species density and diversity along the altitudinal gradient During the study macrozoobenthos were represented by 21 taxa among which insects dominated the benthic fauna throughout the stretch of the stream.

Ganie *et al.* (2014) studied the water quality of Lar stream, Kashmir using Macro-invertebrates as variable tolerant to diverse levels of pollution. During the study, a total of 26 species of macro-invertebrates were registered from Lar stream which belonged to the orders Diptera, Trichoptera, Hirudinae, Ephemeroptera, Plecoptera, Gastropoda, Coleoptera, Arachnida, Lepidoptera, Crustacea and Oligochaeta. Among all the 11 orders, Dipterans registered a highest of 7 species (27%) and was the most dominant order. Similarly, Ephemeroptera, Oligochaeta, Hirudinae, Plecoptera and Gastropoda which registered 2 species (8%) each were the next dominating. Taxa representing Coleoptera, Arachnida, Lepidoptera and

Crustacea which registered only 1 species (4%) The present study concludes that the presence of some pollution indicator species such as *Tubifex tubifex*, *Limnodrilus* sp. (among Annelida) *Chironomous* sp. and *Tabanus* sp., etc. (among Arhropoda) *Lymnea* sp. (among Mollusca) points towards shifting status of the stream from non-polluted to polluted.

Hassan *et al.* (2014) studied the distributional pattern of macro-invertebrates across river Jhelum in Kashmir valley. During the study it was concluded that the diversity and abundance of zoo-benthos in the River Jhelum were influenced not only by pollution level but, also by bottom substratum. Altitude, geology and the substratum of the river plays an important role in the distribution of macro-invertebrates, though the organic pollution, impairment and increase in encroachment strongly affect he abundance of benthos.

According to Rafia and Pandit (2014) macro-invertebrates forms an important constituent of an aquatic ecosystem and had functional importance in assessing the trophic status as the abundance of benthic fauna mainly depends on physical and chemical properties of the substratum. This review discusses the occurrence, composition, distribution of macro-invertebrates of lakes and wetlands.

Habib and Yousuf (2014) studied benthic macro-invertebrates of a fourth order stream in Kashmir Himalaya. The study shows that substrate type has an effect on the distribution of benthic organisms. A seasonal variation in abundance of individual indicates that temperature and its factors have a propound influence on the life cycle of invertebrates. Altogether 6 orders under 2 phyla namely, Arthropoda and Annelida were recorded from the stream and also indicated that the seasonal dynamics showed greater diversity and density in summer than in winter.

Rashid *et al.* (2015) studied species composition and biomass of macro-benthos Wullar lake. During the investigation in terms of species composition and biomass of annelids, 10 taxa of annelids were recorded which belonged to 2 major classes namely Oligochaeta (7) and Hirudineae (30). Species *Aelosoma* spp., *Placobdella* spp. and unidentified taxon. In general it was indicated that Oligochaeta comprised 95% of the total annelid community and remaining 5% was constituted by Hirudinea.

Chapter-3

MATERIALS AND METHODS

The present study was carried on Anchar Lake. Water quality of the lake was assessed by various physico-chemical parameters viz. air temperature, water temperature, depth, transparency, pH, dissolved oxygen, free carbon dioxide, total alkalinity, nitrate nitrogen, ammonical nitrogen, orthophosphate and total phosphorus. Besides this Annelida (oligochaeta) population was also determined. The sampling was done from December 2015 to May 2015 at pre-designated four 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^{o} E Longitude and 34.2^{o} 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 as depicted in Plate-1.

Site-2:- This site is situated almost in the centre of the lake in the open water. The site is located in the coordinates of 74.78^{o} E Longitude and 34.149^{o} 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 as depicted in Plate-2.

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

Plate-1: A view of Anchar Lake at site-I (Sind)

Plate-2: A view of Anchar Lake at site-II (Centre)

Plate-3: A view of Anchar Lake at site-III (SKIMS)

Plate 4: A view of Anchar Lake at site-IV (outlet)

from the drainage system of the SKIMS and the adjacent areas as depicted in Plate-3.

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^o E Longitude and 34.138^o N Latitude. The site has maximum water depth of 1.2m. The water from this site finally flows into the river Jhelum as depicted in Plate-4.

3.1 Collection of water samples

Surface 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 A.P.H.A (2005) and Adoni (1985)

3.2 Physico-chemical parameters

3.2.1 Water and Air temperature

Both Water and Air temperature were recorded with the help of a digital thermometer. The thermometer had a preferable range from -50 to 150^{o}C and the result are expressed in ^{o}C.

3.2.2 Depth

The depth of the lake at all sampling sites was measured with the help of a weight tied to string. The weight was poured into the lake until it reached the bottom. A mark was made on the string at this level, after lifting up the string, the depth was measured by a measuring tape. The result are expressed in m.

3.2.3 Transparency

Transparency were recorded by using a standard secchi disc. A secchi disc (diameter 20 cm), tied to graduated nylon rope, and was used for obtaining the extent of light penetration in water. Mean of the depth at which secchi disc disappeared and then re-appeared was taken as transparency of water. The clearer the water the greater the distance and the result are expressed in m.

3.2.4 pH

The pH of water was measured with a water proof digital pH meter (Eutech) which was standardized previously with buffer solution of 4, 7 and 10 pH.

3.2.5 Dissolved oxygen

Modified Wrinkler's method was followed for determination of the D.O content. To a sample collected in a 125 ml D.O bottle, 0.5 ml of each manganous sulphates solution and alkaline iodide azide solution was added one after the other with separate pippets. The precipitate (manganous hydroxide floc) formed as dissolved with the help of 0.5ml concentrated sulphuric acid. The fixed samples were carried to the laboratory where these were titrated against 0.025 N sodium thiosulphate solution, using starch solution as indicator. The end point was noted at the first disappearance of blue colour. The process was repeated 3 times and the mean of the 3 reading were taken as the final reading. The amount of D.O present was then calculated by using the formula:

$$\text{D.O (mg/l)} = \frac{\text{Vol. of titrant} \times \text{N} \times 1000}{\text{Vol. of sample}}$$

Where,N= Normality of titrant

Vol. = volume in ml

The results are expressed in mg/L

3.2.6 Free CO_2

The free CO_2 content of the sample was determined by titrating the samples against 0.227N sodium hydroxide (titrant) using phenolphthalein as indicator till the faint pink colour developed. The process was repeated 3 times and a mean of 3 readings was taken as the final reading. The CO_2 present was calculated by using the formula:

$$CO_2\ (\text{mg/litre}) = \frac{\text{Vol. of titrant} \times N \times 44000}{\text{Vol. of sample}}$$

Where,N= Normality of titrant

Vol.= volume in ml.

The result are expressed in mg/L

3.2.7 Total alkalinity

For estimation of phenolphthalein alkalinity (i.e, alkalinity due to OH^- and HCO_3^-) a sample volume of 50 ml was titrated against 0.02 N H_2SO_4 in presence of phenolphthalein indicator till disappearance of pink colour. Volume of titrant used was noted. Then for estimation of total alkalinity (i.e. alkalinity due to $OH^/$, $CO_3^/$ and $HCO_3^/$), the same sample was titrated with 0.02 N NaOH in presence of methyl orange indicator till the colour changed from yellow to orange. The total volume of titrant was noted. On the other hand, when there was no pink colour formation after addition of phenolphthalein indicator, the sample was run through the sample procedure followed by the addition of methyl orange indicator. The procedure was repeated 3 times and a mean of 3 readings was taken as the final reading. The phenolphthalein alkalinity (P) and Methyl orange alkalinity (M) were calculated by using the formula as given below:

$$\text{P.A. (mg/l) } CaCO_3 = \frac{A \times B \times 50000}{\text{ml of sample}}$$

Where, A= ml of titrant

B = Normality of titrant

The total alkalinity was determined by adding the values for phenolphthalein and methyl orange alkalinities. The results were finally expressed in mg/L.

3.2.8 Nitrate nitrogen (NO_3-N)

To 50 ml of water sample, sodium arsinite solution was added in half proportion to the titrant used in chloride (this was done in order to remove the interference on account of chloride). Then to 10 ml of this treated sample 2 ml sodium chloride solution was added followed by 10 ml of nitrate reagent, in cold water bath. The contents were shaken vigorously then 0.5 ml bromine sulphate reagent was added and the flask placed in boiling water bath for 20 minutes. After cooling intensity of yellow colour developed was measured on X-ma 1000 spectrophotometer at 410 nm, using distilled water blank. Results were compared with standard curve and are expressed in µg/L.

3.2.9 Ammonical nitrogen (NH_4-N)

To 25 ml of water sample, 1 ml phenol solution, 1 ml sodium nitroprusside solution (0.5%) and 2.5 ml sodium hypochlorite solution (5%) was added with thorough mixing after each addition. An intense blue colour developed after 1 hour was measured on X-ma 1000 spectrophotometer at 640 nm, using distilled water blank and results compared with standard curve. The results are expressed in µg/L.

3.2.10 Orthophosphate (PO_4-P)

The concentration of orthophosphate was estimated by stannous chloride method. To 100 ml of sample one drop of phenolphthalein indicator was added. Pink colour developed, was discharged by strong acid (mixture of concentrated H_2SO_4 and concentrated HNO_3). After thorough mixing 4.0 ml ammonium molybidate and 0.5 ml (10 drops) stannous chloride was added. The intensity of blue colour developed after a pause of 10 minutes was measured on X-ma 1000 spectrophotometer at 690 nm, using distilled water blank and result compared with standard curve. The results are expressed in µg/L.

3.2.11 Total phosphorus

Total phosphorus was estimated by digesting 25 ml of water sample containing 1 ml concentrated sulphuric acid and 5 ml nitric acid to 1 ml colourless solution. On cooling 20 ml of distilled water was added. The sample was titrated with 1N NaOH solution using 0.005 ml (1 drop) phenolphthalein indicator till a faint pink end point. The sample was raised to 100 ml with distilled water. Then pink color was discharged by adding strong acid (mixture of concentrated H_2SO_4 and concentrated HNO_3). After thorough mixing 4 ml ammonium molybidate and 0.5 ml (10 drops) stannous chloride was added. The intensity of blue colour developed after a pause of 10 minutes was measured on X-ma 1000 spectrophotometer at 690 nm, using distilled water blank and result compared with standard curve. The results were expressed in µg/L.

3.3 Collection of benthic annelids

The benthic fauna encompassing annelids was collected from all four sites of the lake with an Ekman Dredge (15 × 15cm) (Plate-5). The samples were taken in viols. The sediment samples collected were washed *in situ* and sieved through No. 40 (256 meshes/cm^2) (Plate-6) for checking annelids. The macroscopic organisms were collected with the help of forceps and brushes and then preserved in 4% formalin at the sampling sites and brought to AEM laboratory, Faculty of fisheries, were sorted under Stereo-microscope and preserved in 70% alcohol. The preserved annelids were identified by observing them under a sterio-microscope and identification was done with the help of standard taxonomical work of Edmondson (1992), Pennak (1978) and Adoni (1985). The abundance of these organisms was calculated as number per square meter by applying the following formula:

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

Where, O = No. of organisms counted.

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

S = No. of samples taken at each stations.

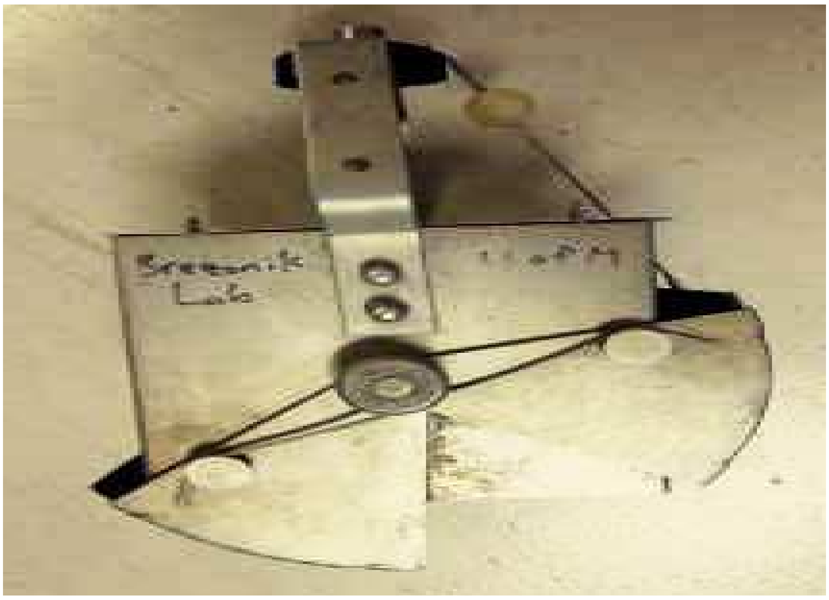


Plate5: Ekman Dredge (15 × 15cm)

Plate 6: Sieve No. 40 (256 meshes/cm^2)

Chapter-4

EXPERIMENTAL FINDINGS

The quality of natural water is generally analysed by various physico-chemical and biological parameters. The present study was under taken to study various physico-chemical parameters viz., air temperature, water temperature, depth, transparency, pH, dissolved oxygen, free carbon dioxide, total alkalinity, nitrate nitrogen, ammonical nitrogen, orthophosphate and total phosphorus of Anchar lake.

4.1 Water quality parameters

Four sites were selected from Anchar lake are Inlet (Site-I), Centre (Site-II), SKIMS (Site-III), and Outlet (Site-IV) for water quality analysis. Assessments of these sites are given below:

4.1.1 Air temperature

At Site-I where Sindh nalla enters into the lake air temperature recorded a minimum value of 3^{o}C in the month of February while a maximum air temperature of 25.5^{o}C was recorded in the month of May with a mean value of 10.01±7.98^{o}C (Table 1, Fig. 2).

At Site-II, a minimum air temperature of 3.3^{o}C was recorded in the month of February while a maximum air temperature of 22^{o}C was recorded in the month of May, with a mean value of 10.8±8.28^{o}C (Table 1, Fig. 2).

At Site-III, a minimum temperature of 3.4^{o}C was recorded in the month of February while a maximum air temperature of 24^{o}C was recorded in the month of May, with a mean value of 11.21±8.84^{o}C (Table 1, Fig. 2).

At Site-IV, a minimum temperature of 3.2^{o}C was recorded in the month of January while a maximum air temperature of 25.5^{o}C was recorded in the month of May, with a mean value as 11.23±9.39^{o}C (Table 1, Fig. 2).

The overall air temperature during the study period ranged from a minimum of 3^{o}C at Inlet (Site-I) in the month of February to a maximum of 25.5^{o}C at outlet (Site-IV) in the month of May (Table 1, Fig. 2).

Table-1: Monthly variation in air temperature (^{o}C) at different sites of Anchar lake

Sites	Dec.	Jan.	Feb.	March	April	May	Min.	Max.	Mean±SD
Inlet	3.9	3.2	3	11	18	21	3	21	10.01±7.98
Centre	4.3	3.8	3.3	12.5	19	22	3.3	22	10.0±8.28
SKIMS	4.4	3.8	3.4	12.5	19.2	24	3.4	24	11.21±8.84
Outlet	4.2	3.2	3.8	11.2	19.5	25.5	3.2	25.5	11.23±9.39

4.1.2 Water temperature

At Site-I, a minimum water temperature of 1.6^{o}C was recorded in the month of January while a maximum water temperature of 11^{o}C was recorded in the month of May, with a mean value of 5.61±3.80^{o}C (Table 2, Fig. 3).

At Site-II, a minimum water temperature of 2.1^{o}C was recorded in the month of January while as the maximum water temperature of 19^{o}C in the month of May, with a mean value was 6.1±3.69^{o}C (Table 2, Fig. 3).

At Site-III, a minimum water temperature of 2.3^{o}C was recorded in the month of February while a maximum water temperature of 12.5^{o}C was recorded in the month of May, with a mean value of 5.95±4.22^{o}C (Table 2, Fig. 3).

At Site-IV, a minimum water temperature of 2.1^{o}C was recorded in the month of January while a maximum water temperature of 12^{o}C was recorded in the month of May, with a mean value of 6.28±3.99^{o}C (Table 2, Fig. 3).

The Overall water temperature during the study period ranged from a minimum of 1.6^{o}C at Inlet (Site-I) in the month of January to a maximum of 12.5^{o}C at Outlet (Site-IV) in the month of May (Table 2, Fig. 3).

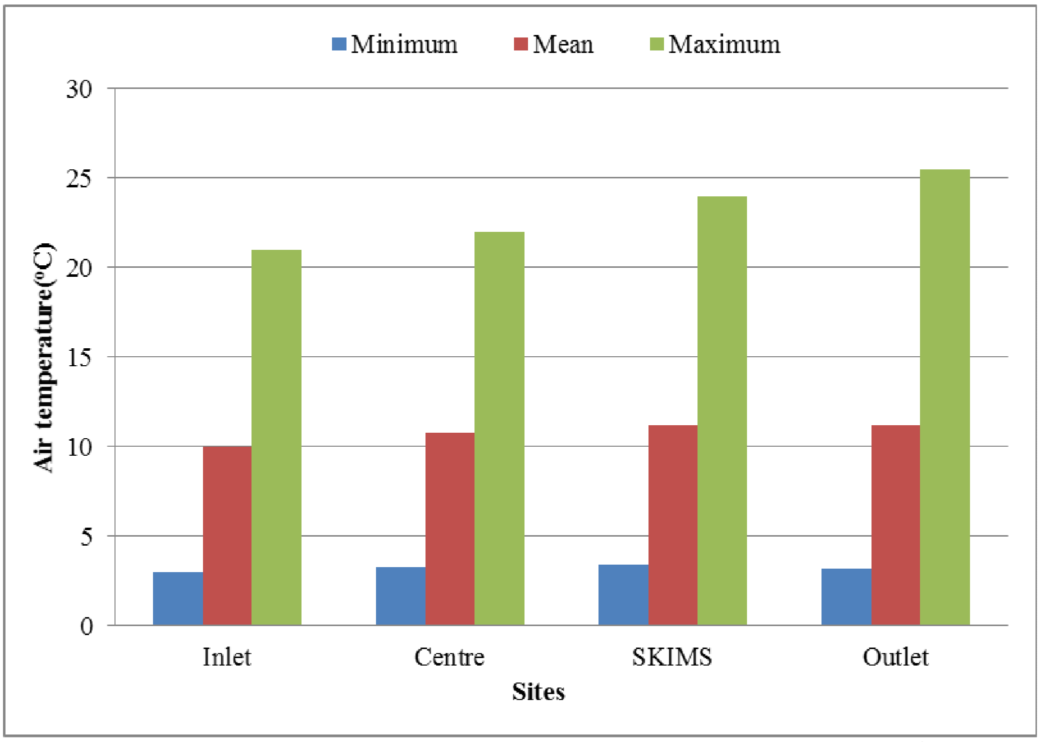


Fig. 2: Minimum, Maximum and Mean valves of Air temperature (°C) at different site of Anchar lake

Table 2: Monthly variation in water temperature (^{o}C) at different sites of Anchar lake

Sites	Dec.	Jan.	Feb.	Mar.	Apr.	May	Min.	Max.	Mean±SD
Inlet	1.9	1.6	4.2	6	9	11	1.6	11	5.61±3.80
Centre	2.4	2.1	4.6	7	9.5	11	2.1	11	6.1±3.69
SKIMS	2.6	2.5	2.3	6.8	9.0	12.5	2.3	12.5	5.95±4.22
Outlet	2.5	2.1	4.3	7.3	9.5	12.0	2.1	12.0	6.28±3.9

4.1.3 Depth

At Site-I, a minimum water depth of 1.1m was recorded in the month of December, January, February, April and May while a maximum water depth of 1.2 m was recorded in the month of March, with a mean value of 1.11±0.04 m (Table 3, Fig. 4).

At Site-II, a minimum water depth ranged from of 2.0 m was recorded in the month of May while a maximum water depth of 2.2 m was recorded in the month of December, January and February, with a mean value 2.13±0.08 m (Table 3, Fig. 4).

At Site-III, a minimum water depth of 0.6 m was recorded in the month of May while a maximum water depth of 0.9 m was recorded in the month of December, January and February, with a mean value of 0.8±0.12 m (Table 3, Fig. 4).

At Site-IV, a minimum water depth of 1.1 m was recorded in the month of March, April and May while a maximum water temperature of 1.2 m was recorded in the month of December, January and February, with a mean value of 1.15±0.05 m (Table 3, Fig. 4).

The overall water depth during the study period ranged from a minimum of 0.6m at SKIMS (Site-III) in the month of May to a maximum of 2.2 m at Centre (Site-II) in the month of December, January and February (Table 3, Fig. 4).

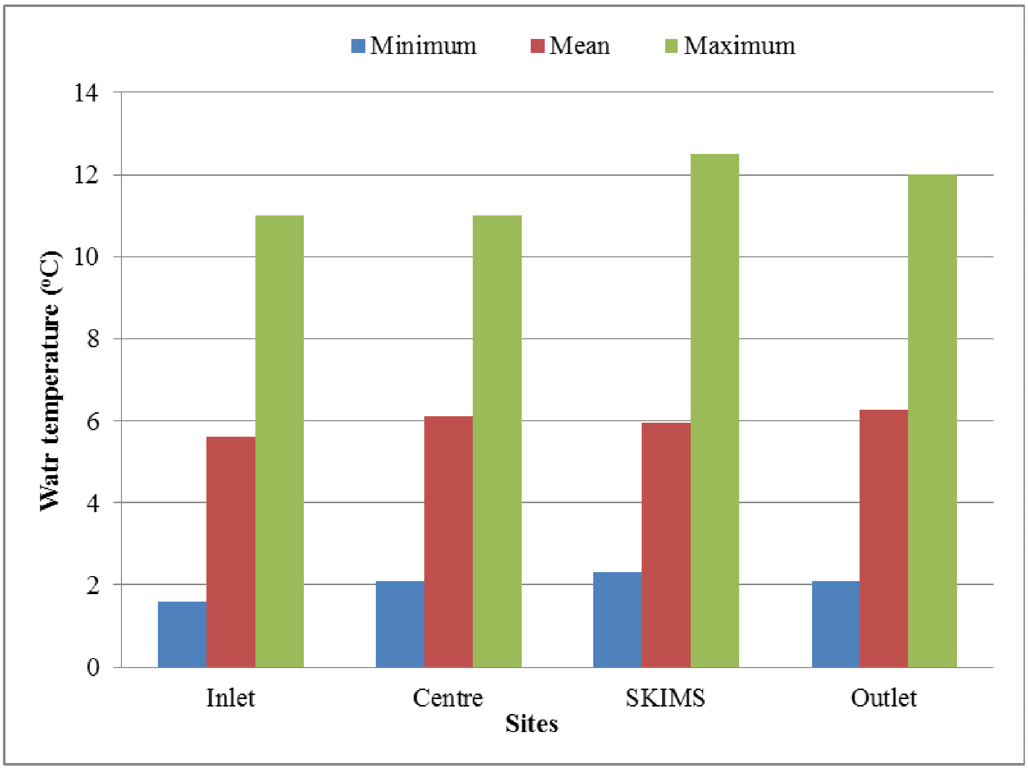


Fig. 3: Minimum, maximum and mean valves of water temperature (°C) at different sites of Anchar lake.

Table-3: Monthly variation of depth (m) at different sites of Anchar lake

Sites	Dec.	Jan.	Feb.	Mar.	April	May	Min.	Max.	Mean±SD
Inlet	1.1	1.1	1.1	1.2	1.1	1.1	1.1	1.2	1.11±0.04
Centre	2.2	2.2	2.2	2.1	2.1	2.0	2.1	2.2	2.13±0.08
SKIMS	0.9	0.9	0.6	0.8	0.7	0.9	0.6	0.9	0.8±0.12
Outlet	1.2	1.2	1.2	1.1	1.1	1.1	1.1	1.2	1.15±0.05

4.1.4 Transparency

At Site-I, a minimum water transparency of 0.19 m was recorded in the month of May while as the maximum water transparency of 0.40 m was recorded in the month of January and February, with the mean value of 0.30±0.08 m (Table 4, Fig. 5).

At Site-II, a minimum water transparency of 0.7 m was recorded in the month of January, February and May while as the maximum water transparency of 0.75m was recorded in the month of December, March and April, with a mean value was 0.72±0.02 m (Table 4, Fig. 5).

At Site-III, a minimum water transparency of 0.21 m was recorded in the month of December while as the maximum water transparency of 0.30 m was recorded in the month of February, with a mean value of 0.21±0.04 m (Table 4, Fig. 5).

At Site-IV, a minimum water transparency of 0.60 m was recorded in the month of December, January and February while as the maximum water transparency of 0.70 m was recorded in the month of February, March and a April, with a mean value of 0.65±0.05 m (Table 4, Fig. 5).

The overall transparency during the study period ranged from a minimum of 0.21 m at Inlet (Site-I) in the month of May to a maximum of 0.75 m at Centre (Site-II) in the month of December, March and April (Table 4, Fig. 5).

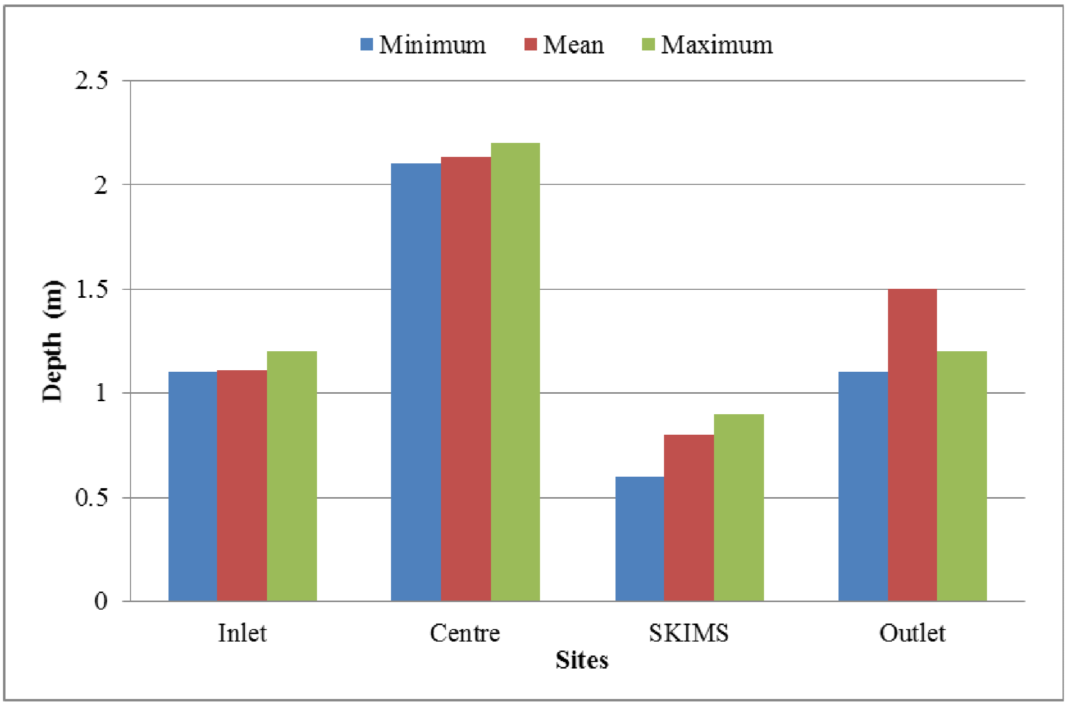


Fig. 4: Minimum, maximum and mean valves of depth (m) at different site of Anchar lake

Table 4: Monthly variation of transparency (m) at different sites of Anchar lake

Sites	Dec.	Jan.	Feb.	Mar.	April	May	Min.	Max.	Mean±SD
Inlet	0.25	0.40	0.40	0.25	0.36	0.19	0.19	0.40	0.30±0.08
Centre	0.75	0.70	0.70	0.75	0.75	0.70	0.70	0.75	0.72±0.02
SKIMS	0.21	0.23	0.30	0.24	0.20	0.20	0.20	0.30	0.21±0.04
Outlet	0.60	0.60	0.70	0.70	0.70	0.60	0.60	0.70	0.65±0.05

4.1.5 pH

At Site-I, a minimum pH value of 7.4 was recorded in the month of May while as the maximum pH value of 8.0 in the month of December and January, with a mean value of 7.79±0.22 (Table 5, Fig 6).

At Site-II, a minimum pH of 7.3 was recorded in the month of May while as the maximum pH of 7.9 was recorded in the month of January, with a mean value of 7.61±0.2 (Table 5, Fig. 6).

At Site-III, a minimum pH of 6.9 was recorded in the month of May while a maximum pH of 7.3 in the month of February, with a mean value of 7.03±0.13 (Table 5, Fig. 6).

At Site-IV, a minimum pH value of 7.4 was recorded in the month of January while as the maximum pH of 7.7 in the month of March, with a mean value of 7.5±0.10 were recorded (Table 5, Fig. 6).

The overall pH during the study period ranged from a minimum of 6.9 at SKIMS (Site-III) in the month of January to a maximum of 8.0 at Inlet (Site-I) in the month of December and January (Table 5, Fig. 6).

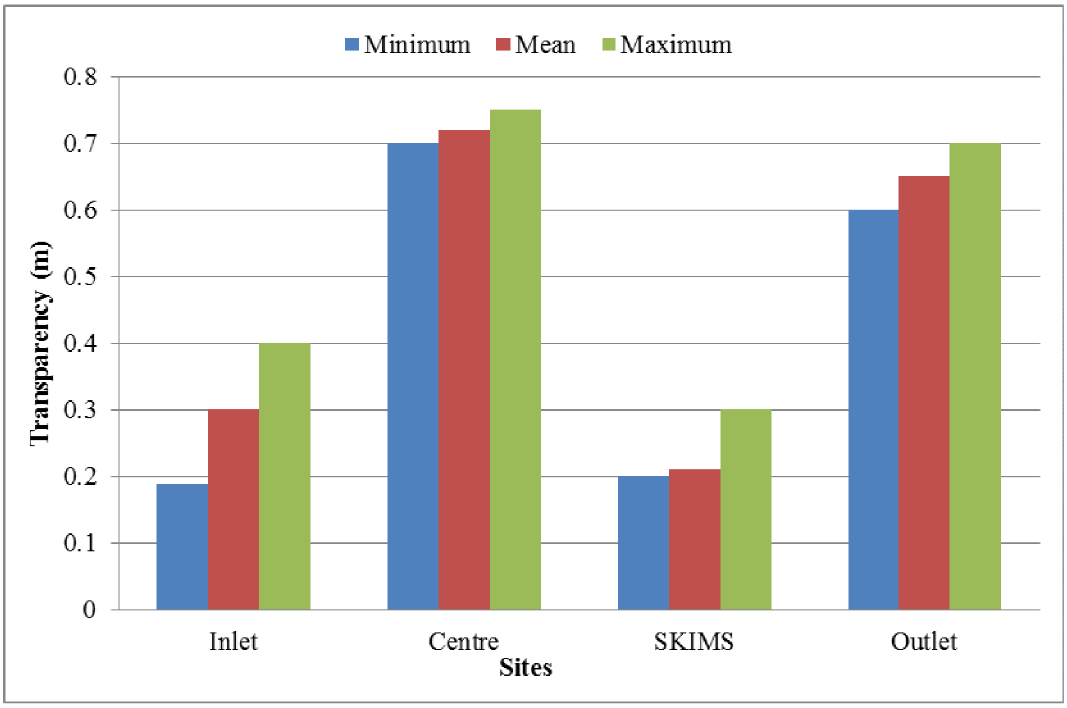


Fig. 5: Minimum, maximum and mean valves of transparency (m) at different site of Anchar lake

Table 5: Monthly variation of pH at different sites of Anchar lake

Sites	Dec.	Jan.	Feb.	Mar.	Apr.	May	Min.	Max.	Mean±SD
Inlet	8.0	8.0	7.8	7.85	7.7	7.4	7.4	8.0	7.79±0.22
Centre	7.8	7.9	7.5	7.7	7.5	7.3	7.3	7.9	7.61±0.2
SKIMS	7.2	7.1	7.3	7.2	7.1	6.9	6.9	7.3	7.03±0.13
Outlet	7.5	7.4	7.6	7.7	7.5	7.6	7.4	7.7	7.5±0.10

4.1.6 Dissolved oxygen

At Site-I, a minimum dissolved oxygen of 7.9 mg/L was recorded in the month of April and May while as the maximum dissolved oxygen of 8.5 mg/L was recorded in the month of December and January with a mean value of 8.2±0.27 mg/L (Table 6, Fig. 7).

At Site-II, a minimum dissolved oxygen of 7.0 mg/L was recorded in the month of May while a maximum dissolved oxygen of 7.7 mg/L was recorded in the month of December, with a mean value of 7.4±0.29 mg/L (Table 6, Fig. 7).

At Site-III, minimum dissolved oxygen of 4.0 mg/L was recorded in the month of May while a maximum dissolved oxygen of 4.9 mg/L in the month of December, with a mean value of 4.6±0.31mg/L (Table 6, Fig. 7).

At Site-IV, a minimum dissolved oxygen of 6.5 mg/L was recorded in the month of April while a maximum dissolved oxygen of 7.9 mg/L was recorded in the month of December, with a mean value of 6.9±0.5 mg/L (Table 6, Fig. 7).

The overall dissolved oxygen during the study period ranged from a minimum of 4.0 mg/L at SKIMS (Site-III) in the month of May to a maximum of 8.5 mg/L at Inlet (Site-I) in the month of December and January (Table 6, Fig. 7).

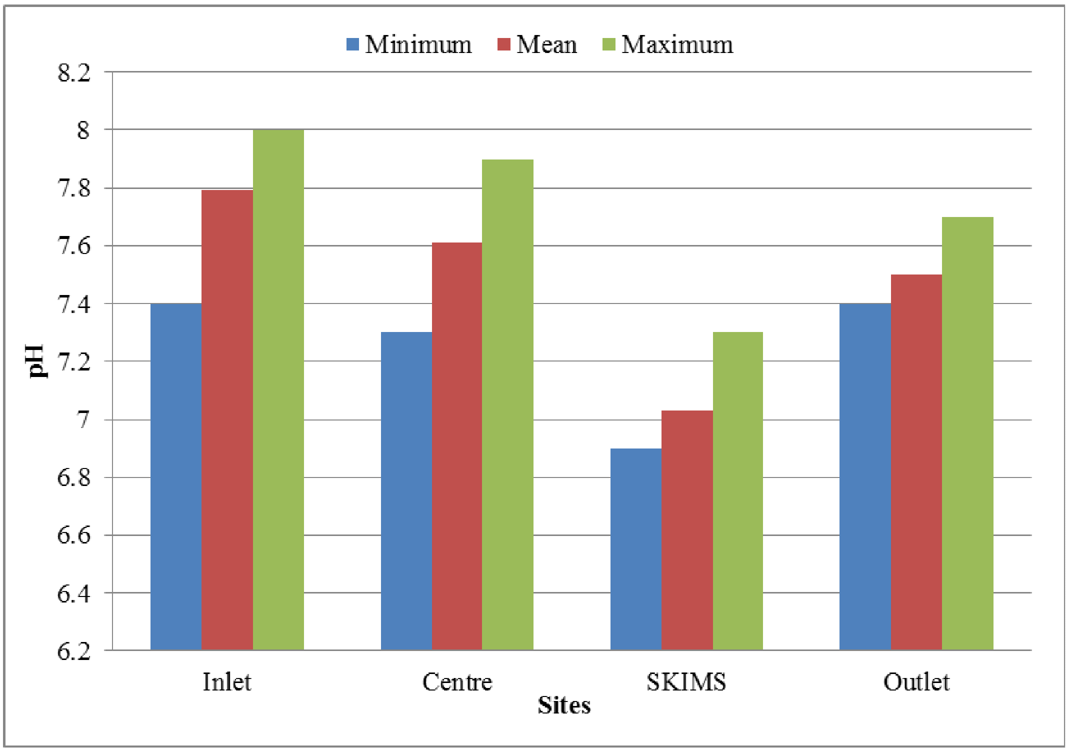


Fig. 6: Minimum, maximum and mean valves of pH at different site of Anchar lake

Table 6: Monthly variation of dissolved oxygen (mg/L) at different sites of Anchar lake

Sites	Dec.	Jan.	Feb.	Mar.	Apr.	May	Min.	Max.	Mean±SD
Inlet	8.5	8.5	8.3	8.1	7.9	7.9	7.9	8.5	8.2±0.27
Centre	7.7	7.6	7.6	7.5	7.1	7.0	7.0	7.77	7.4±0.29
SKIMS	4.9	4.7	4.8	4.6	4.6	4.0	4.0	4.9	4.6±0.31
Outlet	7.9	6.9	6.8	6.7	6.5	6.6	6.5	7.9	6.9±0.5

4.1.7 Free CO_2

At Site-I, a minimum free carbon dioxide from of 6.5 mg/L was recorded in the month of December while as a maximum free carbon dioxide of 14.3mg/l was recorded in the month of May, with a mean value of 9.96±3.39 mg/L (Table 7, Fig. 8).

At Site-II, a minimum free carbon dioxide of 10 mg/L was recorded in the month of December and January while a maximum free carbon dioxide of 16.5mg/L was recorded in the month of May, with a mean value of 12.41±3.0 mg/L (Table 7, Fig. 8).

At Site-III, a minimum free carbon dioxide content of 13 mg/L was recorded in the month of January while a maximum free carbon dioxide of 21 mg/L was recorded in the month of April and May with a mean value of 16.91±3.41mg/L (Table 7, Fig. 8).

At Site-IV, a minimum free carbon dioxide of 10.5 mg/L was recorded in the month of December and February while a maximum free carbon dioxide of 14 mg/L was recorded in the month of March, with a mean value of 11.75±1.5 mg/L (Table 7, Fig. 8).

The overall free carbon dioxide during the study period ranged from a minimum of 6.5 mg/L at Inlet (Site-I) in the month of December to a maximum of 21 mg/L at SKIMS (Site-III) in the month of April and May (Table 7, Fig. 8).

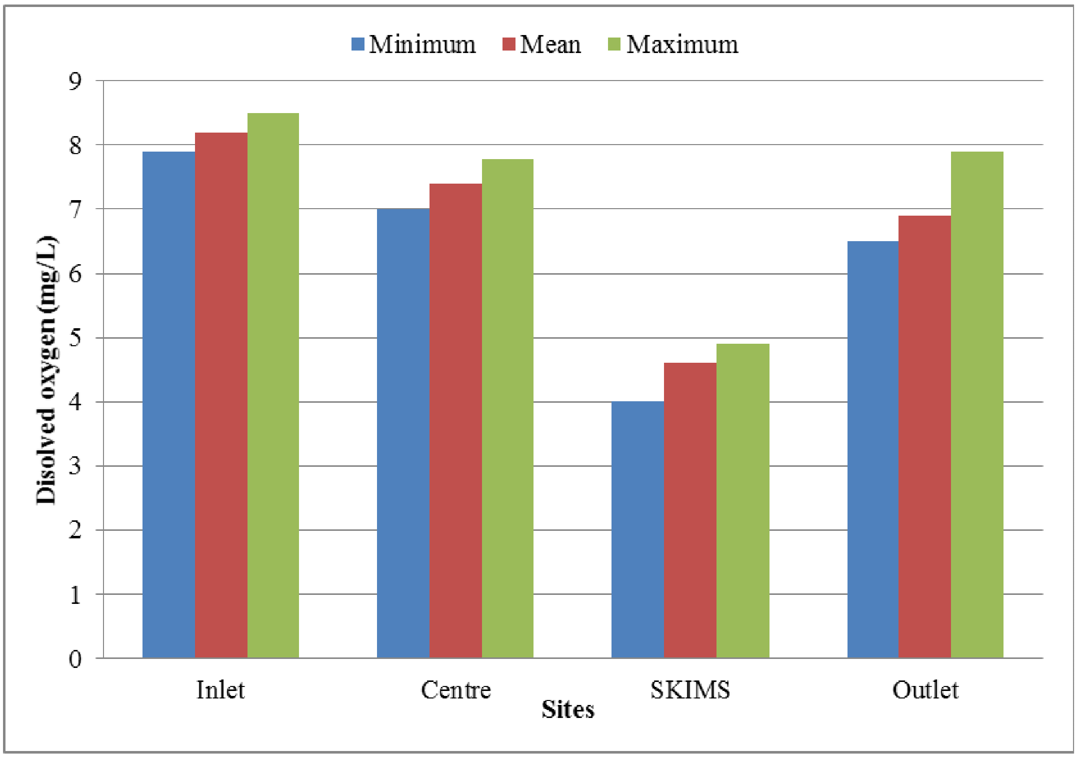


Fig. 7: Minimum, maximum and mean valves of dissolved oxygen (mg/L) at different sites of Anchar lake

Table-7: Monthly variation of free CO_2 (mg/L) at different sites of Anchar lake

Sites	Dec.	Jan.	Feb.	Mar.	Apr.	May	Min.	Max.	Mean±SD
Inlet	6.5	7	9	9	14	14.3	6.5	14.3	9.96±3.39
Centre	10	10	11	11	16	16.5	10	16.5	12.41±3.0
SKIMS	14	13	16	16.5	21	21	13	21	16.91±3.41
Outlet	10.5	13.5	10.5	14	11	11	10.5	14	11.75±1.5

4.1.8 Total alkalinity

At Site-I, a minimum of total alkalinity of 125 mg/L was recorded in the month of December while a maximum total alkalinity of 180 mg/L was recorded in the month of May, with a mean value of 146.83±18.98 mg/L (Table 8, Fig. 9).

At Site-II, a minimum total alkalinity of 98 mg/L was recorded in the month of May while a maximum total alkalinity of 174mg/L was recorded in the month of December with a mean value of 134.6±32.54 mg/L (Table 8, Fig. 9).

At Site-III, a minimum total alkalinity of 160 mg/L was recorded in the month of April while a maximum total alkalinity of 197 mg/L was recorded in the month of May with a mean value of 180.66±15.65 mg/L (Table 8, Fig. 9).

At Site-IV, a minimum total alkalinity of 135 mg/L was recorded in the month of January while a maximum total alkalinity of 145 mg/L was recorded in the month of December and April, with a mean value of 141.83±3.86 mg/L (Table 8, Fig. 9).

The overall total alkalinity during the study period ranged from a minimum of 98 mg/L at Centre (Site-II) in the month of May to a maximum of 197 mg/L at SKIMS (Site-III) in the month of May (Table 8, Fig. 9).

Fig. 8: Minimum, maximum and mean valves of free CO_2 (mg/L) at different sites of Anchar lake

Table 8: Monthly variation of total alkalinity (mg/L) at different sites of Anchar lake

Sites	Dec.	Jan.	Feb.	Mar.	April	May	Min.	Max.	Mean ±SD
Inlet	125	155	144	136	141	180	125	180	146.83±18.98
Centre	174	98	139	121	105	171	98	174	134.6±32.54
SKIMS	185	187	193	194	160	197	160	197	180.66±15.65
Outlet	145	135	144	140	145	142	135	145	141.83±3.86

4.1.9 Nitrate nitrogen (NO_3-N)

At Site-I, a minimum nitrate nitrogen content of 325 µg/L was recorded in the month of April while a maximum nitrate nitrogen content of 480 µg/L was recorded in the month of January and March, with a mean value of 420.83±58.68 µg/L (Table 9, Fig. 10).

At Site-II, a minimum nitrate nitrogen content of 260 µg/L was recorded in the month of May while a maximum nitrate nitrogen content of 440 µg/L was recorded in the month of February, with a mean value of 365±58.4 µg/L (Table 9, Fig. 10).

At Site-III, a minimum nitrate nitrogen content of 600 µg/L was recorded in the month of February and May while a maximum nitrate nitrogen content of 690 µg/L was recorded in the month of March, with a mean value of 644.33± 37.61µg/L (Table 9, Fig. 10).

At Site-IV, a minimum nitrate nitrogen content of 415 µg/L was recorded in the month of May while a maximum nitrate nitrogen content of 490 µg/L was recorded in the month of April, with a mean value of 445.83±33.5 µg/L (Table 9, Fig. 10).

The overall nitrate nitrogen content during the study period ranged from a minimum of 260 µg/L at Centre (Site-II) in the month of May to a maximum of 690 µg/L at SKIMS (Site-III) in the month of March (Table 9, Fig.10).

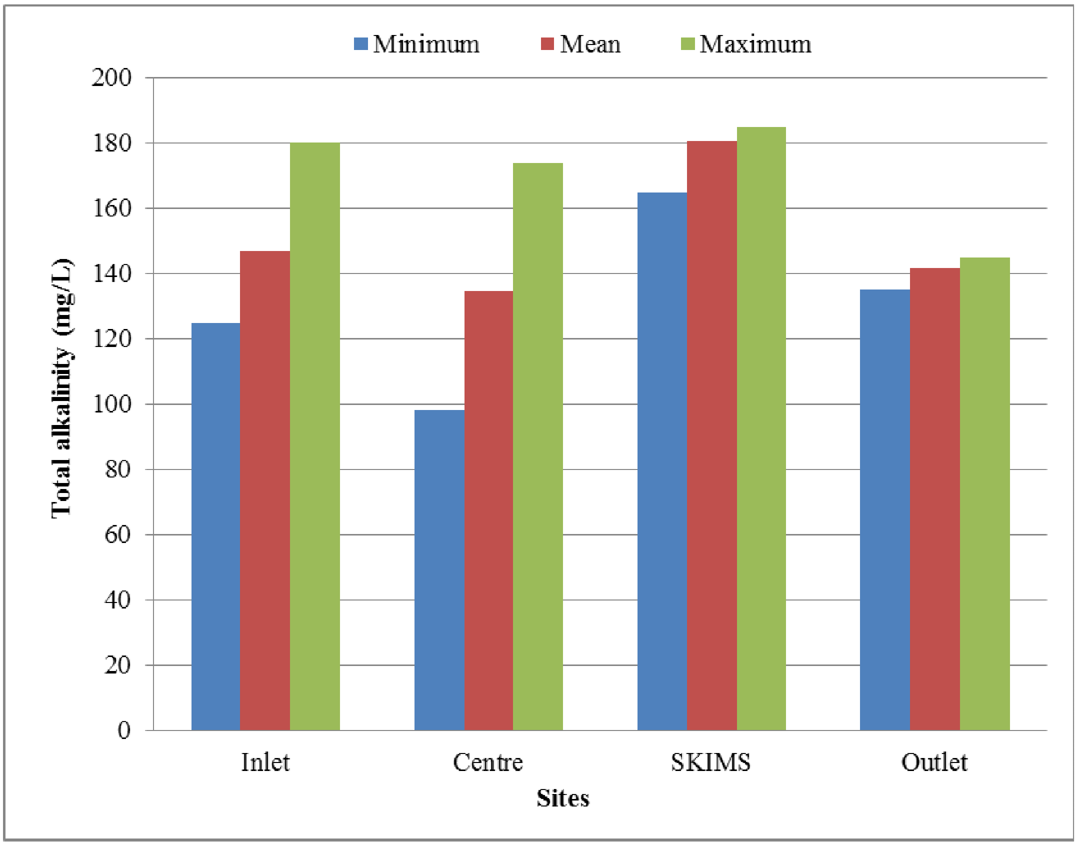


Fig. 9: Minimum, maximum and mean valves of total alkalinity (mg/L) at different sites of Anchar lake

Table 9: Monthly variation of nitrate nitrogen (µg/L) at different sites of Anchar lake

Sites	Dec.	Jan.	Feb.	Mar.	Apr.	May	Min.	Max.	Mean±SD
Inlet	420	480	430	480	325	390	325	480	420.83±58.68
Centre	380	380	440	365	365	260	260	440	365±58.4
SKIMS	655	674	600	690	635	600	600	690	644.33±37.61
Outlet	430	450	480	410	490	415	415	490	445.83±33.5

4.1.10 Ammonical nitrogen (NH_4-N)

At Site-I, a minimum ammonical nitrogen content of 100µg/l was recorded in the month of December while a maximum ammonical nitrogen content of 164 µg/L was recorded in the month of February, with a mean value of 136± 23.09 µg/L (Table 10, Fig. 11).

At Site-II, a minimum ammonical nitrogen content of 113 µg/L was recorded in the month of May while a maximum ammonical nitrogen content of 180 µg/L in the month of February, with a mean value of 149.83±25.32 µg/L (Table 10, Fig. 11).

At Site-III, a minimum ammonical nitrogen of 201µg/L was recorded in the month of May while a maximum Ammonical nitrogen content of 292 µg/L was recorded in the month of March, with a mean value of 250.83±37.98 µg/L (Table 10, Fig. 11).

At Site-IV, a minimum ammonical nitrogen content of 110 µg/L was recorded in the month of May while a maximum of 175 µg/L was recorded in the month of February, with a mean value of 147.5±24.8 µg/L (Table 10, Fig. 11).

The overall ammonical nitrogen content during the study period ranged from a minimum of 100 µg/L at Inlet ((Site-I) in the month of December to a maximum of 292 µg/L at SKIMS (Site-III) in the month of March. (Table 10, Fig. 11).

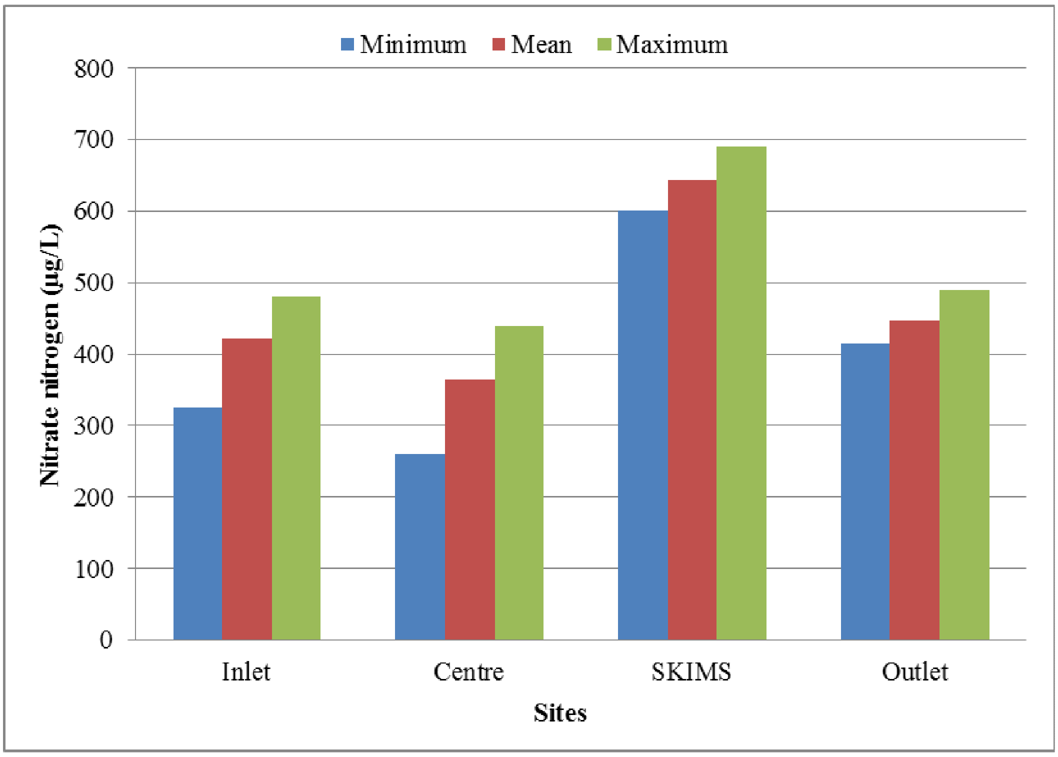


Fig. 10: Minimum, maximum and mean valves of total nitrate nitrogen (µg/L) at different sites of Anchar lake

Table-10: Monthly variation of ammonical nitrogen (µg/L) at different sites of Anchar lake

Sites	Dec.	Jan.	Feb.	Mar.	Apr.	May	Min.	Max.	Mean±SD
Inlet	100	143	165	152	135	121	100	165	136±23.09
Centre	133	165	180	168	140	113	113	180	149.83±25.32
SKIMS	265	285	210	292	252	201	201	292	250.83±37.98
Outlet	137	165	175	165	133	110	110	175	147.5±24.8

4.1.11 Orthophosphate (PO_4-P)

At Site-I, a minimum orthophosphate content of 110 µg/L was recorded in the month of December while a maximum Orthophosphate content of 145µg/L was recorded in the month of May, with a mean value of 128.83±13.49 µg/L (Table 11, Fig. 12).

At Site-II, a minimum orthophosphate content of 123 µg/L was recorded in the month of December while a maximum Orthophosphate content of 150 µg/L was recorded in the month of January, with a mean value of 138.8±9.8 µg/L (Table 11, Fig. 12).

At Site-III, a minimum orthophosphate content of 210 µg/L was recorded in the month of December while a maximum Orthophosphate content of 285 µg/L was recorded in the month of May, with a mean value of 265.5±29.48 µg/L (Table 11, Fig. 12).

At Site-IV, a minimum orthophosphate content of 120 µg/L was recorded in the month of April and May while a maximum Orthophosphate content of 145 µg/L was recorded in the month of December, with a mean value of 131.6±9.8 µg/L (Table 11, Fig. 12).

The overall orthophosphate content during the study period ranged from a minimum of 110 µg/L at Inlet (Site-I) in the month of December to a maximum of 285 µg/L at SKIMS (Site-III) in the month of May. (Table 11, Fig. 12).

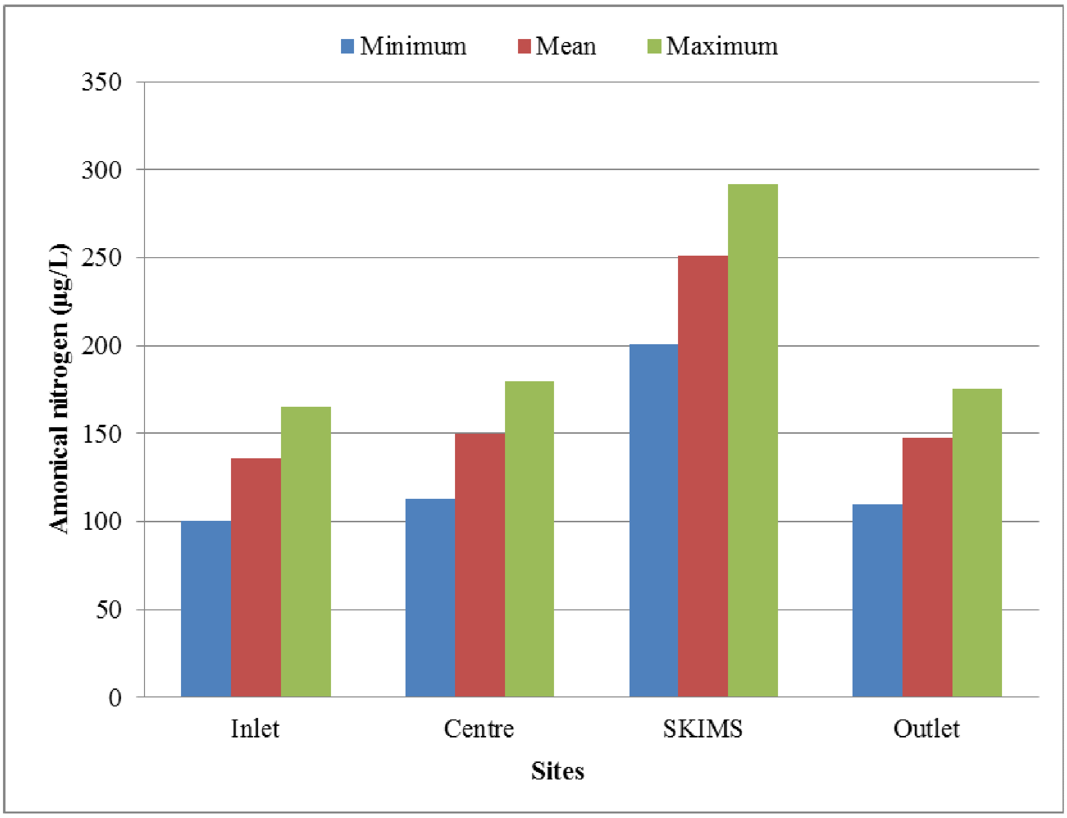


Fig. 11: Minimum, maximum and mean valves of total ammonical nitrogen (µg/L) at different sites of Anchar lake

Table 11: Monthly variation of orthophosphate (µg/L) at different sites of Anchar lake

Sites	Dec.	Jan.	Feb.	Mar.	Apr.	May	Min.	Max.	Mean ±SD
Inlet	110	118	125	135	140	145	110	145	128.83±13.49
Centre	123	150	145	145	135	135	123	150	138.8±9.8
SKIMS	210	275	255	284	284	285	210	285	265.5±29.48
Outlet	145	135	135	135	120	120	120	145	131.6±9.8

4.1.12 Total phosphorus

At Site-I, a minimum total phosphorus content of 309 µg/L was recorded in the month of April while a minimum total phosphorus content of 394 µg/L was recorded in the month of January, with a mean value of 356.83±38.49 µg/L (Table 12, Fig. 13).

At Site-II, a minimum total phosphorus content of 326 µg/L was recorded in the month of December while a maximum total phosphorus content of 378 µg/L was recorded in the month of May, with a mean value of 350.83±20.54 µg/L (Table 12, Fig. 13).

At Site-III, a minimum total phosphorus content of 622 µg/L was recorded in the month of January while a maximum total phosphorus content of 655µg/l was recorded in the month of May, with a mean value of 627.66±18.52 µg/L (Table 12, Fig. 13).

At Site-IV, a minimum total phosphorus of 301µg/L was recorded in the month of December and March while a maximum total phosphorus of 391µg/L was recorded in the month of January, with a mean value of 330.6±34054µg/l (Table 12, Fig. 13).

The overall total phosphorus content during the study period ranged from a minimum of 301 µg/L at Outlet (Site-IV) in the month of December to a maximum of 655 µg/L at SKIMS (Site-III) in the month of May (Table 12, Fig. 13).

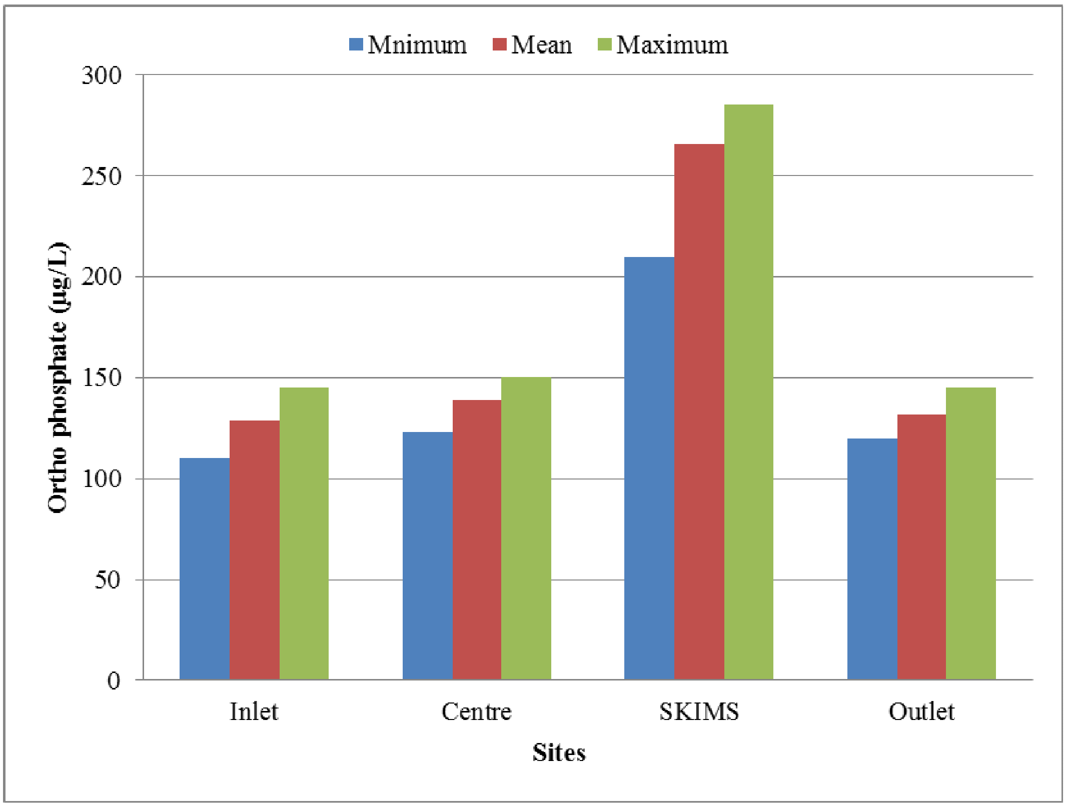


Fig. 12: Minimum, maximum and mean valves of orthophosphate (µg/L) at different sites of Anchar lake

Table 12: Monthly variation of total phosphorus (µg/L) at different sites of Anchar lake

Sites	Dec.	Jan.	Feb.	Mar.	Apr.	May	Min.	Max.	Mean ±SD
Inlet	393	394	365	310	309	370	309	394	356.83±38.49
Centre	326	367	355	350	329	378	326	378	350.83±20.54
SKIMS	623	622	637	630	599	655	622	655	627.66±18.52
Outlet	301	391	334	301	312	345	301	391	330.6±34.54

4.2 Distribution of Annelids

During the present study all the four pre-designated sites were studied for distribution of Annelids. The site wise distribution is given below.

Site-I: - This site is located at the inlet where Sindh nallah enters into the lake. At this site a total of three species of Annelida were recorded viz *Limnodrillus hoffmeister, Erpobdella octoculata,* and *Glassophonia complanata*. Out of which one species (*Limnodrillus hoffmeister*) belonged to class Oligochaeta, while two species (*Erpobdella octoculata,* and *Glassophonia complanata*) belonged to class Hirudinea. A minimum density of 45 Ind./m^2 of *Limnodrillus hoffmeister* was recorded in the month of December while a maximum density of 334 Ind./m^2 was recorded in the month of May, with a mean density of 16.33±117.38 Ind./m^2. *Erpobdella octoculata* recorded a minimum density 23 Ind./m^2 in the month of December, while a maximum density of 289 Ind./m^2 was recorded in the month of April, with a mean density of 178.17±96.13 Ind./m^2. A minimum density of 67 Ind./m^2 of *Glassophonia complanata* were registered in the month of January to a maximum density of 334 Ind./m^2 in the month of May with a mean density of 185.67±99.06 Ind./m^2 (Table 13, Fig. 14).

Table 13: Monthly variation in population density (Ind./m^2) of three species of phylum Annelida were registered in Anchar lake at Site-I

Class	Genus/ species	Dec.	Jan.	Feb.	Mar.	Apr.	May	Min.	Max.	Mean ±SD
Oligochaeta	*Limnodrilus hoffmeister*	45	89	67	178	267	334	45	334	163.33 ±117.38
Hirudinea	*Erpobdella octoculata*	23	134	178	178	289	267	23	289	178.17 ±96.13
	Glassophonia complanata	112	67	156	178	267	334	67	334	185.67 ±99.06

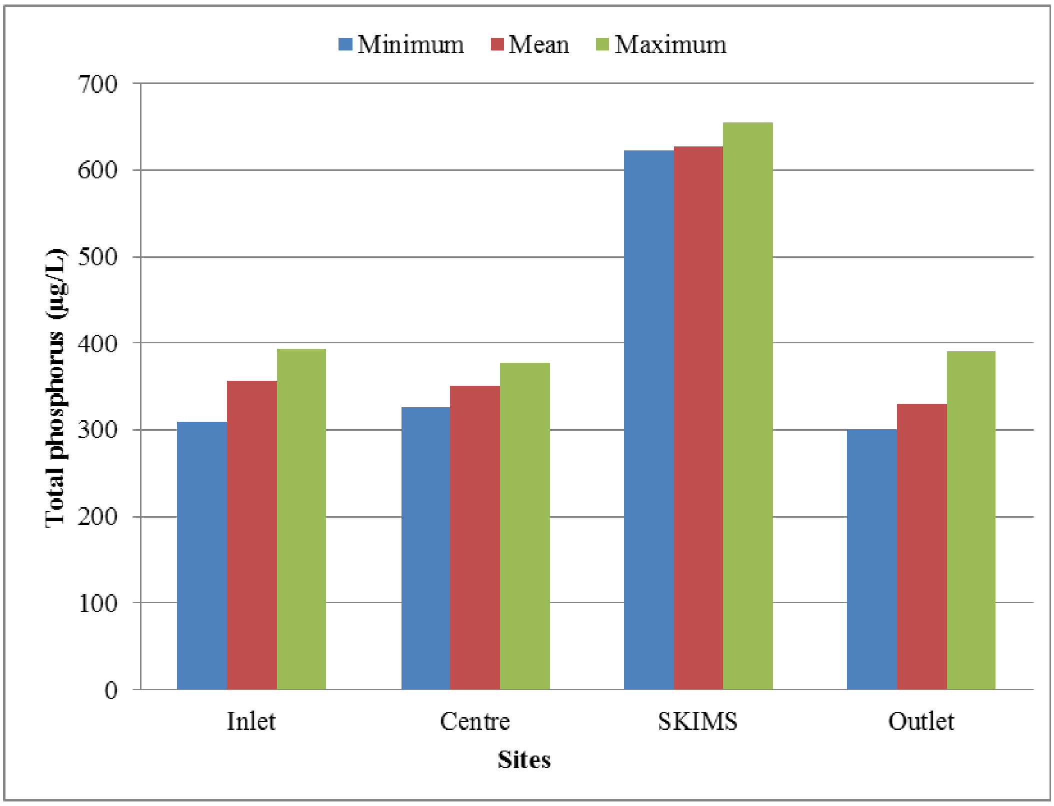


Fig. 13: Minimum, maximum and mean valves of total phosphorus (µg/L) at different sites of Anchar lake

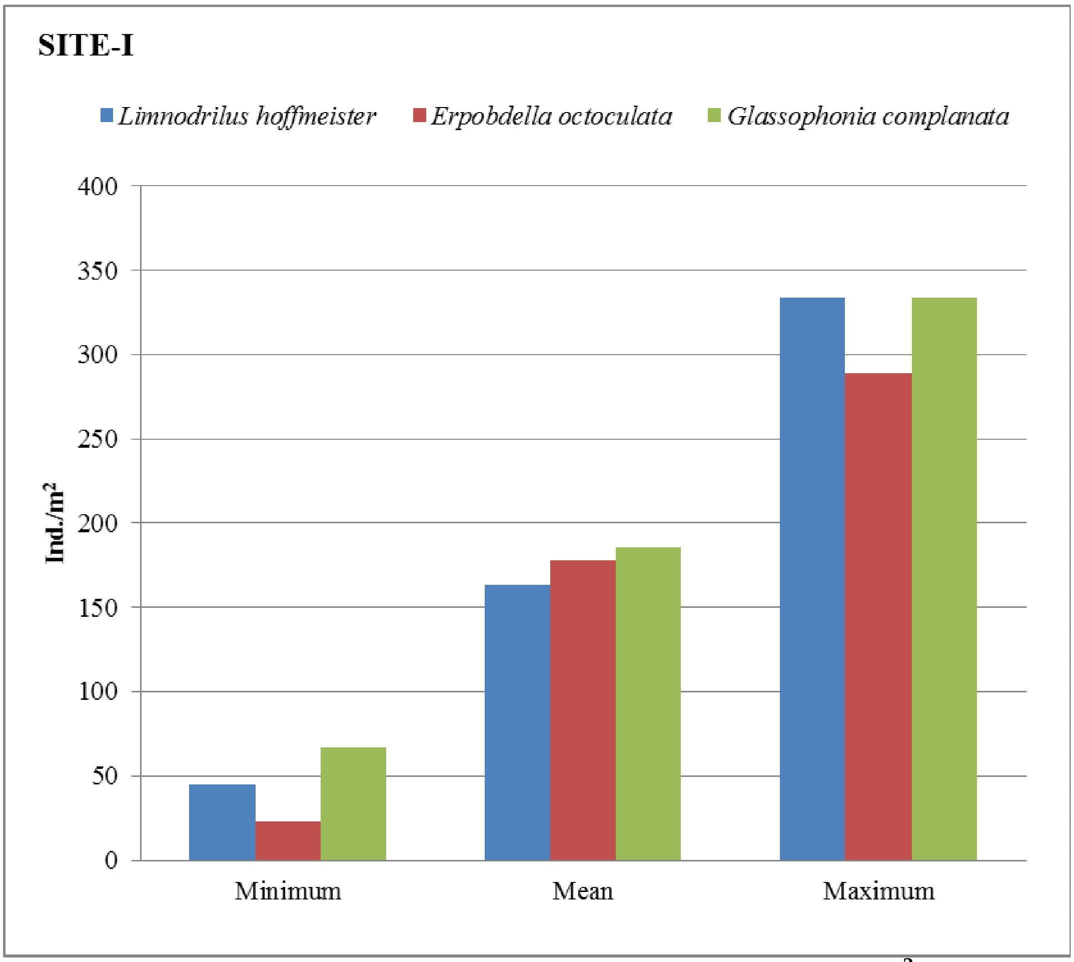


Fig. 14: Minimum, maximum and mean density (Ind./m^2) of three species of phylum Annelida

Site-II: This site is located at the centre of the lake. At this site a total of three species of Annelida were recorded viz *Limnodrillus hoffmeister, Erpobdella octoculata*, and *Glassophonia complanata*. Out of which one specie (*Limnodrillus hoffmeister*) belonged to class Oligochaeta, while two species (*Erpobdella octoculata,* and *Glassophonia complanata*) belonged to class Hirudinea. A minimum density of 45 Ind./m^2 of *Limnodrillus hoffmeister* was recorded in the month of January while a maximum density of 423 Ind./m^2 was recorded in the month of May, with a mean density of 237.5±162.55 Ind./m^2. *Erpobdella octoculata* recorded a minimum density 23 Ind./m^2 in the month of January, while a maximum density of 534 Ind./m^2 was recorded in the month of May, with a mean density of 241.33±196.99 Ind./m^2. A minimum density of 89 Ind./m^2 of *Glassophonia complanata* were registered in the month of December to a maximum density of 400 Ind./m^2 in the month of April with a mean density of 244.67±131.71 Ind./m^2 (Table 14, Fig. 15).

Table 14: Monthly variation in population density (Ind./m^2) of three species of phylum Annelida were registered in Anchar lake at Site-II

Class	Genus/ species	Dec.	Jan.	Feb.	Mar.	Apr.	May	Min.	Max.	Mean ±SD
Oligochaeta	*Limnodrilus hoffmeister*	89	45	156	312	400	423	45	423	237.5 ±162.55
Hirudinea	*Erpobdella octoculata*	45	23	178	356	312	534	23	534	241.33 ±196.99
	Glassophonia complanata	89	134	245	200	400	400	89	400	244.67 ±131.71

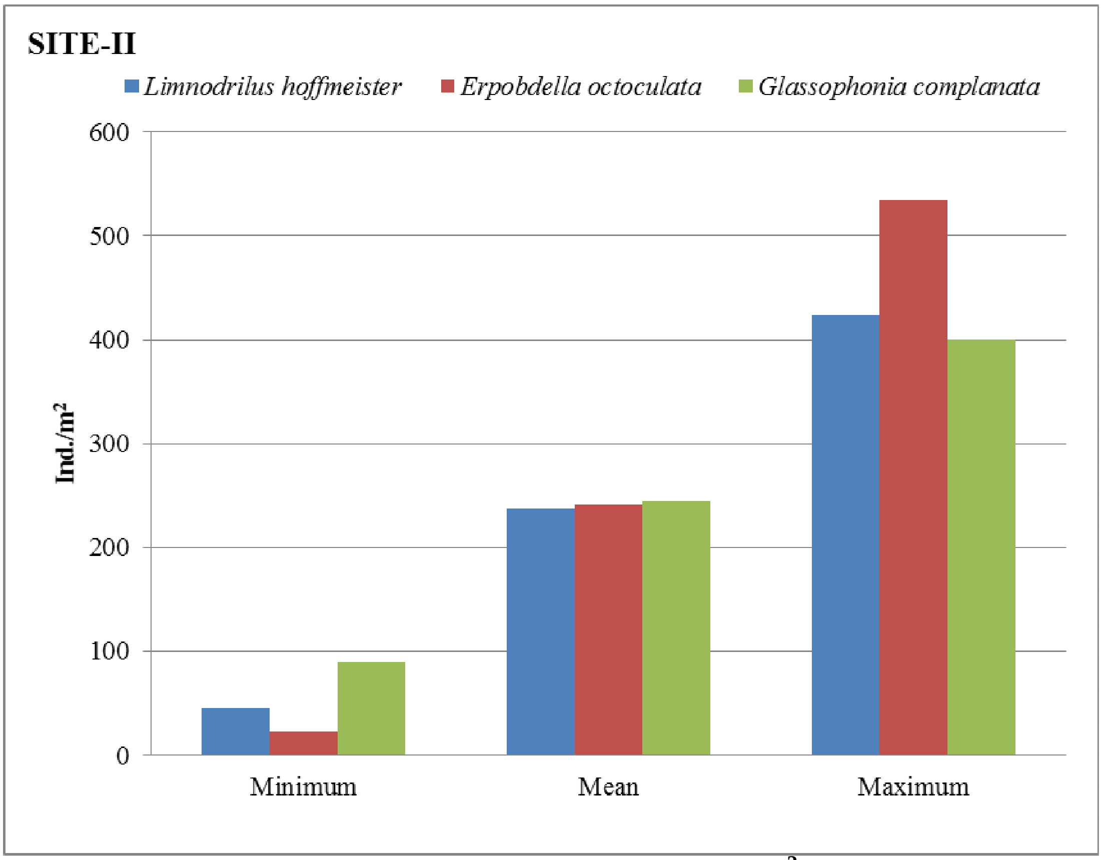


Fig. 15: Minimum, maximum and mean density (Ind./m^2) of three species of phylum Annelida

Site-III:- This site is located towards the SKIMS side.. At this site a total of three species of Annelida were recorded viz. *Limnodrillus hoffmeister, Erpobdella octoculata*, and *Glassophonia complanata*. Out of which one specie (*Limnodrillus hoffmeister*) belonged to class Oligochaeta, while two species (*Erpobdella octoculata*, and *Glassophonia complanata*) belonged to class Hirudinea. A minimum density of 200 Ind./m^2 of *Limnodrillus hoffmeister* was recorded in the month of December while a maximum density of 978 Ind./m^2 was recorded in the month of May, with a mean density of 611.57±308.27 Ind./m^2. *Erpobdella octoculata* recorded a minimum density 245 Ind./m^2 in the month of December, while a maximum density of 889 Ind./m^2 was recorded in the month of May, with a mean density of 537.56±289.36 Ind./m^2. A minimum density of 245 Ind./m^2 of *Glassophonia complanata* were registered in the month of December to a maximum density of 845 Ind./m^2 in the month of May with a mean density of 541.33±223.52 Ind./m^2 (Table 15, Fig. 16).

Table 15: Monthly variation in population density (Ind./m^2) of three species of phylum Annelida were registered in Anchar lake at Site-III

Class 3	Genus/ species	Dec.	Jan.	Feb.	Mar.	Apr.	May	Min.	Max.	Mean ±SD
Oligochaeta	*Limnodrilus hoffmeister*	200	378	512	667	934	978	200	978	611.5 ±308.27
Hirudinea	*Erpobdella octoculata*	245	312	289	712	778	889	245	889	537.5 ±289.36
	Glassophonia complanata	245	400	423	623	712	845	245	845	541.33 ±223.52

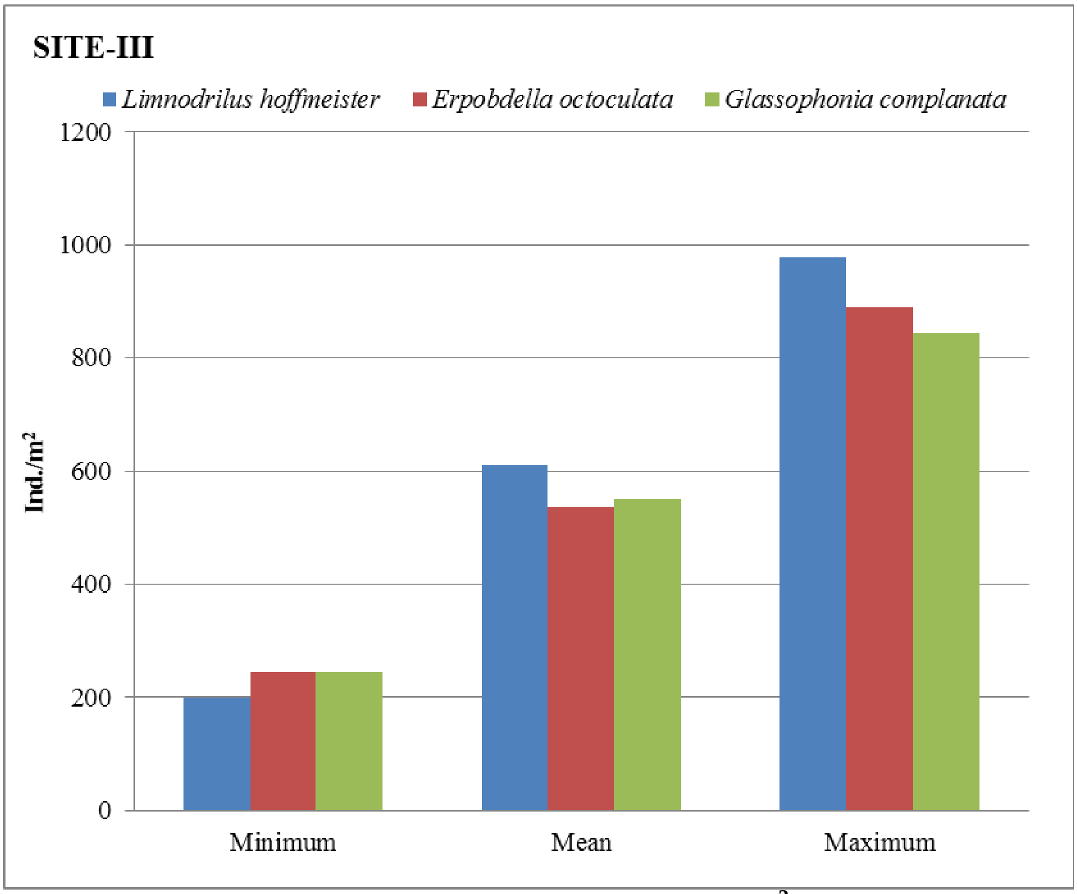


Fig. 16: Minimum, maximum and mean density (Ind./m^2) of three species of phylum Annelida

Site-IV This site is located towards the outlet were the lake flows into the river Jhelum. At this site a total of three species of Annelida were recorded viz *Limnodrillus hoffmeister, Erpobdella octoculata,* and *Glassophonia complanata*. Out of which one specie (*Limnodrillus hoffmeister*) belonged to class Oligochaeta, while two species (*Erpobdella octoculata,* and *Glassophonia complanata*) belonged to class Hirudinea. A minimum density of 23 Ind./m^2 of *Limnodrillus hoffmeister* was recorded in the month of December while a maximum density of 734 Ind./m^2 was recorded in the month of May, with a mean density of 304.33±331.72 Ind./m^2. *Erpobdella octoculata* recorded a minimum density 45 Ind./m^2 in the month of December and January, while a maximum density of 512 Ind./m^2 was recorded in the month of April, with a mean density of 322.67±218.48 Ind./m^2. A minimum density of 67 Ind./m^2 of *Glassophonia complanata* were registered in the month of January to a maximum density of 512 Ind./m^2 in the month of May with a mean density of 200.33±175.18 Ind./m^2 (Table 16, Fig. 17).

Table 16: Monthly variation in population density (Ind./m^2) of three species of phylum Annelida were registered in Anchar lake at Site-IV

Class 3	Genus/ species	Dec.	Jan.	Feb.	Mar.	Apr.	May	Min.	Max.	Mean ±SD
Oligochaeta	*Limnodrilus hoffmeister*	23	89	45	223	712	734	23	734	304.33 ±331.72
Hirudinea	*Erpobdella octoculata*	45	45	489	400	512	445	45	512	322.67 ±218.48
	Glassophonia complanata	89	67	178	67	289	512	67	512	200.33 ±175.18

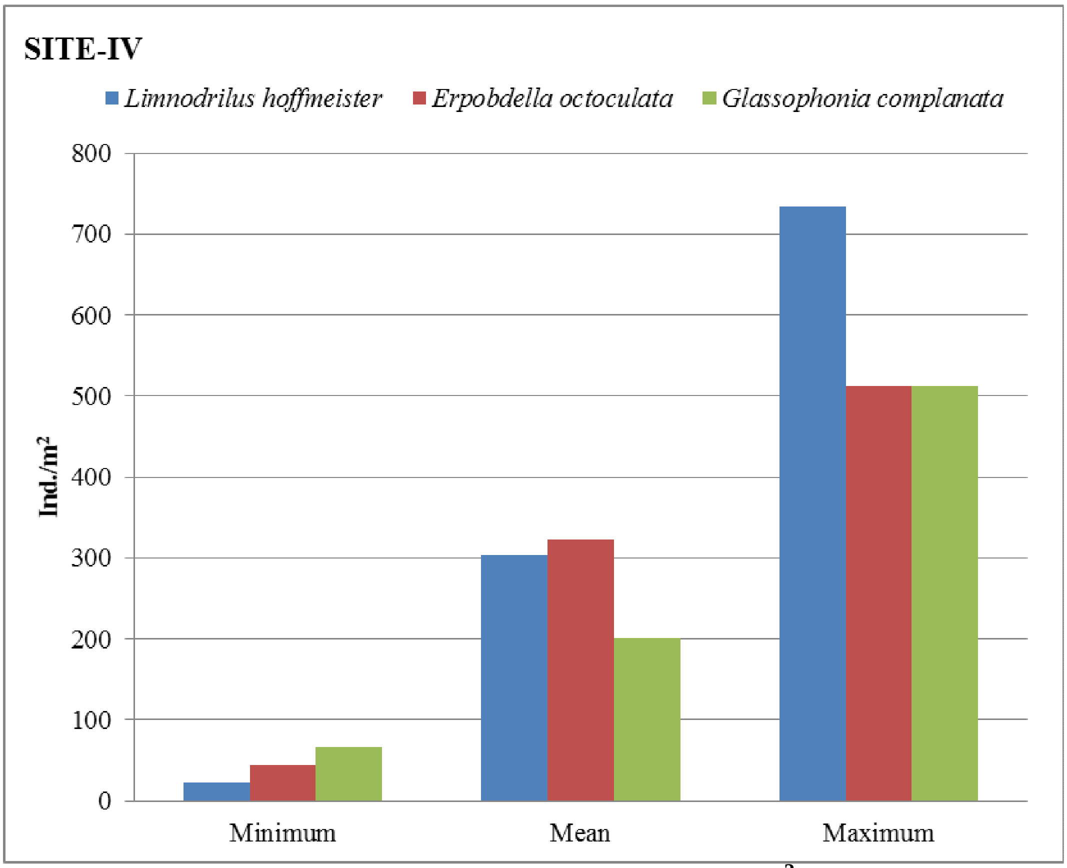


Fig. 17: Minimum, maximum and mean density (Ind./m^2) of three species of phylum annelida

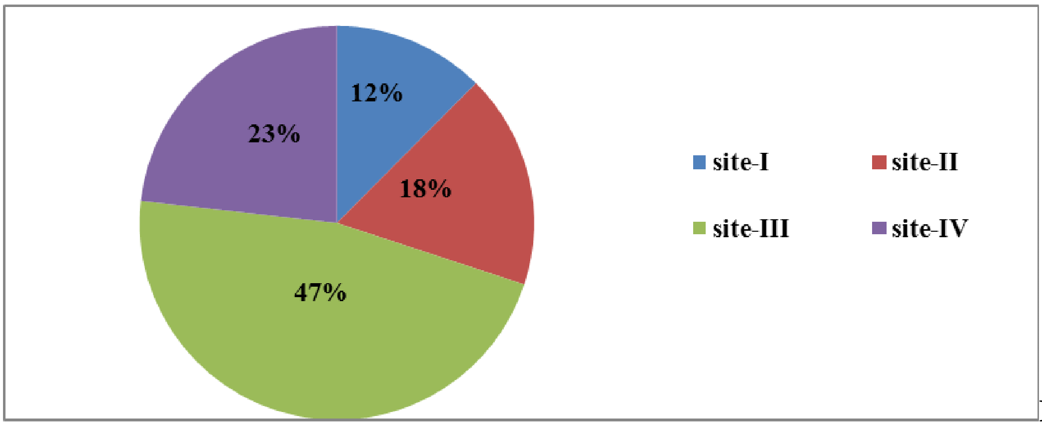
4.2.1 Overall species composition

During the present study a total of three species viz *Limnodrillus hoffmeister, Erpobdella octoculata*, *Glassophonia complanata* (Plate-7) of phylum Annelida were recorded from four sites of Anchar lake, which belonged to class Oligochaeta and Hirudinea. Among the three species two belonged to class Hirudinea (*Erpobdella octoculata*, *Glassophonia complanata*) and one belonged to class Oligochaeta (*Limnodrillus hoffmeister*).

Among the Oligochaetes, *Limnodrilus hoffmeister* recorded highest density of 3669 Ind./m^2 at Site-III followed by 1826 Ind./m^2 at Site-IV, 1425 Ind./m^2 at Site-II and 980 Ind./m^2 at Site-I (Table-17). The percentage contribution of *Limnodrilus hoffmeister,* was 47, 23.36, 17.71 and 12.53% at site-III, site-IV, site-II, site-I respectively (Fig. 18).

Among the Hirudinea, *Erpobdella octoculata* recorded highest density of 3225 Ind./m^2 at Site-III followed by 1936 Ind./m^2 at Site-IV, 1448 Ind./m^2 at Site-II and 1069 Ind./m^2 at Site-I (Table-17). The percentage contribution of *Erpobdella octoculata*, was 21.94, 13.16, 9.83 and 7.26% at Site-III, Site-IV, Site-II, Site-I respectively (Fig. 19).

Glassophonia complanata, recorded highest density of 3248 Ind./m^2 at Site-III followed by 1468 Ind./m^2 at Site-IV, 1202 Ind./m^2 at Site-II and 1114 Ind./m^2 at Site-I (Table-17). The percentage contribution of *Glassophonia complanata,* was 22.09, 9.98, 8.17 and 7.56% at Site-III, Site-IV, Site-II, Site-I respectively (Fig. 20).



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ig. 18: Percentage composition of *Limnidrillus hoffmeister* at four sites of Anchar lake

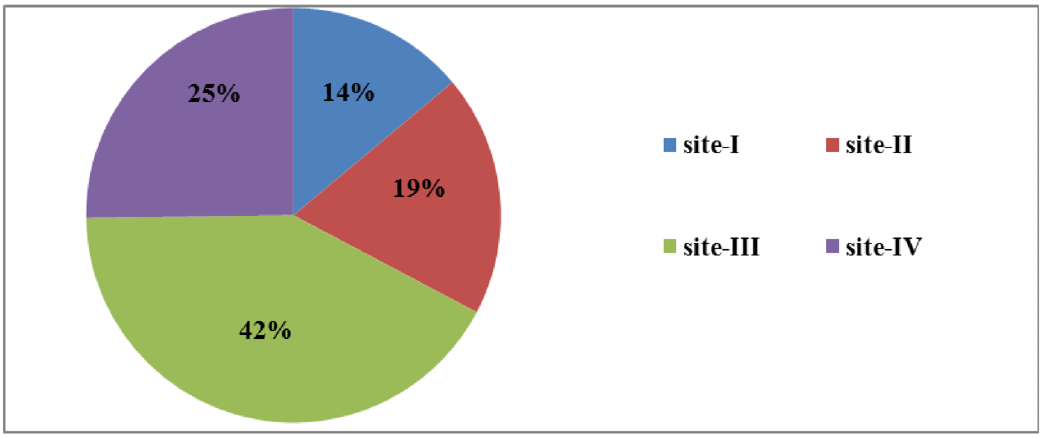

Fig. 18:Percentage composition of *Erpobdella octoculata* at four sites of Anchar lake

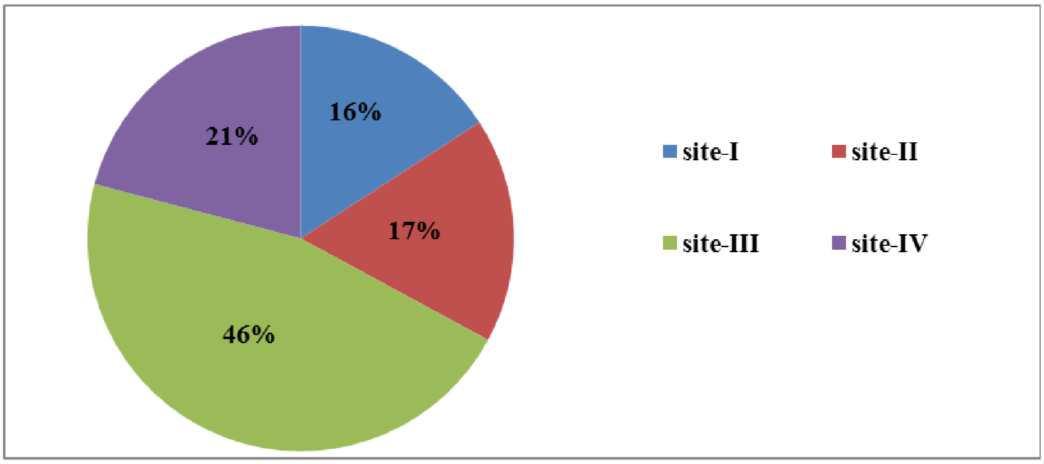

Fig.20:Percentage composition of *Glassophonia complanata*at four site of Anchar lake


Limnodrilus hoffmeister


Erpobdella octoculata


Glassophonia complanata

Plate-7 : Three speices of Phlum Annelida

Table-17: Overall population density (Ind./m^2) of Annelida (Oligochaeta/Hirudenia) at four sites of Anchar lake

Class	Genus/Species	Inlet	Central	SKIMS	Outlet	Min	Max	Mean ±SD
Oligochaeta	*Limnodrilus hoffmeister*	980	1425	3669	1826	980	3669	87.75±53.80
Hirudinea	*Erpobdella octoculata*	1069	1448	3225	1936	1069	3225	86.25±42.29
	Glossophenia complanata	1114	1448	3248	1202	1114	3248	72.75±42.44

Chapter 5

DISCUSSION

5.1 Physico-chemical parameters

5.1.1 Air temperature

Temperature is one of the major important factor that can affect the speed of chemical reaction, solubility of chemical compounds and also effect the interaction of pollutants with their environment (Aziz *et al.*, 2013). Air temperature strongly influences lake temperature because it affects three important heat exchange process between water and atmosphere –convective heat exchange, evaporative heat exchange and the atmospheric emission of long wave radiation (Edinger, 1968). During the present study the overall mean air temperature was recorded 10±8.08 ^{o}C. The minimum air temperature of 3^{o}C was recorded in winter and a maximum air temperature of 25.5^{o}C in spring (Table 18). 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.* (2014), Indresha and Patra (2014), Umerfaruq and Solanki (2015). They also recorded the highest air temperature in summer season and lowest air temperature in winter season. Monisa and Balkhi (2013), also recorded the same results while working on Dal lake ecosystem

The air temperature has a significant positive correlation with water temperature ($p \leq 0.01$, r= 0.974) (Table 19), it means that as the air temperature increases in summer season water temperature also increase and vice versa. This is in confirmation with work of Chandrakiran *et al.* (2104), 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.

5.1.2 Water temperature

Water temperature is plays a critical factor in aquatic ecosystems. The response of water temperature to air temperature depends on the size of water body. It affects biological reactions, physical and chemical characteristic of water Balaji (2015). It is necessary to study the temperature variation in water body, because water density and oxygen content are temperature related and hence individually affects osmoregulation, respiration, behaviour and metabolism of animals. The present data showed fluctuation 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 (1979). The overall mean value of water temperature was found to be 5.97±3.69 ^{o}C (Table 18). The maximum water temperature of 12.5^{o}C was recorded during the summer season and the minimum water temperature of 1.6 ^{o}C during the winter season. (Table18). 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.* (2012), 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. Mahmoud (2002) reported that the decrease or increase in water temperature are mainly dependent on the climatic conditions, sampling times, and was also affected by specific characteristic of water environment such as turbidity, plant cover and humidity.

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 19).

5.1.3 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 (2002), Bhat *et al.* (2013) and Sushil *et al.* (2014), in their study, 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 19) which is in conformation with Monisa (2011) who also recorded the positive correlation between depth and transparency at different basins of Dal lake.

5.1.4 Transparency

Transparency is one of the important physical property of water, indicative of the degree to which sun light can penetrate through water. Transparency of natural water is an indicator of productivity Balaji (2015). During the present study the mean transparency was (0.48±0.23 m) (Table 18). The higher transparency value of 0.75 m (Table 18) was observed at the centre in winter, which may be due to low organic matter production with poor planktonic growth. while as the lowest transparency value of 0.20 m (Table 18) was observed at SKIMS (Site-III) in summer season, due to algal blooms and inflow of sewage. The results are in agreement with Ahangar *et al.* (2012), Bhat *et al.* (2013) and Sushil *et al.* (2014). 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 19). Bhat *et al.* (2014), also recorded the significant positive correlation between transparency and dissolved oxygen in Anchar lake.

5.1.5 pH

pH is the measure of acidity or alkalinity of water, hence it is an important factor for water quality analysis. The term pH reflects the activity of hydrogen ion in natural waters, it also shows the variation due to photosynthetic activity wherein PH increase due to utilization of carbon dioxide. During the present study the overall mean pH was found to be (7.51±0.31) (Table 18) depicting an alkaline nature of Anchar Lake. During the present investigation the pH ranged (6.9 to 8), \the minimum pH was found during the summer season at the SKIMS (Site-III). While as higher 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 (Wangneo, 1984; Kundangar *et al.,* 1996 and Abubakr, 2010).

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) (Table 19) while as significant positive correlation with dissolved oxygen ($p \leq 0.01$, r=0.850) (Table 19).

5.1.6 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. Oxygen content of water varies with temperature, turbulence, photosynthetic activity of algae, higher plants and atmospheric pressure (Bhat *et al.,* 2013). It is considered as the factor which can reveal the nature of entire ecosystem. During the present study the overall mean dissolved oxygen was (6.69±1.48 mg/L) (Table 18). The range of dissolved oxygen was (4 mg/L to 8.5 mg/L) (Table 18). The lower value of dissolved oxygen, was recorded at SKIMS (Site-III), during summer season, was due to increased amount of organic matter, agricultural runoff and presence of sewage, 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 (1988), Bhat *et al.* (2013) 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 19), which means that with the increase in dissolved oxygen content CO_2 content decreases.

5.1.7 Free CO_2

Free carbon dioxide is the indicator of the biological respiration activities of ecosystem. It alters the pH of water by forming carbonic acid, which further dissociate into carbonate and bicarbonate. During the present study the mean free CO_2 in was found to be (12.76±3.79 mg/L) (Table 18). The range of free CO_2 concentration was found to be (6.5mg/L to 12 mg/L) (Table 19). 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 waste water and sewage effluents, fertilizers and other point and non-point source from the agricultural fields, which increase the free CO_2 concentration The result is in conformation of Ahanghar *et al.* (2012), who also revealed that CO_2 liberated during respiration and decay of organic matter which depends upon the water temperature, depth rate of respiration, decomposition of organic matter and chemical nature of bottom, which 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 19). Similar results have been observed by Bahura (1998) and Bhat *et al.* (2014), during their study.

5.1.8 Total alkalinity

Alkalinity is a measure of buffering capacity of water and is important for aquatic life in a fresh water system (Kaushik and Saxena, 1989). During the present study, overall mean alkalinity was (151±26.28 mg/L) (Table 18). 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. The result is in conformation with Sahai and Shrivastava (1976), who observed low concentration of bicarbonate in summer in Chilka Lake owing to the increased use by phytoplankton and submerged macrophytes. Umerfaruq and Solanki (2015), 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.

5.1.9 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. The presence of nitrate in any aquatic ecosystem depends on the activity of nitrifying bacteria on nitrogen source of domestic and agricultural origin. The conversion of nitrate from ammonia in nitrification process chiefly depends upon the presence of oxygen. Increase in concentration of nitrate is harmful as it increase the growth of algal blooms which makes water unsuitable for use. 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 the presence of high amount of domestic sewage, decaying of organic matter and the agricultural runoff bringing with it nitrate fertilizers and detergents. This is in agreement with the finding of Bhattacharya *et al.* (2002) and Singh *et al.* (2013) who reported higher concentration of nitrate during summer and lower concentration in winter, respectively in upper stretch of Gangetic West Bengal and major rivers in Imphal. Abubakr and Kundangar (2004) 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.

5.1.10 Ammonical nitrogen (NH_4-N)

Ammonia dissolves in water to form ammonium hydroxide and hydroxyl ions these ammonium ions are readily taken up by aquatic autotrophs with preference over nitrates, thus usually preventing it to reach to toxic level. The higher concentration of ammonia is generally found in polluted waters (Shrivastiva *et al.,* 2015). In the present study the mean concentration of ammonical nitrogen was recorded as (17.04±54.28 µg/L) (Table 18) and the range of ammonical nitrogen was found to be (100 µg/L to 292µg/L) (Table 18). 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 as the lower value was recorded during the winter season. The result is agreement with Sushil *et al.* (2014) who also reported the higher concentration of ammonia in Anchar lake and attributed it due to organic pollution and agricultural wastes. Wetzel (2001) 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).

5.1.11 Orthophosphate (PO_4-P)

Phosphorus is an essential element for fertility of lakes and is regarded as key nutrient in the productivity of waters. In natural waters phosphorus exist as soluble phosphate, which, when in higher concentration, cause eutrophication of fresh water system (Bandela *et al.*, 1999 and Rabalais, 2002). Phosphorus enters the surface waters from human generated wastes and land runoff. 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 18). 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). The result is in complete agreement with Herney *et al.* (2013), which corresponded higher value of phosphate during warmer season to rapid evaporation and mineralization of decomposed materials in water.

5.1.12 Total phosphorus

Presence of phosphorus in excess of 30 µg/L in water bodies is regarded as a major nutrient triggering eutrophication Welch (1980). It is available in different forms viz. orthophosphate, condensed phosphate and organically bound phosphate (Bandela *et al.*, 1999) and is considered as critical limiting nutrient of fresh water system Rabalais (2002). 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 18). The minimum valve of total phosphorus was found during colder months at the outlet of the lake, it may be due to the out flowing water which carries all nutrients (especially phosphate) into the river Jhelum, 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) rapid evaporation and other effluents. The result is in complete agreement with Herney *et al.* (2013). The same has been inferred by Abubakr and Kundangar (2004) that increase in nitrogen and phosphorus in lake waters are attributed 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 19).

5.2 Benthic macro-invertebrates (Annelida; Oligochaeta)

Benthic macro-invertebrates are integral part of an aquatic ecosystem as they form a major portion of total biota in both lotic and lentic ecosystem. They carry on many functions by acting as grazers, collectors, Shredders or predator within an aquatic system (Wallace and Webster, 1996, Lobinske *et al.*, 1997 and Pearson, 2006). They spend at least a part of their life cycle at the bottom substrate (Pamplin *et al.*, 2006). According to Rashid and Pandit (2014) Macro-invertebrates especially the oligoichaetes acts as indicator of water pollution. In the present study a total of three species representing the main phylum Annelida was recorded at all the site of the Anchar lake. Three species of annelida viz *Limnodrilus hoffmeister, Erpobdella octoculata and Glassophonia complanata* were recorded, one species (*Limnodrilus hoffmeister*) belonged to class Oligochaeta while as two species (*Erpobdella octoculata* and *Glassophonia complanata*) belonged to class Hirudinea. The higher mean population density of *Limnodrilus hoffmeister, Erpobdella octoculata, Erpobdella octoculata* (611.5± 308.27 Ind./m^2, 537.5± 289.36 Ind./m^2, 541.33± 223.52 Ind./m^2) (Table 15, Fig 16) respectively, was at the SKIMS site. The higher density may be due to presence of sand, silt, detritus and organic matter, sewage effluent, which favour the growth of all the identified species a indicating higher pollution in the lake. Lower population density of *Limnodrilus hoffmeister, Erpobdella octoculata, Erpobdella octoculata* (163.33±117.38 Ind./m^2, 178.17±96.13 Ind./m^2, 185.67± 99.06 Ind./m^2) (Table 13, Fig. 14) respectively, was recorded at the inlet site. The lower density at this site may be due to less detritus and organic matter sold, little human interference, and by the inflow of fresh and cold water from Sindh nalla. The result is in conformation with Qadri and Yousuf (2004) who reported two species of Oligocheates viz *Tubifex tubifex* and *Branchiura sowerbyi* in Nigeen lake and the author may conclude that the macrozoobenthic organism prefer the lake areas with silty, sand substrate having rich macrophytic growth.

In the present study, Oligochaeta (*Limnodrilus* sp.) recorded a highest density at all the sites as compared to Hirudinea (*Erpobdella* sp. and *Glassophonia* sp.). The highest density of Oligochaeta indicates the lake is more polluted as oligochaetes have been observed to thrive well in soft depositing substrates rather than stony beds and nutrient rich sediment. They have greater power of utilizing the organic matter. According to Brinkhurst (1965) and Chowdhary *et al.* (2013), oligochaetes are more encountered in grossly polluted and organically enriched water bodies with low oxygen, the same has been found in our study. Abida *et al.* (2012) reported pollution tolerant taxa, such as Chironomidae, Oligochaeta and Hirudinea at the sites in river Jhelum with anthropogenic stress, municipal sewage and domestic waste. The author concluded that pollution indicator species such as *Limnodrilus* sp. among Annelida, *Chironomou* sp. and *Gammarus pulex* among Arthropoda, *Lymnea* sp. and *corbicula* sp. among Mollusca directly points to the shifting status of river from non-polluted to polluted. Thus our present investigation points out that Anchar lake is facing severe threat of pollution and nutrient enrichment, which is confirmed by the presence of *Limnodrilus hoffmeister* species.

The study also revealed that the percentage contribution of *Limnodrilus hoffmeister* was (47, 23.36, 17.71 and 12.53%) at Site-III, Site-IV, Site-II, Site-I, respectively (Fig. 19). *Erpobdella octoculata* was (21.94, 13.16, 9.83 and 7.26%) at Site-III, Site-IV, Site-II, Site-I, respectively (Fig. 19) and of *Glassophonia complanata* was (22.09, 9.98, 8.17 and 7.56%) at Site-III, Site-IV, Site-II, Site-I, respectively (Fig. 20). In an aquatic ecosystem the life of aquatic biota (Annelida) is closely dependent on the physical, chemical and biological characteristics of water that directly act as a controlling factor (Yaqoob and Pandit, 2009). Thus the percentage abundance of Annelida during the present investigation varied at different sites because of the different physical and chemical properties of substratum. According to Chowdhary *et al.* (2013), Oligochaetes are more encountered in grossly polluted and organically enriched water bodies with low dissolved oxygen. In the present study, The *Limnodrilus* sp. among oligochaetes favours this agreement as they were more in number at sites near (SKIMS), which is more organically polluted. This 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. These results are confirmed by the studies of Yap *et al.*(2003), Chowdhary *et al.* (2013) and Sharma *et al.* (2015).

Table 18: The overall minimum, maximum and Mean and standard deviation of physico-chemical characteristics of water of Anchar Lake during the present study

S. No.	Parameter	Minimum	Maximum	Mean±SD
1	Air temperature (^oC)	3	25.5	10.82±8.08
2	Water temperature (^oC)	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

Table 19: 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.

Table 20: 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

Chapter 6

SUMMARY AND CONCLUSION

The present research work deals with the distribution of benthic macro-invertebrates (Annelida; Oligochaeta) of Anchar lake. The physic-chemical parameters of water were analysed to determine the influence and interrelationship between abiotic factors and benthic macro-invertebrates.

- Qualitative and quantitative samplings were carried out by following proper methodology. The organisms identified and the density of benthic species was expressed in number of organisms per square meter.
- Statistical analyses were carried out by SPSS.
- Air and water temperature showed a minimum value during winter whereas the maximum value during summer. The overall mean value of air and water temperature was 10.82±8.08 ^{o}C and 1.3±0.52 ^{o}C respectively.
- Depth recorded a minimum value at SKIMS (Site-III) in the month of February whereas, maximum value of at centre (Site-II) in the month of December, and January. The overall mean value of water depth was 1.3±0.52 m.
- Transparency recorded a minimum value at SKIMS (Site-III) AT SKIMS (Site-III) in the month of May whereas, maximum value at centre (Site-II) in the month of December. The overall mean value of water transparency was 0.48±0.23 m.
- The minimum pH was recorded at SKIMS (Site-III) in the month of May whereas, maximum pH was recorded at inlet (Site-I) in the month of December and January. The overall mean value of pH was 7.51±0.31.

- The minimum dissolved oxygen content was recorded at SKIMS (Site-III) during summer whereas, maximum dissolved oxygen content was recorded at Inlet (Site-I) during winter. The overall mean dissolved oxygen content was 6.69±1.48 mg/L
- The minimum free CO_2 was recorded at Inlet (Site-I) during winter whereas, maximum free CO_2 was recorded at SKIMS during summer. The overall mean free CO_2 was 6.69±1.48 mg/L
- Total alkalinity recorded a mini um value at centre (Sire-II) in the month of January whereas, maximum total alkalinity was recorded at SKIMS (Site-III) in the month of May. The overall mean total alkalinity was 151±26.28 µg/L
- The minimum NO_3-N was recorded at centre (Site-II) in the month of May where as maximum NO_3-N was recorded at SKIMS (Site-III) in the month of March. The overall mean value of NO_3-N was recorded as 468.5± 115.96 µg/L.
- NH_4-N Showed a minimum value at Inlet (Site-I) in the month of December whereas, the maximum at SKIMS (Site-III) in the month of March. The overall mean NH_4-N was recorded 171.04±54.028 µg/L.
- The minimum orthophosphate value was recorded at Inlet (Site-I) in the month of December whereas, maximum orthophosphate value of was recorded at SKIMS (Site-III) in the month of May. The overall mean orthophosphate recorded in the lake was 166.21±60.94 µg/L.
- The minimum total phosphorus value was recorded at outlet (Site-IV) in the month of December whereas, maximum total phosphorus value was recorded at SKIMS (Site-III) in the month of May. The overall mean total phosphorus recorded in the lake was 416.5±137.89 µg/L.
- 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* was belonged to class Oligochaeta whereas *Erpobdella octoculata and Glassophonia complanata* where belonged to class Hirudinea.

- The overall Mean population density (Ind./m^2) of *Limnodrilus hoffmeister* recorded in the lake was 87.75±53.80 Ind./m^2, The maximum density 3669 Ind./m^2 of *Limnodrilus hoffmeister* was recorded at SKIMS (Site-III) whereas minimum density of 980 Ind./m^2 was recorded at Inlet (Site-I).
- The overall; mean population density (Ind./m^2) of *Erpobdella octoculata and Glassophonia complanata* recorded in the lake 6.25±42.29 Ind./m^2 and 72.75± 42.44 Ind./m^2 respectively. The maximum density 3225 Ind./m^2 of *Erpobdella octoculata* was recorded at SKIMS (Site-III) whereas, minimum density of 1069 Ind./m^2 was recorded at Inlet (Site-I) and the maximum density 3248 Ind./m^2 of *Glassophonia complanata* was recorded at SKIMS (Site-III) whereas minimum density of 1114 Ind./m^2 was recorded at Inlet (Site-I).
- All the three species viz *Limnodrilus hoffmeister, Erpobdella octoculata and Glassophonia complanata* 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. Thus based on present study Oligochaetes can be used as indicators of water quality because they are found in poor water quality of lake.

CONCLUSION

- During the present survey/research work it was established that Anchar lake exhibits and elevated state of eutrophication. This is clearly reflected by higher nutrient (N & P) concentration.
- The occurrence of three species of phylum Annelida viz. *Limnodrilus hoffmeister, Erpobdella octoculata and Glassophonia complanata* with higher number is due to the presence of organic rich waters and also due to entry of sewage which favours growth of these worms.
- Oxygen concentration (indicated by D.O) is found to be influential factor in affecting the distribution of Annelida especially *Limnodrilus* sp. This is further validated by *Limnodrilus* showing strong negative correlation with dissolved oxygen ($p \leq 0.01$, $r = -0.770$).
- The worm distribution is generally influenced by NO_3 and NH_4 these two nutrients along with phosphorus seems an important parameter for the distribution of Oligochate.
- The distribution of *Limnodrilus* sp showed positive correlation with NO_3-N and NH_4.-N. This indicates that both high level of nutrients (N&P) are important factor for abundance and presence of *Limnodrilus hoffmeister, Erpobdella octoculata and Glassophonia complanata* and they are resistive benthic macro-invertebrates to these excessive level of nutrient.
- The present data signified the resistance and tolerance of *Limnodrilus* sp. in the polluted part of Anchar lake and therefore, they can be used as good bio indicator of polluted ecosystem since they are found in the poor water quality sites of the lake. The presents result are supports by the work of Yap *et al.* (2006).

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CERTIFICATE

Certified that all the corrections/amendments as suggested by External Examiner Dr. Ulfat Jan, Professor of Zoology University of Kashmir Hazratbal, Srinagar during viva voce examination held on 03.02.2017 have been incorporated in the manuscript entitled **"Distribution of Benthic Macro-invertebrates (Annelida; Oligochaeta) in Relation to Water Quality of Anchar Lake"** submitted by **Mr. Altaf Ahmad Gojar (Regd. No. 2013-F-24-M).**

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