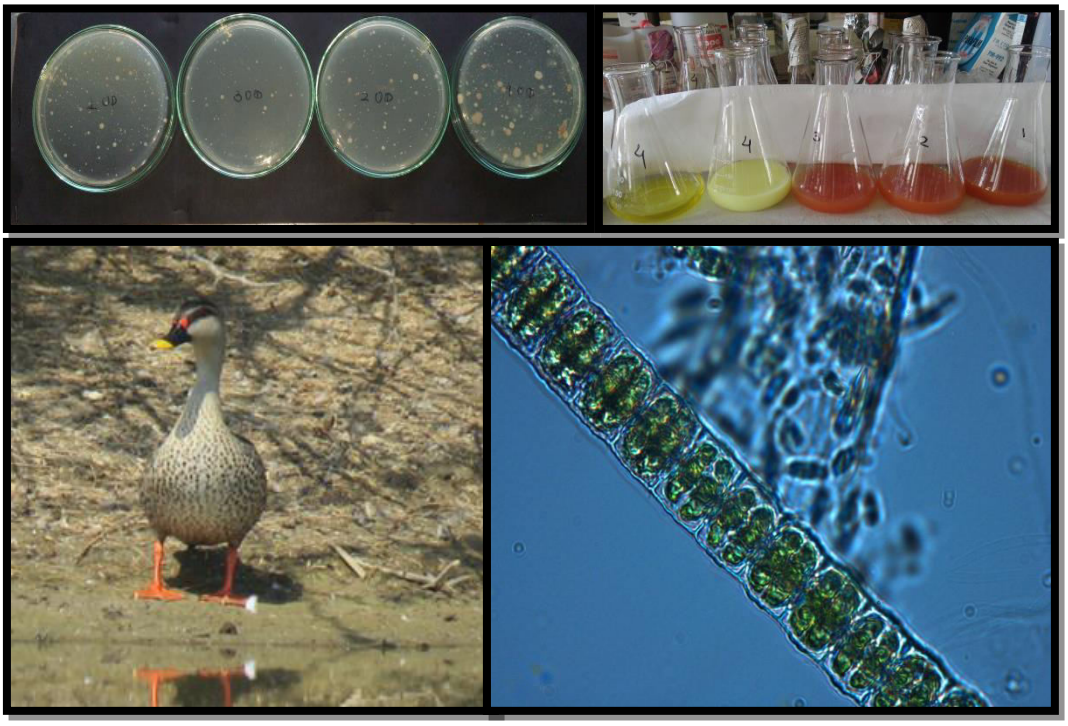
An investigation of water quality, floral and faunal diversity, and microbial quality at Pariej Lake

A dissertation report submitted to

P.G. Department of Biosciences

Sardar Patel University



Submitted By

Rinku A. Bhati

Exam No. 22

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An investigation of water quality, floral and faunal diversity, and microbial quality at Pariej Lake

Dissertation submitted to

Sardar Patel University, Vallabh Vidyanagar

For the partial Fulfillment of the degree of

MASTER OF SCIENCE ZOOLOGY

Submitted By

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Declaration

I, Rinku Amitbhai Bhati hereby declare that my thesis and title **'An investigation of water quality, floral and faunal diversity and microbial quality at Pariej lake'** is the result of my own research work carried out under the guidance of Dr.Sujata S. Bhatt at P.G. Department of Biosciences, Sardar Patel University, Vallabh Vidyanagar.

I further declare that no part of this work has been fully or partially submitted to any other university for any type of degree.

Rinku A. Bhati

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Abbreviations Used:

- **pH –** Potentia hydrogenii
- **DO –** Dissolved oxygen
- **BOD -** Biological oxygen demand
- **COD –** Chemical oxygen demand
- **TDS –** Total dissolved solids
- **TSS -** Total suspended solids
- **TS -** Total solids
- **TA -** Total Alkalinity
- **PA** - Phenolphthalein Alkalinity
- **SPC -** Standard plate count
- **MPN** - Most probable numbers
- **EMB -** Eosin methylene blue
- **mg -** Miligram
- **L -** Liter
- **Min -** Minute
- **Ppm -** Parts per million
- **˚C -** Celcius
- **rpm** - Rotation per minute
- **BDL** -Below the detection limited
- **ND -** Not detected
- **S(1 to 4) -** Sampling sites

Contents

Chapters

Introduction

Chapter: 1

- **General account:**

1.1 Area Study:

The word **area** is generally used as the most inclusive generic term for a part of the earth's surface, is conceived as intensely, or even randomly, chosen segment of the earth's surface, in contrast to "place," "region," or "space," with no specified character other than internal continuation and contiguity among its sub-areas. But in "area studies," the term signifies in practice a certain part of the world, often one country or state, where interdisciplinary programs of training or research have been established.

Area study is an observation or an analysis of physico-chemical or biological parameters of a selected region by scientific methods.

The unit-world is comprised of three domains: ecological, social, and cultural. The ecological domain is studied by the "ecology" of the environment, nature, artifacts, population or behavior. The social domain is studied by "sociology" of power, institution, polity, marketer or agency. The cultural domain involves studies on the "symbology" of logic, meaning, information, language, arts, etc. Eco-identity is a unifying theme over-arching the three domains. ***(*Tachimoto*, 2004)***

1.1.1 Ecological Area Study

The term 'ecology' was devised in 1866 by the German scientist Ernst Haeckel, is the branch of biology, which studies the relations among organism and their environment. Ecology addresses the full scale of life, from the microbial to the other beings on earth; the diversity of life is organized into different habitats, from terrestrial to aquatic ecosystems. Ecosystems are dynamically interacting systems of organisms, the communities they make up and the non-living component of their environment.

An aquatic ecosystem has huge diversity, among other ecosystem, is an ecosystem which made communities of organisms that are dependent on each other and on the environment, they directly and indirectly connected with the water body. The aquatic ecosystem, mainly divided into two types:

- Marine ecosystem, cover approximately 71% of the Earth's surface.

- Freshwater ecosystem, cover 0.78% of the earth's surface and inhabits 0.009% of its total water. Freshwater ecosystem has three basic types which are; lentic (pools, ponds, lakes), lotic (streams, rivers), and wetlands. **(Boyd *et al*., 2006, Levner *et al*., 2005)**

1.2Wetland

As defined in Ramsar Convention of Wetlands, Iran 1971, wetland is an area where water is the primary factor controlling the environment and associated plant and animal life. It includes areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, areas of marine water the depth of which at low tide does not exceed six meters. Wetlands are habitat to aquatic flora and fauna, support all forms of life, mitigate floods, recharge ground water and provide buffer shorelines against erosion**.** The wetland has its own biodiversity, the land where we can see the natural creatures which includes microbes, flora, fauna and human too. Wetlands are the resources which are useful in the activities include, fisheries, agriculture, tourist, and it also provides the economic, social and cultural advantages.

- **The wonders of wetlands,** as described by World wide fund for nature (WWF), 2017; wetlands are home to some of the richest biodiversity on earth. They are found all over the world from the equatorial tropics to the frozen plains of Siberia and are as crucial to the planet's well-being as any other finely balanced part of nature.

1.2.1 Classification of wetlands:

	Inland Wetlands	**Coastal wetlands**
Natural	○ Lakes/ponds ○ Oxbow lakes/ cutoff meanders ○ Waterlogged (seasonal) ○ Playas ○ Swamps/marsh	○ Estuary ○ Lagoon ○ Creek ○ Backwater (Kayal) ○ Bay ○ Tidal flat/split/bar ○ Coral reef ○ Rocky coast ○ Mangrove forest ○ Salt marsh / marsh vegetation ○ Other vegetation

Man-made	○ Reservoirs ○ Tanks ○ Waterlogged ○ Abandonned quarries ○ Ash pond/ cooling pond	○ Salt pans ○ Aquaculture

1.3 Wetland Ecology (Limnology):

Life zones in a lake are distributed as shown in the fig. 1, they are

I. **Littoral zone** – also called riparian zone, near the shore region, nutrient rich zone, where sunlight penetrates all the way to the sediment and allows aquatic plants (macrophytes) to grow, such as cattail, pond-lilies, rooted in the mud under water and their upper leaves and stem emerge above the water. The gradation of plants from land into water represents a transition from one environment to another and is known as the zone of succession (hydrosere). The zone provides habitat for insects like dragonflies (*Odonata*), mayflies (*Ephemeroptera*), Stonefly (*Plecoptera*), caddis flies (*Trichoptera*) and midges (*Diptera*) and other creatures such as pond snail, crustaceans (crabs and shrimps).

II. **Limnetic zone –** also called the pelagic zone or photic zone. Is the open water area where light does not penetrate to the bottom, it is the home of plankton and Nekton. Zooplankton depends on phytoplankton for food and they are linked between the algae and the much larger creatures such as birds and fish. Pelagic fishes are important for human and for birds too, as a food, most birds like ducks and geese are eating the fish by diving or catching the prey, they are commonly fed in this zone.

III. **Profundal zone –** called aphotic zone, which is deeper, colder and darker zone, open waters away from the shore. Located below the range of light penetration hence very trace amount of light, rich to the zone or no light.

IV. **Benthic zone –** the term benthic applies to the flora and fauna living at the bottom, some shallow lakes, benthic algae may be an important source of food but most benthic animals beyond the littoral zone derive their food from detritus raining down from the open water. The larger inhabitants of this zone are worms, larvae of Chironomid flies, mollusks, and the smaller creatures such as nematode worms and ostracods. Many of the worms found in fresh waters have haemoglobin in the blood, which help trap oxygen. Carps are typical benthic fish which feed on whatever

available. Some benthic fish has whiskers as a sense organ because they cannot find their prey by sight. **(Keddy, 2000)**

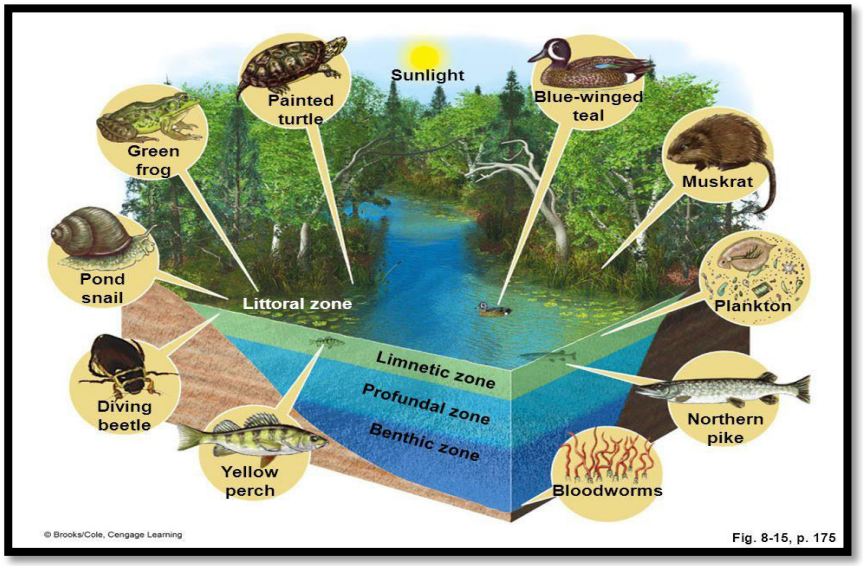


Figure.1 (showing different zones of typical lake and the creatures according to their adaptation)

Based on productivity lakes are classified as follows:

i. Oligotrophic lakes	Have low primary productivity because lakes contain very low concentrations of those nutrients which are essential for plant growth. They tend to be saturated with oxygen. Good water quality and less sediment volume.
ii. Mesotrophic lakes	Increased productivity with the elevation of nutrient contents in the water, transition from oligotrophic to eutrophic conditions. Higher sediment accumulation and decaying matter moderately clear water.
iii. Eutrophic lakes	Have a high concentration of nutrients which leads to the high biomass productivity and low transparency, high buildup of sediments and decaying matter. Low oxygen concentration.
iv. Hypereutrophic lakes	These are lakes at the extreme end of eutrophication with very high concentration of nutrients and associated biomass production, anoxia or complete loss of oxygen.
v. Dystrophic lakes	These are organic rich lakes (humic and fulvic acids) fed by external inputs of the lake (watershed).

1.4 Analysis of water quality

To manage the wetland ecosystem, to know the characteristics of a particular water body, to know the health of the wetland, water analysis requires. Water testing results can give us the data to know the future threat or present situation of the wetland.

1.5 Water Quality Parameters

The water quality parameters are roughly divided into three categories which includes; (1) Physical (2) Chemical (3) Biological

1.5.1 Physical parameters:

1. PH - is the measure of the intensity of acidity or alkalinity and measure the concentration of hydrogen ions in water **(Trivedi and Goel, 1986).** It is also a causative factor influencing various biological activities of aquatic micro- flora. The key component regulating pH in natural waters is the Carbonate comprises of CO_2, H_2CO_3, and HCO^{3-} **(Soni and Mathai., 2015)**

2. The temperature – Water Temperature has an important function controlling an abiotic characteristics and biotic activities of an aquatic ecosystem, which directly effect on significant aspects such as growth, oxygen demand, food requirements, and food conversion efficiency of various biotic communities. **(Soni and Mathai, 2015)**

3. Solids - refer to matter suspended or dissolved in water or waste-water **(APHA, 1998)**. Dissolved solids (DS) main constitutes are carbonates, bicarbonates, chlorides, sulfates, phosphates, and nitrates of calcium, magnesium, sodium, potassium, iron, and manganese, present in natural waters. Dissolved solids also play an important role to maintain drinking water quality and taste, which give a particular taste to the water at higher concentrations and also reduce palatability. High concentration of DS near 3000mg/L, may lead to distress in cattle and livestock, crops are also adversely affected by the higher content of solid in irrigation water. It increases the salinity of the soil and in industries also it may produce the scaling of boilers, corrosion, and degraded quality of the product. **(Trivedi and Goel, 1986).**

1.5.2 Chemical parameters

1. Dissolved oxygen: Dissolved oxygen analysis measures the amount of gaseous oxygen (O2) dissolved in an aqueous solution by diffusion from the surrounding air, by aeration (rapid movement), and as a product of photosynthesis. The amount of dissolved oxygen in water is largely dependent upon the water temperature; colder water can carry more dissolved oxygen than warmer water. The levels of DO in natural and waste waters depend on the physical, chemical, and biochemical activities in the water body, it is the factor which governing and indicating the pollution status of aquatic systems, also necessary for aerobic metabolism of all aquatic biota. Heavy contamination by organic

matter can lead to low oxygen in water may kill fish and other organisms present in water. The analysis of the DO should be performed immediately and in situ. It can be expressed either as a concentration (in mg/l), which is an absolute value, or as percentage saturation, which is an expression of the proportion of dissolved oxygen in the water relative to the maximum concentration of oxygen that water at a particular temperature, pressure, and salinity can dissolve. When in equilibrium with the atmosphere, at this maximum concentration the water is said to be saturated or at 100% saturation of dissolved oxygen. **(Rani, 2014, Trivedi and Goel, 1986, Soni and Mathai, 2015)**

2. Total Alkalinity: Alkalinity symbolizes the buffering capacity of water and its ability to resist a change in pH and is the overall measure of the substance in water that has 'acid-neutralizing ability'. It is a measure of total concentration of bases in water, including carbonates, bicarbonates, hydroxides, phosphates, borates, dissolved calcium, magnesium and other compounds which influence the pH. The water evaporates and decomposition of organic matter also increases the alkalinity and the excessive alkalinity may cause eye irritation in humans and chlorosis in plants **(Sandhya *et al*. 2012)**.

3. Chloride: Chloride is an anion generally present in natural waters, the presence of which can be attributed to the dissolution of salt deposits discharge of effluents from chemical industries, oil well operations, sewage discharges and irrigation drainage. Chloride is useful to fishes in maintaining their osmotic balance, but beyond the permissible limit it indicates the pollution. (**Dickman** and **Gochnauer 1978; Sonzogni *et al*. 1983; Birge *et al*. 1985**, **Rani, 2014)**

4. Free CO_2: Free CO_2 in water bodies is generally detected when the oxygen remains negligible or absent, mainly due to decomposition and degradation of organic matter by microbes in the bottom of a water body, resulting in rapid production of Free Carbon Dioxide. **(Welch, 1952; Antwi** and **Danson, 1993)**.

5. Chemical Oxygen Demand (COD): COD determines the oxygen required for chemical oxidation of organic matters, it is an indicative measure of the amount of oxygen that can be consumed by reactions in a measured solution. It is helpful in quantifying the amount of oxidizable pollutants, including non-degradable materials found in surface water.

6. Biological Oxygen Demand (BOD): BOD is the measurement of the amount of biologically oxidizable organic matter present in the waste which is used for determination of requirement of oxygen for stabilizing household and industrial wastes. The effluents disposed by domestic and industries into the surface and ground water contaminate the quality of the water which can be assessed by BOD determination. The increased levels of BOD indicated the nature of chemical pollution (**Thakore *et. al.*, 2011, (Gupta, *et al*, 2017**).

7. Total phosphorus: The maximum use of fertilizer is the main source of phosphate, which comes from agricultural or residential cultivated land into surface waters with storm runoff. The high concentration of this nutrient in fresh water indicates pollution through sewage and industrial waste; create the pollution due to the presence of phosphates which caused the growth of nuisance for micro-organisms. High phosphate levels causes muscle damage, problems with breathing and kidney failure in humans and in wetland it leads to eutrophication and depletion of dissolved oxygen concentrations. **(Gupta, Pandey, Hussain, 2017; Vankar *et.al,* 2018)**

8. Sulfate: Sulfate originates in water from the oxidation of sulfate ores and another source is leaching of gypsum and other minerals. High concentration of sulfate can have a laxative effect and it will be enhanced if consumed in combination with magnesium. Sulfate ion does not affect the taste of water if present in low concentration **(Thakore *et. al.*, 2011; Rani, 2014)**

9. Total Hardness: Hardness is the property of water, which prevents the lather formation with soap and increases the boiling point of water and it is mainly depends upon the presence of calcium and magnesium ions. Hardness is an important indicator of the toxic effect of poisonous elements. **(Vankar *et.al,* 2018)**

10. Calcium: Calcium is found in greater abundance in all natural waters as its main source is the weathering of rocks in the form of leachate and the amount of calcium in natural water is also depends upon it. A small concentration of calcium is reduced corrosion in water pipes. Calcium and Magnesium play an important role in antagonizing the toxic effects of various ions in neutralizing excess acid produced. **(Thakore *et al.*, 2011; Soni and Mathai, 2015)**

11. Magnesium: Magnesium is essential for photosynthesis of chlorophyll bearing plants and therefore it can act as a limiting factor for the growth of phytoplankton. **(Vankar *et.al,* 2018)**

12. Total Nitrogen: Total Kjeldal Nitrogen (TKN) is the total concentration of organic nitrogen and ammonia. It is the sum of nitrogen in bound in organic substances, nitrogen in ammonia (NH_3-N) and in the ammonium (NH^{4+}-N) in the chemical analysis of water. Ammonia and organic nitrogen can enter into the water through sewage effluent and runoff from the land where chemical fertilizers have been applied or stored.

13. Nitrite: Nitrites are unstable and their presence indicates fresh input of organic load into a water system, should be analyzed immediately after collection. It is an intermediate product of the aerobic nitrification bacterial process. The highest concentration of nitrite is toxic cause the 'Brown-gill' disease in fishes. The concentration below 0.2ppm of water soluble nitrite is usually considered to be safe for aquaculture. **(Vankar *et.al,* 2018, Rani, 2014)**

14. Heavy metals: They have a marked effect on the aquatic ecosystem which through bio- magnification enters into the food chain; affecting the human beings as well. The heavy metals in drinking water, which linked to human poisoning, are lead, iron, cadmium copper, zinc, chromium etc. Cadmium is more toxic even in low concentrations, and will bio-accumulate in organisms and ecosystems, lead is one of the most common heavy metals in drinking water, if occurred more than its permitted limit shows general metabolic poison and enzyme inhibitory. **(Mohod and Dhote, 2014)**

15. Fluoride: A fluoride concentration of approximately 1.0mg/L in drinking water effectively reduces dental caries without harmful effects on health, it may occur naturally in water or it may be added in controlled amounts. Fluorosis may occur when the fluoride level exceeds the recommended limits.

16. Chlorophyll: Chlorophyll level in aquaculture pond is considered as a good indicator of pond productivity. Chlorophyll-a is a blue-green microcrystalline solid, while chlorophyll-b is green black microcrystalline solid. Chlorophyll a mainly presents in the green plants and chlorophyll b occurs in higher plants and green algae. Concentration of chlorophyll is an indirect estimation of the biomass and the photosynthetic rate of the

primary producers. In planktonic algae, chlorophyll constitutes about 1% to 2% of the dry weight.

1.5.3 Biological parameters

Biological taxation is a useful alternative tool for assessing the ecological quality of aquatic ecosystems, used mainly in finding out the bio-indicators of pollution, to recognize the ecological disturbance caused by water pollution. It includes the microbiological counts for measuring level of contamination, identification of an organism which is bio-indicators. The aim of this analysis is to identify the organisms (bacteria, zooplankton, phytoplankton and macroinvertebrates, fish, etc.) From non-polluted and polluted localities and understand the degree of pollution. (Trivedi and Goel, 1984)

- **Plankton, Nektons, Macrohydrophytes and Microbes**

1. **Plankton:** They are microscopic organisms; either comprises characteristics of plant or animal. The planktonic organism with the characteristic of plants identified as phytoplankton, contain chlorophyll and they are autotrophic. The planktonic organism with the characteristic of animals is counted in zooplankton division.

- **Phytoplankton** is an essential module of freshwater wetlands, which significantly pay towards succession and dynamics of zooplankton and fish. Phytoplankton is the chief most organisms among aquatic micro- flora, including blue, green algae, diatoms, desmids, euglenoids etc. Phytoplankton forms the main producers of an aquatic ecosystem, which control the biological productivity. They not only provide an estimation of standing crop, but also represent a more comprehensive biological index of the environmental condition. They form the primary link in the food chain of all aquatic animals. Many herbivores, mostly zooplankton, graze upon the phytoplankton, thus passing the stored energy to its subsequent higher trophic levels. The study of phytoplankton composition provides information for the characterization of aquatic ecosystems. These organisms constitute the first and quantitatively most imperative link in the food chain representing the main source of oxygen and energy to the higher trophic level organisms of the aquatic environment **(Soni and Thomas, 2013)**

- **Zooplankton** is the intermediate linkage between phytoplankton and fish, and plays a key role in cycling of organic materials in an aquatic ecosystem. The rotifers, protozoans, cladocerans, copepods, ostracods, are included in this category. Zooplanktons not only form an integral part of the lentic community but also contribute to the biological productivity of the freshwater ecosystem. It discloses that places of low zooplankton population usually have rapidly multiplied phytoplankton population, attributing to higher food availability and avoidance of predators. Zooplanktons are globally recognized as pollution indicating organisms in the aquatic environment. **(Soni and Thomas, 2013)**

2. **Nektons:** The large group of free swimming animals includes macro-invertebrates and vertebrates such as annelids, mollusks, fishes, frogs, snakes and turtles. They can move on their own and do not require water currents for locomotion. **(Munshi, 2010)**
3. **Macrohydrophytes:** Aquatic macrophytes are one of the effective aspirants as limnological indicators **(Soni and Thomas, 2014)**, which comprise the free-floating, rooted and floating, submerged and emergent types. These macro-vegetation providing food and shelter to mollusks, insects, fishes and birds. They have an important role in the colonization of faunistic components. Submerged plants are habitat of the periphyton, and other free swimming species of insects and fishes. They are food for water birds such as swans, diving ducks, coots, etc. They also provide substrate for the colonization of some sessile and attached aquatic invertebrates which directly attract the predators i.e. Birds. The emergent plants harbor almost all the aquatic fauna groups and afford shelter to adult stages of insects, mollusks and birds.
4. **Microbes:**

   Indicator bacteria, including total Coliforms, fecal Coliforms, and fecal streptococci, may become stressed and injured in waters and stressed waters, in surface water they are common indicator of fecal contamination. **(APHA, Clesceri *et al*., 1995)**

- The present research highlights the associative depend on biotic components, preferably phytoplankton, zooplankton and aquatic macrophytes, which may be used as pollution markers in freshwater ecosystems. **(Soni and Thomas, 2014)**

Review of Literature

Chapter: 3

Last 50 years, there has been rapid growth indicating positive aspects of developments. But at the same time some negative aspects of this rapid development has brought in. The degradation of watersheds has started showing signs of negative impacts on aquatic ecosystems cycles including biotic communities. Therefore, in issue that has gained increasing recognition in recent years in that all water bodies including fresh and marine should be considered as a management having strategy, planning and implementation.

Studies on ecology of rivers, wetlands and reservoirs with relation to aquatic floral and faunal diversity have been carried out extensively in many countries, to know the water qualities and status of aquatic communities. A brief account of ecological studies in the world and India is given as below:

World level:

Lodege (1990) chosen a base of all the food web in aquatic ecosystem for study, he worked on 'Herbivory on freshwater macrophytes' he first ever demonstrated that macrophytes biomass, productivity and species composition is often influenced by different vertebrates and invertebrate grazers. He gave the review on the interrelationship between grazers and macrophytes production. The small and big grazers of aquatic plants like floating or floating with rooted, submerged were damaged by some small grazers like waterfowls, insects etc. but emergent macrophytes less susceptible to damage. Many breeding ducks and swans, colonially nesting geese were also used macrophytes and damage to growth in their growing season. He showed that how the grazing animals were control the macrophytes production, aquatic macrophytes and microalgae contain the various components like alkaloids, flavonoids, saponins, steroids, phenolics, including tannin and glucosinolates etc., were chosen by different grazers. Likewise waterlily beetles and they determined that the subemergents contain alkaloids or phenolics were preferd by grazers. He gave future idea to work on plant- animal interaction.

Hiromi kobori (2009) carried out the study of current trends in conservation education in Japan. Conservation education (CE) was an important component of environmental education, Goal was to teach of preservation and restoration of biodiversity affected by

human activities so the awareness of conservation issues and change their attitudes and behavior to promote environmental conservation. Under this project they perform many tasks to recover degraded habitats through anthropogenic activity. The tasks include hands on learning through restoration on agricultural wetland, restoration of dragonfly pond, creating a butterfly biotope in University campus, it was very important because the wetland were converted into paddy fields in many regions of Japan. By using questionnaire survey, they had monitored biodiversity of winter-flooded rice paddies. **Zhao *et al.* (2010)** studied on Wetland Biodiversity in China, they established the mire science, and said that mire is the main component of wetland which means damp and low-lying land. The researchers proposed definition of wetland plants first time in China that was plant that grows and completes its life cycle in stagnant water or extremely wet soil. They focus on conservation of wetland resources, the fishing ban and ecological restoration of rivers, lakes and wetlands in China, monitoring of wetland biodiversity Seed banks for recovering and reconstruction of wetland, Networking for conservation of plant diversity.

Enderlein *et al.* (1997) prepared a chapter called water quality requirements and established national water quality criteria in Nigeria, New Guinea, and Viet-Nam etc. They decided a criteria for drinking water, irrigation, live-stock watering, commercial and sports fishing, suspended particulate matter and sediment for achieving a water quality. Major objectives for this study to water resources management is that it focuses on solving problem caused by conflicts between demands of different water resources. Their target to improve water quality which is healthy for human as drinking water and also functions of ecosystem has to maintain. They classified the water quality on the basis of requirements for a particular use. The functional integrity of aquatic ecosystems is characterized by a number of physical, chemical, hydrological, and biological factors and their interaction.

India level:

Hussainy (1966) studied the physico-chemical condition in relation to the biological condition in lake for one year; were used as a drinking water supply and has of great importance; he enlighten the title ‘Studies on the Limnology and primary production of a

Tropical lake' for which he chosen Vihar lake situated at Sahyadri hill of Western Ghat for the research. He used light and dark bottle technique for estimation of chlorophyll as primary producer for 12 hours and other physicochemical parameters such as pH, temperature, DO, CO_2, Alkalinity, turbidity, total hardness, chloride, nitrite, phosphate and total iron also analyzed for such purpose. He observed that surface water temperature was more than that of bottom temperature, seasonal variation in DO content, (during colder months DO concentration increase and suddenly decrease during warmer months) and conclude that the planktons were occupied a zone below 20˚C. He also reported that the alkalinity of surface water less alkaline in cooler months compare to warmer months and stated that due to photosynthetic activity of algae it may be seen, and concluded that in tropical lake temperature is the determining factor and he gave idea about the phosphate and chlorophyll interrelation.

Hussain *et al*.(2018) was carried out the study on Seasonal variations in the water quality of a tropical wetland dominated by floating meadows and its implication for conservation of Ramsar wetlands. And his study area was Loktak lake, Manipur India and the analysis was carried out during 2008 to 2010 by using one way ANOVA ad t-Test method. And he concluded that the natural properties of the Loktak Lake are changing due to accumulation of nutrient, decreased DO and increased BOD leading to decreased water quality indicating a severe organic biodegradable contamination.

Mili et al., (2016) carried out one year (2014-2015) study to investigate the phytoplankton diversityof three ponds in Eastern Kolkata, and she recorded four groups of phytoplankton such as Chlorophyceae. Bacillariophyceae, Euglenophyceae and Cyanophyceae. During study she analyzed hardness of water, nutrients such as phosphorus-phosphate, Nitrate-Nitrogen, DO, TS, TDS, free CO_2, pH, temperature,etc and found a correlation with phytoplankton. She conducted two methods for data analysis that is ANOVA and Pearson correlation revealed that the variance of phytoplankton diversity in all the months and ponds.

State level:

Goswami and Mankodi (2012) carried out the 'Study on Zooplankton of Fresh Water Reservoir Nyari – II Rajkot, Gujarat' which is fresh water reservoir and water used for

irrigation, for community water supply by Rajkot municipality and as stock pond for IMC. In one year study they collected surface water samples trice in month, plankton preservation in 4% formalin, the plankton qualitatively analyzed by Sedgewick – Rafter Cell and expressed as numbers per litre. And they observed dominancy of Cladocera and Copepods among other families and plankton diversity maximum in the month of October and minimum in the month of March. He concluded that the high diversity of zooplankton was seen between September – November and evaluate the fresh water reservoir status as ecologically and fisheries point of view.

Soni and Thomas (2013), the paper highlights the 'Preliminary assessment of surface water quality of tropical pilgrimage wetland (Dakore Sacred wetland) of central Gujarat' And for the study they had chosen the sites where anthropogenic interventions and domestic sewage contaminate the wetland. To evaluate the health status of wetland they analyzed physicochemical parameters and collected data were correlated to draw conclusion about the surface water quality. They concluded the wetland need the restoration and management strategies to maintain, preserve, conserve and stop the ecological imbalance and disturbance in hydro-geo-chemical and hydro-biological cycles which unpleasantly affect the food chain and food-web of the pond ecosystem.

Parmar and Acharya (2013) were documented study on Spider diversity of Pariej lake, during four month observation he reported 59 species belonging to 42 genera of 16 families. The spiders were collected through many methods includes visual searching, ground hand collection, aerial hand collection, vegetative beating and hand picking and they recorded some genera which were previously not recorded in Gujarat such as aseriophora, bavia, plegra, ptocasius, ebrechtella and asceua.

Soni and Thomas (2014) also carried out the work on 'Associate dependence among plankton and macrophytes as pollution markers at tropical lentic environ', and they chose three sampling stations of Gomati catchment of Central Gujarat. Study was conducted for one year and at monthly interval samples were collected. The data were analyzed by using the Palmer Index Score method, Nygaard's Trophic State index method and correlation matrix, interpreted the data. From this work, they concluded that Chlorophycean taxa were more dependent on zooplankton, the pollution indicator species of plankton ((Euglena, Oscillatoria, Navicula, Nitizchia, Cyclops, Daphnia etc.) and

macrophytes (Eochhornia, Potamagoteon, Lemna) were frequent and abundant which signify the eutrophic level of pond. To overcome this problem, have to remove non-invasive species which harm the ecological condition of pond and stop the unwarranted anthropogenic activities.

Vankar, Tatu and Kamboj (2018) were studied on Water quality of two important Inland Wetlands (Pariej and Kanewal) in the Neighbouring Districts of Central Gujarat, both are well-known man-made wetlands. The study was carried out to understand the seasonal dynamics of various physic-chemical parameters and overall water quality status of the wetlands. The samples were seasonally collected between the years 2016 to 2017 to cover all three season to analyzed 16 parameters. And they concluded from this comparative study of two wetlands that the Pariej was moderately eutrophic wetland than Kanewal wetland. The water of Pariej wetland shows higher values of turbidity, electrical conductivity, total hardness, nitrate, etc. High concentration of nitrate indicates that the wetland is moderately eutrophicated and they also noted that the water quality of both wetlands deteriorated due to anthropogenic activities occurring in their vicinity.

Aims and Objectives

Chapter : 3

Each ecosystem has mainly two constituents:

- **Biotic components** (the living organisms including plants, animals, microbes etc.)
- **Abiotic components** (non-living components like temperature, gases, pH of water and soil etc.)

Interactions among different biotic (biological) and abiotic factors (Physicochemical) is an important aspect to understand the health status of any ecosystem.

Pariej lake is the fresh water reservoir that is located at the Nadiad plain (Matar) of Kheda district in the central Gujarat. The lake is spread over 2.5 kilometers in an area with a depth varying from 4-12ft and is used for variety of purposes such as aquaculture, irrigation purpose and drinking water by tourists at the ecotourism camp site. It is one of the eight nationally important wetland of Gujarat. It is a marsh type of wetland covered by dense macrophytes i.e. Typha angustifolia.

Awareness is an essential requirement for conservation of any huge and versatile wetland. Maintenance is important to keep healthy status of the lake.

The main aim of the study was to understand the interaction between physicochemical parameters and floral-faunal diversities of lake during the months of December, 2017 to April, 2018. The present research aimed at assessing and evaluating the parameters that might help indicate the status of wetland.

Objectives of the current study:

- ✓ To know the physicochemical properties of water
- ✓ To study floral-faunal, microbial and plankton diversities of lake
- ✓ To assess the levels of BOD and COD
- ✓ To study the food-chain in aquatic ecosystem

And the interaction among these aspects would be helpful to understand the parameters which are essential for probable maintenance of the water body.

Chapter: 4

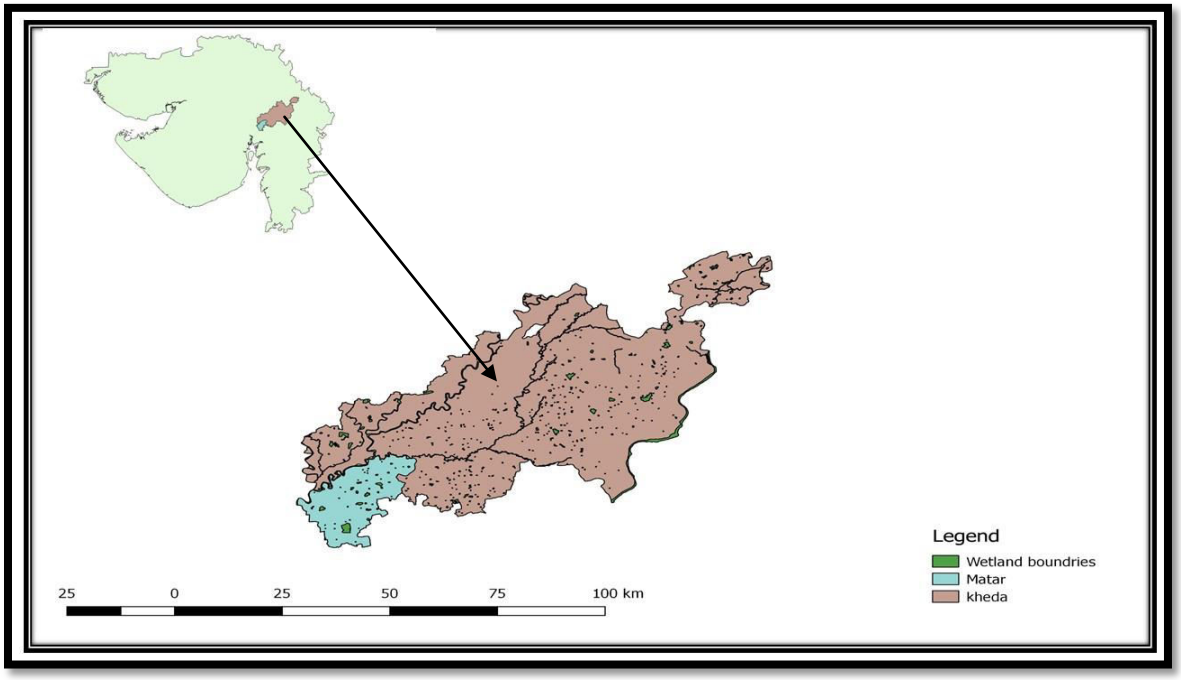


Figure I: Kheda district map

4.1 Kheda

The district of Kheda takes its name from the town of Kheda which stands on a rising ground near the confluence of the 'Vatrak' and the 'Shedh' river, the district is situated in the middle of the state Gujarat. The other name of this district is 'Charotar' which is derived from the Sanskrit word C**haru** meaning beautiful. The land is fertile and green with vegetation which makes it quite pleasing to the eyes and hence the name **Charotar**. Total 10 talukas are included in Kheda district and 'Mater' is one of them. Kheda covers 2.01% of the total area of Gujarat State. Density (Population per sq. Km) of Kheda district is 582 and is the 7th highest district in the State. Kheda district is also known by the name "GOLDEN LEAF" as it is the major producer of tobacco in the State and most people here are connected with agricultural fields.

Matar has total 55 villages and 'Pariyej' is one of them. From five macro-regions of Kheda, Matar comes under Sabarmati Vatrak-plain and Nadiad-plain.

4.1 Geology

The geological structure of this region is formed of alluvium, blown sand, Deccan Trap formations, etc. There are nine rivers in Kheda district, of which Mahi and Sabarmati are principal perennial rivers. The river Mahi is known as Mahisagar. Mahi is very useful for irrigation. It originates from Aravalli Mountains and enters into the boundary of the district at the 'Khadiarapura' village of Matar taluka and ends into the Gulf of Khambhat.

4.2 Climatic condition:

4.2.1 Temperature:

Kheda District has normal temperature. It is observed by the Government Census of Gujarat that the maximum temperature in the district reaches to 40.8 centigrade in May while minimum temperature in the district reaches to 12.2 centigrade in January.

4.2.2 Rainfall:

As per the Government Census of Gujarat**,** the annual rainfall of this district is

551 mm in the year 2011 and highest rainfall of this district is 1,388 mm in the year 2006.

4.2.3 Fishery:

The district mostly covers inland fisheries, which play an important role in the national economy through the food supply. The variety of fishes available in the district are Catla, Rohu, Mrigal, Mullet, Bombay duck and Prawn. Cold water fish found in the district are as follows: Fausta, the Zinga, the Zinga Chola, the Bamvlo, the Biu and the Kantia. Some rainy season fishes such as the Palva, the Dodi and Magra have also been found in the district.

4.3 Pariej lake: (Data collected from the head of Panchayat, Pariej)

The Pariej Lake (22°32'44 N, 72°36'57 E) is widely known man-made irrigation reservoir of Central Gujarat, constructed somewhere in between 1939 and 1942 by the Water Resources Department (WRD) of Nadiad. The conservation of this lake is carried out by the Deputy Conservator of Forest (DCF), Nadiad. The water source of the lake is

Narmada canal, Mahi river water and Rain water (during monsoon). The water is transferred through pipeline to Saurashtra regions (i.e., Amreli, Junagadh, Rajkot, Botad etc.) for agricultural use. The water from this lake is treated at the pump house and then provided as a source for drinking water to the villages nearby.

The purpose behind construction of this lake was to fulfill the water requirements of the Pariyej and other surrounding villages (i.e., Daloli, Sayla, Bhalada, Baman gam, Indarvana, Viroja, Sinjiwada).

The Pariej Lake situated at Matar Taluka, Kheda district, Gujarat-388180. It is 45 km from Anand, 40km from Nadiad and 60 km from Ahmedabad via Kheda-Khambhat highway/Tarapur Matar Road, between Tarapur and Limbasi village. It is one of the 8 Nationally Important wetlands of Gujarat. It covers an area of about 5 sq.km with a circumference of about 12 km with water depth varying between 1.2m to 3.0m **(Vankar *et.al,* 2018)**

The diversity of Pariej includes the residential/migratory avi-fauna, aquatic flora, mollusks, arthropods, reptiles and mammals. It is an attraction for nature lovers. Many aquatic bird species are recorded at this wetland.

There are four sites from where water samples were collected (As shown in figure below).These sites were chosen in a way such that various activities like anthropogenous, fisheries, water usage for domestic and agricultural purposes could be observed.

Figure II: Showing the sample collection sites

Figure III: First sample at Site-1

- Site 1 is an Eco-tourism camp where the bird-watchers and other people come to visit this lake. Construction work of Eco-tourism was ongoing during my study and heavy aquatic vegetation was covering the whole lake area. Among these, Typha angustifolia is the most dominant species.

Figure IV: Second sample at Site-2

- Site 2 is where the fishing activity is high and boating and cage culture activities are seen. The fishermen release the seeds of fish in this area to the fishes grow and export them for food purpose. The Nymphaea sp. is more common in this site. Avian, mammals, amphibians and reptiles can also be observed here.

Figure V: Third sample at site-3

- Site 3 is the location where people are using water directly as drinking water and for veterinary uses. There is one bird watch tower using which we can observe the waders.

Figure VI: Fourth sample at site-4

- Site 4 is along with the Kheda-Khambhat highway road and is part of Pariej wetland where many aquatic fauna and flora diversity is observed. There are many elevated areas on which water birds are coming for basking. This is a site where the Sarus cranes and many migratory birds land and rest for some time.

Materials and methodology

Chapter: 5

5.1 Water sample collection

Surface water samples were collected twice, on 17th January, 2018 and 20th February, 2018 in the morning time from 9:00 am to 11:00 am, in polyethylene bottles from four different sites of Pariej lake. Temperature, dissolved oxygen (DO), pH was analyzed on the spot and remaining Physico-chemical parameters, water samples were brought into the laboratory. The samples were preserved in a labeled amber glass bottle and stored at 4 °C in refrigerator for further analysis.

5.2 Plankton collection

The planktons were collected from the same sites of water collection. It was performed by 20µ size plankton net. For the collection of plankton, 50Litre water was filtered. The water was taken from littoral and limnetic zones with the help of the plastic bucket having a 16Litre capacity of water. At the end, the plankton net contains concentrated planktons on the tube. The planktons were preserved in 4% formalin, 70% Alcohol and in Acetomethanol.

5.3 Biological Analysis

The phytoplankton and Zooplanktons were observed in Olympus light microscope using 4X, 10X and 40X, 100X. The photographs were taken by using a photo analyzer at the same magnification.

5.4 Analysis of Physico-chemical Parameters

Parameters like water pH, Temperature, TS, TDS, DO, BOD, COD, CO2, Alkalinity, Total Hardness, Total Nitrogen, Chlorophyll, sulfate, Total phosphorus, Nitrite, Fluoride, Heavy metals were analyzed.

5.5 Physical parameter

A. **Temperature:** The temperature of water was measured at the site using a mercury thermometer by dipping the thermometer in the bottle containing sample water.

B. pH: The concentration of H^+ ions was determined by the digital pH meter to evaluate the acidic or alkaline condition of water.

C. **Solids:** In the method of Total solids (TS) known amount of unfiltered water sample was taken in a preweighed evaporating dish and was allow evaporating with using hot plate or oven.

For Total dissolved solid (TDS) known amount of filtered sample was taken in a preweighted evaporating dish and was evaporated. After the evaporation process, the difference of weight of dish before and after evaporation was calculated.

Total suspended solids were measured by TSS= TS-TDS.

5.6 Chemical parameters

- **Dissolved-Oxygen(DO):** For Dissolved oxygen the samples were collected from the surface water in a glass- stopper bottles and as soon as possible $MnSO_4$ and KI were added at a sampling spot for precipitation and analyzed by Winkler´s Iodometric method (Trivedi and Goel, 1984).
- **Total Alkalinity:** Total alkalinity was estimated by titrating samples with hydrochloric acid in the presence of methyl orange and phenolphthalein as an indicator by the method described by Trivedi and Goel (1984).
- **COD:** The chemical oxygen demand was performed by HACH COD meter.
- **BOD:** The BOD of the samples were measured by 5- days incubation method. On the initial day, DO was measured by the DO meter. Then it was incubated for 5 days at about 20^0C. At the end of 5^{th} day incubation again DO was measured in all the samples and BOD was calculated using the following formula: BOD mg/L = $D_0 - D_5$ Where, D_0 = 0 day dissolved oxygen (mg/L); D_5 = Dissolved oxygen after 5^{th} day incubation
- **Nitrite:** The Nitrite content in the water sample was determined by using EDTA, sulphanilic acid, α-naphthylamine hydrochloride and sodium acetate solution. The color so produced obeys the Beer`s law and determined colorimetrically using a spectrophotometer at 520nm. (Trivedi and Goel, 1984)
- **CO_2:** Free CO_2 present in the water sample determined by the titrating sample using a NaOH solution and phenolphthalein as an indicator with using the titrimetrics method as described in APHA, 1998.
- **Total hardness:** Total hardness with calcium and magnesium were estimated by the EDTA method as described in Trivedi and Goel (1984).
- **Total Nitrogen:** The total nitrogen of the sample was determined by the Micro-Kjeldahl Method (Trivedi and Goel, 1984) at the Home - Science Department.

- **Sulfate:** Sulfate was determined in the water sample by the Turbidimetric method (Barium chloride precipitated method) as described by Trivedi and Goel (1984)
- **Total phosphorus:** Total phosphorus present in the water sample was estimated by the H_2SO_4-HNO_3 method for digestion by using Ammonium molybdate-stannous chloride reagent. (APHA, 1998)
- **Fluoride:** Fluoride was analyzed by the Fluoride test kit of ORLAB Instruments Private Limited.
- **Heavy metals:** The heavy metals like Chromium, Cadmium, Arsenic, Mercury and Lead were estimated by SICART (SOPHISTICATED INSTRUMENTATION CENTRE FOR APPLIED RESEARCH AND TESTING) using ICP-OES (Inductive Coupled Plasma-Optical Emission Spectrometer) instrument.
- **Chlorophyll:** Chlorophyll was measured from the water samples as the following method:

0.5L sample water aliquot was taken and centrifuged at 5000rpm for 10 minutes. After centrifugation supernatant was discarded and pellets were collected in the conical bottom centrifuge tubes. Then 5ml of 80% methanol was added to same tubes and pellets were crushed with a Homogenizer. The tubes were centrifuged again at 5000rpm for 5 minutes. Centrifugation time was strictly followed. The supernatant was collected from the tube and O.D. (Optical density) was taken at 664nm, 647nm, 630nm, 750nm. Blank was prepared with 80% methanol.

Values of different OD were added into following formula: 664nm – 750nm= x; 647nm – 750nm =y; 630nm – 750nm =z The values of x, y and z were added to the final formula which gave the amount of chlorophyll present in the water samples in mg/L.

Ca= 11.85(OD 664) – 1.54(OD 647) – 0.08(OD 630); Cb= 21.03(OD 647) – 5.43(OD 664) – 2.66(OD 630); Cc= 24.52(OD 630)- 7.60(OD 647) – 1.67(OD 664)

Where, Ca, Cb, Cc= Concentration of chlorophyll a, b and c in mg/l

OD 664, OD 647 and OD 630 = optic densities at the respective wavelengths (Latif *et.al,* 2013)

- **Microbiological examination of water:** The microbiological examination of water was performed to know the status of pollution in the Pariej Lake. In this study, three methods were followed:
  1) Standard plate count or Total viable count (SPC or TVC)
  2) Most Probable Number (MPN) of Coliforms
  3) Gram Staining

These methods were carried out as described in Patel, Trivedi and Goel (1984)

Results and Discussion

Chapter: 6

6.1 Physicochemical parameters

Water samples were collected from four different points (S1-S4) of the Pariej Lake and analyzed to know the present health status of the water body. The parameters which were analyzed are as shown in the Table: 1 with the standards of each.

Parameters	Indian standard	Sources
pH	6.0-9.0	Ezeanya, 2015
Temperature	15˚-30˚C	Ezeanya, 2015
TDS	500 – 2000mg/L	ICAR, BIS
TSS	10-20mg/L	Ezeanya, 2015
Dissolved oxygen	>5mg/L	Bhatnagar, 2004
BOD	3-20mg/L	Ezeanya, 2015
COD	50mg/L	Dist, 2014
CO_2	-	-
Hardness	50-100mg/L	WHO-2003
Calcium	63-250mg/L	ICAR,BIS
Magnesium	30mg/L	ICAR,BIS
Alkalinity	50-300mg/L	ICAR,BIS
Total phosphorus	0.07-1 mg/L	Bhatnagar,2004
Sulfate	200mg/L	ICAR,BIS
Nitrite	0-1 mg/L	Bhatnagar,2004
Total Nitrogen	0.1ppm	(Xu,2014)
Fluoride	1.5mg/L	ICAR, BIS
Chloride	Upto 250mg/L	ICAR,BIS
Cadmium	0.003mg/L	BIS
Chromium	0.05mg/L	BIS
Lead	0.01mg/L	BIS
Mercury	0.0001mg/L	BIS
Arsenic	0.01mg/L	BIS

Table 1: Standards of physicochemical parameters by BIS, ICAR and WHO

All parameters were studied and calculated comparing with permissible values laid down by BIS, ICAR and WHO.

6.2 Physical parameters:

6.2.1 Temperature:

Table : 2		
˚C	January	February
S1	17	24.3
S2	18	24.3
S3	19	24
S4	19	25

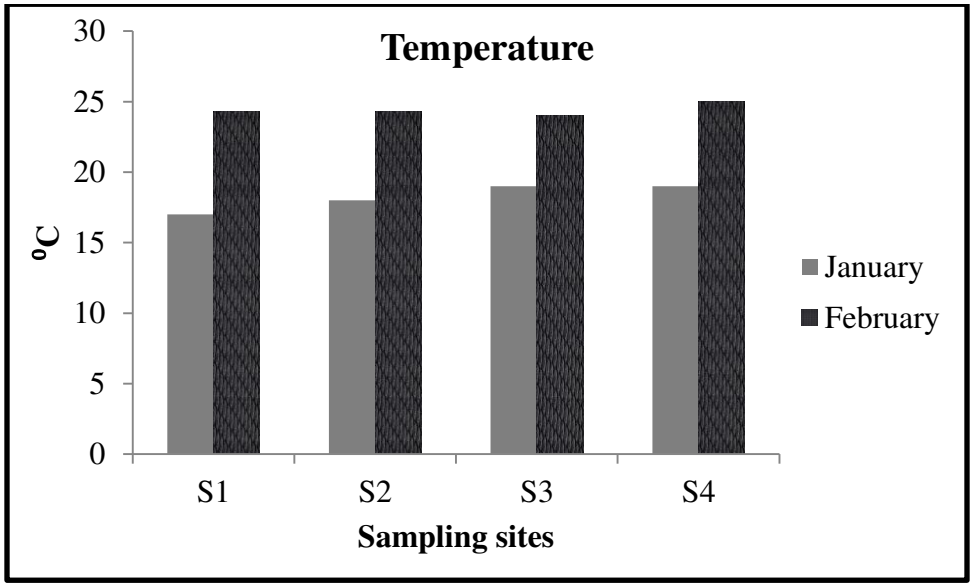


Fig 6.1: Monthly data assessment of water temperature of Pariej Lake

Growth, oxygen demand, food requirements and food conversion efficiency of the various biotic communities are directly affected by the temperature **(Soni and Thomas, 2013)**. The maximum temperature (25˚C) is noted in surface water on S4 site during February. Similar trend was observed by Vankar *et al.* in the winter 2018 in surface water of the same lake and Kanewal Lake, whereas a minimum value (17˚C) is observed in peak winter (January) at S1. Hence, the surface water temperatures at the four sites (S1-S2) of Pariej lake ranged from 17˚C to 25˚C (Fig. 6.1). The temperature of surface water fluctuated with the air temperature. Hence, it is lower in winter compared to summer. As mentioned by Sharma and Bhardwaj, 2011, temperature, which acts as a catalyst, a

depressant, an activator, a stimulator, a controller and a killer is one of the most important and influential quality characteristics for the lives in water. In this study, fluctuation in water temperature indicates the seasonal variation which is also observed by many researchers. This range is suitable for all the biota

6.2.2 pH

Table : 3		
	January	February
S1	6.9	6.91
S2	7.5	7.6
S3	7.7	7.57
S4	8.6	8.51

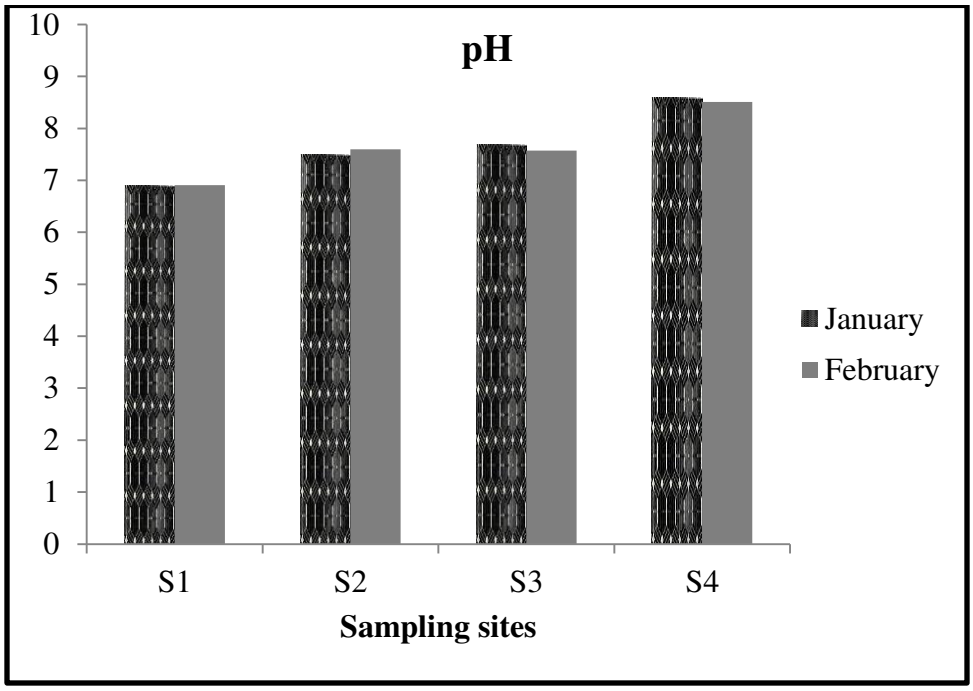


Fig 6.2: Monthly data assessment of water pH of Pariej Lake

pH is a term used universally to express the acidic or basic condition of any of the solution. Many researchers proved that aquatic organisms are affected by pH since most of their metabolic activities are pH dependent (Sharma 2011, Kulinkina 2017 and Vankar 2018). In this bio-assessment, pH values of water sample vary 6.9 to 8.6 and it is within the permissible limit prescribed by the Bureau of Indian Standard and Indian Council of Agricultural Research. The highest pH (8.6) is recorded at S4 point. It indicates the

basicity of the water and similar value were observed by Soni and Thomas, 2013 at Dakore pilgrimage lake whereas the slightly acidic pH (6.9) noted at the ecotourism camp site (S1) (Fig. 6.2) and similar results were observed by Hussain et al., 2018 at Loktak lake. The fluctuation was recorded in all the four sites and it may be attributed increase and decrease in biogenic activities of the system.

6.2.3 Solids

Table: 4

mg/L	Total solids		Total dissolved solids		Total suspended solids	
	January	February	January	February	January	February
S1	310	200	220	-100	90	300
S2	90	210	0	-40	90	250
S3	160	190	290	140	130	50
S4	5540	7040	5240	7870	300	-830

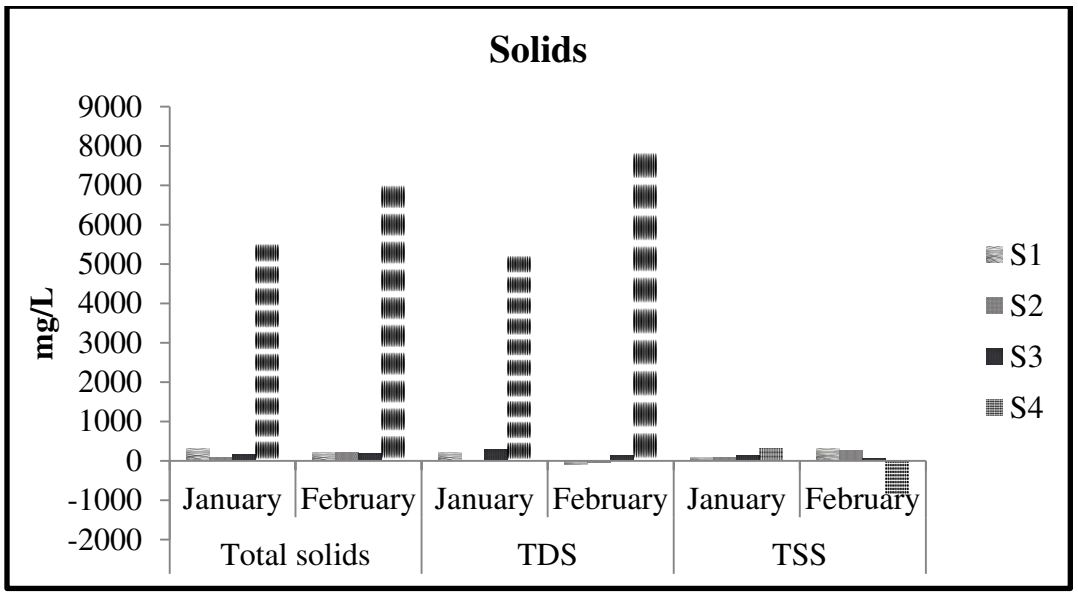


Fig 6.3: Monthly data assessment of TDS, TSS, TS of Pariej Lake

The values of Total Dissolved Solids (TDS) in surface water were found unique, of which the maximum total dissolved solids (5240-7870 mg/L) was recorded at S4 during both months while it was found minimum (-100 mg/L) at S1during colder months(Fig. 6.3)11. The contents of Total Solids (TS) in surface water at S4 with the highest

concentration (5540-7040 mg/L) recorded during both months, while least (90 mg/L) at S2 during January. Total Suspended Solids (TSS) in surface waters at study sites (S1, S2 and S3) were between 50-250mg/L with high content (300 mg/L) at S1 and S4 during January, while low (50 mg/L) at S3 during the February month. The values of TDS are found abnormal at S1 and S2 during the February month, whereas at S4 point the value of TSS is different compared similar form of data at the other three sites. At S4 point, TDS is recorded in very high amount as the various salt concentrations at this site is very high. Hence it is quite unsuitable for most of the usage areas of water. Whereas, In January both S1 and S3 sites reported with good TDS level for organisms, but it suddenly decreased during February month. Vankar *et al.,* 2018 recorded and it was similar to S1 and S3 sites during January. It may indicate the high level of pollution.

6.3 Chemical parameters

6.3.1 Dissolved oxygen

Table : 4

mg/L	January	February
S1	1.62	1.89
S2	7.16	6.62
S3	6.48	5.00
S4	10.67	6.48

Dissolved oxygen concentration of more than 5.00 mg/L favors good growth of flora and fauna (Bhatnagar, 2004). Higher amount of DO (10.67 mg/L) was observed at S4 (Fig. 5.4) and the same trend is noted by Hussain et al., 2018 at Loktak lake. Lower value (1.62 mg/L) was recorded in the month of January at S1 and the similar value observed by Vankar *et al.,* at Kanewal lake. It may be due to the dense Typha and other aquatic plants. This site contains very low DO which does not come under permissible limits given by BSI and WHO. It affects the growth of fish and fish mortality. Higher DO during January at S4 might be due to photosynthetic activity at upper level (Sharma and Bhardwaj, 2011). Other sites are suitable for fish culture or any other activities. It is most important factor of the aquatic ecosystem which directly affects the fauna and flora (Soni and Thomas, 2013)

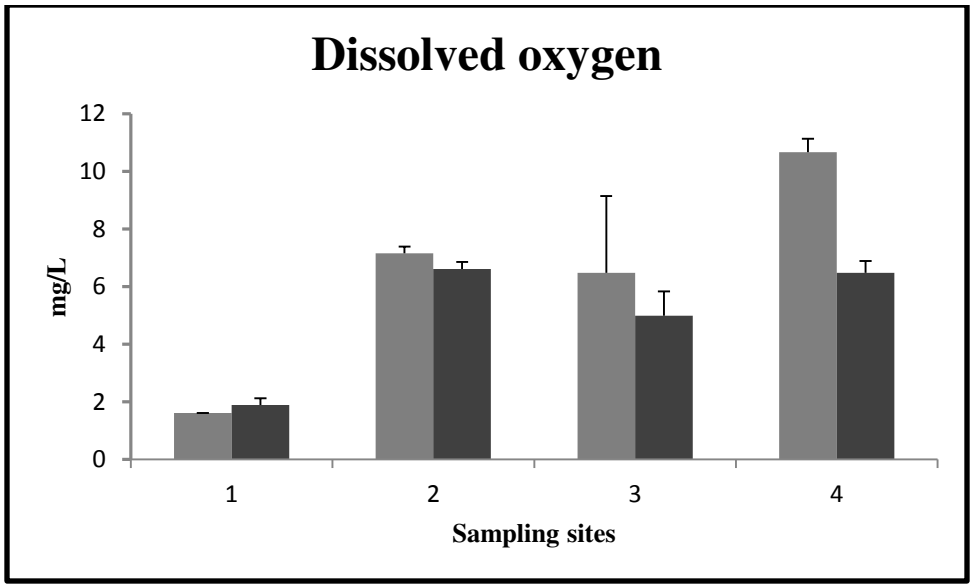


Fig 6.4: Monthly data assessment of DO of water in Pariej Lake

6.3.2 Biological Oxygen Demand

Table : 5		
mg/L	January	February
S1	12	4.22
S2	1.98	4.35
S3	2.55	1.5
S4	4.82	1.73

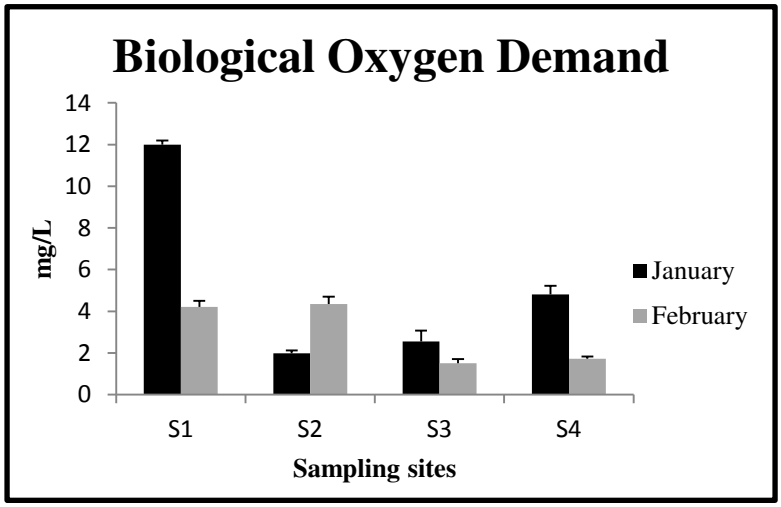


Fig 6.5: Monthly data assessment of BOD of water in Pariej Lake

BOD is an important parameter for determination of the quality of water. The effluents disposed by domestics and industries into the surface and ground water contaminate the quality of water. The acceptable range of BOD is 3-20mg/L (Ezyeanya, 2015), the level of BOD at S1 was found highest (12mg/L) compared to other sites during January month whereas the lowest value noted at S3 during February month. For fish survival, the BOD level should be less than 10mg/L and similar trend was reported by Hussain *et al.,* 2018.Decreased DO and increased BOD leading to decreased water quality indicates a severe organic biodegradable contamination at S1 location. It may decrease during February month. (Fig. 6.5)

6.3.3 Chemical Oxygen Demand

Table : 6

mg/L	January	February
S1	40.67	64
S2	39.33	99
S3	140.67	121.33
S4	37.33	103.33

The COD of water represents the amount of oxygen required to oxidize all the organic matter by a strong chemical oxidant (Dist, 2014). COD level is found to be highest (140.67 mg/L) at S3 (Fig.6.6) whereas, lowest (37.33 mg/L) at S4 during January month. The values changed in the February data. Decreased value is observed at S3 (121.33mg/L) and increased value at S4 (103.33 mg/L). The data which were analyzed are indication of high pollution at S1 compared to other points. Similar type of trend seen in the Hussain *et al.,* (2017) Loktak lake, Manipura. More organic matter pollution may be the reason of increased COD at S3. During February, at S4 sudden increase in COD indicates increase in some chemical substances utilizing the oxygen for oxidation because the lake is surrounded by the agricultural fields and the pesticides were introduced into the lake water which caused interference in the ecosystem.

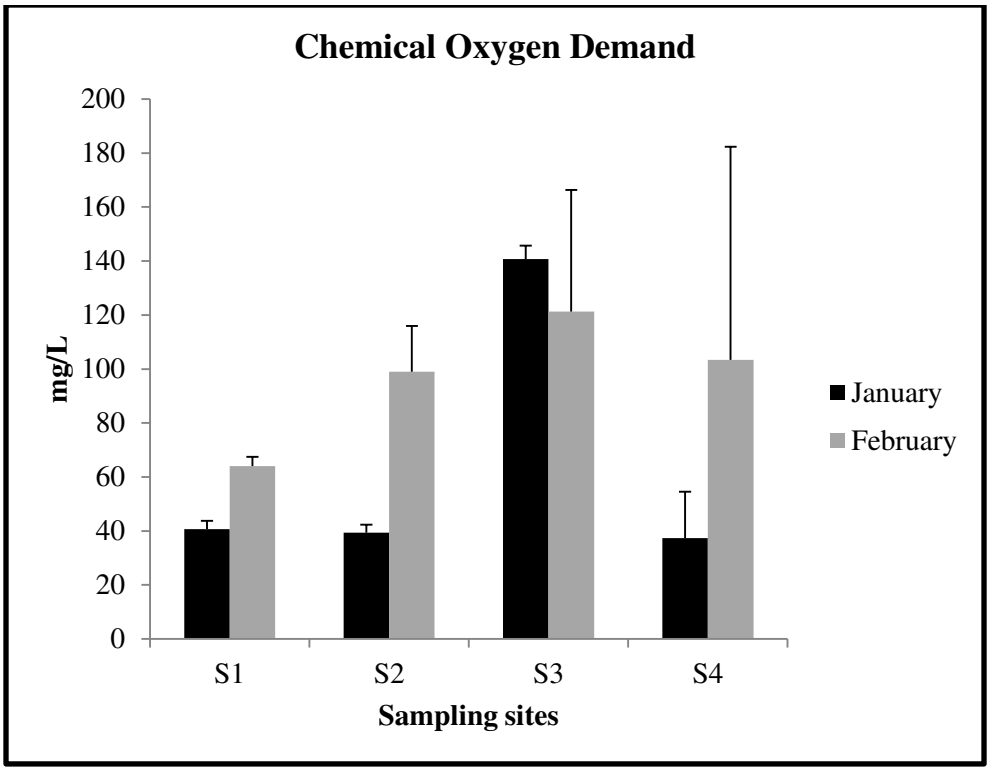


Fig 6.6: Monthly data assessment of COD of water in Pariej Lake

6.3.4 Free CO_2

Table: 7		
mg/L	January	February
S1	16.13	14.67
S2	10.27	14.67
S3	13.2	14.67
S4	ND	ND

Where, ND = Not detected

The average concentration of Free CO_2 is observed maximum (16.13 mg/L) at S1 and minimum (10.27 mg/L) at S2. The absence or presence of free carbon dioxide in surface water is mostly governed by its utilization by algae and also through its diffusion of air. Free CO_2 in water body is generally reported when the oxygen remains negligible or absent, mainly due to decomposition of organic matter by microbes in bottom, resulting in rapid production of free CO2 (Soni and Thomas, 2013). Hence, during January month increased amount of free CO_2 and decreased DO makes water to become slightly acidic.

The alkalinity of water at S4 is very high; hence the free CO_2 is not detected. Durborow and Robert (1992) gave desired range of pH, CO_2 and Alkalinity and the idea about their interaction. High level of CO_2 suffocates the fishes but the catfish can tolerate 20-30mg/ L carbon dioxide. Many cat fish species are recorded which indicates the level of pollution in the reservoir.

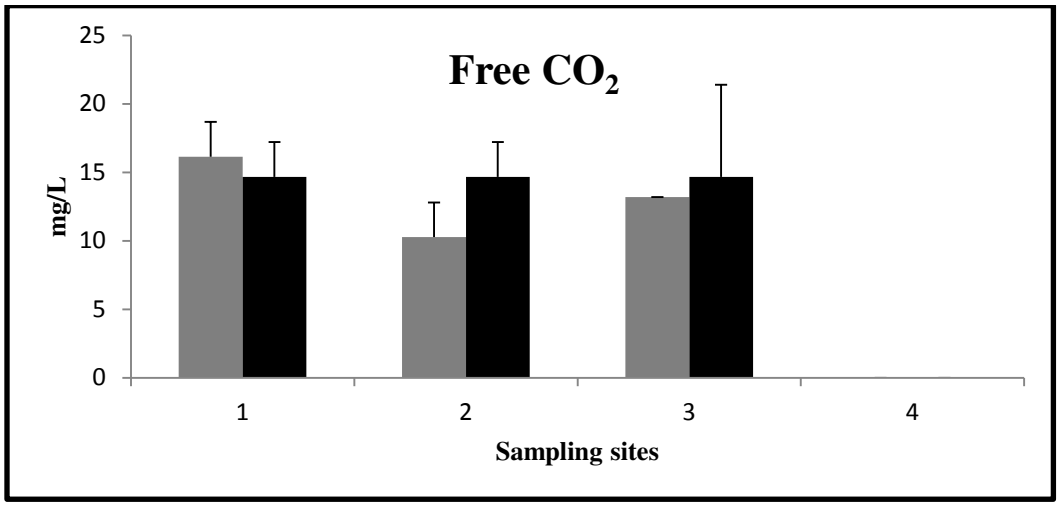


Fig 6.7: Monthly data assessment of free CO_2 of water in Pariej Lake

6.3.5 Alkalinity

Table: 8				
	January		February	
mg/L	PA	TA	PA	TA
S1	0	226.67	0	196.67
S2	0	206.67	0	190
S3	0	196.67	0	180
S4	126.67	626.67	126.67	870

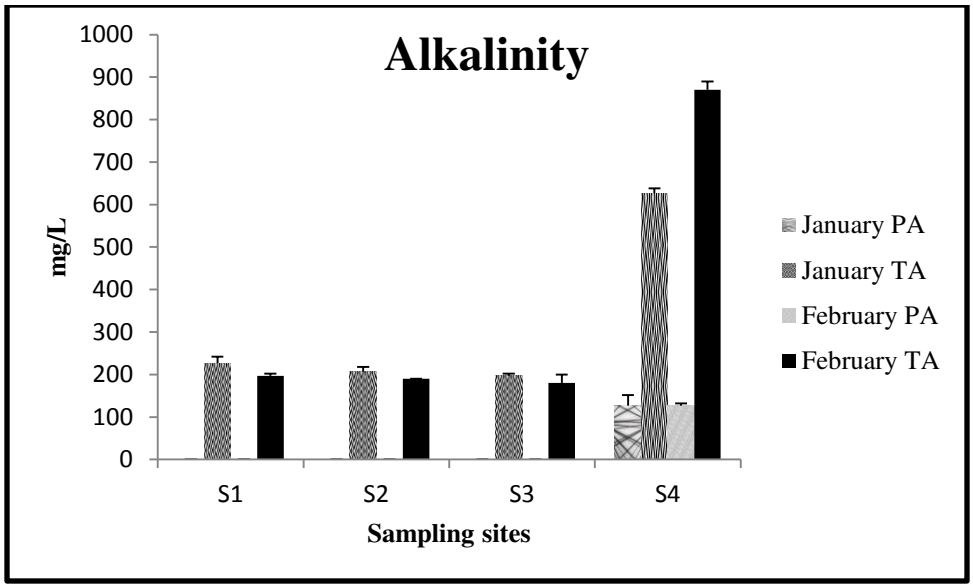


Fig 6.8: Monthly data assessment of Alkalinity of water in Pariej Lake

Phenolphthalein alkalinity is found only at S4 that is 126.67mg/L during two months. Total alkalinity is estimated by measuring the amount of acid (e.g. hydrochloric acid) needed to bring the sample to a pH of 4.2. At this pH, all the alkaline compounds in the sample are 'used up'. The values of TA in surface water at sampling stations (S1, S2, S3 and S4) are shown in the Table: 8 of which, the maximum total alkalinity concentration (626.67 & 870 mg/L) is recorded at S4, while minimum (180 mg/L) is noted at S3 during January. Alkalinity itself is not harmful to human beings. Static water supplied with less than 100 mg/L of alkalinity is desirable for domestic purpose. Water with pH greater than 8.3 is said to have phenolphthalein alkalinity (S4) which is primarily due to the presence of carbonate or hydroxide ions. (Soni and Thomas, 2013) but the drinking water should be below 200mg/L. Same trend observed by Vankar *et al.,* 2018 at Pariej lake. S1 and S3 are near the permissible limit and they have a neutral pH and normal CO_2 content which may not be damageable to any organism.

6.3.6 Total Hardness

Table: 9		
	January	February
S1	148	139.33
S2	139.33	142
S3	160.67	133.33
S4	ND	ND

Where, ND = Not detecteted

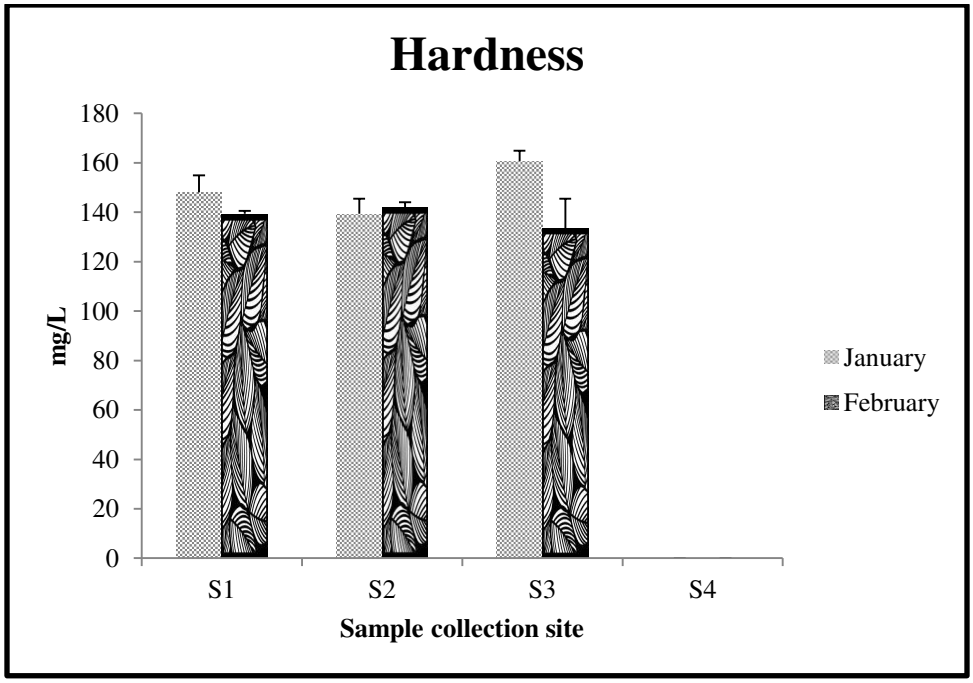


Fig 6.9: Monthly data assessment of Total Hardness of water in Pariej Lake

Hardness can be a mixture of divalent salts; calcium and magnesium. High amount (148 mg/L) of total hardness is observed in the month of January at S1, whereas low value (133 mg/L) is recorded in February at S3 which was slightly higher compared to the standards given by WHO. Similar type of trend observed by Sharma & Bhardwaj, 2011 and Soni & Thomas, 2014. The resultant impact could be due to regular addition of domestic sewage, and detergent which increased the Hardness of water. Calcium and magnesium are essential in the biological processes of fish (bone and scale formation, blood clotting and other metabolic reactions).

5.3.7 Calcium

Table: 10		
mg/L	January	February
S1	29.39	27.26
S2	26.18	26.45
S3	24.05	24.31
S4	10.42	16.57

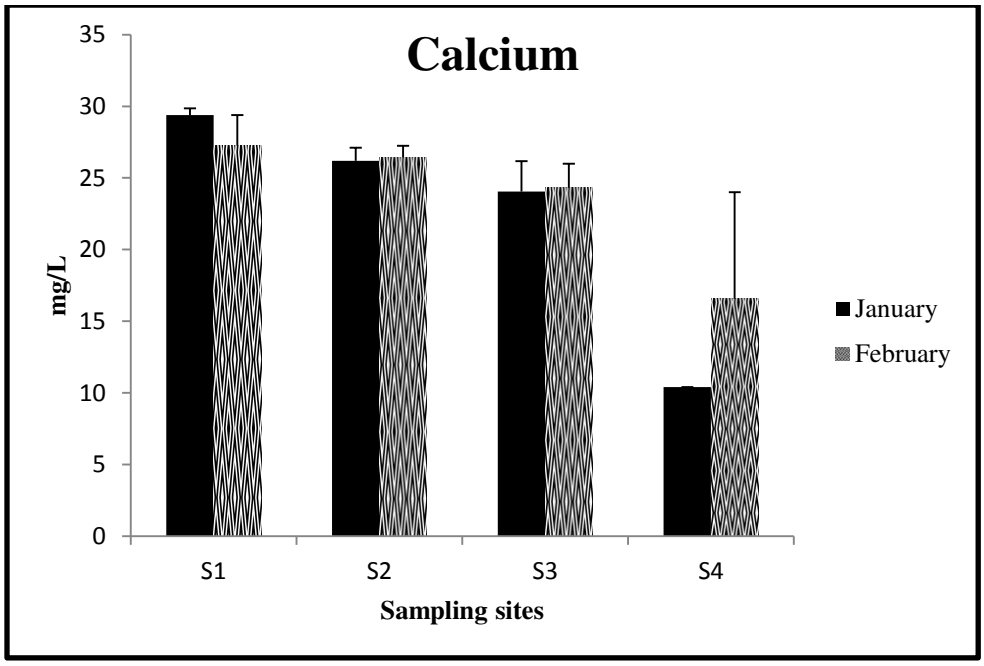


Fig 5.10: Monthly data assessment of Calcium of water in Pariej Lake

In aquatic environment, calcium serves as one of the vital micronutrients for most of the organisms. Sodium, Potassium and Calcium are most important salts for fish culture. They help in maintaining salts. The low and high values of calcium hardness of surface water are shown in the Table: 10 of which, the high content (29.39 mg/L) is reported at S2 during January, and minimum (10.42 mg/L) is noted at S4 during February. Similar type of data reported at Pariej Lake by Vankar *et al.,* 2018. The amount of dissolved oxygen matter may be responsible for low calcium in water (S-4). Striped cat fish and other cat fishes observed in Pariej reservoir have high tolerance power to survive in the water containing high calcium. (Durborow and Robert, 1992)

5.3.8 Magnesium

Table: 11		
mg/L	January	February
S1	56.21	53.70
S2	55.97	58.47
S3	73.24	55.22
S4	-18.51	-30.02

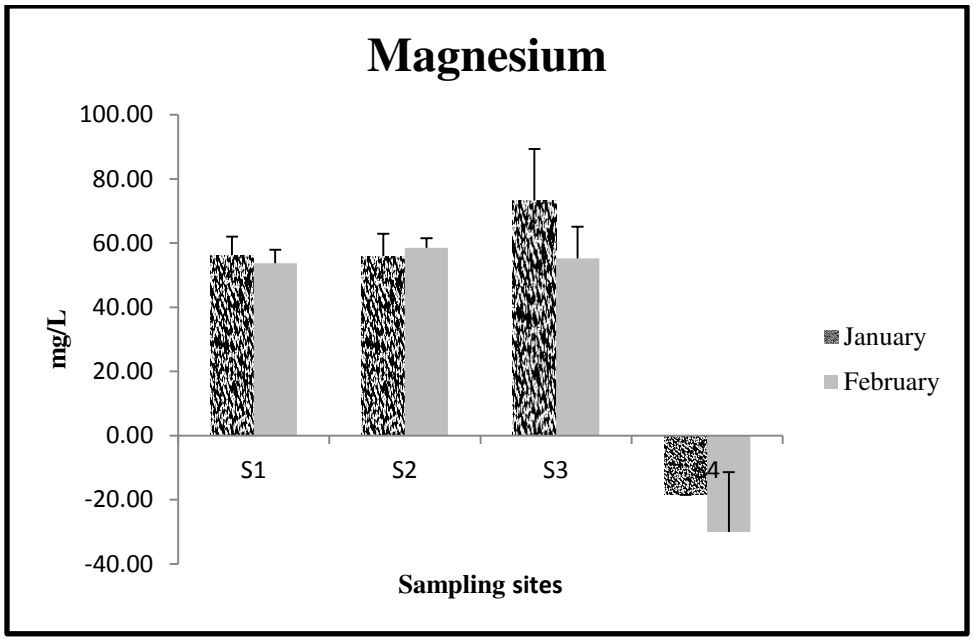


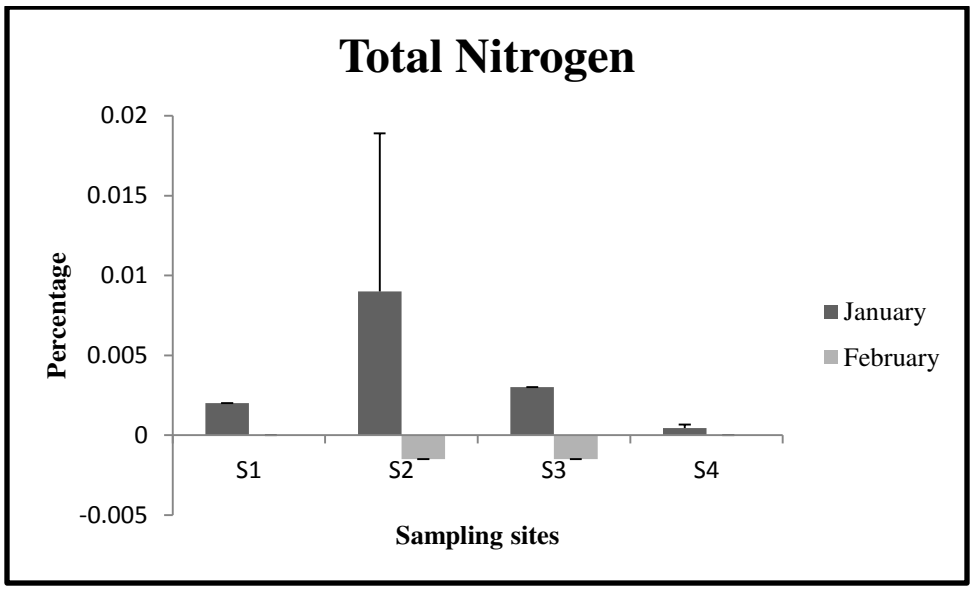
Fig 5.11: Monthly data assessment of Magnesium of water in Pariej Lake

Magnesium is essential for photosynthesis of chlorophyll bearing plants and therefore it can act as a limiting factor for the growth of phytoplankton. The lowest and the highest contents of magnesium hardness in surface water of all study stations is show in the Table: 11 of which, the peak gradient (73.24 mg/L) is observed at S3 during January and very low content is recorded at S4 during this research work. Similar type of trend is reported by Vankar et al., 2018, at Pariej Lake. The magnesium concentration is high due to the agricultural waste and other sewage.

6.3.9 Total Nitrogen

Table: 12		
mg/L	January	February
S1	0.002(10ppm)	0(0ppm)
S2	0.009(90ppm)	-0.0015(-15ppm)
S3	0.003(30ppm)	-0.0015(-15ppm)
S4	0.00045(4.5ppm)	0(0ppm)

Fig 6.12: Monthly data assessment of Total Nitrogen of water in Pariej Lake



All organisms require nitrogen for the basic process of life to synthesize protein for growth and reproduction (Soni and Thomas, 2013). The total Nitrogen content is found the highest at S2 (90ppm) in January month, above the permissible limit and the Nitrogen content tremendously decreased and became 0ppm in the February month. It may indicate the low activity of Nitrogen fixation bacteria at low temperature and hence it could not be trapped during estimation. Increased temperature supports high microbial activity leading to algal blooms and eutrophication the same trend was observed by Hussain *et al.*, (2017). Hence, increased nitrogen concentrations in surface layers influence the plankton production, leading to algal blooms.

6.3.10 Nitrite

Table: 13		
	January	February
S1	0.34	0.33
S2	0.31	0.33
S3	0.32	0.33
S4	0.5	0.52

Nitrite concentration in surface water is noted high (0.52 mg/L) at S4 in February, while it is low at other three sites (S1-S3). Similar type of trend is reported by Vankar *et al.,* 2018. High concentration of Nitrite indicates the pollution of water, because it is formed after the ammonification of ammonium ion by aerobic and anaerobic bacteria. The high activity of bacteria or availability of these bacteria induces the formation of nitrite ions. Increased temperature supports high microbial activity leading to algal blooms and eutrophication.

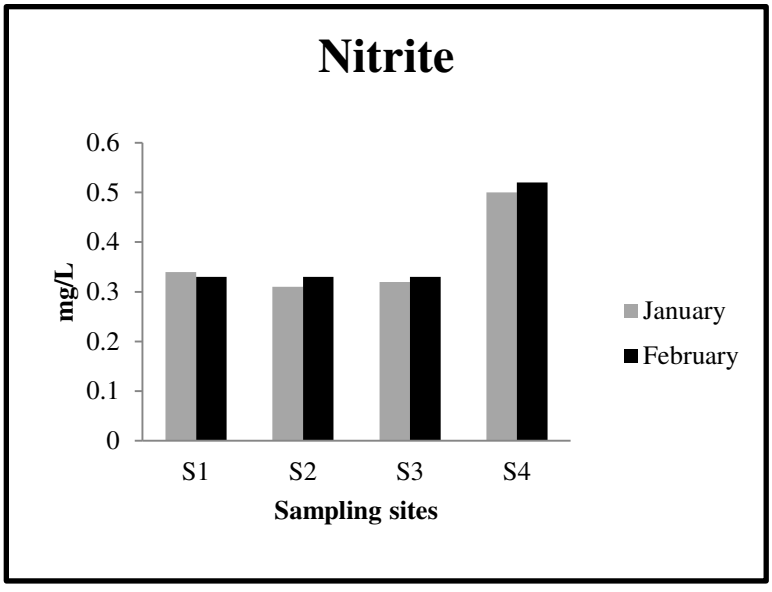


Fig5.13: Monthly data assessment of Nitrite content of water in Pariej lake

6.3.11 Total phosphorus

Table: 13		
mg/L	January	February
S1	0.1	0.1
S2	0.1	0.1
S3	0.1	0.1
S4	0.1	0.1

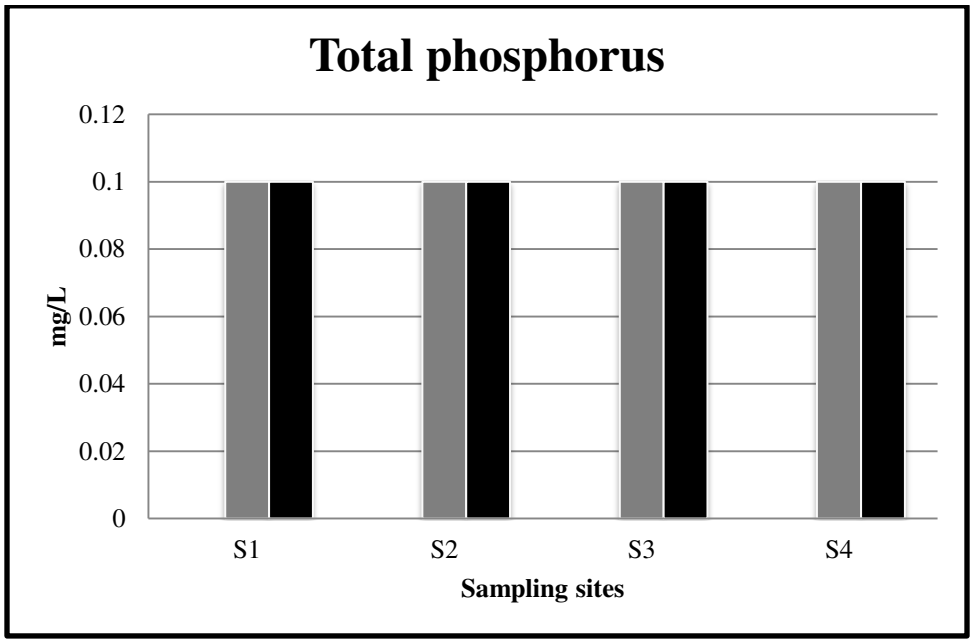


Fig 6.13: Monthly data assessment of Nitrogen of water in Pariej Lake

Phosphorus is always present in the form of organic or inorganic phosphate (PO^{4-}). Phosphate is an important nutrient maintaining the fertility of water body. The total phosphorus level found is within the permissible limit which remained constant (0.1 mg/L) during both months at all the study stations (S1-S4). Studies at global scales have shown that algal biomass in lakes have a strong correlation with total phosphorus concentration. Similar type of data analyzed by Vankar et al., (2018), Hussain et al., (2017) and Soni and Thomas (2013) at Pariej lake, Loktak lake and Dakore pond respectively. They also observed the rise in phosphorus during summer leads to eutrophication of water body.

6.3.12 Sulphate

Table: 14		
mg/L	January	February
S1	15.34	13.96
S2	18.95	14.22
S3	53.87	15.68
S4	86.3	86.3

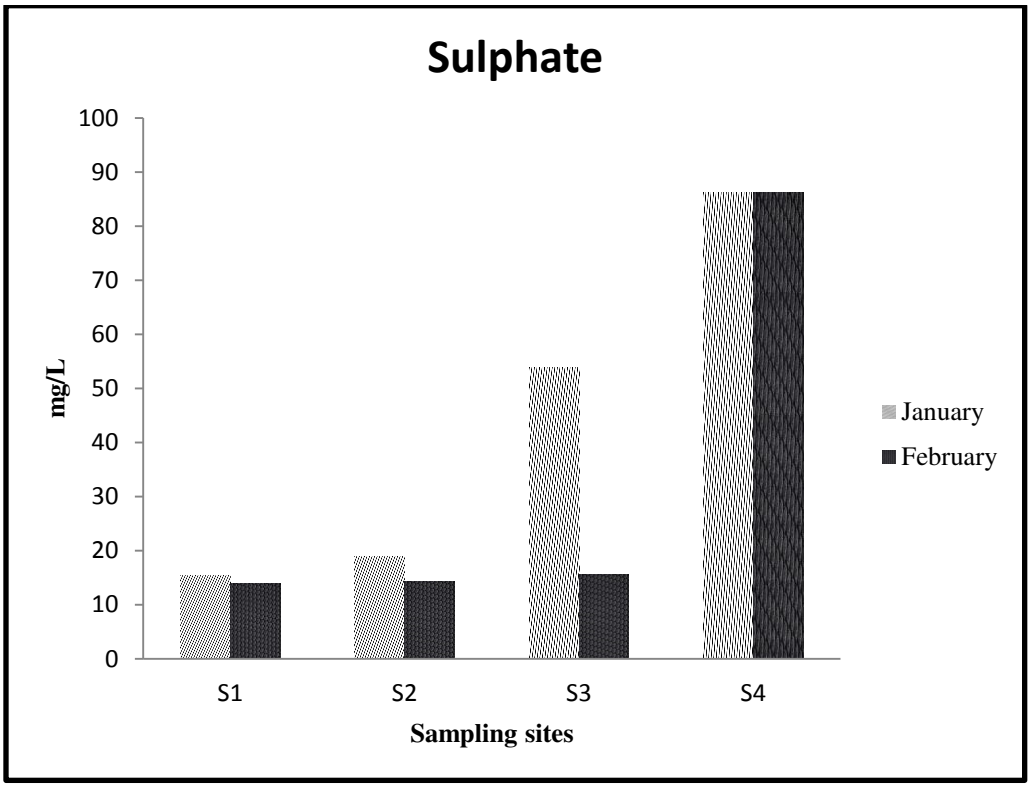


Fig 6.14: Monthly data assessment of Sulphate content of water in Pariej Lake

The lowest and the highest contents of sulphate in surface water of all sampling stations is shown in Table: 14 of which the highest amount of sulphate is noted at S4 during (86.3mg/L) both months and the lowest value is observed at S1(13.96) during February month. Peak increase of sulphates of water is derived from sulphides produced during organic decay in the bottom deposits by oxidation in winter. Its concentration decrease when anaerobic bacteria are reduced. (Soni and Thomas, 2013)

6.3.13 Chloride

Table: 15		
mg/L	January	February
S1	39.76	44.02
S2	37.87	40.71
S3	34.08	41.18
S4	ND	ND

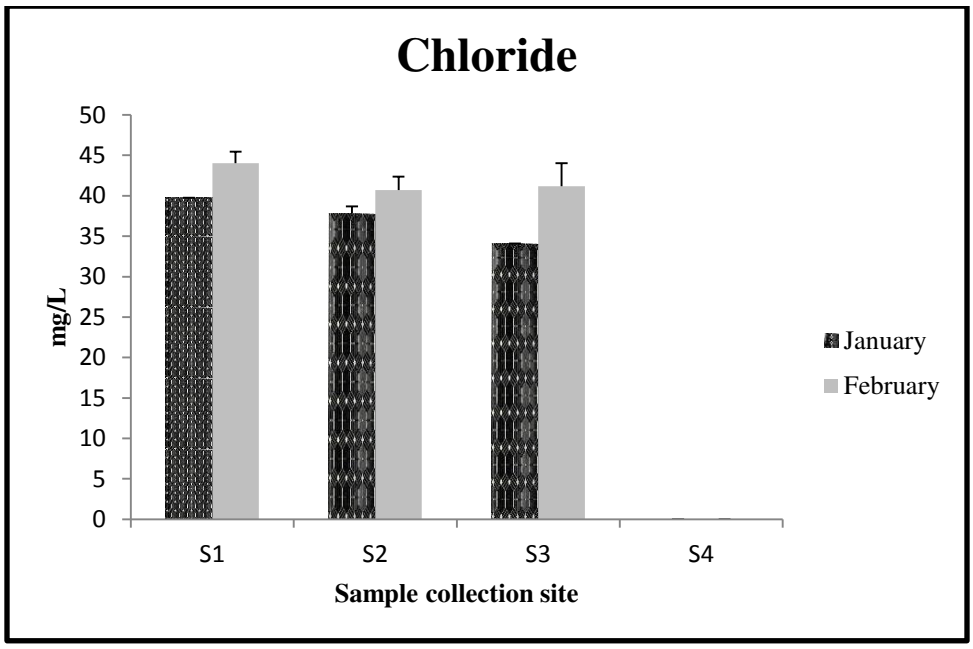


Fig 6.15: Monthly data assessment of Chloride content of water in Pariej Lake

The fluctuating contents of chloride in surface water of S1, S2, S3 and S4 are as shown in the Table: 15 of which, elevated concentration (44.02 mg/L) is documented at S1 during January, and depleted content is determined at S4 indicating the absence of chloride ions. In January, the concentration of chloride ions declined. The high amount of chloride ions in freshwater is an important indicator suggesting organic pollution. The present investigation is very well-corroborated with the findings of Vankar *et al*., (2018) at Pariej Lake which tremendously decreased during summer.

6.3.14 Fluoride

Table: 16		
mg/L	January	February
S1	1.5	1.5
S2	1.5	1.5
S3	1.5	1.5
S4	3	3

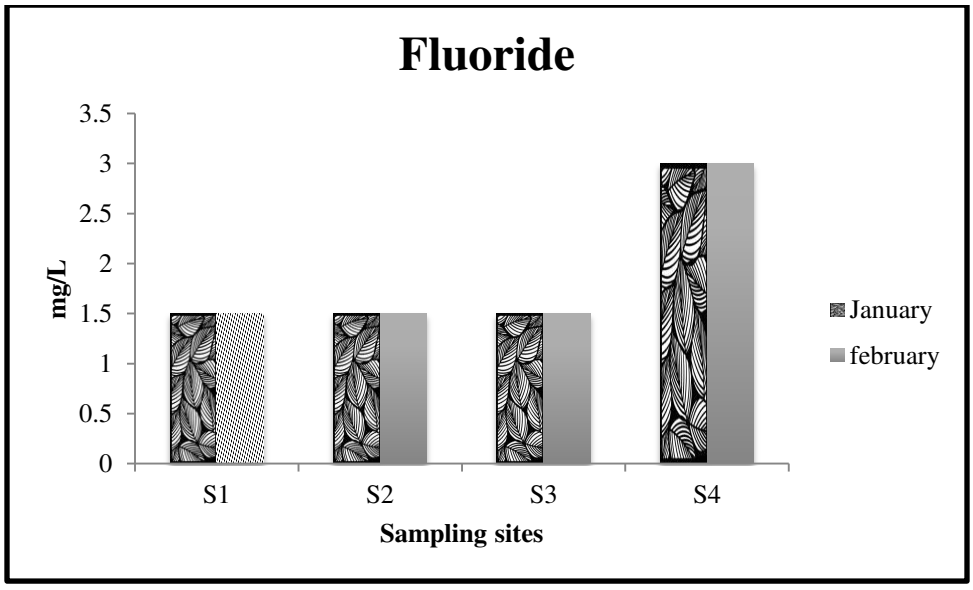


Fig 6.16: Monthly data assessment of Fluoride content of water in Pariej Lake

Similar contents of Fluoride in surface water of all three study stations are observed during both months of which, the peak value (3 mg/L) is perceived at S4 during colder days. The permissible limit given by WHO is 1.5mg/L is detected at S1 to S3. High concentration of Fluoride in water leads to Fluorosis in humans and also damages crops if used for irrigation. Many group of animals like insects and fishes are also affected.

6.3.15 Chlorophyll

Table: 17						
	January			February		
mg/L	Ca	Cb	Cc	Ca	Cb	Cc
S1	-0.051	0.001	-0.5	0.064	0.196	0.069
S2	-0.051	0.077	-0.28	-0.063	-0.113	-0.064
S3	0.003	-0.034	-0.05	0.517	0.29	-0.182
S4	0.244	0.371	0.37	-0.01	-0.005	-0.089

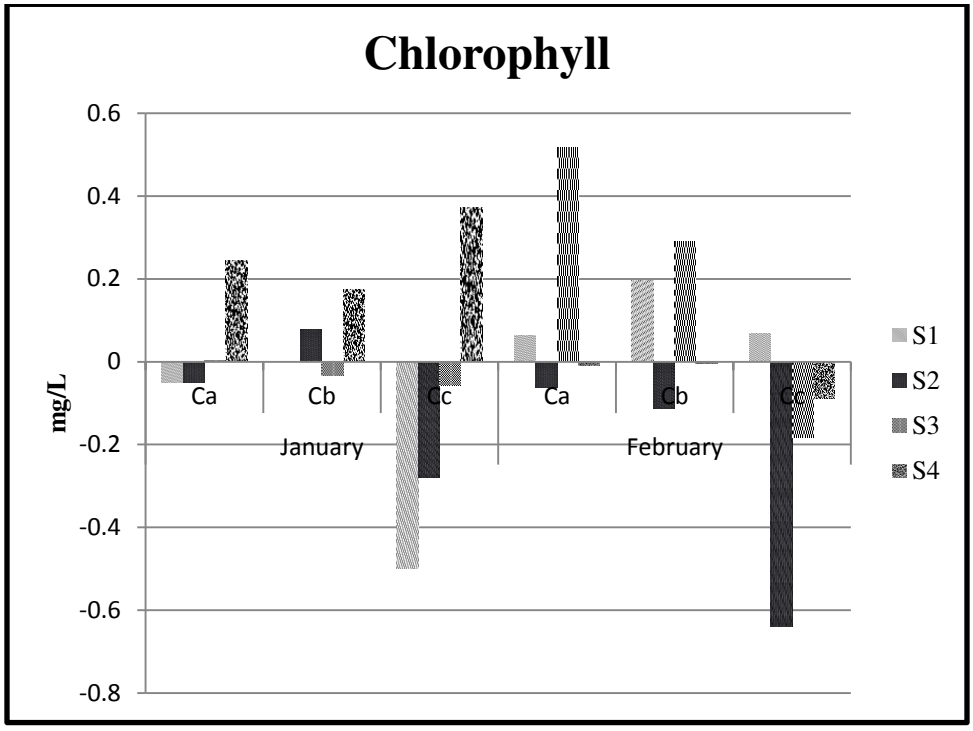


Fig 6.17: Monthly data assessment of Fluoride content of water in Pariej Lake

Chlorophyll is basically found as macrophytes, phytoplankton and protozoa in water. The concentration of them is measured and indicates the total concentration of chlorophyll. During month of January, the peak value of chlorophyll a, b and c are obtained at S4 point whereas, S1 and S2 sites noted with high chlorophyll b value in the same month. The chlorophyll a, b and c contents decreased at S4 location and increased at S1, with the S3 station reporting highest value of chlorophyll a and b.

6.3.16 Heavy Metals

Table: 18					
	Arsenic	Cadmium	Chromium	Mercury	Lead
S1	BDL	BDL	BDL	BDL	BDL
S2	BDL	BDL	BDL	BDL	BDL
S3	BDL	BDL	BDL	BDL	BDL
S4	BDL	BDL	BDL	BDL	BDL

BDL = Below Detection Limit of the instrument ICP-OES

Heavy metals like Cd, Cr, Pb, Hg and As were analyzed by ICP-OES instrument and the content present in the water were not detected because they are below the detection limit of the instrument.

6.4 Biological parameters

6.4.1 Fauna

- **Avian fauna**

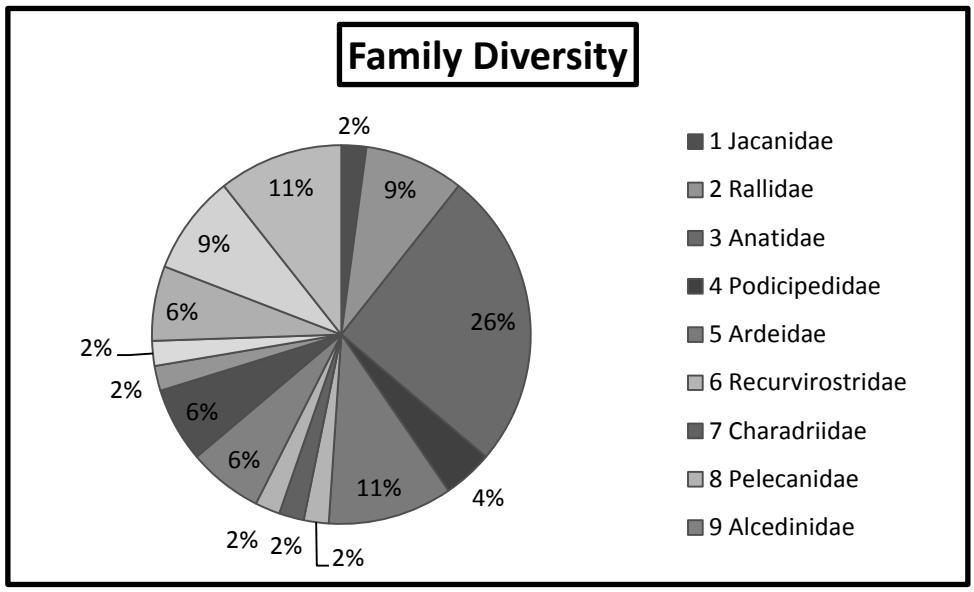


Fig 6.18 Showing the family diversity of Pareij lake

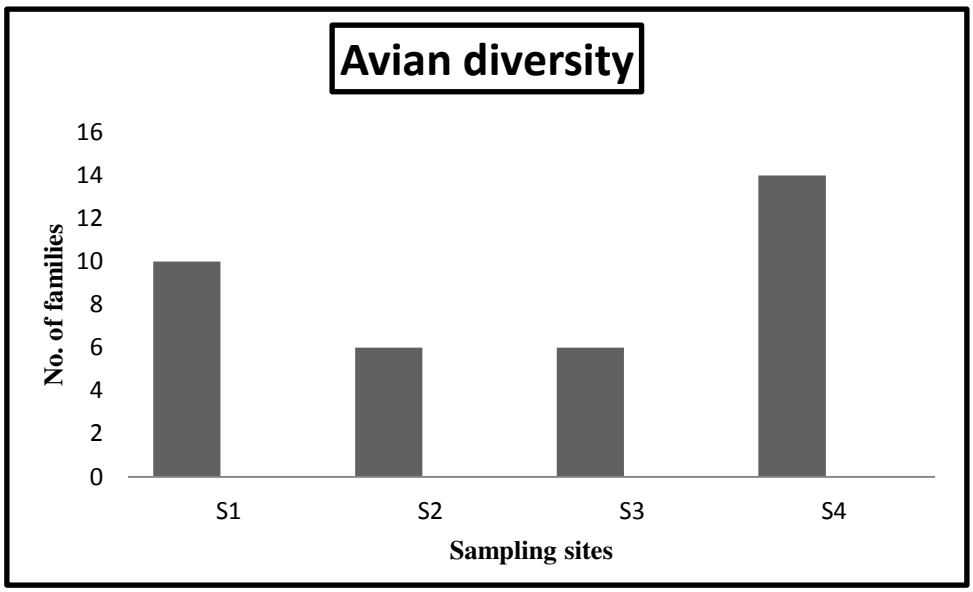


Fig 6.19 The aquatic bird families per each site of the study

SCIENTIFIC NAME	FAMILY	STATUS	Site -1	Site -2	Site -3	Site -4
Metopidius indicus	Jacanidae	Widespread resident	√			
Porphyrio porphyrio	Rallidae	Widespread resident	√	√	√	√
Gallinula chloropus	Rallidae	Widespread resident	√			√
Amaurornis phoenicurus	Rallidae	Widespread resident	√	√	√	√
Fulica atra	Rallidae	Widespread resident/Winter visitor	√	√	√	√
Anas clypeata	Anatidae	Widespread winter visitor	√			√
Anas querquedula	Anatidae	Widespread winter visitor				√
Anas crecca	Anatidae	Widespread winter visitor	√			√
Anas acuta	Anatidae	Wide spread winter visitor	√			√
Anas platyrhynchos	Anatidae	Wide spread winter visitor	√			√
Anas strepera	Anatidae	Widespread winter visitor	√			√
Anas poecilorhyncha	Anatidae	Widespread winter visitor	√			√
Sarkidiornis melanotos	Anatidae	Resident	√			√
Tadorna tadorna	Anatidae	Widespread winter visitor	√			√
Tadorna ferruginea	Anatidae	Widespread winter visitor	√			√
Dendrocygna javanica	Anatidae	Widespread resident	√			√
Aythya ferina	Anatidae	Winter visitor	√			√
Tachybaptus ruficolllis	Podicipedidae	Resident	√			√
Podiceps cristatus	Podicipedidae	Winter visitor	√			√
Ardeola grayii	Ardeidae	Resident	√	√	√	√
Ardea cinerea	Ardeidae	Resident/passage migrant/winter visitor	√			√
Ardea purpurea	Ardeidae	Resident/widespread/winter visitor	√	√	√	√
Casmerodius albus	Ardeidae	Widespread resident	√	√	√	√
Mesophoyx intermeida	Ardeidae	Widespread resident	√	√	√	√
Himantopus himantopus	Recurvirostridae	Resident				√
Vanellus indicus	Charadriidae	Widespread resident	√	√	√	√
Pelacanus pristus	Pelecanidae	Winter visitor				√
Pelecanus onotrotalus	Pelecanidae	Winter visitor				√
Halcyon smyrnensis	Alcedinidae	Resident	√	√	√	√
Alcedo atthis	Alcedinidae	Resident	√	√	√	√
Ceryle rudis	Alcedinidae	Resident	√			√

Microcarbo niger	Phalacrocoracidae	Widespread resident	√	√	√	√
Phalacrocorax fuscicolis	Phalacrocoracidae	Widespread resident	√	√	√	√
Phalacrocorax carbo	Phalacrocoracidae	Widespread resident	√	√	√	√
Anhinga melanogaster	Anhingidae	Widespread resident	√			√
Antigone antigone	Gruidae	Resident				√
Ciconia episcopus	Ciconiidae	Widespread resident				√
Mycteria leucocephala	Ciconiidae	Widespread resident				√
Anastomus oscitans	Ciconiidae	Widespread resident				√
Platalea leucorodia	Threskiornithidae	Widespread resident				√
Plegadis falcinellus	Threskiornithidae	resident/winter-visitor		√		√
Psuedibis papillosa	Threskiornithidae	Widespread resident		√		√
Threskiornis melanocephalus	Threskiornithidae	Widespread resident		√		√
Tringa stagnatillis	Scolopacidae					√
Actitis hypoleucos	Scolopacidae	Widespread winter-visitor				√
Calidris pugnax	Scolopacidae	Widespread winter visitor/passage migrant				√
Limosa limosa	Scolopacidae	Widespread winter-visitor				√
Tringa totanus	Scolopacidae	Widespread winter-visitor				√
Tringa glareola	Scolopacidae	Widespread winter-visitor				√

Table: 19 List of aquatic avian fauna reported during the study periods (Random visits)

1	Common babbler	Turdoides caudata	Leiothrichida
2	Jungle babbler	Turdoides striata	Leiothrichida
3	Asian paradise flycatcher	Terpsiphone paradisi	Monarchidae
4	Golden oriole	Oriolus kundoo	oriolidae
5	Common hawk-cuckoo	Hierococcyx varius	Cuculidae
6	Greater coucal	Centropus sinensis	Cuculidae
7	White-eared bulbul	Pycnonotus leucotis	Pycnonotidae
8	Red-vented bulbul	Pycnonotus cafer	Pycnonotidae
9	Rose-ringed parakeet	Psittacula krameri	Psittasidae
10	Indian peafowl	Pavo cristatus	Phasianidae
11	White-browed fantail	Rhipidura aureola	Rhipiduridae
12	Rufous treepie	Dendrocitta vagabunda	Corvidae
13	Indian robin	Copsychus fulicatus	Muscicapidae
14	European stonechat	Saxicola rubicola	Muscicapidae
15	Oriental magpie robin	Copsychus saularis	Muscicapidae
16	Ashy-crowned sparrow	Eremopterix griseus	Alaudidae
17	Crested lark	Galerida cristata	Alaudidae
18	Green bee-eater	Merops orientalis	Meropidae
19	Rosy starling	Pastor roseus	Sturnidae
20	Brahminy starling	Sturnia pagodarum	Sturnidae
21	Bank myna	Acridotheres ginginianus	Sturnidae
22	Spotted dove	Spilopelia chinensis	Columbidae
23	Laughing dove	Spilopelia senegalensis	Columbidae
24	Eurasian collard dove	Streptopelia decaocto	Columbidae
25	Rock dove(Pigeon)	Columba livia	Columbidae
26	Black-rumped flameback woodpecker	Dinopium benghalense	Picidae
27	Great grey shrike	Lanius excubitor	Laniidae
28	Long-tailed shrike	Lanius schach	Laniidae
29	Common tailorbird	Orthotomus sutorius	Cisticolidae
30	Ashy prinia	Prinia socialis	Cisticolidae
31	plain prinia	Prinia inornata	Cisticolidae
32	Black drongo	Dicrurus macrocercus	Dicruridae
33	Hoopoe	Upupa epopus	Upupidae
34	Spotted owlet	Athene brama	Strigidae
35	Western marsh harrier	Circus aeruginosus	Accipitridae
36	European honeybuzzard	Pernis apivorus	Accipitridae
37	Black kite	Milvus migrans	Accipitridae
38	Wire-tailed swallow	Hirundo smithii	Hirundinidae
39	Western yellow wagtail	Motacilla flava	Motacillidae
40	Grey wagtail	Motacilla cinerea	Motacillidae

Table: 20 List of other than aquatic birds observed during study period (Random visit)

In the Table: 19, 50 genus and 9 families of aquatic birds are observed. They are sited at different selected locations. The S1, S2, S3 and S4 locations are found with 10, 6, 6 and 14 Families respectively other than these 40 other bird species are observed from 23 families. We can observe the migratory and some residential avian fauna during all the months of winter. The main attractions of migratory birds are good climatic conditions and food availability.

Pisces: 8 species of fish are recorded from 5 different families. At S2 location fishes are cultured using Cage-culture and open-culture methods. Cat fishes have tolerance to survive in polluted water but in February month, some fishes started to die due to increase in temperature which may have led to change in the physico-chemical parameters of lake.

Class : Pisces

Table : 21The list of Pisces observed during study period

Sr. No.	Common name	Scientific name	Family
1	Rohu	Labio rohita	Cyprinidae
2	Mrigal	Cirrhinus mrigala	Cyprinidae
3	Catla	Catla calta	Cyprinidae
4	Stinging cat fish	Heteropneustes fossilis	Heteropneustidae
5	Walking Cat-fish	Clarias batrachus	Clariidae
6	Common snakehead	Channa striata	Channidae
7	Giant river cat fish	Separata sheenghala	Bagridae
8	Grass carp	Ctenopharyngodon idella	Cyprinidae

Mammalia:

The common mammalian fauna are observed during random visit of Pariej lake. 12 Species from 7 families are reported. They also play important role in food chain by the intake of producers and consumers of the ecosystem.

Mammalia group

Table: 22 The list of class mammalia noted during study period

Sr.No.	Common name	Scientific name	Family
1	Indian grey mongoos	Herpestinae edwardsi	Herpastidae
2	Indian flying fox	Pteropus giganteus	Pteropodidae
3	Three striped palm squirrel	Funambulus palmarum	Sciuridae
4	Blue bull	Boselaphus tragocamelus	Bovidae
5	Jungle cat	Felis chaus	Felidae
6	Domestic cat	Felis silvestris	Felidae
7	Indian pariah dog	Canis lupus familiaris	Canidae
8	Water buffalo	Bubalus bubalis	Bovidae
9	Bullock (ox)	-	Bovidae
10	Domestic cow	Bos taurus	Bovidae
11	Domestic goat	Capra aegagrus hircus	Bovidae
12	Gray langur	Semnopithecus	Circopithecidae

Reptilia: The 3 species from 3 different families are commonly found at these four sites and they also play a major role as secondary consumer.

Table : 23The list of class reptilia found during investigation

Sr.No.	Common name	Scientific name	Family
1	Checkered keelback	Xenochorphis piscator	Colubridae
2	Oriental garden lizzard	Calote versicolor	Agamidae
3	Indian cobra	Naja naja	Elapidae

Arthropoda: It is the most diversified group on this planet. Some group of insects that are observed at Pariej lake shown in the Table: 24, 25 and 26

Table: 24 The list of Arachnids observed during study periods

Sr.No.	Scientific name	Family
1	Argiope anasuja	Araneidae
2	Hasarius adasoni	Salticidae
3	Menemerus sp.	Salticidae
4	Neoscona araneus	Araneidae
5	Oxypus javanus	Oxyopidae

6	Harsilia savignyi	Hersilidae
7	Plexipus paykullii	Salticidae
8	Achaearanea sp.	Theridiidae
9	Elica sp.	Gnaphositae
10	Thayene sp.	Salticidae

Table: 25 The list of butterflies reported during study period

Order: Lepidoptera

Sr. No.	Common name	Scientific name	Family
1	The tawny coster	Acraea terpsicore	Nymphalidae
2	Striped tiger	Danaus genutia	Nymphalidae
3	The blue tiger	Tirumala limniace	Nymphalidae
4	The great eggfly	Hypolimnas bolina	Nymphalidae
5	Danaid eggfly	Hypolimnas misippus	Nymphalidae
6	Common evening brown	Melanitis leda	Nymphalidae
7	Common four ring	Ypthima huebneri	Nymphalidae
8	Lemon pansy	Junonia lemonias	Nymphalidae
9	Peacock pansy	Junonia almanac	Nymphalidae
10	Blue pansy	Junonia orithya	Nymphalidae
11	Parrhasius small cupid	Chiladus parrhasius parrhasius	Lycaenidae
12	Indian lesser grass blue	Zizina otis indica	Lycaenidae
13	Common grass yellow	Eurema hecabe	Pieridae
14	Commo gull	Ceopora nerissa	Pieridae
15	Yellow orange tip	Ixias pyrene	Pieridae
16	Oriental mottled emigrant	Catopsilia pyranthe	Pieridae
17	Indian skipper	Spialia galba	Hesperiidae
18	The tailed jay	Graphium agamemnon	papilionidae

Parmar and Acharya (2014) observed 59 species from 16 families at Pariej lake. Many other researches on odonates and butterflies have been published which gives the idea about the huge diversity and fertility of the Pariej lake. Dr. B.M. Parashariya reported 34 species of Odonata from 7 different families. Here during investigation, some species of arachnids from 6 families, 18 species of butterflies from 5 families and 5 species of moths from 2 families were observed. These are the food-base for flycatchers and some aquatic bird families.

Table: 26 showing order Lepidoptera(Heterocera)			
Sr.No.	Common name	Scientific name	Family
1	Common emerald	Hemithea aestivaria	Geometridae
2	Sandalwood defoliator	Amata passalis	Erebidae
3	-	Traminda mundissima	Geometridae
4	Waker's owl moth	Erebus macrops	Erebidae
5	Tiger moth	Lemyra sp.	Erebidae

5.4.2 Floral diversity:

Although it was believed that macrophytes are rarely consumed are unimportant in aquatic food-web, Lodge (1990) gave data about all the macrophytes and their role in ecosystem. He demonstrated that macrophytes biomass, productivity and species are often influenced by vertebrate and invertebrate grazers. Algae, emergent macrophytes, floating macrophytes, submerged, terrestrial grasses are commonly found at any aquatic ecosystem. They provide food to many animals like fish, some insects and provide base for egg laying, larval formation and work as substratum for free living animals.

Similar trend was observed by Soni and Thomas (2014) at Dakor wetlands, observed some remarkable pollution indicator such as Eichhornia crassipes, Lemna minor, Potamogeton nodusus are frequent and abundant, signifying eutrophic condition.

All the four locations are covered by aquatic vegetation from that Typhaceae family is more dominant at all the sampling sites and the other families were shown in the fig.5.21

There are 18 species of aquatic flora reported from 14 different families, which are shown in Table: 27. They play important role to complete food-web of aquatic ecosystem. These flora are the basic need for the entire food web, since they are the only autotrophic organsims on this earth.

Sr.No.	Common name	Scientific name	Family	S1	S2	S3	S4
1	Water lilies	Nymphea	Nymphaeaceae		√	√	
2	Cattail	Typha angustifolia	Typhaceae	√	√	√	√
3	Club rush	Scirpus	Cyperaceae	√			
4	Spike rush	Eleocharis	Cyperaceae	√			√

5	Pond weed	Potemogeton	Potamogetonaceae	√		√	
6	Coontail	Ceratophyllum	Ceratophyllaceae		√		
7	Eel grass	Vallisneria	Hydrocharitaceae	√			
8	Water weed	Elodea	Hydrocharitaceae		√		
9	Common stonewart	Chara vulgaris	Characeae		√	√	
10	Stonewort	Nitella	Characeae		√	√	
11	Duckweed	Lemna	Lemnoideae	√			
12	Water hyacinth	Eichhornia	Pontederiaceae	√			
13	Water clover	Marsilea	Marcileaceae	√			
14	Indian lotus	Nelumbo nucifera	Nelmbonaceae			√	
15	Water spinach	Ipomea aquatica	Convolvulaceae			√	
16	Knot weed	Polygonum	Polygonaceae	√			
17	Blunt arrowhead	Limnophyton obtusifolium	Alismataceae			√	
18	Waterthyme	Hydrilla verticillata	Hydrocharitaceae		√		

Table: 27 The list of aquatic plants observed during two month research at lake

6.4.3 Microbial analysis :

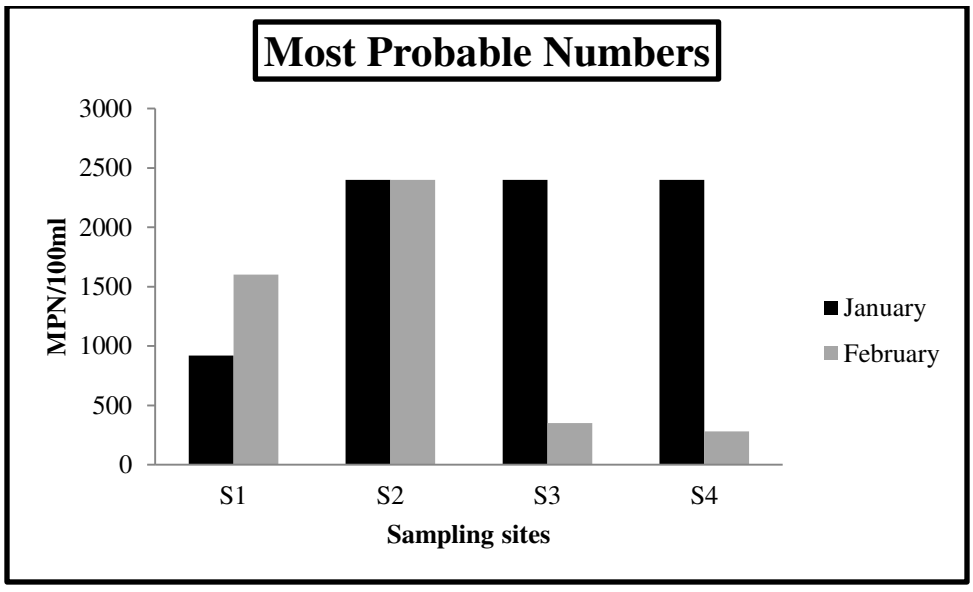


Fig 6.20 MPN/100ml for various combinations of positive results when 5 tubes each of 10, 1 and 0.1ml sample fractions are used

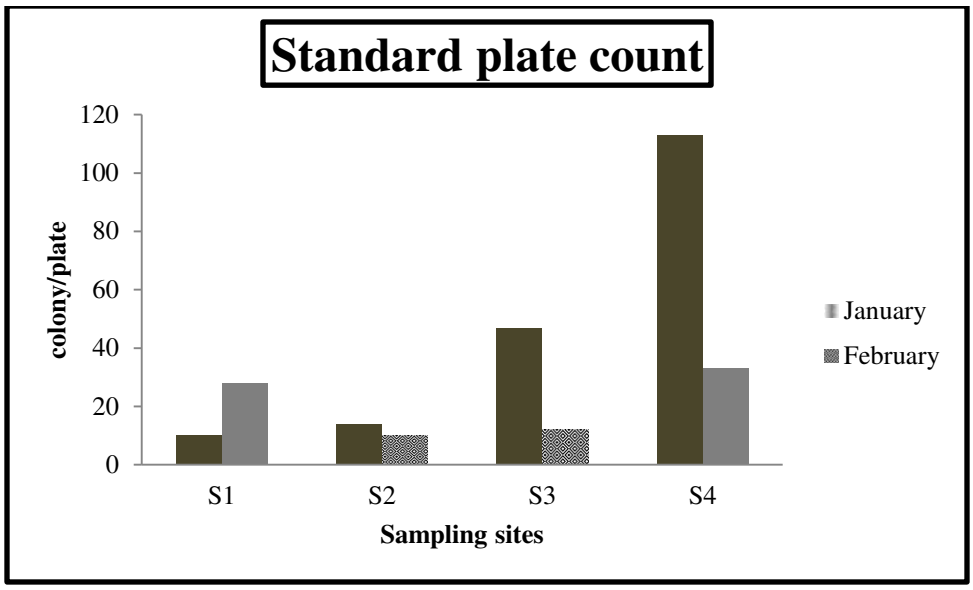


Fig 6.21 Results of total viable count of microbial colony on plate

During two months of microbiological analysis the microbial load in the lake water were estimated as shown in the above graphs. Three methods were used for microbiological examination of water and the results of each test are as follows;

In MPN method the highest positive test is noted during January month which decreased in February except at one location,

S2. Maximum value of 2400 MPN/100ml is analyzed whereas, minimum value of 280MPN/100 ml are observed at S4 in month of February. This method is only applicable to Lactose fermenting bacteria given that gas formation has occurred. E.Coli bacterial colony grow on EMB Agar marked with metallic green sheen coloured only observed in S4 water samples.

Total viable count (SPC) provides the density of aerobic organism present in the water samples. These values were noted. The maximum colonies are found at S4 and the minimum colonies are found at S1 during January month. The density of these colonies decreased in February due to increase in temperature.

Another method to differentiate the Gram negative and Gram positive bacteria is by using Gram-staining method. It can then be observed by microscope. Before Gram-staining the

bacterial growth allow on the Nutrient agar (NA) plate and after incubation they allow to growth on plate for isolation of particular one colony which are stained by the Gram staining method and observed characteristics of the isolated bacteria are as follows;

- S1 – long and short rod shape, cocci, gram-positive bacteria
- S2 – Small rod, long rod, long chain, cocci, gram-positive bacteria
- S3 – large chains of rod shape bacteria, single small rod, gram-positive bacteria
- S4 – cocci, small rods, gram-negative bacteria

  Hence, from above characteristics, isolated colonies may be from Monococcus, Diplococcus, Streptococcus and Bacillus typr of bacteria.

Diversity of Planktons

Phytoplankton, The study of phytoplankton composition provides information for the characterization of aquatic ecosystems. These organisms constitutes the first and quantitatively most imperative link in the food chain representing the main source of oxygen and energy to the higher trophic level organisms of the aquatic environment (Soni and Thomas, 2014)**.** The phytoplanktons from 8 orders and 25 species were reported during the present study at Pariej lake. The major families are Chlorophyceae, Cyanophyceae, Bacillariophyceae and euglenophyceae are reported. Among the total recorded species diatoms are abundance in all 4 study sites. . The peak gradient of phytoplankton species is observed at Site 4 reflected by the existence of members of family Bacillariophyceae. The dominance of same species is reported by Soni and Thomas (2014) at Dakor wetland.

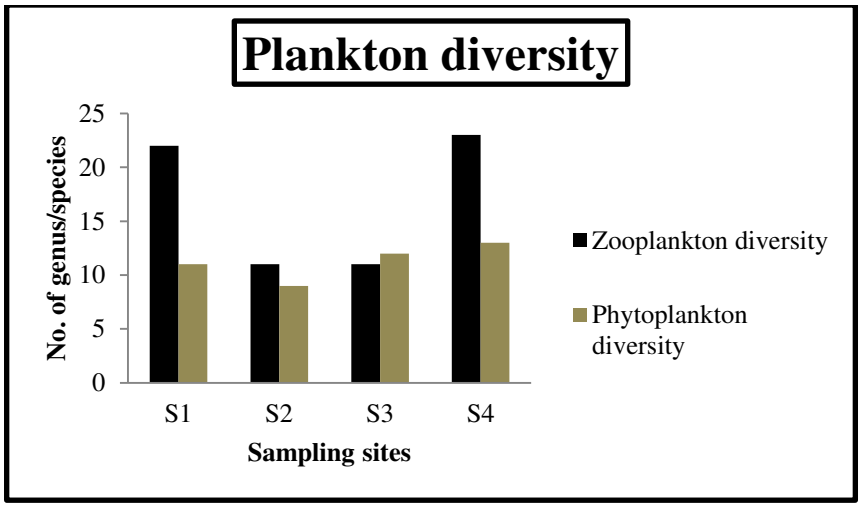


Fig. 22 showing the diversity of zooplankton and phytoplankton at four study sites of Pariej lake

Table:28 The list of phytoplankton observed during investigation

SrNo.	PHYTOPLANKTONS	S-1	S-2	S-3	S-4
1	Mastoglia	✓			
2	Euglena sp.				✓
3	Chlorella sp.				✓
4	Oscillatoria sp.			✓	✓
5	Nitchia lorenziana		✓	✓	✓
6	Nitzchia acicularis		✓	✓	✓
7	Scenedesmus quacricauda		✓	✓	
8	Desmidium sp.		✓	✓	
9	Zygnema sp.		✓	✓	
10	Spirogyra sp.	✓	✓	✓	✓
11	Microspora sp.				✓
12	Navicula radiosa	✓	✓	✓	✓
13	Fragilaria sp.	✓			
14	Hydrodictyon sp.	✓			
15	Phytoconis sp.	✓			
16	Spirulina sp.	✓			
17	Pinnularia	✓	✓	✓	✓
18	Cymbella tumidula		✓	✓	
19	Protococcus viridis	✓			
20	Closterium				✓
21	Phacus orbicularis	✓			✓
22	Eudorina			✓	
23	Pleodorina			✓	

24	Scenedesmus opaliensis				✓
25	Gloeotrachia	✓			✓

Zooplankton

Zooplanktons not only form an integral part of the lentic community but also contribute to the biological productivity of the freshwater ecosystem, they are globally recognized as pollution indicator organisms in the aquatic environment. In Gujarat, Sharma and Bhardwaj (2011) investigate zooplankton of Mahi river, Soni and Thomas worked at Dakor wetlands for plankton diversity, Mankodi (2012) worked at Nayri- 2 river situated at Rajkot. Hence many researchers are now focusing on the plankton diversity to know the health status of wetland using some pollution indicator species. Seasonal variation effects on the diversity of planktons.

In the present study 40 species of zooplanktons are recorded from 5 major groups. Among the recorded species most abundant group is Rotifera which exhibited their occurance throughout the study periods at all the four stations. The most abundant group is copepod, observed in all the four sampling sites.

Sr.no.	SARCOMASTIGOPHORS	S-1	S-2	S-3	S-4
1	Arcella discoides	✓	✓		
2	Pyxidicula cymbalum	✓			
3	Centropyxis aculeate	✓			
	ROTIFERS				
4	Brachionus caudatum	✓			✓
5	Brachionus urceolaris	✓			✓
6	Brachionus calyciflorus				✓
7	Brachionus bidentata				✓
8	Brachionus plicatilis				✓
9	Brachionus murrayi				✓
10	Brachionus forficyla	✓			✓
11	Ascomorpha ecoudis				✓
12	Asplanchna priodata				✓
13	Asplanchna sieboldi				✓
14	Cphalodella hyaline				✓
15	Trochosphaera sp.				✓
16	Keratella cochlearis			✓	
17	Lepadella rhomboids				✓

18	Microcodides robustus				✓
19	Microcodon				✓
20	Monostylanlunaris	✓			
21	Plationus patulus			✓	
22	Platiyas quadridentatus	✓			✓
23	Testudinella patina patina	✓			✓
	CLADOCERA				
24	Bosmina longirostris	✓			
25	Daphnia lumholtizi	✓	✓	✓	
26	Daphnia pluroxus uncinatus	✓			
27	karualona karua	✓	✓		✓
28	Kurzia longirostris	✓			
29	Pleuroxus laevis laevis	✓	✓		✓
	COPEPODA				
30	Microcyclops rubellus	✓	✓	✓	
31	Macrocyclops	✓	✓	✓	
32	Megacyclops viridis		✓	✓	
33	Macrosetella gracilis	✓			✓
34	Skistodiaptomus		✓	✓	✓
35	Cyclops varicans rubellus			✓	✓
	OSTRACODA				
36	Hemicypris anomala	✓			
	LARVA				
37	Bryozoan statoblast	✓	✓	✓	
38	Nauplius larva (Artemia shrimp)		✓	✓	
39	Nauplius larva copepod	✓	✓	✓	✓
40	Pelecypod larva of bivalvia	✓	✓		

Table: 29 The list of Zooplanktons observed during two months study

The physico-chemical and microbial analysis of the Pariej lake water samples revealed that most of the observed parameters are below or beyond the permissible limits as per WHO and BIS standards. The applied methodology formed and useful tool for quick assessment of water quality and the obtained data indicates the necessity to save this lake. It is significant tool note that the concentrations of chemical parameters were higher in Pariej lake water samples.

Conclusion

- The observed values of BOD and COD are beyond their permissible limits which further leads to the mortality of the fishes.
- The phytoplankton especially diatoms and zooplankton (Rotifers) diversity in the lake is higher, which is an indicator for higher pollution in the lake.
- The higher nutrient contents in the lake leads to the overproduction of exotic species such as *Eichhornia* and *Nymphaea* sp.
- It is found to be Mesotrophic lake that leads to increased productivity with the elevation of nutrients content in water.
- Higher bacterial load can be correlated with the higher plankton diversities.
- The finding suggests that the lake is suitable for catfish culture because they have a high tolerance to the climatic condition in this region.
- The avifaunal diversity during winter at peak because the lake has large biomass of fish, planktons and algae food-base for the migratory waders and ducks.
- The current condition of the lake, being Mesotrophic is quite threatful for its health.
- Though, if proper maintenance takes place, it can be converted into oligotrophic lake.

Plate 1

Sr.No.	Microbial analysis
1	Gram positive rod shape bacteria
2	Standard plate count
3	EMB plates of fecal coliform
4	E.Coli. Growth on EMB Agar plate
5	Gram positive long rod bacteria

Sr.No.	Common name (Flora)
1	Water hyacinth
2	Duckweed
3	Nymphaea sp.
4	Indian lotus

Plate 2

Butterfly	
Sr. No.	Common names
1	Danaid eggfly female
2	Danaid eggfly male
3	Striped tiger
4	Common gull
5	Common five-ring
6	Tailed Jay
Moth	
1	Amata sp.
2	Lemyra
3	Traminda sp.
4	Common emmerald
Odonata	
1	Long legged marsh glider
2	Senegal golden dartlet
3	Yellow waxtail
4	Scarce blue tailed

Plate 3

Avifauna	
Sr.No.	Common name
1	Shank
2	Ashy crown sparrow
3	Indian cormorant
4	Honey Buzzard
5	Paradise flycatcher
6	Common sandpiper
7	Ruff
8	Black wing stilt
9	Northern shoveler
10	Godwit
11	Spot-billed duck
12	Glossy ibis
13	Grey heron
14	Painted stork
15	Eurasian spoonbill
16	Crested lark
17	Baya weaver
18	Sarus crane
19	Black headed stonechat
20	Western marsh harrier
21	Common hoopoe

APPENDIX

Plate: 1

Microbial analysis



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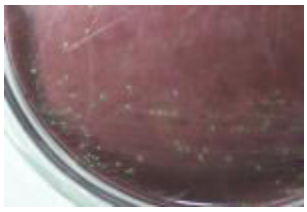


4. 5.

Floral diversity



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Plate 2

Lepidoptera (Butterflies)



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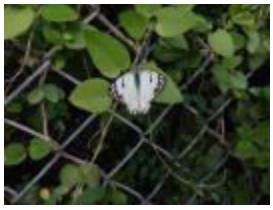

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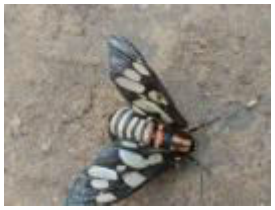
Lepidoptera (Heterocera)




1. **2.** **3.** **4.**

Odonata

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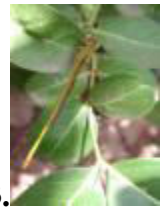


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Plate 3


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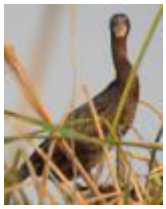
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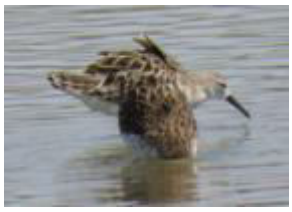
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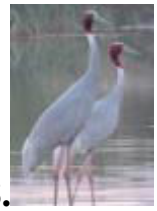
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21.

Plate 4

Zooplankton	
Sr.No.	Scientific name
1	Daphnia lumholtizi
2	Microcodon sp.
3	Centropyxis aculeata
4	Bryozoan statobloas
5	Brachionus sp. With eggs
6	Brachionus urceolaris
7	D. Pluxorus uncinatus
8	Ephemeroporus barroisi barroisi
9	Kurzia longirostris
10	Microcodides robustus
11	Microcyclopes rubellus
12	Nauplius larva
13	Pelecypod larva of bivalvia
14	Plationus patulus
15	Pleuroxus laevis laevis
16	Trochosphara sp
17	Microcyclops sp.
18	Hemicypris anomala
19	Lepadella rhomboides
20	Arcella discoides

Plate 4

Zooplankton

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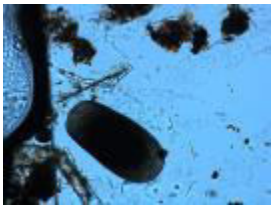

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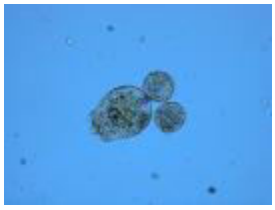

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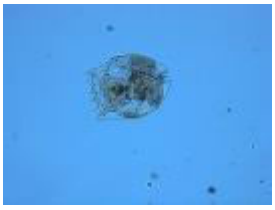

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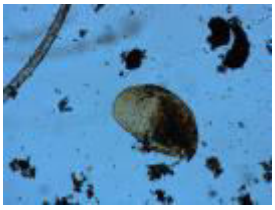

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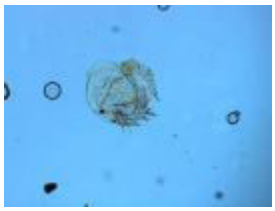

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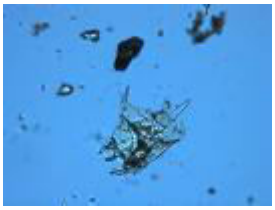

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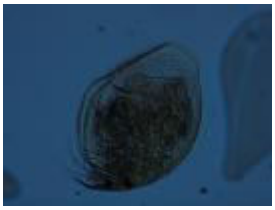

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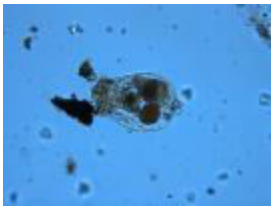

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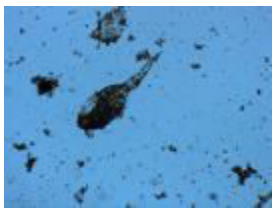

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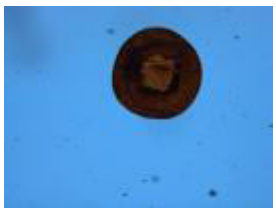

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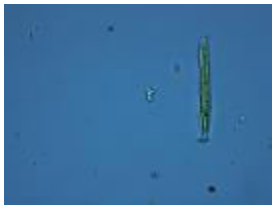
Plate 5

Phytoplankton	
Sr.No.	Scientific name
1	Mastoglia sp.
2	Hydrodictyonphyta
3	Hildenbrandida
4	Fragilaria
5	Euglena sp.
6	Desmidium
7	Cymbella tumidula
8	Chlorella
9	Pleudorina
10	Microspora
11	Spirulina
12	Spirogyra sp.
13	Scenedesmus sp.
14	Scenedesmus opaliensis
15	Phytoconis
16	Phacus orbicularis
17	Oscillatoria
18	Zygnema
19	Nitzchia acicularis

Plate 5

Phytoplankton



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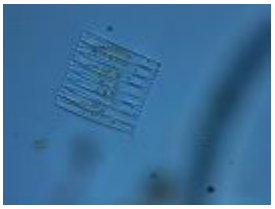

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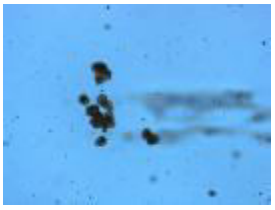

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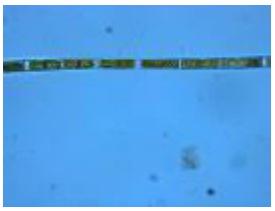

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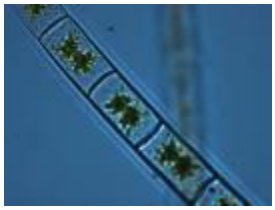

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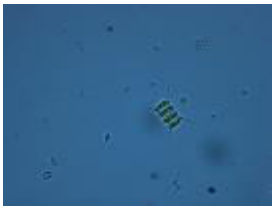

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Plate 6

1.During water sampling

2. Fish mortaliy

3. Cage culture

4. Plankton collection

Taking GPS location at Kheda- Khambhat Highway (S4)

References

Chapter: 8

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