Assessment of trophic status of Nigeen Lake, Kashmir

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(2014-F-26-M)

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Dedicated
to my loved ones

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

Certificate – I

This is to certify that the thesis entitled, **"Assesment of trophic status of Nigeen Lake, Kashmir"** submitted in partial fulfillment of the requirements for the award of the degree of **Master of Fisheries Sciences (Fisheries Resource Management)**, to the **Faculty of Post-graduate Studies, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir** is a record of bonafide research work carried out by **Ms. Amardeep Kaur (Regd. No. 2014-F-26-M)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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Title of the Thesis	:	**Assessment of trophic status of Nigeen Lake, Kashmir**

ABSTRACT

The purpose of the study was to evaluate the trophic status of Nigeen lake, through the interaction of nutrient concentration based on Carlson's TSI. In order to determine the trophic status of Nigeen lake, surface water samples from six different sites of the lake were collected from December 2015 to May 2016. Seasonal variation among different parameters was observed during the study period. Highest temperature was recorded during spring season along with higher values of depth, conductivity, ortho phosphate, total phosphorous and chlorophyll-a during this season. However, dissolved oxygen, transparency and pH values were minimum during spring and maximum in winter season. The data analysis from Carlson's TSI indicates that the average TSI(SD) was in the range of

47.19 to 56.26, TSI(TP) ranged from 84.63 to 85.6 and TSI (Chl-a) was in the range of 58.24 to 61.37. The overall results of the study showed that the Carlson's TSI(Total) of Nigeen lake ranged from 65.7 to 67.6 indicating that the lake is in hyper-eutrophic condition. The myriad ways in which people use the lake along with the numerous pollutant-generating activities have stressed the lake ecosystem in diverse ways. The study suggests that managers and policy makers should take action to slow down or halt eutrophication by applying best management practices for conservation of Nigeen lake.

Key words: Nigeen Lake, physico-chemical parameters, trophic status, Carlson's TSI, eutrophication

Signature of Student | Signature of Major Advisor

Dated: ___________ | Dated: ________________

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Amardeep Kaur

Place : Rangil

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Chapter-1

INTRODUCTION

Water is the most abundant as well as critical resource found in nature which covers approximately 3/4th of earth's surface. Although being so abundant, there are many factors which limit its actual use for humans. Ninety seven percent of water comprises of oceans and remaining is present in freshwater bodies, such as rivers, lakes, streams, glaciers and underground water. Of these, lakes are the "best available source of fresh water" on earth's surface. India is well known for its huge variance in lakes. In the Western Himalaya, there are picturesque, high altitude valley lakes, mountains, snow and spring fed meadows and alpine forests.

The valley of Kashmir is known as "Paradise on Earth". However, the most fascinating character that nature has gifted is its water resources, which are not only important for ecological, socio-economic and cultural heritage of the state but also serve as primary source for the upliftment of local economy. Kashmir valley is covered by high snow clad mountains and a number of freshwater lakes, with different hyrological settings such as Dal lake, Manasbal lake, Wular lake, Anchar lake and Nigeen lake (Sarah *et al.,* 2011). The origin of these lakes is either tectonic or fluvial, as all lakes lie on the floodplain of river Jhelum (Malik, 2015).

Dal lake, known as the "Jewel of Kashmir" is a world famous lake, comprising five basins namely, Hazratbal, Nehru park, Nishat, Nigeen and Brarinambal. Within the lake exist a number of springs (Kundangar*et al.,* 1995) which act as permanent source of water to the lake. Besides this, fifty one peripheral springs have been identified to maintain the volume of the lake (Abubakr & Kundangar, 2005). Nigeen lake, one of the basins of Dal lake, (Lat. 34º06´N and Long. 74º45´) situated in the heart of Srinagar, the summer capital of

Jammu & Kashmir, covering an area of 4.5 sq. km is a narrow stretch of water, making it an ideal place for stationary houseboats and conducting aquatic sports.

The water supply of Nigeen lake is maintained by Dal lake in addition to springs within the lake and atmospheric precipitation. The agricultural run-off and domestic effluent being other source of water supply. For a long time it was believed that the large volume of water contained in lakes would act as safeguard against serious damage to the ecosystem. But during recent times the rapidly increasing population has resulted in the establishment of new human settlement around the lakes which has resulted in the deterioration of water quality as well as aquatic ecosystem. As a result, the Nigeen lake ecosystem is under tremendous anthropogenic pressure since more than three decades (Shah and Shah, 2013).

The principal water quality problems encountered in lakes arise from the process of eutrophication, sedimentation and contamination. Sedimentation is the deposition and accumulation of both organic and inorganic matter in lake bottom. Contamination is the process by which a health hazard is created when some harmful substances are added to a lake. Nutrient enrichment of lakes is one among the major environmental problems in many countries (Oczkowski & Nixon, 2008). Though, it stimulates the growth of plants (algae as well as higher plants), nutrient enrichment ultimately leads to deterioration of water quality and degradation of entire ecosystem (Guyuan *et al*., 2011). Eutrophication is defined as "the biological effects of an increase in concentration of plant nutrients- usually nitrogen and phosphorous on aquatic ecosystem" (Harper, 1992). Eutrophication is a natural lake process over time and has been shown to occur more quickly as a result of human activities. The more rapid process is referred to as cultural eutrophication. This accelerated or cultural eutrophication is caused largely by the increase in the phosphorous and nitrogen export from the land to the water bodies, arising from the agricultural intensification and urbanization processes (Gray, 1985). The effects of cultural eutrophication are primarily manifested in the lakes and reservoirs as their quiescent condition causes the nutrients present in them to accumulate. Cultural eutrophication, in contrast to natural eutrophication, is rapid, but can be reduced or reversed by restricting or limiting the rate of supply of nutrients to the lake. The biological results of eutrophication are vast but the most apparent is discoloration due to the large increase of algae in the lake because of the high level of nutrients (Henderson-Seller and Markland, 1987). Two of the major causes are the runoff of fertilizers from agricultural land and runoff or direct input of sewage and waste water into a lake. Agricultural runoff and sewage both are high in plant nutrients like phosphorous and nitrogen, necessary for algal growth. Commonly, the level of eutrophication in a lake is referred to as the trophic status.

Although the trophic status is a statement about the nutrient concentration within the water body (Naumann, 1929) and the analysis of the physical and chemical characteristics of water is most widely accepted approach for the assignment of trophic status to the water body (Rawson, 1960; Rast & Lee, 1978; Carlson, 1977; & Jorgensen, 1980), there are many problems associated with it (Cairns & Schalie, 1980) such as physic-chemical characteristics may fluctuate daily or even on hourly basis and certainly fluctuate widely seasonally, chemicals present in a natural system are in a mixture and interact in various ways with each other and organisms and their interactions cannot be predicted with precision with chemical analysis.This has led to the idea of using aquatic organisms for monitoring of the trophic status. In this approach species autecology, speciation and community structures and functional approaches have been used extensively (Rawson, 1956).

Traditional systems of classification of lake on the basis of trophic status divide the continuum into three classes: oligotrophic, mesotrophic and eutrophic. There is often no clear delineation of these divisions. Some lakes may be considered oligotrophic by one criterion and eutrophic by another; this problem is sometimes circumvented by classifying lakes that show characteristics of both oligotrophy and eutrophy as mesotrophic. Two or three ill-defined trophic states cannot meet contemporary demands for a sensitive, unambiguous classification system. The addition of other trophic states, such as ultra-oligotrophic, meso-eutrophic etc. could increase the discrimination of the index, but at present these additional divisions are no better defined than the first three and may actually add to the confusion by giving a false sense of accuracy and such reasoning may have fostered multiparameter indicts (e.g. Brezonik and Shannon, 1971; Michalski and Conroy, 1972).

A multiparameter index is limited in its usefulness because of the number of parameters that must be measured. This new approach was developed because of frustration in communicating to the public both the current nature or status of lakes and their future condition after restoration when the traditional trophic classification system is used.

The ideal trophic state index should incorporate the best of both the above approaches, retaining the expression of the diverse aspects of trophic state found in multiparameter indices yet still having the simplicity of a single parameter index. This can be done if commonly used trophic criteria are interrelated. If many of the commonly used trophic criteria could be related by series of predictive equations, it would no longer be necessary to measure all possible trophic parameters to determine trophic status.

Several investigators have attempted to develop indices of lake water quality using responses of algae as a measure of perturbation of aquatic ecosystem. Carlson (1977) proposed using a trophic state index (TSI) to predict the status of lakes. The TSI correlates relationship among phosphorous, algal blooms, chlorophyll-a and secchi disc transparencies. The index has been used to classify waters, to predict trophic changes and as a lake management tool.

Phosphorous is commonly the growth limiting nutrient for phytoplankton and plants in lakes (Horne and Goldman, 1994). The amount of biologically available phosphorous (also called phosphate or orthophosphate) is small in relation to the quantity required for algal and plant growth. An increase in phosphorous will result in productivity (Mason, 1991), therefore total phosphorous level must be measured. Total phosphorous includes phosphorous forms in water as well as in particles and algae. One molecule of phosphorous promotes the incorporation of 7molecules of nitrogen and 40 atoms of carbon in aquatic algae (Wetzel, 2001 and Kasige and Takashi, 2008). Thus the water rich in phosphorous and nitrogen change the oligotrophic lake into eutrophic.

The chlorophyll-a gives a quantitative measure of the algal biomass by the amount of photosynthetic pigment present. The quality and quantity of aquatic flora and fauna and especially plankton, macrophyton, benthos and periphyton have been considered to indicate trophic status. Among higher aquatic plants abundant growth of certain weeds such as water hyacinth has been considered sign of eutrophication for the fact that high amount of nutrients are required to support such hydrobionts. Among phytoplankton, blue-green algae and particularly microcystis sp. has been reported to flourish abundantly in the eutrophic waters. Similarly, quantity of phytoplankton represented by a few species is expected to be appreciably higher in nutrient rich (eutrophic) waters as compared to nutrient deficient (oligotrophic) waters. Moreover, on the basis of algal abundance several diversity indices have been proposed by various scientists (Trivedy*et al*., 1987) for assessing the trophic status of surface waters.

Light penetration or transparency is a measure of the depth to which light can penetrate into the water. The secchi disc is used as a measure of transparency of the water which can be a function of the density of varying algal population (Heiskary, 1985). Transparency is useful in determining the depth of photic zone-the depth to which sufficient light to permit the survival and growth of water plants. Light penetration, as measured by a secchi disc, is expressed as the depth at which the secchi disc disappears when viewed vertically from the shaded side of a vessel. Although secchi disc transparency is a function of many factors including water color, suspended and dissolved solids, phytoplankton and zooplankton abundance, it serves as a convenient index of water clarity. In clear oligotrophic waters, secchi disc visibility is high and water plants grow to greater depths. In contrast, in turbid, eutrophic waters secchi disc transparency is low and plant life is restricted to relatively shallow waters. secchi disc transparency values provide a useful index for evaluating water clarity. The transparency of water body is affected by the factors like planktonic growth, rainfall, sun's position in the sky, angle of incidence of rays, cloudiness, visibility and turbidity due to suspended inert particulate matter.

CARLSON'S TROPHIC STATE INDEX

Robert E. Carlson proposed an index method for determining the trophic state of lake based on secchi depth, chlorophyll-a concentration and total phosphorous concentration. This system was designed in order to simplify some of the more complex multi-parametered models that are sometimes used in the fields. While these models are beneficial, they are sometimes avoided due to a number of parameters that must be measured. His model was tried and tested on many lakes located in Minnesota (Carlson, 1977).

The Carlson TSI is calculated by using three empirical equations, each based on one of the parameters listed above, and then taking the average of those three equations. The empirical equations used are defined below:

TSI_{SD}= 60-14.41 LN (SD)

TSI_{chla}= 9.81 LN (chla) + 30.6

TSI_{TP}= 14.42 LN (TP) + 4.15

$$\mathrm{TSItot} = \frac{\mathrm{TSI(SD)} + \mathrm{TSI(chla)} + \mathrm{TSI(TP)}}{3}$$

Where: chla= chlorophyll-a concentration (µg/l)

SD= secchi disc depth (meters)

TP= total phosphorous concentration (µg/l)

TSI= trophic state index

The Carlson model will be implemented in this study for all lake samples. The TSI will be then used to determine the trophic state classification based on these criteria.

TABLE 1: TROPHIC STATE CLASSIFICATION BASED ON CARLSON'S TSI

CLASSIFICATION	SUB-CLASSIFICATION	TROPHIC STATE INDEX
Oligotrophic	Strongly-oligotrophic Oligotrophic Slightly-oligotrophic	0-25 26-32 33-37
Mesotrophic	Slightly –mesotrophic mesotrophic Strongly- mesotrophic	38-42 43-48 49-53
Eutrophic	Slightly –eutrophic eutrophic Strongly- eutrophic	54-57 58-61 62-64
Hyper-Eutrophic	Hyper-Eutrophic	65+

(Source: Alexander, 2013)

NEED FOR PRESENT STUDY

Nigeen lake was once a favourite water skiing and sports center of international standard and also significant because of its serene waters, so the name 'Nigeen' (as clear as crystal).However, during the past few decades, lake has suffered from degradation due to several anthropogenic factors. Therefore, the conservation of this lake was taken up by the J&K government under auspices of Lake and Waterways Development Authority. The project proposal formulated for the conservation of this lake revealed high ingress of domestic waste waters from the immediate catchment, hence formulated a ring sewer system around the lake with Sewage Treatment Plant. However, lateral sewers were laid but the main trunk sewer and the STP remained unaccomplished jobs till date. As a result the non-point sources of pollution became the point source of pollution as all the lateral sewers continued to pollute the lake through entry of raw sewage resulting further deterioration of the lake. Therefore it becomes imperative to study the current status of the lake in order to ascertain its present trophic status.

Chapter – 2

REVIEW OF LITERATURE

2.1 Work done abroad

Carlson (1977) stated that the trophic state of lake indicates their biological productivity; however, it is usually assessed from data on phosphorous and chlorophyll-a concentrations and visibility of secchi disc.

Carlson & Schoenberg (1983) suggested that one of the reason for the reluctance to use fish species manipulation as a management tool was that grazing was not thought to constitute true reduction in trophic state.

Carlson (1991) expanded the trophic state concept to identify non-nutrient limited lakes & reservoir. He observed that defining trophic on the basis of algal & macrophyte biomass produces a concept that is not only useful but also quantitative & therefore predictive. He concluded that measuring phosphorous is a perfectly adequate indicator of trophic state, as long as phosphorous is the factor that limits biomass.

Bachmann *et al.* (1995) studied the relationship between trophic state indicators and fish in Florida (U.S.A.) lakes. Through their study, they concluded that the total fish biomass per unit area was positively correlated with total phosphorus, total nitrogen, chlorophyll *a*, andinversely correlated with Secchi disk transparency in 65 Florida (U.S.A.) lakes selected to range from oligotrophic tohypereutrophic. Species numbers were positively related to lake surface area but not trophic state. There were some shifts inspecies composition with changes in trophic state. Florida lakes do not have deep, cold hypolimnia, do not have salmonid species, and have no ice in the winter and is the possible reasons that they are more eutrophic. Increases in trophic state did not result in a decrease in thenumber of fish species per lake. The lake surface area accountedfor most of the variance in total species numbers. There was no correlationbetween the number of fish species per lake and the varioustrophic state indices.

Sass *et al.* (2006) examined the utility of Landsat TM imagery in deriving indicators of trophic status in remoteand relatively undisturbed lakes on the Boreal Plain of northern Alberta. Based on data collected during survey of lakes in 2001, they found that the normalizedexoatmospheric reflectance values of the red band explained 68, 82, and 47% of the variance in chlorophyll a, turbidity, and Secchi disk depth,respectively. They found that temporal factors accounted for 10% and spatial factors accounted for 50% ofthe total variation in trophic status, with a minimum of 10 years and 20 lakes needed to reach stability in the contributions of these factors. The study suggested that regional factors that are external to the lake explained the majority (60%) of the variation in trophic status of the lakes.

Ayse*et al.* (2008) in their study on evaluation of trophic state of lake Uluabat, Turkey analyzed Carlson′s trophic state index value based on total phosphorous, secchi disc transparency & chlorophyll, indicated that the lake Uluabat is a eutrophic system. The ecological stability of lake Uluabat is threatened by the impact of lake regulation and water extraction for agriculture, industries & residents. The result of the study suggested that phosphorous was the limiting nutrient in the lake water.

Liu *et al.* (2011) studied the effects of watershed land use and lake morphometry on the trophic state of Chinese lakes. Their research findings concluded that approximately 75% of the 19 studied lakes were eutrophic. Naturally vegetated land, namely forest and grassland, was thedominant land use in watersheds of Yunnan plateau lakes, accountingfor 57.99% of the total area. Correlation analysis based on all 19 lakes indicated that both watershedland use and lake morphology were significantly correlatedwith all trophic state parameters. Among land use types, cropland was recognized as the most importantsource of nonpoint-source of pollution affecting lakes and rivers in many countries. Approximately92% of the annual nitrogen input to the Yangtze River comes fromagriculture runoff.

Rahmati *et al.* (2011) studied the trophic status ofa shallow lake (North of Iran) based on water quality and the phytoplankton community. The qualitative and quantitative characteristics of phytoplankton community and also environmental variables were determined and compared with the TSI in order to describe the water quality status. In this research, 97 taxa from 6 algal classes such as Bacillariphyta, Chlorophyta, Chrysophyta, Cyanophyta, Dinophyta and Euglenophyta were identified. The Palmer organic pollution index revealed high organic pollution in whole of the year.TSI data and some other criteria indicated that the area has high trophic level.

Nawrocka and Kobos (2011) determined the trophic state of the Vistula lagoon using Reynold′s functional groups of phytoplankton as an indicator of eutrophication for the first time. Some keyconcepts of the EU Water Framework Directive were implemented in this study. The phytoplankton structure and biomass, plus the chlorophyll *a* andnutrient concentrations indicate that the Vistula Lagoon ecosystem is stableand eutrophic. The dominant species belonging to8 functional groups confirmed the eutrophic nature of this water body.The contributions of groups K (containing cyanobacterial picoplanktonspecies) and J (green algae) were the most significant.

Karabin (2012) during his study on the usefulness of zooplankton as lake ecosystem indicators; rotifer trophic state index tested the usefulness of rotifer abundance and species composition as indicator of trophic state of lakes. The data were used to estimate the relationship between the rotifer community structure and the indices of trophic state of lakes, like concentration of chlorophyll-a and secchi disc visibility calculated according to Carlson (1977) and widely used recently.

Watanabe *et al.* (2015) estimated chlorophyll-a concentration and trophic status of Barra Bonita hydroelectric reservoir using OLI/Landsat-8 images. The estimated chlorophyll-a concentration was used to classify the trophic level from a trophic state index that adopted the concentration of this pigment-like parameter.

The models of Chl-*a* concentration showed reasonable results, but their performance was likely impaired by the atmospheric correction. Consequently, the trophic level classification also did not obtained better results.

Al-Haidarey *et al*. (2016) applied Carlson's Trophic State Index to Bahr Al-Najaf Depression Reservoir (BNDR), Iraq to study its trophic status. The results indicated that the highest value of Carlson's TSI was in summer i.e.71.33 and lowest in winters i.e. 35.11. Overall, they classified BNDR as eutrophic after applying Carlson's Trophic State Index.

Alemayehu and Hackett (2016) studied the water quality and trophic state of Kaw lake, Oklahoma using Carlson's Trophic State Index. They measured the concentration of nitrogen, phosphorous and chlorophyll-a in the lake for a period of three years. The three years of TSI data analysis indicated that the Carlson's TSI ranged between 60-100, indicating that the lake is in eutrophic to hyper-eutrophic condition.

Baker (2016) analysed the trophic status of some selected lakes and streams in Grand Teton National Park using three different water quality models i.e. the Carlson's Model, the Larsen-Mercier Model and the Vollenwieder Model. The samples were analysed for a period of three years. The results of trophic status using different models showed that the water bodies of Grand Teton National Park fall under the category of slightly oligotrophic to eutrophic.

Tizro *et al.* (2016) assessed trophic status in Dam lake (Ekabat Dam) using Carlson's Trophic State Index. The quality of water was studied during July and January, to compare the trophic state and zonation of reservoir in two different seasons (dry & wet). Investigation showed that the value of TSI from different sampling points varied between 35.7- 50.7 in July and between 53.48 to 58.6 in January. Overall, lake was eutrophic in January and mesotrophic in July.

2.2 work done in India

Murthy *et al.* (2008) used Carlson and Simpson's index for trophic classification of nine lakes of Mysore, Karnataka for the conservation of Lake Ecosystem. Their study revealed that Alanahalli lake, Dalvoi lake, Devikere lake and Lingambudhi lake have index above 60 and are considered to be hyper-eutrophic. Mandakalli lake has an index of 47 and is considered mesotrophic, while Karanji lake, Marase lake and Varuna lake has index ranging between 52-57 and classified as eutrophic.

Sharma *et al.* (2010) assessed the trophic status of Mansi Ganga lake, India, using Carlson's trophic state index based on data collected over a period of three years. The results indicated that thelake was oligotrophic during 2006 which has become mesotrophic in the year 2008 showing increase in pollution. After thechemical treatment for the removal of algae, the lake water was drained and results of sampling done in 2009 (pre-monsoon)indicated it to be eutrophic. The results also indicate that both Carlson's TSI and Indiana TSI can be applied to Indian lakes as both gave the same TSIof MGL. It may be concluded that both the systems can bevery well used to assess the TSI of a given water body.

Deviprasad and Siddaraju (2012) used Carlson's Trophic State Index for assessment of trophic state of two lakes i.e. Arakere and Thaggahalli lake, in Mandya, Karnataka. The study was conducted over a period of two years. Results revelaed that Arakere and Thaggahalli lakes were mesotrophic, as the trophic state index of the two lakes ranged from 35-53 during study period.

Gupte and Shaikh (2013) studied seasonal variations in physic-chemical parameters and primary productivity of Shelar lake, Bhiwandi, Maharashtra.The study carried out at Shelar Lake indicated that the physico-chemical parameter of the water body shows its partial or wholly association with the season and the water level in the lake. The seasonal variation in physicochemical parameters indicated that the lake is found to be mesotrophic and slightly eutrophic during premonsoon. The productivity of the lake was found to be average. The conductivity observed in the water body indicated the productive nature of lake.

Upadhyay *et al.* (2013) studied the assessment of lake water quality by using Palmer and trophic state index- a case study of Upper lake in Bhopal. They observed that the cumulative effect of anthropogenic pressure and exerted pollution load from point and non-point sources are affecting water quality and quantity of this urban water bodies. By persuing the result of Palmer index, they found organic pollution in lake, while result of trophic state index indicate that Upper lake is in higher stage of eutrophy due to high nutrient loading.

Mamatha *et al.* (2013) monitored and assessed the water quality and trophic status ofKaranjiLake in Mysore city, Karnataka. The trophic status was assessed by using multivariate indices including Carlson trophic status index, Sakamoto, Academy and Dobson index and USEPA-NES which primarily used total phosphorus, chlorophyll-a andsecchi depth parameters. The water quality parameters like pH, temperature, COD and BOD were found to be in the range which supports the aquatic growth in the lake. Based on trophic status given by the multi-variant indices, it was concluded that the Karanji Lake is in moderate eutrophic condition during study period.

Chandrashekhar *et al.* (2014) attempted research to review the work done on the development of TSI for assessment of trophic status of lake and applicability of most important TSI method for Indian lakes.The research also dealswith the methods of restoration of Byramangala lake. The results of analysis of water samplesrevealed that lake is categorized under Hypereutrophic. The heavy metals like copper,Iron, Zinc, Manganese and Chromium arefound to contain much above thepermissible limits. Thus water is found to be unfit fordrinking and irrigation purpose. As the results show the TSI value is above 71, at all locations of Byramangala lake, the lake is said to be Hypereutrophic. The lake was found to have heavyalgal blooms possible throughout thesummer, dense macrophyte beds, butlimited light penetration. Soil samples collectedhave low organic carbon, micro andmacronutrients.

Barki and Singa (2014) while studying the assessment of trophic state of lakes in terms of Carlson's trophic state index on five lakes of Haveri town revealed that out of five lakes, three are moderately eutrophic and two lakes are highly eutrophic because of discharge of untreated sewage. Through their study,they suggested that the index can be used as a teaching tool as change in plant biomass affects oxygen and fish species and possible effect on food chain and recreational potential.

Ramesh and Krishnaiah (2014) used USEPA technique to assess the trophic status of Bellandur lake, Bangalore, India. The result of six locations indicated that the lake has TSI value 85 and approached to hypereutrophic Stage. Hence conservation measures like control of point sources and in lakes treatment methods are being essentials to revive the lake. As Carlson's Trophic State index needs minimum data and easy to understand, it is ideal for volunteer water conservation programmes and to educate the common man regarding the threats to the water bodies like lakes and conservation strategies that can be adopted.

Sadhna and Karan (2014) in their study on assessment of water quality and trophic state index of river Mandakini, M.P., reveals that small areas as well as large areas which fall in the way of river, dumps domestic and toxic wastes in the river. The result of their study showed that the river water at Ram ghat and Karwi ghat is highly polluted with reference to water quality index. Higher values of WQI clearly show that the status of river is not safe for human drinking and bathing purose and Carlson's trophic state index categorized Mandakini river in between oligotrophic and mesotrophic state.

Srikantha *et al.* (2014) while assessing eutrophication for the Dantaramakki lake of Chikmagalur city using GIS technique found that rapid industrialization and urbanization in urban areas has greatly decreased the available water resources in India. They concluded using GIS and Carlson's trophic state index calculations that the lake is moderately eutrophic.

Yadav *et al.* (2015) in their research on ecological health assessment of Chambal river use multiple indices viz. NSFWQI, CTSI and SDI. The result shows that overall ecological health of river is in good health. The water can be used for irrigation, bathing, aquaculture etc. not for drinking purpose. The present ecological health of river is also attracting large number of aquatic birds and animals. In order to bring it to excellent EHI (0-1), conservation measures need to be taken well in advance.

Upadhyay and Chandrakala (2016) studied the water quality of Dalvoy lake, Mysore to assess the quality of water for human consumption using Water Quality Index (WQI). The Water Quality Index was calculated on the basis of Weighted Arithmetic Index. Their study revealed that the WQI of two selected sites was found to be 147 and 158 respectively, showing that the quality of water is extremely poor.

Saluja and Garg (2017) in trophic state assessment of Bhindawas lake, Haryana, focused on spatial and temporal variations in the trophic state and detected the possible causes of its divergence in Bhindawas lake. Their results revealed that the Carlson's TSI during summer was 73.9 and during monsoon was 71.2, classifying it under hyper-eutrophic. During winter, the Carlson's TSI was found to be 64.6, classifying it under eutrophic.

2.3 Work done in Jammu& Kashmir

Kundangar *et al.* (1995) published the hydrobiological features of Nigeen lake, studied during 1991-1992. According to the author, the lake basin had enriched to a large extent due to the sewage and effluents from the immediate catchment. The author reported high population density of diatoms, green algae and blue green algae besides 75 species of zooplankton.

Qadri and Yousuf (2004) studied the physico-chemical parameters of Nigeen Lake and found that the pH of the lake ranged from 7.05-7.67, suggesting the alkaline nature of the water body. The dissolved oxygen, free carbon dioxide and chloride values were recorded as 6.0-7.8 mg/l 18.6-36.5 mg/l and 11.9-13.0 mg/l.

Kundangar and Abubakr (2004) made a comparison of the water quality changes in Dal Lake over a period of three decades in its different basins and found out that the pH and dissolved oxygen content of Hazratbal basin was 7.7-9.5 (in 1977) Vs (in 2000) and 2.2-12mg/l (in 1977) Vs 3.6-9.4 mg/l (in 2000), respectively. Similarly, for Nishat basin it was 7.4-9.5 (in 1977) Vs 7.3-8.8 (in 2000) and 5.5-11.5 mg/l (in 1977) Vs 5.2-9.8 mg/l (in 2000), respectively. For Nehru park basin, 7.5-9.5 (in 1977) Vs 7.6-9.2 (in 2000) and 4.5-10.5 mg/l (in 1977) Vs 2.0-9.2 mg/l (in 2000) respectively and for Nigeen basin 7.7-9.2 (in 1977) Vs 7.2-9.0 (in 2000) and 0.8-10 mg/l (in 1977) Vs 3.2-10 mg/l (in 2000), respectively.

Yakoob *et al.* (2008) in their study on comparative physic-chemical limnology of three lakes of Kashmir Himalaya concluded that the upper mountain lake (Sheshnag) falls under mesotrophic condition, while the forest lake (Nilnag) is marching towards high trophic state due to heavy influx of nutrients from catchment areas. The authors also reported that the valley lakes (Dal, Nigeen) falls under eutrophic category, due to tremendous anthropogenic pressure. The constant stress on valley lakes is responsible for their rapid deterioration.

Singh *et al.* (2008) assessed the water quality and trophic status of various lakes situated in the western Himalayan part of India, using Carlson′s TSI (TP). Their results indicated that Mansar, Surinsar and Tsomoriri fall under eutrophic category, having TSI (TP) 70, 61 and 53 respectively, while Dal, Tsokar and Renuka lakes fall under hyper-eutrophic category, with TSI (TP) 72, 86 and 81.6 respectively.

Abubakr and Kundangar (2009) recorded the changes in hydrochemistry and biodiversity of Dal and Nigeen lake during last three decades besides giving the current ecological status of the lake. During their research they found that improved techniques for littoral zone and aquatic macrophyte management need to be developed. Empowerment of the lake authority to enforce the rules and regulations with proper legislation to curb the lake encroachments and violations is necessary for the success of Dal and Nigeen restoration programme.

Murtaza *et al.* (2010) while assessing the impact of pollutants on physic-chemical characteristics of Dal lake (Nigeen basin) over a period of two years, concluded that the parameters like total alkalinity, nitrate nitrogen, silicate, conductivity and water temperature increased from 2007-2008. This increase in water parameters was attributed to the continued drought conditions and eutrophication in lake. The parameters like total phosphorous, dissolved oxygen, ammonical nitrogen and air temperature showed a decreasing trend from 2007-2008, which was accredited to the thermal stratification and subsequent utilization of these elements by macrophytic vegetation in the lake.

Najar and Basheer (2012) while conducting research on assessment of seasonal variation in water quality of Dal lake using multivariate statistical techniques found that input from domestic wastewater and agricultural runoff are mainly responsible for high pollution levels at Hazratbal basin. Bod Dal basin is moderately polluted whereas Nigeen and Gagribal basins are less polluted basins. PCA/FA identified latent factor as NH_4-N, NO_3-N, BOD_5, COD, DO and T explaining 75.78%, 83.25%, 87.33%, 78.96% of total variance for winter, spring, summer and autumn season respectively, standing for domestic wastewater, seasonal variation, agricultural runoff and catchment geology.

Shah and Shah (2013) studied physico-chemical dynamics in littoral zone of Nigeen basin of Dal lake, Kashmir and revealed that the dynamics of physic-chemical parameters depends on both autochthonous and allochthonous inputs and interactions taking place in the lake littorals. Their findings also indicated that lake dwellers and sewage runoff are considerable source of ionic inputs to the lake littorals.

Shafi *et al.* (2013) while working on phytoplankton dynamics of Nigeen lake in Kashmir Himalaya found out that the water of lake was alkaline in nature and the total hardness was mainly due to bicarbonates of Ca^{2+} and Mg^{2+}. In total 30 genera of phytoplankton were identified, in which Chlorophyceae was the dominant class with 12 species, followed by Bacillariophyceae with 9 species, 7 belong to Cyanophyceae and only 2 belongs to Euglenophyceae. The value of

Shannon-Wiener index, Simpson index, evenness, Bray-Curtis cluster signifies that the lake has high relative diversity with moderate pollution.

Khan *et al.* (2014) while studying the limnological of Dal lake, Srinagar revealed that there is higher value for nitrogen, showing the excessive use of nitrogenous fertilizers in floating gardens of lake and agricultural fields surrounding the lake. Phosphate value also remained on the higher side indicating the eutrophic nature of lake. The values of iron were also high, while as the result of alkalinity revealed that the lake waters fall under the category of hard waters. Transparency of Dal lake ranged from 1.5m to 2.15m.

Malik *et al*. (2015) investigated the trophic status of Nigeen lake based on Carlson′s TSI. The authors analyzed water samples from three sites namely littoral site, limnetic site and the outlet site of the lake and reported TSI values of 66.7, 61.14 and 65.48 respectively. They concluded that the lake was in eutrophic state at all the sites of observation which was directly related to the high input of nutrients and organic biomass into the lake′s basin from the adjoining areas.

Mukhtar *et al.* (2015) recorded the water quality index of Nigeen lake at three sites i.e. central site, saderbal site and pokhribal site as 34.27, 43.87 and 30.56 respectively and categorized it under grade ″B″ indicating good water quality. However, the author recorded elevated physic-chemical parameters in the lake and correlated it to the direct discharge of agricultural waste and municipal sewage water into the lake. Further, the author also attributed lake water deterioration to the fishing and boating activity during summer months.

Naik *et al.* (2015) studied changes in physic-chemical parameters at different sites of Manasbal lake of Kashmir, India. The investigation revealed that the pollution load is increasing in lake, especially at littoral sites due to agricultural runoff and human settlement disposing sewage, besides anthropogenic stresses in catchment area. The higher values of nitrogen, phosphorous, chloride, alkalinity, hardness, conductivity, free CO_2 and lower values of dissolved oxygen and transparency are clearly pointing towards higher trophic status of lake especially at littoral sites. Hence, the study urges the need for immediate remedial measures for protection and conservation of this lake in order to save it from further deterioration.

Sharma *et al.* (2015) carried out limnological research on Dal lake water quality and concluded that the physic-chemical parameters were beyond permissible limits. The authors linked the reduced water quality of the lake to the organic and inorganic pollutant load, which has accelerated the macrophytic growth leading to reduced recreational and aesthetic appeal of the lake. The authors further reported a musty odour of Nigeen lake implying the presence of raw or partially treated sewage, livestock waste or algae.

Wani *et al.* (2015) analyzed the physic-chemical parameters of Dal lake, Kashmir and reported that the values of EC, TDS, TH, chloride, nitrate, sulphate and K^+have significantly increased, while D.O. values has decreased over past few decades. The author related this change in water chemistry of the lake over the years to deforestation in the catchment area and subsequent increase in inflow of nitrogen and phosphorous into the lake.

High pH values were recorded in Hazratbal and Nigeen basin of Dal lake by Rashid *et al*. (2016) during their study on the trophic status of Dal lake. The authors reported high value of chloride in Nigeen basin and attributed it to the high retention time of water in this basin. They further reported values of nitrate-nitrogen in the range of 200-1300µg/l and accredited it to the close proximity of this basin to the human settlements.

Chapter-3

MATERIALS AND METHODS

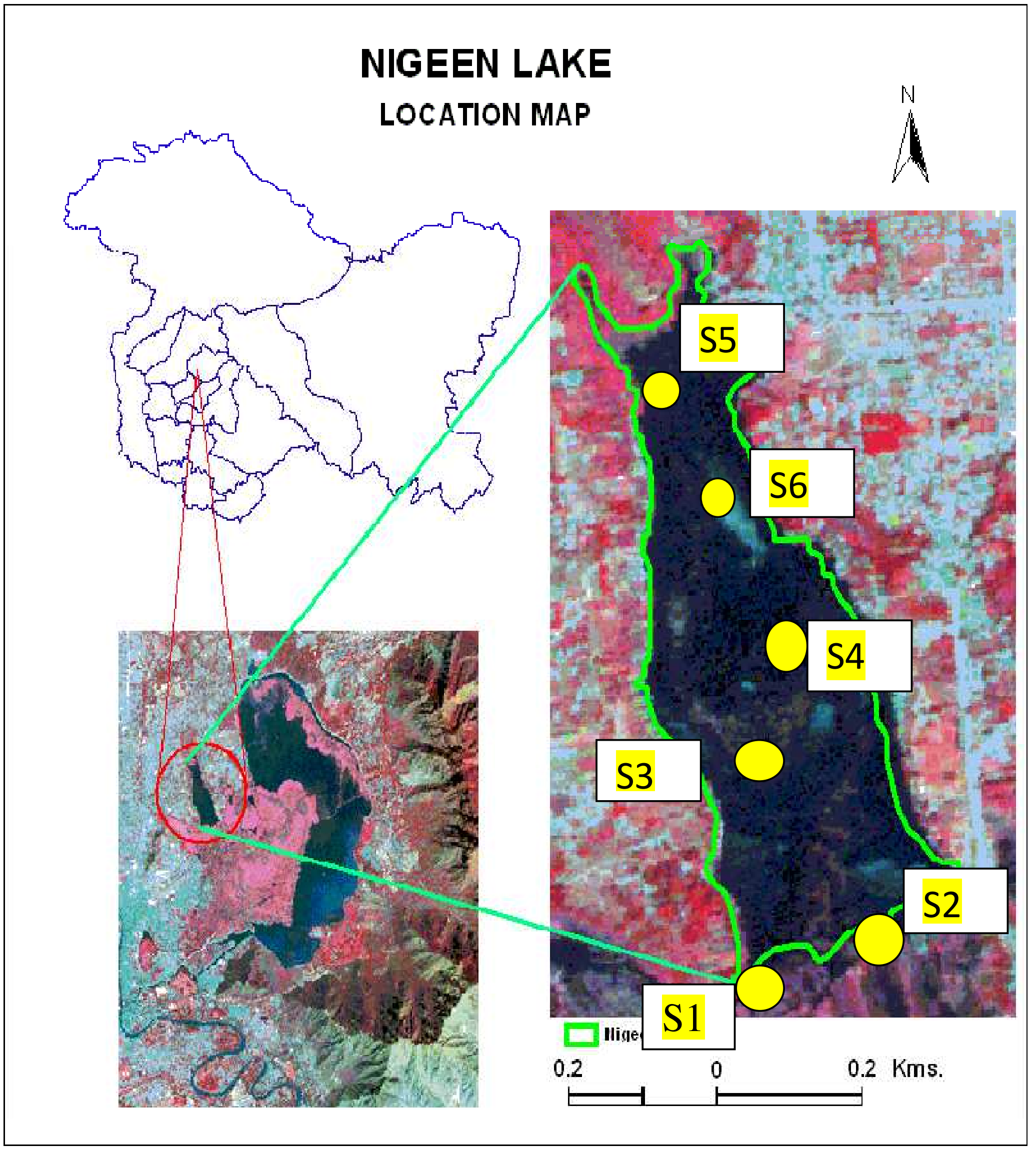
3.1 Description of study area

One of the famous lake of Kashmir, Nigeen lake is a Himalayan urban lake and is situated between coordinates Lat. 34º07´N, 74º49´ E, at an altitude of 1584m a.m.s.l., covering an area of 4.5km². (Rather *et al*., 2013). This lake is source of attraction for tourists and a number of houseboats reside within the lake that provide excellent residing station for tourist and a source of income for the lake dwellers. The lake is of drainage type and is fed by Dal lake from Ashaibagh bridge, from the North-East. It is also connected to Khushal Sar and Gil Sar lake on its North-West side via an exit channel known as Nallah Amir Khan (Map1). In addition to this, the Nigeen lake also receive water by some springs within the lake bed and from precipitation. In recent decades, population growth, agricultural practices and sewage runoff from its immediate catchment have increased nutrient inputs many folds, resulting in accelerated eutrophication. The present research was conducted with an aim to determine the trophic status of Nigeen lake using Carlson's trophic state index.

3.2 Morphometry and site selection

The lake has maximum length of 2.7 km, maximum width of 0.82 km and surface elevation is 1,584m a.m.s.l. the mean water depth of this lake is 1.37m and the open water area is 0.89sq Km (Abubakr and Kundangar, 2009). It is considered as the deepest basin of Dal lake with a maximum depth of 6 meters and is post glacial lake of warm monomictic type with average depth of about 3 meters (Bhat *et al*., 2016). Due to rapid urbanization and increasing settlement in the immediate catchment besides agricultural activities within the lake body, the lake is under severe biotic stress.

Map 1: Showing Nigeen lake and sampling sites



S1: Exit gate

S2: Lake inlet

S3: Central station

S4: Houseboat area

S5: Saderbal area

S6: Nigeen ghat

Site selection:

1. Site 1^{st}: This site is located near the sewage treatment plant, and acts as an outflow of Nigeen lake, where from water drains into Gilsar and Khushalsar lakes. This site is rich in submerged and free-floating macrophytes.
2. Site 2^{nd}: This site is located near Ashaibagh Bridge in the North-East side of Hazratbal basin. This site receives water from Dal lake and act as an inlet source of Nigeen lake. The site is also marked with the presence of floating gardens on one side. Submerged and free-floating macrophytes are abundant in this site.
3. Site 3^{rd}: This site is at the centre of the lake and has maximum depth. The site is usually free from aquatic macrophytes, however, sometimes free floating macrophytes can be seen spread on the surface.
4. Site 4^{th}: This site is marked by the presence of house boats and receives direct inflow of raw domestic sewage from houseboats into the lake. This site has rich growth of submerged and free-floating macrophytes.
5. Site 5^{th}: This site is near Saderbal area, which is inhabited by human habitation and few houseboats. The area is relatively shallow and few surface drain discharge effluents directly at this site. This zone is usually dominated by submerged and floating acrophytes.
6. Site 6^{th}: This site is near famous Nigeen ghat, which is usually dominated by submerged macrophytes. Shikara boats usually remain parked near this site.

Plate 1: Picture depicting Exit gate (Site 1)

Plate 2: Picture showing lake inlet (Site 2)

Plate 3: Picture depicting Central Station (Site 3)

Plate 4: Picture showing houseboat area (Site 4)

Plate 5: Picture depicting Saderbal area (Site 5)

Plate 6: Picture showing Nigeen ghat (Site 6)

3.3 Collection of water samples

Surface water samples were collected by hand from the shallow areas, using water sampling bottles. The sampling was done usually between 10:00 am to 11:30 am for a period of 6 months (December 2015 to May 2016). For dissolved oxygen, stop cock glassbottles of 125ml capacity were used and the fixation of the samples was done on the spot. Air temperature, water temperature, depth, transparency and pH were determined at the sampling spots and the detailed analysis of samples (chlorophyll-a, total phosphorous, dissolved oxygen and conductivity) was done in AEM laboratory at FoFy. The water analysis was carried out using the methods outlined in APHA (2005), Edmondson (1992), Golterman & Clymo (1969).

3.3.1 Temperature: The ambient and surface water temperature was recorded with the help of a digital thermometer. The measurement of air temperature was done at the time of sampling by keeping the thermometer in shade for about two to three minutes while the water temperature was determined by immersing the thermometer in water for about two minutes. The temperature is recorded in degree Celsius (ºC).

3.3.2 Depth: The depth of lake at all sampling stations was measured with the help of a weight tied to string. This string along with weight was poured into the lake until the weight reached to the bottom and a mark was made on the string at this level. After lifting the string up, the depth was measured by a measuring tap graduated and result was expressed in meters (m).

3.3.3 Secchi transparency: The transparency was measured using a Secchi disc which was lowered by hand into the water to the depth at which it vanishes from sight and the depth at which it reappears. The mean of depths at which the disc disappeared and then reappeared was recorded. The transparency is calculated by the formula given below and expressed in meter (m)

$$\text{Secchi disc transparency} = \frac{A+B}{2}$$

Where, A= point of disappearance of secchi disc and

B= point of reappearance of secchi disc

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

3.3.5 Specific conductivity: Conductivity was measured with the help of direct reading of digital conductivity meter (MK-509 Systronics). The results are expressed as μScm^{-1} at 25ºC.

3.3.6 Dissolved Oxygen: The water samples were collected in air tight stoppered glass bottles of 125 ml capacity. The samples were fixed in the field with 1 ml of manganous sulphate solution and 1 ml of alkaline iodide. The bottles were transferred to the laboratory where the precipitate of the sample was dissolved by adding 1ml of H_2SO_4. 50 ml of this solution was titrated against 0.025N sodium thiosulphate using starch as indicator. The volume of sodium thiosulphate used in the titration recorded and the dissolved oxygen content was estimated using the following formula:

$$\text{DO (mg/litre)} = \frac{\text{Volume of titrant used x N x 8 x 1000}}{\text{ml of sample}}$$

Where, N= Normality of titrant.

The results are expressed in mg/l.

3.3.7 Ortho phosphate:The concentration of orthophosphate was estimated by stannous chloride method. To 100 ml of sample one drop of phenolphthalein indicator was added. Pink color developed, was discharged by strong acid (mixture of concentrated H_2SO_4 and concentrated HNO_3). After thorough mixing 4.0 ml ammonium molybdate and 0.5 ml (10 drops) stannous chloride was added. The intensity of blue color developed after a pause of 10 minutes was measured on X-ma 1000 spectrophotometer (Human Corporation, Japan) at 690 nm, using distilled water blank and result compared with standard curve. The results are expressed in $\mu g\ l^{-1}$

3.3.8 Total phosphorus:: Total phosphorus was estimated by digesting 25 ml of water sample containing 1 ml concentrated sulfuric acid and 5 ml nitric acid to 1 ml colorless solution. On cooling 20 ml of distilled water was added. The sample was titrated with 1N NaOH solution using 0.005 ml (1 drop) phenolphthalein indicator till a faint pink end point. The sample was raised to 100 ml with distilled water. Then pink color was discharged by adding strong acid (mixture of concentrated H_2SO_4 and concentrated HNO_3). After thorough mixing 4 ml ammonium molybdate and 0.5 ml (10 drops) stannous chloride was added. The intensity of blue color developed after a pause of 10 minutes was measured on X-ma 1000 spectrophotometer (Human Corporation, Japan) at 690 nm, using distilled water blank and result compared with standard curve. The results are expressed in $\mu g\ l^{-1}$.

3.3.9 Chlorophyll a: To 1000 ml of water sample, 3-5 drops of aqueous solution of Magnesium carbonate (50%) were added in order to avoid the degradation of chlorophyll. Then the sample was filtered through 47mm membrane filter which was folded into quarters, wrapped in aluminum foil and placed in desiccators. Then the filter containing concentrated algal sample was transferred to a centrifuge tube to which about 10ml of 90% acetone was added, capped tightly and placed in refrigerator for 6-10 hours to allow complete extraction of chlorophyll. The contents of tube were centrifuged at 3000 rpm for about 15 minutes. Then the supernatants were carefully transferred to a spectrophotometric cell and the optical density of the extract was recorded at 630nm, 645nm, 663nm and 750nm. The chlorophyll a content was calculated using following equation:

$$\text{Chlorophyll a } (\mu g/L) = \frac{\{11.64(\text{Abs}663) - (\text{Abs}645) + 0.10(\text{Abs}630)\}E(F)}{V(L)}$$

Where, F = dilution factor (i.e. if the Abs is >0.99 with the 1 cm cell, dilute, re-analyze and insert the dilution factor in the equation)

E = the volume of acetone used for extraction (mL)

V = the volume of water filtered (L)

L = the cell path length (cm)

The results are expressed in $\mu g\ l^{-1}$.

3.4 Trophic State Index

The Carlson TSI is calculated by using three empirical equations, each based on one of the parameters listed above, and then taking the average of those three equations. The empirical equations used are defined below:

TSI_{SD}= 60-14.41 LN (SD)

TSI_{chla}= 9.81 LN (chla) + 30.6

TSI_{TP}= 14.42 LN (TP) + 4.15

$$\text{Carlson's TSI} = \frac{[\text{TSI(TP)} + \text{TSI(chla)} + \text{TSI(SD)}]}{3}$$

Where: chla= chlorophyll-a concentration (µg/l)

SD= secchi disc depth (meters)

TP= total phosphorous concentration (µg/l)

Chapter-4

EXPERIMENTAL FINDINGS

4.1 Water Quality Parameters

4.1.1 Air Temperature

The air temperature at site I varied from a minimum of 8.2ºC in the month of January to a maximum of 28.7ºC in the month of May. The average air temperature of site I was recorded as 17.2±3.13ºC.

The minimum air temperature of site II recorded during the study was 8.3ºC in the month of January. The maximum temperature of this site was recorded as 29.2ºC in the month of May. The average air temperature of site II was recorded as 17.61±3.21ºC.

The air temperature at site III was a minimum of 8.3ºC in the month of January. The maximum air temperature of 30.1ºC was recorded in the month of May. The average air temperature of site III was recorded as 17.8±3.33ºC.

The air temperature at site IV varied from a minimum of 8.5ºC in the month of January to a maximum of 30.4ºC in the month of May. The average air temperature of this site was recorded as 18.25±3.36ºC.

The minimum air temperature at site V was 8.5ºC in the month of January. The maximum temperature of this site was 30.8ºC in the month of May. The average air temperature of site V was recorded as 18.48±3.42ºC.

The air temperature of site VI ranged from a minimum of 8.5ºC in the month of January to a maximum of this site was recorded as 31.1ºC in the month of May. The average air temperature of site VI was recorded as 18.63±3.46ºC.

The monthly results of air temperature in ºC are given in table (2), and graphically in figure (1).

Table 2. Monthly variations in air temperature (ºC) at different sites of Nigeen Lake.

Site	Dec	Jan	Feb	Mar	Apr	May	Avg.	S.E
Site I	11.6	8.2	13.3	18.7	22.9	28.7	17.23	3.13
Site II	11.6	8.3	13.8	19.3	23.5	29.2	17.61	3.21
Site III	11.8	8.3	13.9	19.7	24.0	30.1	17.96	3.33
Site IV	12	8.5	14.1	20.2	24.3	30.4	18.25	3.36
Site V	12.1	8.5	14.3	20.5	24.7	30.8	18.48	3.42
Site VI	12.2	8.5	14.4	20.7	24.9	31.1	18.63	3.46
AVERAGE	**11.8**	**8.3**	**13.9**	**19.8**	**24.0**	**30.0**		

Overall, the average air temperature of Nigeen lake ranged from a minimum of 8.3ºC (January) to a maximum of 30ºC (May) during the study period (Table 2)

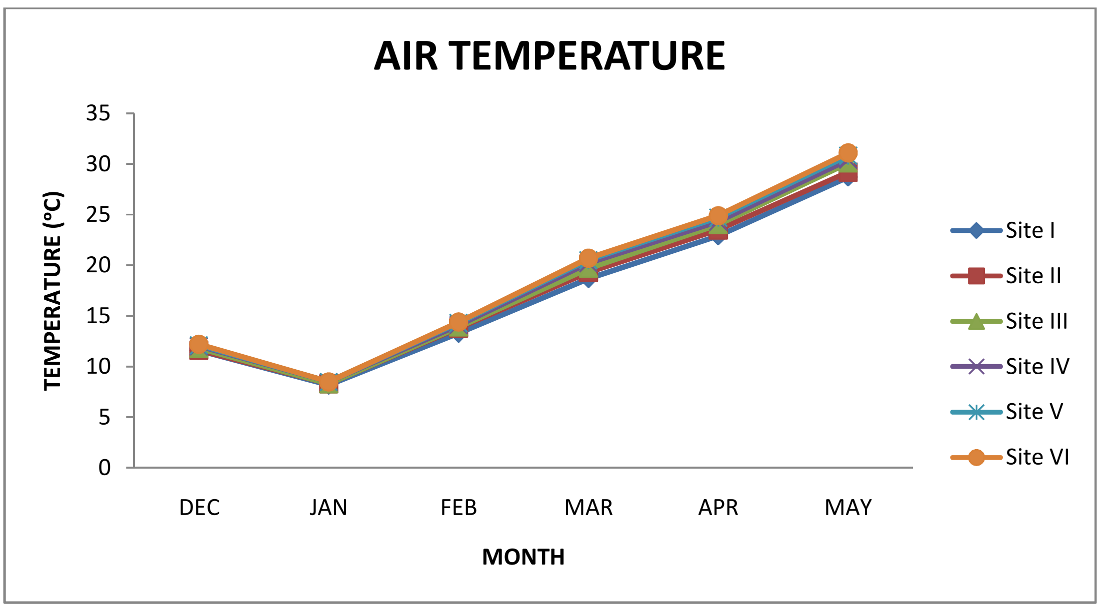


Fig. 1. Monthly variation in Air Temperature (°C) at different sites of Nigeen lake

4.1.2 Water Temperature

The minimum water temperature of site I was 6.3ºC in the month of January and the maximum water temperature was 22.7ºC in the month of May during the study. The average water temperature of this site was recorded as 13.76±2.65ºC.

The water temperature of site II was recorded as a minimum of 6.5ºC in the month of January and the maximum water temperature as 22.9ºC in the month of May during the study. The average water temperature of this site was recorded as 14.01±2.67ºC.

The minimum water temperature of site III was found to be 6.5ºC as minimum in the month of January. The maximum temperature of this site was recorded as 23.3ºC in the month of May. Site III recorded an average water temperature as 14.25±2.73ºC.

Site IV recorded minimum water temperature as 6.7ºC in the month of January and maximum as 23.9ºC in the month of May during the study. The average water temperature of site IV was recorded as 14.68±2.78ºC.

The water temperature of site V varied from a minimum of 6.8ºC in the month of January to a maximum of 24.4ºC in the month of May. Site V recorded an average water temperature as 14.91±2.85ºC.

The site VI recorded water temperature as minimum as 6.8ºC in January and maximum as 25ºC in the month of May during the study. The average water temperature of this site was recorded as 15.18±2.94ºC

The monthly results of water temperature in ºC are given in table (3), and graphically in figure (2).

Table 3. Monthly variations in water temperature (ºC) at different sites of Nigeen Lake.

Site	Dec	Jan	Feb	Mar	Apr	May	Avg.	S.E
Site I	7.6	6.3	10.9	16.6	18.5	22.7	13.76	2.65
Site II	7.7	6.5	11.2	16.9	18.9	22.9	14.01	2.67
Site III	7.8	6.5	11.5	17.2	19.2	23.3	14.25	2.73
Site IV	8.2	6.7	11.9	17.8	19.6	23.9	14.68	2.78
Site V	8.3	6.8	12	17.9	20.1	24.4	14.91	2.85
Site VI	8.4	6.8	12.2	18.0	20.7	25.0	15.18	2.94
AVERAGE	**8.0**	**6.6**	**11.6**	**17.4**	**19.5**	**23.7**		

Overall, the average water temperature of Nigeen Lake ranged from 6.6ºC (January) to 23.7ºC (May) during the study period (Table 3).

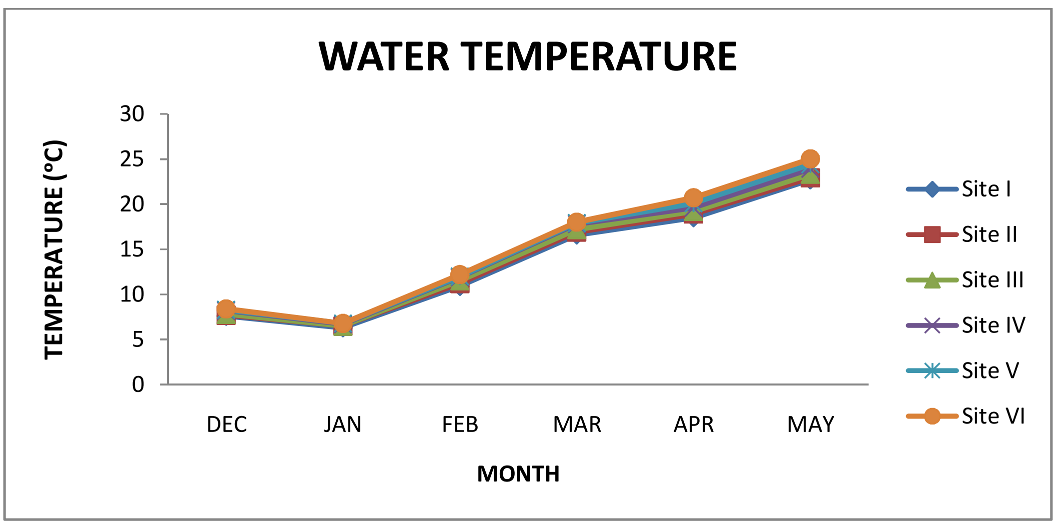


Fig.2. Monthly variation in Water Temperature (°C) at different sites of Nigeen lake.

4.1.2 Depth

The minimum depth of site I was recorded as 2.8m in the month of December to February. The maximum depth of site I was 2.9m from March to May. The average depth of site I during the study was recorded as 2.85±0.02m.

Site II recorded minimum depth of water as 3.2m in the month of February. The maximum depth of site II was found to be 3.4m in March and April. The average depth of this site during the study was recorded as 3.31±0.03m.

This water depth of site III varied from a minimum 5.8m from December to February to a maximum of 6.0m in April. The average depth of this site during the study was recorded as 5.9±0.03m.

The depth of site IV was recorded as minimum as 2.1m from December to February to a maximum of 2.3m in March and April. The average depth of this site during the study was recorded as 2.2±0.04m.

The minimum depth of site V ranged from a minimum 4.1m in the month of December to a maximum as 4.4m in March and April. The average depth of this site during the study was recorded as 4.25±0.05m.

Site VI recorded minimum water depth as 2.2m in December and January. The maximum depth of this site was recorded as 2.5m in March and April. The average depth of this site during the study was recorded as 2.35±0.05m.

The monthly results of depth in meter are given in table (4), and graphically in figure (3).

Table 4. Monthly variations in depth (m) at different sites of Nigeen Lake.

Site	Dec	Jan	Feb	Mar	Apr	May	Avg.	S.E
Site I	2.8	2.8	2.8	2.9	2.9	2.9	2.85	0.02
Site II	3.3	3.21	3.2	3.4	3.4	3.3	3.31	0.03
Site III	5.8	5.8	5.8	5.9	6.0	5.9	5.9	0.03
Site IV	2.1	2.1	2.1	2.3	2.3	2.2	2.2	0.04
Site V	4.1	4.2	4.2	4.4	4.4	4.2	4.25	0.05
Site VI	2.2	2.2	2.3	2.5	2.5	2.4	2.35	0.05
AVERAGE	**3.3**	**3.3**	**3.4**	**3.5**	**3.5**	**3.4**		

Overall, the average depth of Nigeen Lake ranged from a minimum of 3.3m (December and January) to a maximum of 3.5m (March & April) during the study period (Table 4).

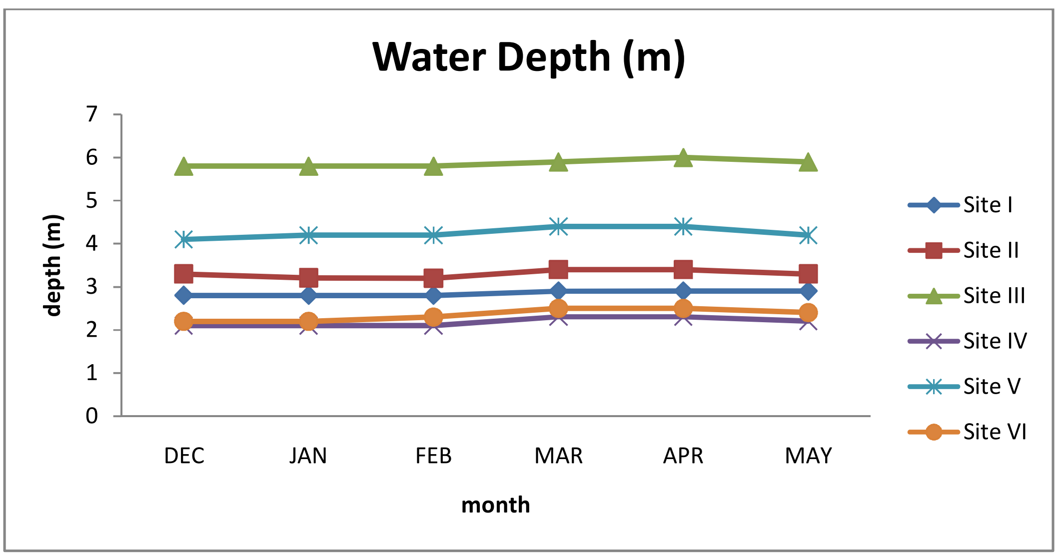


Fig.3. Monthly variation in Water Depth (m) at different sites of Nigeen lake

4.1.4 Transparency

The transparency of site I was recorded as a minimum of 1.0m in the month of February. The maximum transparency of this site was recorded in the months of December, January & March as 1.2m. The average transparency of site I was recorded as 1.1±0.04m.

The minimum transparency of site II varied from a minimum of 1.3m in the month of April and May to a maximum transparency as 1.72m in December. The average transparency of site II was recorded as 1.5±0.08m.

The minimum transparency of site III was recorded as 2.9m in the month of May and maximum in the month of March as 3.5m. The average transparency of this site was recorded as 3.2±0.09m.

Site IV recorded a minimum of 1.0m transparency in the months of March and April. The maximum transparency of site IV was 1.3m in the month of May. The average transparency of this site was recorded as 1.1±0.05m.

The minimum transparency site V was recorded as 1.1m in the month of April and maximum transparency as 1.3m in the months of December and January. The average transparency of site V was recorded as 1.2±0.03m.

The transparency of site VI ranged from a minimum of 0.9m in the month of May to a maximum 1.2m in March and May. The average transparency of site VI was recorded as 1.0±0.04m

The monthly results of transparency in meter are given in table (5), and graphically in figure (4).

Table 5. Monthly variations in transparency (m) at different sites of Nigeen Lake.

Site	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Avg.**	**S.E**
Site I	1.2	1.2	1.0	1.2	1.0	1.0	1.1	0.04
Site II	1.72	1.7	1.6	1.7	1.3	1.3	1.5	0.08
Site III	3.3	3.4	3.1	3.5	3.0	2.9	3.2	0.09
Site IV	1.2	1.21	1.2	1.0	1.0	1.3	1.1	0.05
Site V	1.3	1.3	1.2	1.2	1.1	1.11	1.2	0.03
Site VI	1.0	0.93	0.95	1.2	1.1	0.9	1.0	0.04
AVERAGE	**1.6**	**1.6**	**1.5**	**1.6**	**1.4**	**1.4**		

Overall, the average transparency of Nigeen Lake varied from a minimum of 1.4m (April and May) to a maximum of 1.6m (December, January and March) during the study period (table 5).

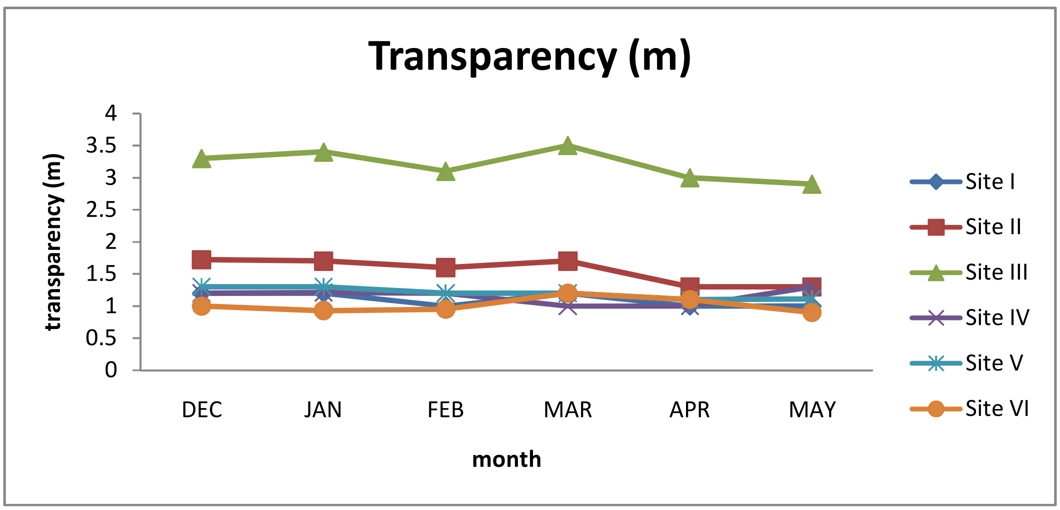


Fig.4. Monthly variation in Transparency (m) at different sites of Nigeen lake.

4.1.5 pH

Site I recorded a minimum pH of 8.0 in the month of March and a maximum pH of 8.5 in the month of December. The average pH of site I was recorded as 8.3±0.08.

The pH of site II varied from a minimum of 7.7 in the month of April to a maximum pH 8.0 in the months of December and January. The average pH of site II was recorded as 7.9±0.04.

The minimum pH of site III was recorded as 7.9 in the month of May and maximum as 8.5 in the month of December. The average pH of this site was recorded as 8.2±0.09.

Site IV recorded a minimum pH of 7.42 in the month of April. The maximum pH of this site was 7.8 in the months of January and March. The average pH of this site was recorded as 7.7±0.05.

The minimum pH of site V ranged from 7.2 in the month of January and February to a maximum of 7.8 in the month of March. The average pH of this site was recorded as 7.5±0.09.

Site VI recorded a minimum pH of 7.2 in the months of January and February and a maximum pH as 7.71 in the month of March. The average pH of this site was recorded as 7.4±0.07.

The monthly results of pH are given in table (6), and graphically in figure (5).

Table 6. Monthly variations in pH at different sites of Nigeen Lake.

Site	Dec	Jan	Feb	Mar	Apr	May	Avg.	S.E
Site I	8.5	8.4	8.3	8.0	8.1	8.1	8.3	0.08
Site II	8.0	8.0	7.9	7.8	7.7	7.8	7.9	0.04
Site III	8.5	8.4	8.2	8.0	8.0	7.9	8.2	0.09
Site IV	7.7	7.8	7.7	7.8	7.42	7.71	7.7	0.05
Site V	7.4	7.2	7.2	7.8	7.5	7.4	7.5	0.09
Site VI	7.4	7.2	7.2	7.71	7.4	7.3	7.4	0.07
AVERAGE	**7.9**	**7.8**	**7.7**	**7.8**	**7.6**	**7.7**		

Overall, the average pH of Nigeen Lake varied from a minimum of 7.6 (April) to a maximum of 7.9 (December) during the study period (table 6).

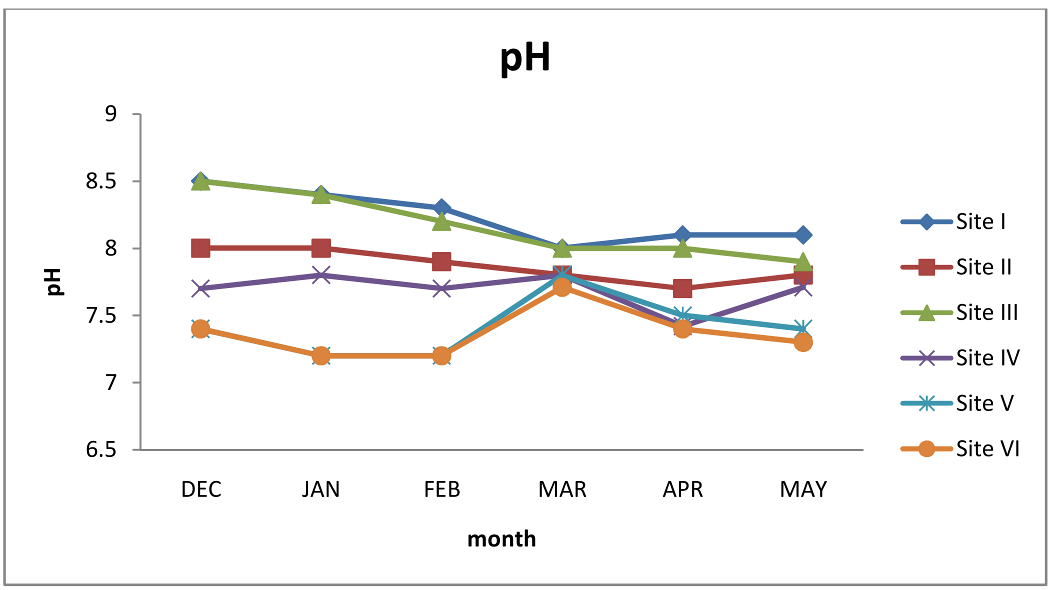


Fig.5. Monthly variation in pH at different sites of Nigeen lak

4.1.6 Electrical Conductivity

The minimum electrical conductivity of site I was recorded as 321µS/cm in December and the maximum electrical conductivity as 390µS/cm in the month of January. The average electrical conductivity of site I recorded was 346±12.7µS/cm.

Site II recorded a minimum electrical conductivity value as 293µS/cm in April to a maximum electrical conductivity as 301µS/cm in the month of January. The average electrical conductivity of site II recorded was 297±1.09µS/cm

The electrical conductivity of site III varied from a minimum of 214µS/cm in February to a maximum electrical conductivity as 292µS/cm in the month of January. The average electrical conductivity of site III recorded was 243±12.6µS/cm.

The electrical conductivity of site IV ranged from a minimum of 306µS/cm in January to a maximum as 330µS/cm in the month of January. The average electrical conductivity of this site recorded was 317.9±4.15µS/cm.

Site V recorded a minimum electrical conductivity as 293µS/cm in February to a maximum electrical conductivity of 319µS/cm in the month of April. The average electrical conductivity of site V recorded was 306.9±4.0µS/cm.

The minimum electrical conductivity of site VI was recorded as 308µS/cm in December and the maximum as 357µS/cm in the months of January and May. The average electrical conductivity of site VI recorded was 342±7.5µS/cm.

The monthly results of electrical conductivity in µS/cm are given in table (7), and graphically in figure (6).

Table 7. Monthly variations in Electrical Conductivity (µS/cm) at different sites of Nigeen Lake

Site	Dec	Jan	Feb	Mar	Apr	May	Avg.	S.E
Site I	321	390	322	337	382	326	346.4	12.7
Site II	298	301	298	296	293	296	297	1.09
Site III	215	239	214	268	292	230	243	12.6
Site IV	330	306	329	308	315	319	317.9	4.15
Site V	299	315	293	310	319	305	306.9	4.0
Site VI	308	357	338	340	352	357	342	7.5
AVERAGE	**295**	**318**	**299**	**309**	**325**	**305**		

Overall, the average electrical conductivity of Nigeen Lake varied from a minimum of 295µS/cm (December) to a maximum electrical conductivity of 325µS/cm (April) during the study period (table 7).

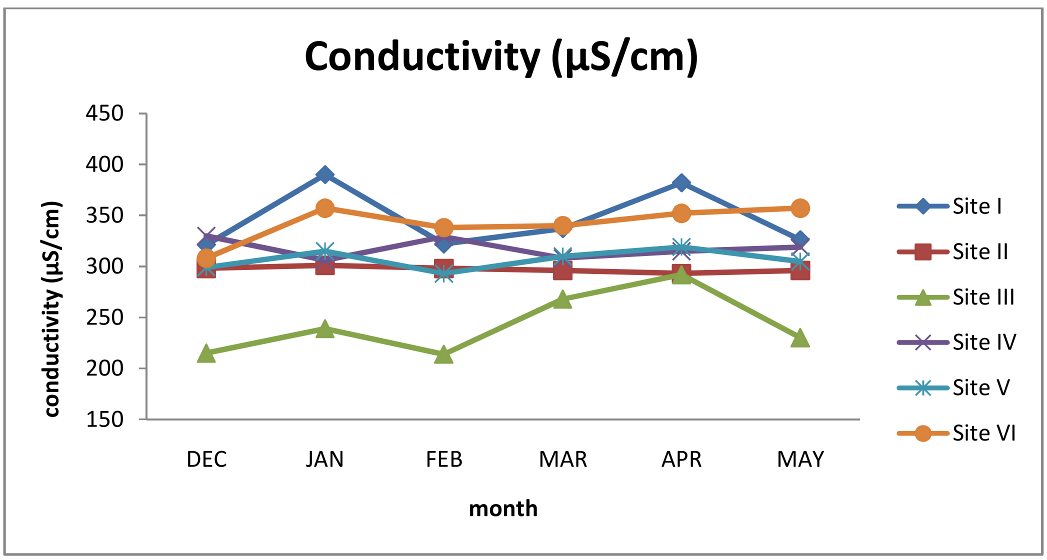


Fig.6. Monthly variation in Conducivity (µS/cm) at different sites of Nigeen lake.

4.1.7. Dissolved Oxygen

D.O of site I varied from a minimum of 11.4mg/l in the month of May to a maximum of 12.4mg/l in the month of December. The average D.O of site I was recorded as 11.7±0.14mg/l during the study period.

The D.O of site II ranged from a minimum 9.0mg/l in the month of February to a maximum 11.6mg/l in March. The average D.O of this site was recorded as 10.2±0.35mg/l.

Site III recorded a minimum D.O as 9.6mg/l in the months of February and May and maximum D.O as 11.5mg/l in December. The average D.O of site III was recorded as 10.5±0.37mg/l during the study period.

The D.O of site IV varied from a minimum 8.4mg/l in March to a maximum D.O 10.8mg/l in December. The average D.O of this site was recorded as 9.6±0.45mg/l.

The minimum D.O of site V was recorded as 7.5mg/l in the month of March. The maximum D.O of this site was recorded as 8.4mg/l in January. The average D.O of site V was recorded as 8.0±0.12mg/l.

D.O of site VI ranged from a minimum 8.0mg/l in the month of April to a maximum D.O as 8.6mg/l in February and May. The average D.O of site VI recorded during the study period was 8.4±0.09mg/l.

The monthly results of dissolved oxygen in mg/l are given in table (8), and graphically in figure (7).

Table 8. Monthly variations in Dissolved Oxygen (mg/l) at different sites of Nigeen Lake.

Site	Dec	Jan	Feb	Mar	Apr	May	Avg.	S.E
Site I	12.4	11.6	11.5	11.6	11.6	11.4	11.7	0.14
Site II	10	10.4	9.0	11.6	9.6	10.4	10.2	0.35
Site III	11.5	11.0	9.6	10.5	10.5	9.6	10.5	0.37
Site IV	10.8	10.6	10.4	8.4	8.8	8.6	9.6	0.45
Site V	8.2	8.4	7.8	7.5	7.9	8.0	8.0	0.12
Site VI	8.4	8.2	8.6	8.4	8.0	8.6	8.4	0.09
AVERAGE	**10.2**	**10**	**9.4**	**9.6**	**9.4**	**9.4**		

Overall, the dissolved oxygen of Nigeen Lake varied from a minimum of 9.4mg/l (February, April and May) to a maximum of 10.2mg/l (December) during the study period (table 8).

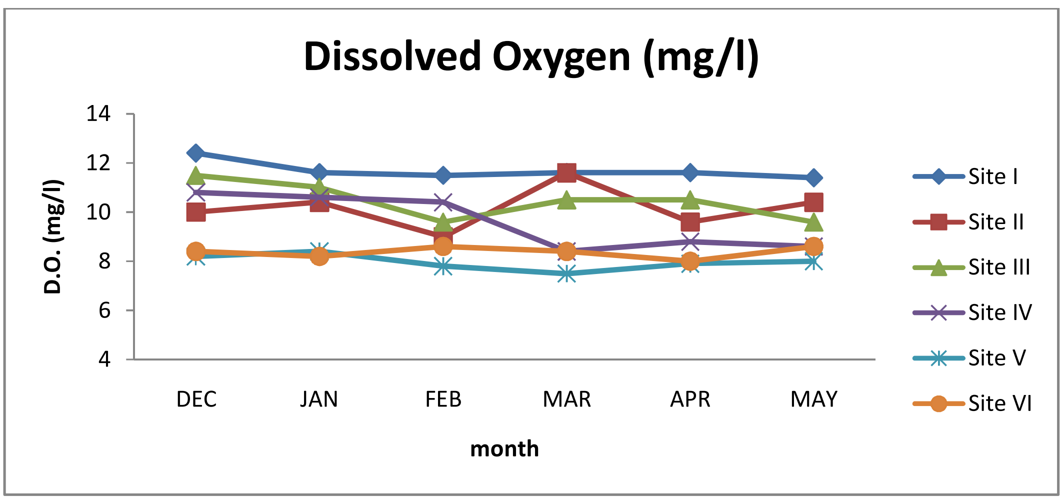


Fig.7. Monthly variation in Dissolved Oxygen (mg/l) at different sites of Nigeen lake.

4.1.8. Ortho Phosphate

The minimum ortho phosphate of site I was recorded as 116µg/l in February. The maximum ortho phosphate of site I was 142µg/l in May. The average ortho phosphate of this site was recorded as 131.6±4.02µg/l.

Site II recorded a minimum ortho phosphateas 88µg/l in January and a maximum ortho phosphate as 102.5µg/l in May. The average ortho phosphate of site II was recorded as 94.2±2.1µg/l during the study period.

The ortho phosphate of site III varied from a minimum of 82.9µg/l in March to a maximum ortho phosphate as 98µg/l in February. The average ortho phosphate of site III was recorded as 87.2±2.2µg/l.

The minimum ortho phosphate of site IV was recorded as 125µg/l in January to a maximum ortho phosphate as 158µg/l in May. The average ortho phosphate of site IV was recorded as 140±5.4 µg/l during the study period.

Site V recorded a minimum ortho phosphate as 164µg/l in January. And the maximum ortho phosphate of this site was recorded as 186µg/l in March. The average ortho phosphate of this site was recorded as 172.5±3.3µg/l.

The ortho phosphate of site VI varied from a minimum of 82µg/l in December to a maximum 138µg/l in May. The average ortho phosphate of site VI was recorded as 110.9±9.3µg/l.

The monthly results of orthophosphate in mg/l are given in table (9), and graphically in figure (8).

Table 9. Monthly variations in Ortho Phosphate (µg/l) at different sites of Nigeen Lake.

SITE	Dec	Jan	Feb	Mar	Apr	May	Avg.	S.E
Site I	126	130	116	135	141	142	131.6	4.02
Site II	95	88	89.5	93	97.7	102.5	94.2	2.1
Site III	83.4	87	98	82.9	87	85	87.2	2.2
Site IV	125.5	125	139	141	152	158	140	5.4
Site V	166	164	171	186	170	178	172.5	3.3
Site VI	82	87.5	105	125	128	138	110.9	9.3
AVERAGE	**112.9**	**113.5**	**119.7**	**127.1**	**129.2**	**133.9**		

Overall, the average ortho phosphate of Nigeen Lake varied from a minimum of 112.9µg/l (December) to a maximum of 133.9µg/l (May) during the study period (table 8).

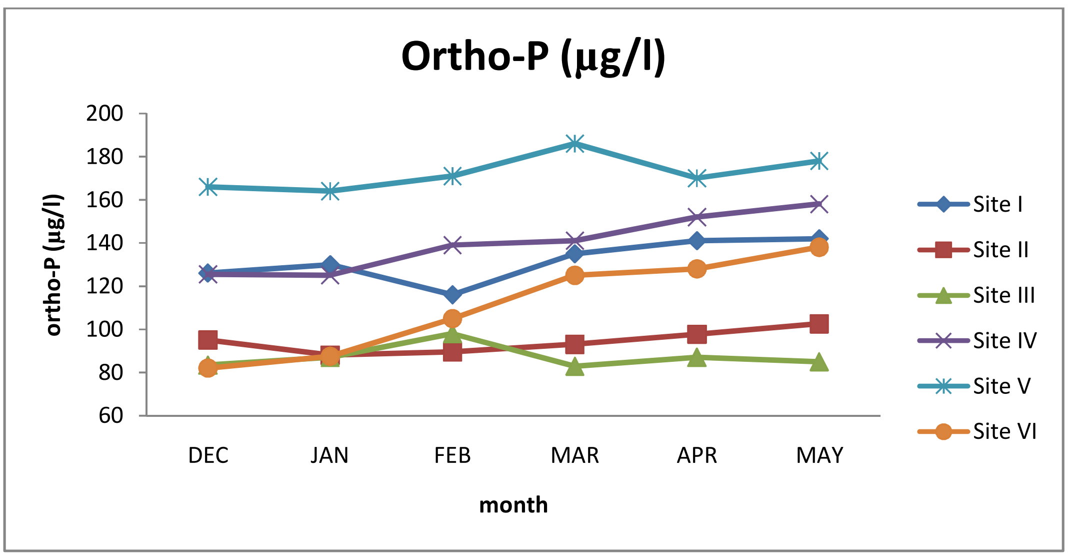


Fig.8. Monthly variation in Ortho-P (µg/l) at different sites of Nigeen lake

4.1.9. Total Phosphorous

The minimum total phosphorous of site I was recorded in the month of February as 280µg/l. The maximum value of total phosphorous of this site was recorded as 310µg/l in May. The average total phosphorous of site I was recorded as 296±4.7µg/l.

The minimum total phosphorous of site II varied from 171.4µg/l in January to a maximum total phosphorous as 205µg/l in the month of May. The average total phosphorous of this site was recorded as 190±5.0µg/l.

Total phosphorous of site III varied from a minimum of 228.5µg/l in January to a maximum total phosphorous as 295.2µg/l in the month of February. The average total phosphorous of this site was recorded as 269.6±9.7µg/l.

The minimum total phosphorous of this site was recorded in May as 245µg/l. The maximum value of total phosphorous of this site was recorded as 293.6µg/l in December. The average total phosphorous of this site was recorded as 278.2±7.0µg/l.

Site V recorded a minimum total phosphorous as 320µg/l in April. The maximum value of total phosphorous of site V was recorded as 384.6µg/l in the month of December. The average total phosphorous of this site was recorded as353.2±11.6µg/l.

Total phosphorous of site VI was recorded as a minimum 211µg/l in December and the maximum value of total phosphorous of this site was recorded as 350µg/l in the month of May. The average total phosphorous of this site was recorded as 307.9±20.6µg/l.

The monthly results of total phosphorous in mg/l are given in table (10), and graphically in figure (9).

Table 9. Monthly variations in Total Phosphorous (µg/l) at different sites of Nigeen Lake.

Site	Dec	Jan	Feb	Mar	Apr	May	Avg.	S.E
Site I	286	294	280	300	306.3	310	296	4.7
Site II	186	171.43	184	201.5	192.07	205	190	5.0
Site III	276.19	228.58	295.2	277.7	284	255.5	269.5	9.7
Site IV	293.6	287	280	287	277	245	278.2	7.0
Site V	384.6	374.6	376.2	338	320	326	353.2	11.6
Site VI	211	305	314	323.8	344	350	307.9	20.6
AVERAGE	**272.8**	**276.7**	**288.2**	**288**	**287.2**	**281.9**		

Overall, the average total phosphate of Nigeen Lake varied from a minimum of 272.8µg/l (December) to a maximum of 288.2µg/l (February) during the study period (table 10).

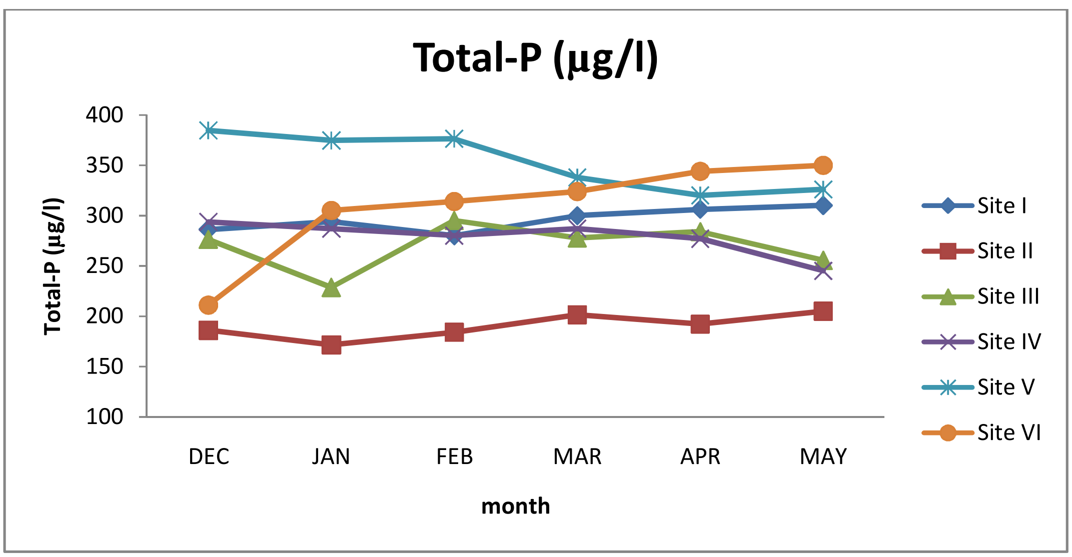


Fig.9. Monthly variation in Total-P (µg/l) at different sites of Nigeen lake

4.1.10. Chlorophyll-a

Site I recorded minimumchlorophyll-a value as 18.11µg/l in February while maximum value of 34.5µg/l was recorded in the month of May. The average chlorophyll-a value of this site was recorded as 26.5±3.2µg/l.

Site II recorded minimum chlorophyll-a value as 15.9µg/l to maximum chlorophyll-a value as 19.5µg/l in May. The average chlorophyll-a value of this site was recorded as 17.6±0.67µg/l.

The chlorophyll-a value of site III varied from a minimum of 19.0µg/l in December to a maximum value of 23.5µg/l in February. The average chlorophyll-a value of this site was recorded as 21.1±0.63µg/l.

The chlorophyll-a value of site IV was recorded as a minimum of 18.1µg/l in December. The maximum value of chlorophyll-a recorded at this site was 24.5µg/l in May. The average chlorophyll-a value of site IV was recorded as 21.1±1.17µg/l.

The chlorophyll-a value of site V ranged from a minimum 20.5µg/l in December to a maximum 27.3µg/l in March. The average chlorophyll-a value of this site was recorded as 24.9±1.1µg/l.

The chlorophyll-a value at site VI ranged from a minimum of 9.49µg/l in December to a maximum 16.5µg/l in May. This site recorded an average of 12.6±1.15µg/l chlorophyll-a value during the study period.

The monthly results of chlorophyll-a in µg/l are given in table (11), and graphically in figure (10).

Table 11. Monthly variations in Chlorophyll-a (µg/l) at different sites of Nigeen Lake.

Site	Dec	Jan	Feb	Mar	Apr	May	Avg.	S.E
Site I	19.18	20.8	18.11	32.31	34	34.5	26.4	3.2
Site II	16.5	15.9	16.0	18.8	19.0	19.5	17.6	0.67
Site III	19.0	20.02	23.5	21.5	22.0	21	21.1	0.63
Site IV	18.1	18.37	19.32	22.8	23.8	24.5	21.1	1.17
Site V	20.5	22.8	26.1	27.3	26.1	27	24.9	1.1
Site VI	9.49	9.68	12.2	13.31	15.0	16.5	12.6	1.15
AVERAGE	**17.1**	**17.9**	**19.2**	**22.6**	**23.3**	**23.8**		

Overall, the average chlorophyll-a value of Nigeen Lake varied from a minimum of 17.1µg/l (December) to a maximum of 23.8µg/l (May) during the study period (table 11).

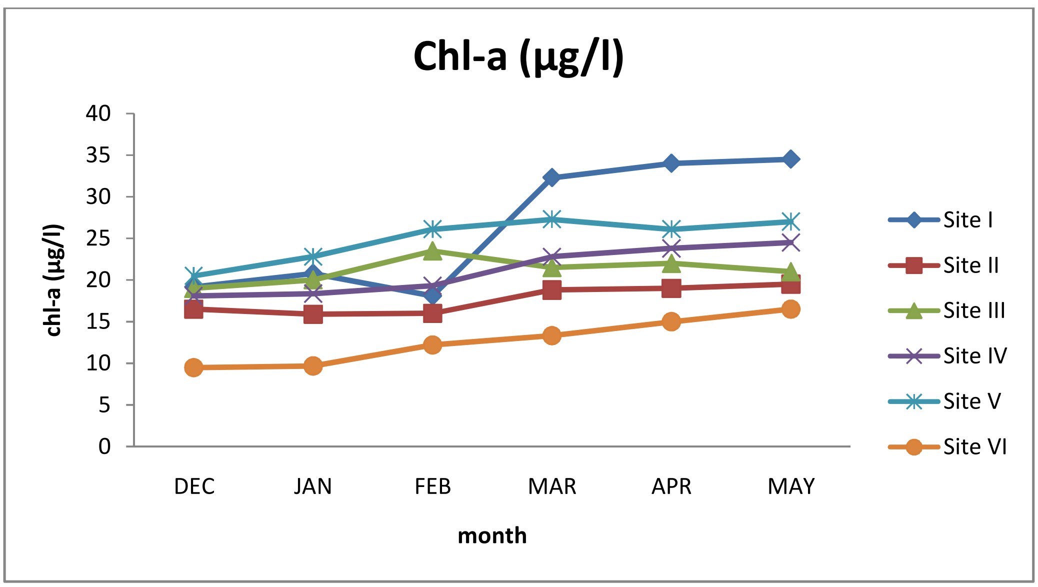


Fig.10. Monthly variation in Chl-a (µg/l) at different sites of Nigeen lake.

4.2. Carlson's Trophic State Index

4.2.1 TSI (SD)

The minimum TSI(SD) of site I was found to be 57.3 in December, January and March and maximum 60 inFebruary, April and May. The average TSI(SD) of site I was found to be 58.65.

The TSI(SD) value of site II ranged from a minimum of 52.35 in the month of December, January and March to a maximum of 56.21 in the month of April and May. The average TSI(SD) value of site II was 53.8.

Site III recorded a minimum TSI(SD) as 41.96 during March and maximum as 44.65 during May. Site III recorded average TSI(SD) value as 43.3 during the study period.

The minimum TSI(SD) value of site IV was recorded as 56.21 in May and maximum TSI(SD) value of this site was recorded as 60 in March and April. This site recorded average TSI(SD) value as 58.01.

The TSI(SD) value of site V varied from a minimum 56.21 during December and January to a maximum of 58.62 during April and May. The average TSI(SD) value of site V was found to be 57.4 during the study period.

Site VI recorded minimum TSI(SD) value as 57.3 in the month of March. The maximum TSI(SD) value of site VI was recorded as 61.51 in the month of May. The average value of TSI(SD) of this site was 59.9 during the study period.

The monthly results of TSI(SD) are given in table (12), and graphically in figure (11).

Table 12. Monthly variations in TSI(SD) at different sites of Nigeen Lake.

	Dec	Jan	Feb	March	Apr	May	Avg
Site 1	57.3	57.3	60	57.3	60	60	58.7
Site2	52.35	52.35	53.22	52.35	56.21	56.21	53.8
Site3	42.79	42.36	43.69	41.94	44.16	44.65	43.3
Site4	57.3	57.3	57.3	60	60	56.21	58.01
Site5	56.21	56.21	57.3	57.3	58.62	58.62	57.4
Site6	60	61.04	60.73	57.3	58.62	61.51	59.9
Avg	**47.19**	**54.42**	**55.36**	**54.35**	**56.26**	**56.18**	

Overall, the average TSI(SD) value of Nigeen lake ranged from a minimum 42.4 (in March and April) to a maximum of 43.3 (in December, January and February) during the study period (table 12)

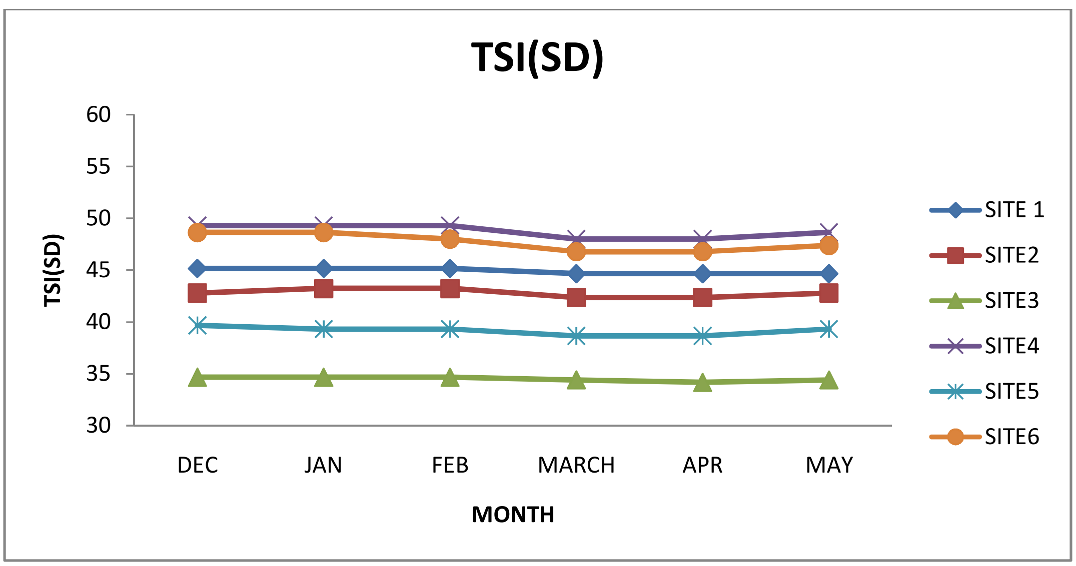


Fig.11. Monthly variation in TSI(SD) at different sites of Nigeen lake.

4.2.2. TSI (TP)

The TSI(TP) value of site I ranged from a minimum of 85.4 in the month ofFebruary to a maximum of 86.69 in the month ofApril. The average TSI(TP) value of site I was found to be 86.15.

The minimum TSI(TP) of site II was found to be 78.32 inJanuary and maximum as 80.9 in May. The average TSI(TP) of site II was found as 79.77.

Site III recorded a minimum TSI(TP) as 82.47 during January and maximum as 86.16 during February. Site III recorded average TSI(TP) value as 84.79 during the study period.

The minimum TSI(TP) value of site IV was recorded as 83.47 in May and maximum TSI(TP) value of this site was recorded as 85.75 in January and March. The average value of TSI(TP) of this site was recorded as 84.28.

The TSI(TP) value of site V varied from a minimum 87.32 in the month of April to a maximum of 89.98 during December. The average TSI(TP) value of site V was found to be 88.71 during the study period.

Site VI recorded minimum TSI(TP) value as 81.32 in December. The maximum TSI(TP) value of site VI was recorded as 88.62 in May. The average value of TSI(TP) for this site was 86.58 during the study period.

The monthly results of TSI(TP) are given in table (13), and graphically in figure (12).

Table 13. Monthly variations in TSI(TP) at different sites of Nigeen Lake.

	Dec	Jan	Feb	March	Apr	May	Avg
Site 1	85.7	86.1	85.4	86.39	86.69	86.67	86.15
Site2	79.5	78.32	79.34	80.65	79.96	80.90	79.77
Site3	85.2	82.47	86.16	85.28	85.6	84.08	84.79
Site4	86.08	85.75	85.4	85.75	85.24	83.47	85.28
Site5	89.98	89.6	89.66	88.11	87.32	87.59	88.71
Site6	81.32	86.63	87.05	87.49	88.37	88.62	86.58
Avg	**84.63**	**84.8**	**85.5**	**85.6**	**85.53**	**85.22**	

Overall, the average TSI(TP) value of Nigeen lake ranged from a minimum 84.63 (in March and April) to a maximum of 85.6 (in March) during the study period (table 13).

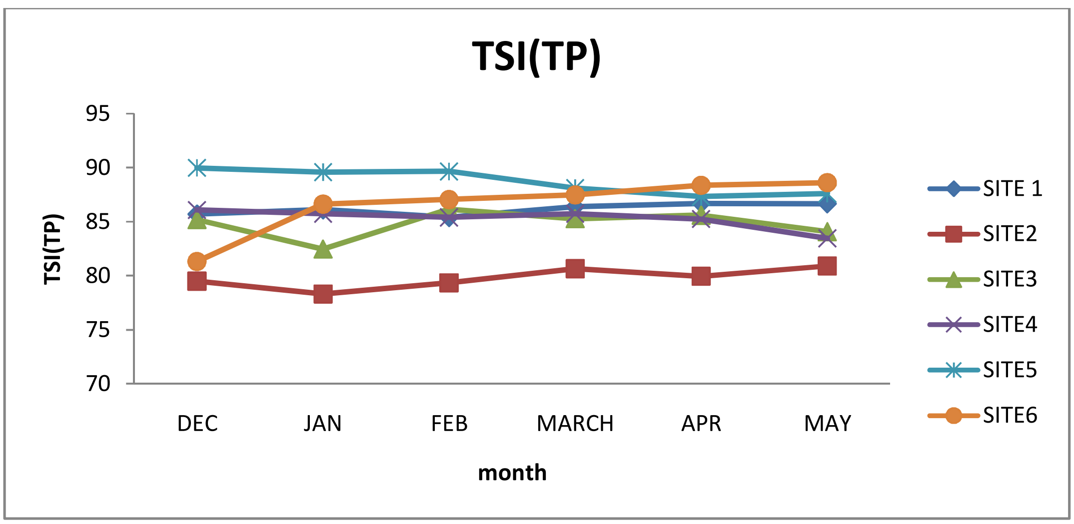


Fig.12. Monthly variation in TSI(TP) at different sites of Nigeen lake

4.2.3TSI (Chl-a)

The minimum TSI(Chl-a) of site I was found to be 59.01 in February and maximum as 65.33 in May. The average TSI(Chl-a) of site I was found to be 62.42.

The TSI(Chl-a) value of site II ranged from a minimum of 57.73 in the month of January to a maximum of 59.73 in the month of May. The average TSI(Chl-a) value of site II was 58.7.

Site III recorded a minimum TSI(Chl-a) as 59.48 during December and maximum as 61.57 during February. Site III recorded average TSI(Chl-a) value as 60.51 during the study period.

The minimum TSI(Chl-a) value of site IV was recorded as 59 in December and maximum TSI(Chl-a) value of this site was recorded as 61.69 in May. The average TSI(Chl-a) value of site IV was recorded as 59.98.

The TSI(Chl-a) value of site V varied from a minimum 60.23 during December to a maximum of 63.04 during March. The average TSI(Chl-a) value of site V was found to be 62.1 during the study period.

Site VI recorded minimum TSI(Chl-a) value as 52.67 in the month of December. The maximum TSI(Chl-a) value of site VI was recorded as 58.1 in May. The average value of TSI(Chl-a) of this site was 55.31during the study period

The monthly results of TSI(Chl-a) are given in table (14), and graphically in figure (13).

Table 14. Monthly variations in TSI(Chl-a) at different sites of Nigeen Lake.

	Dec	Jan	Feb	March	Apr	May	Avg
Site 1	59.97	60.37	59.01	64.69	65.19	65.33	62.42
Site2	58.10	57.73	57.79	59.38	59.48	59.73	58.70
Site3	59.48	59.99	61.57	60.69	60.92	60.46	60.51
Site4	59	59.15	59.15	59.64	61.27	61.69	59.98
Site5	60.23	61.27	62.59	63.04	62.59	62.93	62.10
Site6	52.67	52.86	55.13	55.99	57.16	58.10	55.31
Avg	**58.24**	**58.56**	**59.20**	**60.57**	**61.10**	**61.37**	

Overall, the average TSI(Chl-a) value of Nigeen lake ranged from a minimum 58.24 (in December) to a maximum of 61.37 (in May) during the study period (table 14)

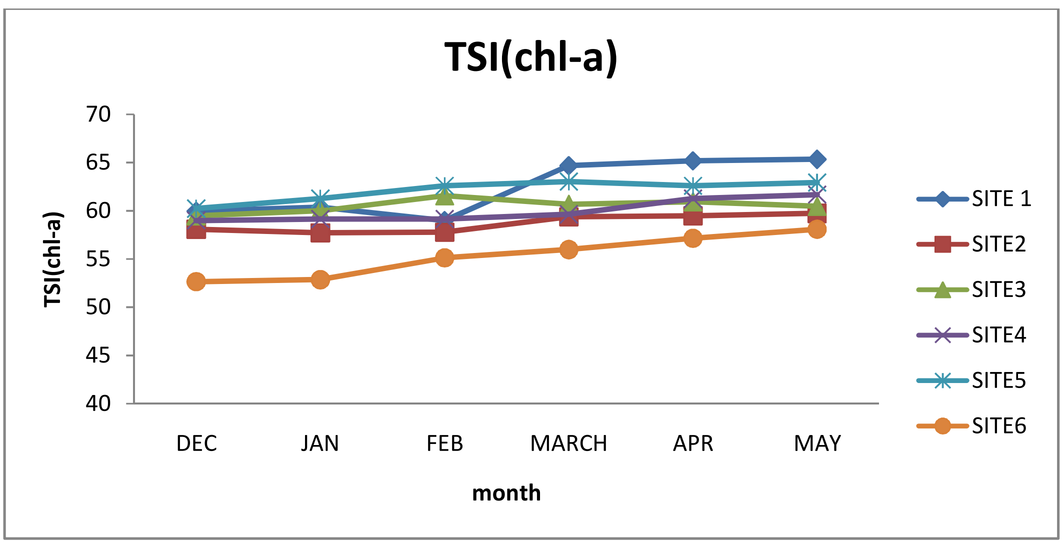


Fig.13. Monthly variation in TSI(chl-a) at different sites of Nigeen lake

4.2.4TSI (Total)

TSI(Total) value of site I ranged from a minimum of 67.62 in December to a maximum 70.66 in May. The average TSI(Total) of site I was found to be 69.06

The minimum TSI(Total) value of site II varied from a minimum of 62.8 in the month of January to a maximum of 65.61 in the month of May. The average TSI(Total) value of site II was recorded as 64.08.

Site III recorded a minimum TSI(Total) as 61.6 during Januray and maximum as 63.8 during February. Site III recorded average TSI(Total) value as 62.85 during the study period.

The minimum TSI(Total) value of site IV was recorded as 67.12 in May and maximum TSI(Total) value of this site was recorded as 68.83 in April. Average TSI(Total) value of site IV was found to be 67.75.

The TSI(Total) value of site varied from a minimum 68.8 during December to a maximum of 69.8 during February. The average TSI(Total) value of site V was found to be 69.38 during the study period.

Site VI recorded minimum TSI(Total) value as 64.66 in the month of December. The maximum TSI(Total) value of site VI was recorded as 69.41 in the month of May. The average value of TSI(Total) for this site was 67.24 during the study period.

The monthly results of TSI(Total) are given in table (15), and graphically in figure (14).

Table 15. Monthly variations in TSI(Total) at different sites of Nigeen Lake.

	Dec	Jan	Feb	March	Apr	May	Avg
Site 1	67.62	67.92	68.13	69.46	70.62	70.66	69.06
Site2	63.31	62.8	63.45	64.12	65.21	65.61	64.08
Site3	62.49	61.6	63.8	62.63	63.56	63.06	62.85
Site4	67.46	67.4	67.28	68.46	68.83	67.12	67.75
Site5	68.8	69.02	69.8	69.48	69.51	69.71	69.38
Site6	64.66	66.84	67.6	66.92	68.05	69.41	67.24
Avg	65.7	65.9	66.7	66.8	67.7	67.6	

Overall, the average TSI(Total) value of Nigeen lake ranged from a minimum 65.7 (in December) to a maximum of 67.7 (in April) during the study period (table 15).

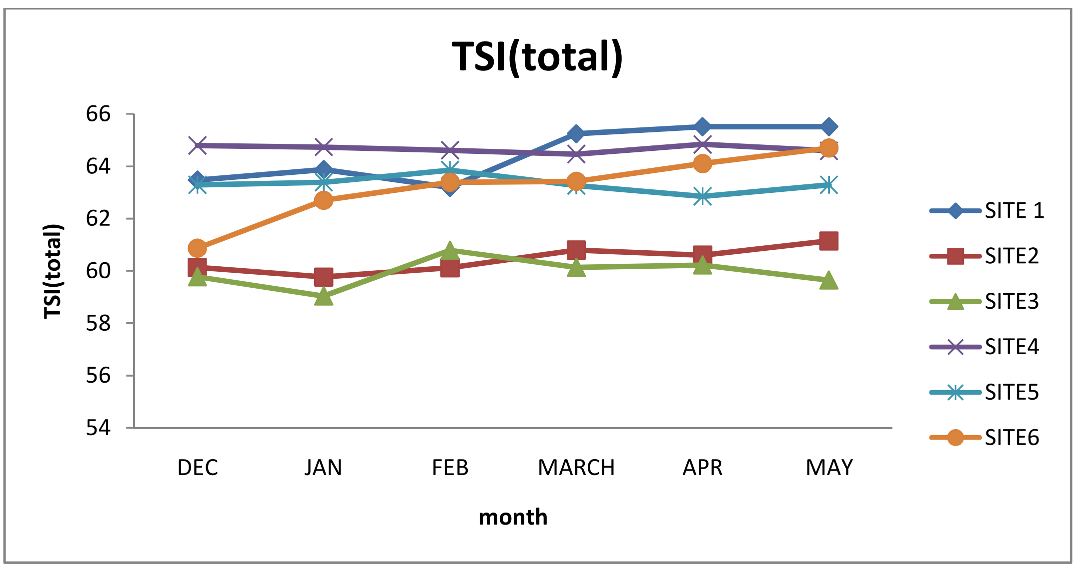


Fig.14. Monthly variation in TSI(total) at different sites of Nigeen lake.

Chapter-5

DISCUSSION

5.1 Physico-Chemical Parameters

5.1.1 Air Temperature

The air temperature controls physical, chemical and biological processes and thus its trend was indicative of the trend of various other activities in the water body (Puri *et al.*, 2011).

In the present investigation, the minimum ambient temperature was recorded in January i.e. in winter and maximum in May i.e. in spring season. A significant seasonal variation in air temperature was observed during the present investigation. The observed low value of temperature in winter is related to lower solar radiation and cold breeze, while high value recorded during spring season could be attributed to high solar radiation.

5.1.2 Water Temperature

Water temperature is a major regulator of physical, chemical and biological processes occurring in lakes. It influences the biological activity and growth of aquatic organisms within a lake ecosystem. Saluja & Garg(2017) reported that higher temperature normally increases biological activity. It is necessary to study water temperature variations because water density and oxygen content are temperature related and hence it indirectly affect osmoregulation and respiration of the animals.

During the present study, the water temperature of Nigeen lake recorded minimum value in winter and maximum in spring season. The variation of water temperature from winter to spring season is related to increased period of solar radiation and increasing air temperature, as air temperature showed a close proportionality to the water temperature.

As describes by Zutshi and Vass (1973) in their study on limnology of Kashmir lakes, the climate of Kashmir is partly Mediterranean and partly temperate with irregularities in annual precipitation, as well as the onset and duration of dry spells. The authors also reported that during the months of March, April and May, rains are frequent and are accompanied by gradual increase in temperature. Hence, the observations of Zutshi and Vass (1973) support the observations made during the present investigation.

Kaul (1977) while studying limnology and trophic status of Kashmir lakes stated that, Nigeen lake develop summer stratification with the formation of distinct thermocline, while Vass and Zutshi (1979) in their study on limnology of Dal lake observed that no stable thermal stratification developed in Nigeen lake, but only a temperature gradient between the upper and lower layer was observed. The authors related this temperature gradient to rapid surface heating.

A strong positive correlation between air temperature and water temperature was observed (r=0.989), which states that the water temperature and air temperature are interrelated. These findings are in line with Balkhi *et al.* (1987), who reported that there is direct relationship of air temperature with water temperature, while studying the hydrobiology of Anchar lake.

5.1.3 Depth

Depth of an aquatic body plays an important role in concentrating ions in water mass, besides being an important factor for growth of various life forms of vegetation (Kaul & Handoo, 1980). Mean depth is regarded as the best single index of morphometric conditions and clearly shows a general inverse correlation to productivity at all trophic levels among large lakes (Goetzman, 1986).

During the present study, the depth of Nigeen lake varied from minimum in winter and maximum in spring season. No significant difference in the mean depth of the lake was observed. However, the slight changes in water depth from winter to spring season are attributed to precipitation received in the form of rain and runoff from the catchment areas.

Zutshi *et al.* (1980) while studying the limnology of a manmade lake observed significant changes in water level and attributed this to precipitation, melting of snow, increase in inflow water and extent of dry period. In the comparative limnology of Dal lake conducted by Kundangar and Abubakr (2006), the authors observed fluctuation in water depth of Nigeen lake and related this to the opening and closing of exit gate of Nigeen lake, as the water level of entire lake is being regulated by the lock gate. However, during the present study, no such observations were made; hence the variation in depth is related to the rainfall and runoff from catchment areas.

5.1.4 Transparency

Secchi disc transparency is basically a function of reflection of light from surface of the disc and therefore, is affected by the absorption characteristics of the water and dissolved particulate matter contained in water (Wetzel, 2001). Besides it is a function of many factors like water color, phytoplankton and zooplankton abundance, suspended and dissolved solids, it also serve as index of water quality (Rawson, 1960).

During the present investigation, the transparency of Nigeen lake varied asminimum in spring season and maximum in winters. The transparency of lake water didn’t show any definite seasonal variation. However, slight changes in transparency can be related to less photosynthetic activity during winter. Kundangar and Abubakr (2006) while studying comparative lumnology of Dal lake, reported low value of transparency of Nigeen lake against the findings of Zutshi (1968), who observed higher transparency of Nigeen lake. The authors related this drastic change to increased quantity of suspended material present in lake basin. The results are also in conformity with Zutshi (1987), Kundangar and Zutshi (1985) and Kaliamurthy (1973).

The average transparency of Nigeen lake was recorded as 1.4-1.6m during the present investigation against the average value of 2.5-3.6m during 1965-66 as recorded by Zutshi (1968). This shows a drastic change in the lake water quality over decades and hence, it can be concluded that the lake is gradually pacing towards higher trophic level. Also, the Nigeen lake with average transparency 1.4m to 1.6m is classified under eutrophic to hyper-eutrophic category (OEDC, 1982).

Transparency recorded negative correlation with water temperature (r=-0.767), which is in line with the observations made by Long *et al.*(2012) who reported similar observations while establishing relationship between phytoplankton and environment factors in lake Hongfeng. The author attributedthis relationship to the fact that with increase in water temperature, there is increase in phytoplankton growth and hence low transparency of the water body.

5.1.5 pH

The pH of water expressively influences the biological activity of aquatic microflora. In natural waters, pH shows diurnal and seasonal changes due to variation in photosynthetic activity. The principal ions that regulate pH in natural waters are CO_2, CO_3^{2+} and HCO_3, which in turn controls the photosynthetic activities of producers (Hutchinson, 1957).

During the present investigation pH didn't show any significant variation during the study period. It remained alkaline, showing water of the lake was well buffered. The slight variation recorded on seasonal basis could be attributed to change in the climatic conditions, photosynthetic activity resulting in higher utilization of carbon source.

Zutshi and Vass (1978) while studying water chemistry of Nigeen lake also observed significant spatial and temporal variations in pH. According to the author, pH of surface water was 7.4-9.6 with high values recorded in May and low in November. These findings are in line with the observations made during the present study.

The pH of typical eutrophic lake ranges from 7.7 to 9.6 (Spence, 1967). The present findings are in support with the observations made by Spence,therefore, Nigeen lake fall under eutrophic category on the basis of its pH range. Abubakr (2010) while studying the sanative role of macrophytes in aquatic ecosystem related fluctuation in pH with dissolved oxygen. The author suggested that with the advancement in seasons, a corresponding enhancement in photosynthesis has resulted in a shift toward more alkaline type of water, which resulted in increased pH. The present study is in line with the findings of Abubakr (2010), hence the increase in pH from winter to spring may be related to increased photosynthetic activity in lake.

5.1.6 Electrical Conductivity

Electrical conductivity is an important water quality variable because it gives a good idea of the amount of dissolved material in water. It is the numerical expression of ability of an aqueous solution to carry electric current. The ability depends on various parameters like the presence of ions and their total concentration, mobility, relative concentration and temperature of measurements (Shinde *et al.,* 2011). The conductivity of water is influenced by various factors like catchment geology, mineralization, lake type and trophic structure of lake.

The present study reveals seasonal variation in the conductivity of Nigeen lake,as it varied from minimum in winter to maximum in spring season. Higher conductivity during spring is attributed to precipitation received in the form of rain and inflow of large amount of domestic sewage along with the rain water.

Kaul *et al.*(1980) while studying the water chemistry of Nilnag lake observed higher conductivity values during winter and spring as compared to autumn and summer. The authors related this to dominance of decomposition resulting in liberation of ions. Zutshi and Vass(1973) while studying variation in water quality of Kashmir lakes observed significant seasonal variation in conductivity of Dal lake and also reported low electrical conductivity in Nigeen lake.

However, Kundangar and Abubakr (2006) compared their observations with the findings of Zutshi (1987) and reported marked increase in electrical conductivity values in Nigeen lake over a period of two decades. Similarly, the conductivity values in present study are much higher than that observed during earlier studies by different authors and hence can be concluded that the trophic status of Nigeen lake increased manifold with the passage of time, higher conductivity reflects pollution status as well as trophic levels of lake.

5.1.7 Dissolved Oxygen

Dissolved oxygen has been referred as the most important limnological parameter that influences all the metabolic processes (Wetzel, 1975). Zutshi and Vass, (1978) reported that the concentration of dissolved oxygen in natural water depends on physical, chemical and biological activities in water body. Singh and Raje (1998) while examining the recurring fish mortalities at Versore found that the main source of oxygen for the aquatic organisms is by diffusion of oxygen in water and photosynthesis by macrophytes and phytoplanktons.

During the present study, dissolved oxygen of Nigeen lake depicted marked variation, with low dissolved oxygen during spring and high during winter. Higher dissolved oxygen level in winters may be due to low temperature, lower biological activity, and prevailing wind action permitting increased solubility of atmospheric oxygen gas. Whereas, lower dissolved oxygen in spring season may be attributed to rise in temperature, increased biological activity and increased rate of decomposition of organic matter.

Seasonal depletion of dissolved oxygen from winter to summer was also observed by Kundangar and Abubakr (2006) while studying the limnology of Nigeen lake. The authors attributed this to number of factors like, temperature, decomposition activities, photosynthesis and load of aeration. The present study revealed negative correlation between dissolved oxygen and water temperature ($r=-0.781$)

which is related to the fact that as warm water becomes more easily saturated with oxygen, it can hold less dissolved oxygen.

Similar observations were made by Kaul *et al.* (1980) during their study on physic-chemical characteristics of Nilnag lake. The authors suggested that the oxygen cycle in water involves a rapid decrease during summer and steady increase through autumn till maximum in winter, following the well-known law of solubility of gases. According to this law, the changes in oxygen content are inversely related to changes in atmospheric temperature.

Abubakr (2010) while studying the sanative role of macrophytes in aquatic ecosystem reported that the water temperature curtail the value of dissolved oxygen, thus negative relationship occur between these two parameters.

5.1.8 Orthophosphate

Orthophosphate is readily available to the biological community and typically found in very low concentration in unpolluted waters. In natural waters, the concentration of orthophosphate provides a good estimation of the amount of phosphorous available for algae and plant growth. Orthophosphate is assimilated by phytoplankton and altered to organic phosphate. Zooplanktons take up organic phosphate by ingesting phytoplankton and excrete it as inorganic phosphate, which is rapidly assimilated by phytoplankton, thereby continue the cycle (Smith, 1998; Holtan *et al.*, 1988).

Orthophosphate, also known as reactive phosphate, is the main constituent in fertilizers used for agriculture purpose. The organic form is bound in plant tissue, waste solids or other organic material. After decomposition, the organic phosphate is converted to orthophosphate. The main sources of orthophosphate in lake water include partially treated and untreated sewage, runoff from agriculture sites and application of some lawn fertilizers.Puri *et al.* (2011) while interpreting the physic-chemical characteristics of lakes of Nagpur city reported that the excessive concentration of orthophosphate is often responsible for eutrophication of lakes, reservoirs and streams. It leads to excessive plant growth, including massive algal blooms that can result in fish kill and foul odour when the algae die and decay.

In the present investigation, the average concentration of orthophosphate of Nigeen lake ranged from a minimum in winter to a maximum in spring season. Higher values during warmer month, while lower values during winters were observedcould be related to decomposition of organic matter at high temperature. Kaul *et al.* (1980) while studying the physic-chemical characteristics of Nilnag lake reported lower concentration of orthophosphate in the lake. The author reported maximum values during spring season and minimum during summers and attributed this to uptake of orthophosphate by phytoplankton and macrophytes, which in turn provide a biological sink.

Study undertaken by Mushtaq *et al.* (2013) on limnology of Dal lake suggested similar observation i.e. the authors reported high orthophosphate content in Nigeen lake during spring and lower during winters. The authors related these seasonal variations to formation of insoluble calcium-phosphate complex.

Abubakr (2010) while studying the sanative role of macrophytes in aquatic ecosystem reported positive correlation between water temperature and orthophosphate. Similar correlation was found between these two parameters during the present study. The author suggested that with increase in temperature, there is increase in mobilization of orthophosphate. Sawyer *et al.* (1945) reported 30µg/l of orthophosphate as critical levels, beyond which blooms indicative of enhanced trophic status can normally be expected. Hence, in the present investigation, the orthophosphate level was far beyond this limit, and Nigeen lake is presently under higher trophic status.

5.1.9 Total Phosphorous

Total phosphorous is considered as the most important element for determining the biological productivity in aquatic ecosystem. It acts as important nutrient for plant growth and fundamental element in the metabolic reactions of plants and animals. It is also considered as an important factor affecting the trophic status of lakes (Vollenweider, 1968; Pandit and Yousuf, 2002). Any change in phosphorous concentration of fresh water can alter its trophic status. Decline in inflow of nutrients reduces phosphorous concentration. It is also considered as the most limiting nutrient for plant growth in natural lakes (Lee and Lin, 2007).

Sondergaard *et al.,* (2003) in their research on lake restoration reported that the key source of phosphorous is bottom sediments in eutrophic lakes. Smith *et al.* (2006) while studying the eutrophication of fresh water and marine ecosystems pointed out that the excessive nutrient load of phosphorous act as the key factor causing eutrophication, which nourishes algal growth causing major threat to aquatic life.

In the present investigation, the average total phosphorous concentration ranged from a minimum in winter to a maximum in spring. Although there was not much difference between the average total phosphorous values, yet some seasonal fluctuations were observed with lower values during winter and higher during spring season. These fluctuations can be related to precipitation in the form of rain, sewage runoff and discharge of untreated human waste directly to the lake. The low values of total phosphorous observed during winters may be due to decreased runoff combined by utilization of phosphorous by phytoplankton.

Sharma *et al.* (2015) while studying the limnology of Dal and Nigeen lake, linked higher phosphorous values of Nigeen lake to direct discharge of untreated human wastes from houseboats and illegal settlement adjoining the lake. Zutshi and Wanganeo (1989) in their study on nutrient dynamics and trophic status of Kashmir lakes suggested that it would be worthwhile to relate mean depth and phosphorous load in order to find out whether a lake is within the acceptable trophic level or not. In the present investigation, mean depth and total phosphorous recorded significant positive correlation (r=0.880) therefore reported higher tropic status based on this relationship.

5.1.10 chlorophyll-a

Chlorophyll-a is the major photosynthetic pigment of phytoplankton and a trophy index in aquatic ecosystem (Vollenweider, 1968; Dillon, 1975). Chlorophyll-a is often used as an estimate of algal biomass, with blooms being estimated to happen when chlorophyll-a concentration go above 40µg/l (Stanley *et al.,* 2003). So a method for the estimation of the growth and development of phytoplankton community is to perform an analysis of photosynthetic pigments, even though the content of chlorophyll in the cells changes with the availability of light (Wetzel, 2001) and thus with depth and trophic gradient (Kasprzak *et al*., 2008). Edmondson (1991) explained that, as eutrophication is defined as an aquatic ecosystem's response to nutrient loading, the ability to identify important factors and predict subsequent algal blooms with the use of chlorophyll-a equation could be a key lake water management tool.

In the present study, the average chlorophyll-a concentration of Nigeen lake ranged from minimum in the winter season to maximum during spring season. Low concentration of chlorophyll-a in winters could be explained by low primary productivity, which is further related to low temperature, less nutrient concentration and less photo-synthetically active radiations (PAR). While higher concentration of chlorophyll-a during spring season may be due to phytoplankton activity and lower water levels in lake ecosystem.

The threshold concentration of chlorophyll-a for eutrophic state within an aquatic ecosystem is identified as 8µg/l (OECD, 1982). According to this, the Nigeen lake fall under eutrophic category, as the chlorophyll-a concentration of all the sites of lake are above 8µg/l.

The present study also revealed negative relationship of chlorophyll-a with secchi disc transparency (r=-0.685), whereas Brown *et al.* (2000) found positive correlation between chl-a and transparency while evaluating the nutrient-chlorophyll relationship. The authors attributed this to the fact that transparency is the key factor affecting chl-a concentration, because it determines euphotic zone and consequently leads to variation in productivity.

A strong positive correlation between chlorophyll-a and orthophosphate (r=0,986) was recorded. Similar observations were made by Randolph (1970) while working on seasonal variation in the trophic state index of Southern Great Plains reservoir. The author observed that seasonal increase and decrease in orthophosphate are accompanied by corresponding increase and decrease in chlorophyll-a concentrations.

Guildford and Hecky (2000) in their research on total nitrogen, total phosphorous and nutrient limitation in lakes and oceans, related the positive correlation of chl-a and total phosphorous to the strong dependence of algal biomass, as represented by chl-a, on the total phosphorous in both cold and warm fresh water lakes.

5.2 Trophic State Index

A number of trophic state index exist today to classify lakes. However, the most suitable and simple index to categorize lakes is given by Carlson (1977). Carlson developed TSI based on the relationship among phosphorous, chlorophyll-a and secchi disc depth. The TSI can be computed from any of the three parameters and should be approximately the same regardless of the parameter chosen. Carlson generated a single number to fit into a numerical scale ranging from 0 to 100 with major trophic divisions at 10 unit increments.

During the present study, the mean TSI (SD) of Nigeen lake was found to be 53.96 based on this value, the lake is classified under eutrophic category. The mean TSI(TP) value recorded from Carlson's TSI was 85.21, resulting in the eutrophic condition of lake. While studying the trophic status of Kashmir lakes, Zutshi and Wanganeo (1989) reported that in lakes of Kashmir, phosphorous is the limiting factor for phytoplankton in lakes. The study also revealed the TSI(chl-a) value of Nigeen lake as 59.84, hence the lake fall under eutrophic category based on this value.The TSI(total) of Nigeen lake was found as 66.33 and is classified under strongly eutrophic category based on Carlson's TSI.

TSI(TP) values were found higher than TSI(SD) and TSI(chl-a), which indicates the increasing phosphorous surplus in the lake water. The increase in phosphorous concentration in lake may be on account of anthropogenic activities in the catchment leading to direct discharge of wastewater from the point source including houseboats. A strong relationship between chlorophyll-a and total phosphorous has been described by Sakamoto (1966), Dillon and Rigler (1974), Jones and Bachmann (1976) and Carlson (1977).

Vollenweider (1976) described direct relationship between total phosphorous and chlorophyll-a as the higher the concentration of phosphorous in water, more is the primary productivity resulting in higher chlorophyll-a concentration. The relationship between secchi disc transparency and chlorophyll-a has been proposed by number of investigators including Edmondson (1970), Bachmann and Jones (1974) and Carlson (1977).

Carlson found that the trophic state indices calculated from secchi disc transparency usually approximated those calculated from chlorophyll-a. The author recognized that secchi disc transparency could give false values in highly colored lakes but concluded that its advantages over-weighted its disadvantages.

The relationship among secchi disc transparency, chlorophyll-a and total phosphorous relate well and proved valuable to assess the trophic status of Nigeen lake.

Chapter-6

SUMMARY AND CONCLUSION

The present study was undertaken for the assessment of trophic status of the Nigeen Lake. Six sites of Nigeen lake were selected during winter and spring seasons. Physicochemical parameters such as temperature, depth, transparency, pH, electrical conductivity, dissolved oxygen, total phosphorus, orthophosphate and chlorophyll-a were studied.

The air temperature recorded a slight variation among the sampling sites in different seasons with minimum of 8.3^{o}C during the month of January and a maximum temperature of 30^{o}C in May. A rise in temperature of water leads to increase in the rate of chemical reactions.

The minimum water temperature recorded was as 6.6^{o}C in month of January and maximum was recorded as 23.7^{o}C during the spring month of May. No significant variation in water temperature among various sites was observed.

The water depth ranged from 3.3m to 3.5m. The minimum of 3.3m was recorded during winters while the maximum 3.5 was recorded during spring season. Significant variations in depth between various sites were observed during the study period.

No significant variation in transparency between various sites and seasons were observed. Overall, the average transparency of Nigeen Lake varied from a minimum of 1.4m (April and May) to a maximum of 1.6m (December, January and March) during the study period.

Overall, the average pH of Nigeen Lake varied from a minimum of 7.6 (April) during spring season to a maximum of 7.9 (December) in winter months during the study period. During the study period the average pH concentrations in all the sites were on alkaline side.

Electrical conductivity of Nigeen Lake varied from a minimum of 295µS/cm (December) in winter months to a maximum electrical conductivity of 325µS/cm (April) in spring season during the study period.

The dissolved oxygen concentration considerably varied among the different seasons with minimum 9.4 mg/l during spring season and maximum 10.2 mg/l during the month of December.

Orthophosphate concentration ranged from a minimum 112.9 µg/l during winters to a maximum 133.9 µg/l during the month of May i.e. in spring season. A significant variation in orthophosphate between the two seasons was observed during the period of the study.

The overall total phosphorus ranged from a minimum 272.8 µg/l during December to a maximum 288.2 µg/l in February. Not much variation in total phosphorus concentration between different seasons was observed.

Chlorophyll-a recorded higher values during spring months with a concentration of 23.8 µg/l, while lowest values were recorded with a concentration of 17.1 µg/l during winter months. A significant variation in chlorophyll-a concentration between various seasons was observed during the period of this study.

Overall, the average TSI(SD) value of Nigeen lake ranged from a minimum 42.4 (in March and April) in spring season to a maximum of 43.3 in the winter months during the study period. No significant variation in TSI(SD) value was observed in the present study.

The average TSI(TP) value of Nigeen lake ranged from a minimum 84.63 (in March and April) during the spring season to a maximum of 85.6 (in March) during the study period. No significant variation in TSI(TP) was observed during the study period.

Overall, the average TSI(Chl-a) value of Nigeen lake ranged from a minimum 58.24 (in December) during winter to a maximum of 61.37 (in May) in spring season during the study period. Slight seasonal variation in TSI(Chl-a) was observed in the present investigation.

The TSI(Total) of Nigeen lake ranged from a minimum 65.7 (in December) during winter season to a maximum of 67.7 (in April) in spring season during the study period. Based on Carlson′s TSI Nigeen lake is categorized under **hyper-eutrophic** category

Conclusion

The water quality assessment carried during the present study in all the six sites of Nigeen Lake revealed high concentration of various chemical parameters viz., specific conductivity, orthophosphate and total phosphorus, while dissolved oxygen remained on lower side. Water quality of Nigeen Lake has been drastically altered because of urbanization and anthropogenic activities.

The overall TSI of Nigeen lake during the present study was recorded as 66.33, therefore the lake is classified under **hyper-eutrophic** category based on Carlson's TSI. Once classified under oligo-mesotrophic category by Zutshi and Wanganeo (1989), Nigeen lake witnessed tremendous changes with respect to increased nitrate and phosphate levels with concomitant decrease in dissolved oxygen levels. Thus, characterizing Nigeen lake under hyper-eutrophic category. The main reason being eutrophication, which has resulted in deterioration/impairment in its water quality posing a serious threat to the portable drinking water resource, fisheries and recreational activities. The major classes of stress, which still continue to degrade the Nigeen lake water quality are-

(i) Excessive input of nutrients and organic matter from point and non-point sources, leading to eutrophication

(ii) Hydrological and physical changes

(iii) Rapid cultural development of its catchment areas with indiscriminate and unauthorized use for cultivation and residential purposes

(iv) Dumping of garbage and sewage and sewerage from the houseboats and adjacent habitations

Nigeen lake management, therefore, needs a holistic approach for its conservation and management, which considers lake as a component of landscape and its restoration at a watershed scale. There is need for immediate systematic monitoring and management to keep lake alive in regard to their aesthetic value, tourist attraction and their importance for aquatic game recreations and economically important animal and plant resources.

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CERTIFICATE

Certified that all the corrections/amendments as suggested by External Examiner Prof. (Dr.)Mustafa Shah, Professor of Zoology, P.G. Deptt. of Zoology, University of Kashmir, Hazratbal, Srinagar, 190009 during viva voce examination held on 23rd May 2017 have been incorporated in the manuscript entitled **"Assessment of trophic status of Nigeen Lake, Kashmir"** submitted by **Ms. Amardeep Kaur (Regd. No. 2014-F-26-M).**

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