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Research Article

Water Quality Monitoring and Trophic status classification of Karanji Lake, Mysore

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Abstract

Large and growing population and rapid pace of development have led to the degradation of natural water system. Lakes are inland bodies of water that lack any directexchange with an ocean. Lakes may contain fresh or saltwater (in arid regions), shallow or deep, permanent or temporary lakes of all types share manyecological and biogeochemical processes.Lake ecosystems are influenced by their watersheds i.e., thegeological, chemical and biological processes that occuronthe land and streams upstream. Lakes play multiple roles in an urban setting. It is essential to restore and maintain the physical, chemical and biological integrity of water bodies to achieve the required water quality, which ensure protection and propagation of fish, wildlife, plants and also recreation in and on water. The overall goal of this study is to monitor the water quality and assess the 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. This study showed that the Karanji Lake is in moderate Eutrophic condition during the study period (Feb, 2013 to May, 2013).

Keywords: *Water quality, Lake ecosystem, Trophic status index, Phosphorus, Chlorophyll-a and Secchi depth, Eutrophication*

1. Introduction

Lakes can be defined as bodies of standing water occupying a basin. They may vary from ponds of less than 0.4 hectares to large water bodies of an area of thousands of kilometres. In geological terms lakes are ephemeral. They originate as a product of geological processes and terminate as a result of the loss of the ponding mechanism, by evaporation caused by changes in the hydrological balance, or by in filling caused by sedimentation or by selfish human intervention/encroachment. The mechanisms of origin are numerous and are reviewed by G. E. Hutchinson(1957), who differentiated 11 major lake types, sub-divided into 76 sub-types (G. E. Hutchinson, 1957).Lake ecosystems are made up of the physical, chemical and biological characteristics contained within these water bodies. Many organisms depend on freshwater for survival, and humans frequently depend on lakes for a great many ‘goods and services’ such as drinking water, waste assimilation, fisheries, agricultural irrigation, industrial activity, boosting of natural groundwater table, habituatingwide variety of flora and fauna and recreation(R. Thomas et al.,1996).Lakes and ponds are one of the landscape features that significantly contribute to increase the quality of life in urban centres, by increasing amenity, providing recreational and educational activities, and even contributing to mitigate the urban climate. Moreover, the watershed of these ecosystems is part of the urban tissue and thus they tend to emphasize environmental problems affecting the metropolitan areas, by collecting and accumulating large amounts of nutrients and pollutants, including microbial contaminants (N. Flores, 2008). Both natural as well as manmade lakes represent a water storage located in a topographic depression. Both receive inflows from usually more than one source. In natural lakes the outflow is dependent on the lake water level which in turn is a function of the stochastic natural inflows. There is usually only one lake out flow. In manmade lakes, mostly created by dams and usually have at least two different outflows, both of which are regulated (G. A. Schultz, 1991).

It is essential to restore and maintain the physical, chemical and biological integrity of water bodies to achieve the required water quality, which ensure protection and propagation of fish, wildlife, plants and also recreation in and on water. The overall goal of this study is to monitor Lake Karanji in the city of Mysore, Karnataka for its water quality and arrive at itstrophic status.

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2. Literature Review

2.1Lake classification

Lakes are classified differently based on origin: tectonic lakes, glacial lakes, and shoreline lakes(E. P. Odum and G. W. Barrett, 1996); based on Temperature and Mixing:Dimictic lakes,Cold monomictic lakes,Warm monomictic,Polymictic lakes,Oligomictic lakes,Amictic lakes (E. P. Odum and G. W. Barrett, 1996); based on Trophic status:Oligotrophic lakes, Mesotrophic lakes, Eutrophic lakes(R. Thomas et al.,1996).

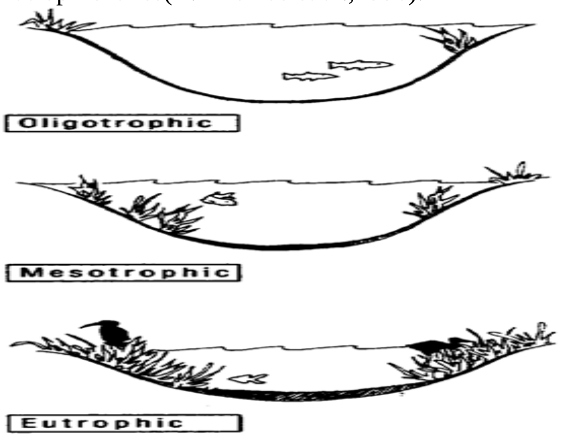

Fig 1: Trophic status classification of lakes

2.2 Role of nutrients

Identifying and quantifying the determinants of algal growth in lakes iscrucial not only for understanding Lake Ecosystem functioning,but also because extensive algal blooms are a nuisance that canbe caused by human activity. Primary production in lakeecosystems depends on nutrients and light as essential resources.Phytoplankton take up nutrients dissolved inlake water whereas rooted macrophytes obtain nutrients from thesediments. Primary producers are potentially limited bycarbon, nitrogen or phosphorus.Nitrogen (nitrate, ammonia, and free nitrogen) and phosphorus (Phosphate) are much less available, suggesting that phosphorus,followed by nitrogen, is most likely to limit algal production in lakes.

2.2.1 Phosphorus

Phosphorus is essential in nucleic acids, phospholipids,adenosine triphosphate (ATP) etc., but is scarce in bio accessible forms in lakes, whereas carbon and nitrogenenter lakes by exchange of CO_2 and N_2 from the atmosphere. The only natural source of phosphorus is weathering from the watershed of PO_4^{3-} ions, which dissolve only poorly in water. Phosphorus plays an important role in lake algal production. However, successful management of many lake ecosystems depends upon controlling phosphorus inputs.

2.2.2 Nitrogen

Algal cells require nitrogen to synthesize proteins. Typically nitrogen is available in lakes in higher concentrations than phosphorus. Most algae take up NH_4 ions (from decomposition) or NO_3^{2-} ions (from bacterial nitrification of NH_4).Lakes can only be nitrogen limited if the relative supply of phosphorus is greater than that of nitrogen. Adding wastewater from sewage to a lake can create this condition, which in turn favours the growth of nitrogen-fixing cyanobacteria because they have an alternative source of nitrogen. This is why lakes with excessive phosphorus inputs tend to have noxious blooms of cyanobacteria.

2.3Trophicstatus criteria for classification of water bodies

The work of M. Sakamoto (1966), National Academy of Science(1972) and H. Dobson(1974), on chlorophyll-a v/s trophic state (Table 1) and subsequently developed multivariate trophic state criteria based on chlorophyll a, total phosphorous and Secchi disc Transparency(SDT).The USEPA National Eutrophication survey(USEPA-NES) (Table 2) and Carlson's trophic state index as shown in Table 3.

2.4 Lake trophic status classification methods

Lake classification generally include two distinct approaches: Trophic state criteria: Classify a lake according to the current quality of the water column, using data from in-lake samples. These typically require measurements of total phosphorus, total nitrogen, chlorophyll a, Secchi disc depth and/or other constituents. The trophic state criteria can provide a multivariable index of present water quality and second approach is nutrient loading criteria can be used to predict the quality state of a lake from data on the P loading and lake geomorphology (no in-lake measurements). The loading criteria focuses on a single nutrient but can be used to predict quality changes over time and estimate carrying capacity.

Trophic state accounts for the total weight of living biological material (biomass) in a water body at a specific location and time. Time and location-specific measurements can be aggregated to produce water body-level estimations of trophic state. Trophic state is understood to be the biological response to forcing factors such as nutrient additions but the effect of nutrients can be modified by factors such as season, grazing, mixing depth, etc., (G. P. Murthy et al., 2008).

The Trophic State Index (TSI) is a classification system designed to "rate" individual lakes, ponds and reservoirs based on the amount of biological productivity occurring in the water. This index provides a quick idea about how productive a lake is.Great efforts have been taken to establish quality criteria and thresholds to classify lakes according to their trophic status based on nutrient (P, N) concentrations and on certain physical (e.g., transparency, dissolved oxygen)and biological (e.g., algae pigments) characteristics. Nutrient ratios (N/P) have been used to explain specific algal populations, or identify a nutrient limiting factor. Of several parameters considered for investigation, phosphorus, chlorophyll-a and secchi depth have been emphasized in developing TSI. The overall TSI of a lake is estimated to be the average of the TSI for phosphorus, the TSI for chlorophyll-a and the TSI for secchi depth.

The TSI ranges from 0 (ultraoligotrophic) to 100 (hypereutrophic). 0-30 is Oligotrophic, where water is very clear and phosphorus is low. 30-50 is an in-between stage where the number of aquatic plants increases due to more available phosphorus.

Table 1: Interpretations of deviations from typical conditions associated with TSI values (Source: T. Brown and J. Simpson,1998)

TSI Relationship	Possible Interpretation
TSI (CHL) = TSI (SD)	Algae dominate light attenuation
TSI (CHL) >TSI (SD)	Large particulates, such as Aphanizomenon flakes, dominate
TSI (TP) = TSI (SD) >TSI (CHL)	Non-algal particulate or dissolved color dominate light attenuation
TSI (SD) = TSI (CHL) >= TSI (TP)	Phosphorus limits algal biomass (TN/TP ratio greater than 33:1)
TSI (TP) >TSI (CHL) = TSI (SD)	Zooplankton grazing, nitrogen, or some factor other than phosphorus limits algal biomass

Carlson's TSI: A popular method for examining algal biomass which relates to trophic state is through the use of the TSI developed by R. E. Carlson (1977)which defines the trophicstatus of a given lake. After establishing the relationship between transparency (Secchi disc) and algal biomass(chlorophyll a), within the scale of transparency variations, Carlson used Secchidisc values to construct the first TSISD. Using regression equations of transparency against total phosphorous and chlorophyll *a*, two other indexes were developed under the same scale (TSICHL, TSITP).
The formulas for calculating the TSI values for Secchi disc, TP, and chlorophyll *a* are as follows:

Table 2: Summary of Trophic status criteria of Sakamoto, Academy and Dobson

Trophic condition	Sakamoto	Academy Chlorophyll-a(mg/m3)	Dobson
Oligotrophic	0.3-2.5	0.4	0-4.3
Mesotrophic	2.5-15	04-Oct	4.3-8.8
Eutrophic	15-140	>10	>8.8

Secchi disc: TSI (SD) = 60 - 14.41 ln (SD)
Chlorophyll *a*: TSI (CHL) = 9.81 ln (CHL) + 30.6
Total phosphorus: TSI (TP) = 14.42 ln (TP) + 4.15

Where ln = natural log.
U.S. EPA National Eutrophication Survey (1974): The EPA developed a relative classification system as part of the National Eutrophication Survey (NES) comparing the work of M. Sakamoto (1966), National Academy of Sciences (1972), H. Dobson (1974) (USEPA, 1974). The system determined the fixed boundaries. Data collected during this national eutrophication survey were later used to develop a probability distribution based upon TP to predict chlorophyll-a and transparency probabilities.

Table 3: U.SEPA-NES Trophic status index

Trophic condition	Chlorophyll-a (mg/m^3)	Phosphorous (mg/m$^{3)}$	Secchi disc Transparency (m)
Oligotrophic	<7	<10	>3.7
Mesotrophic	07-Dec	Oct-20	2-3.7
Eutrophic	>12	>20	<2

Table 4: Carlson Trophic status index

TSI	Trophic category	Secchi disc Transparency (m)	Phosphorous (mg/m$^{3)}$	Chlorophyll-a (mg/m^3)
0	Oligotrophic	64	0.75	0.042
10	Oligotrophic	32	1.5	0.012
20	Oligotrophic	16	3	0.34
30	Oligotrophic	8	6	0.94
40	Oligotrophic	4	12	2.64
50	Mesotrophic	2	24	6.4
60	Eutrophic	1	48	20
70	Eutrophic	0.5	96	56
80	Eutrophic	0.25	192	154
90	Eutrophic	0.12	384	427
100	Eutrophic	0.062	768	1183

R. E. Carlson (1977) conducted experiments on numerical trophic state index for lakes and most lakes range within a scale of 0 to 100. Each major division (10, 20, 30, etc.) represents a doubling in algal biomass. The index number can be calculated from any of several parameters, including Secchi disc transparency, chlorophyll, and total phosphorus.R. G. Cloutier and M. Sanchez (2007) classified the trophic status of 154 lakes located in southern regions of the Quebec province, Canada based on chlorophyll *a*, total phosphorus, transparency (Secchi disc), and total nitrogen. The evaluation of existing relationships among quality parameters were established, and suggestions for priority actions and restoration initiatives were given. Carlson's Trophic State Index(CTSI)applied to two lakes in Mandya, Karnataka, India, ranged between35-53 indicating that they are mesotrophic (A. G. Devi Prasad and Siddaraju, 2012).

2.5 Problems in the lake system

General

- Nuisance algal blooms in the summer
- Reduced dissolved oxygen in the bottom of the lake
- Fish kills due to low dissolved oxygen.
- Taste and odour problems with drinking water
- Reduced water clarity
- Reduced quality of boating, fishing and swimming (T. Brown and J. Simpson,1998)

Eutrophication

Eutrophication is the biological response to excess nutrient inputs to a lake. The resulting increased biomass will in turn results in impaired water use. High nutrient concentrations in a lake are derived from external inputs from the watershed. The final biomass attained is determined primarily by the pool of nutrients available for growth at the beginning of the growing season. The primary nutrients, such as nitrogen and phosphorus, are used until growth is complete and the exhaustion of the pool of either one of them places a final limit on the phytoplankton growth. Eutrophication is a slow, natural part of lake aging, but today human influences are significantly increasing the amount of nutrients entering lakes.

3. Materials and methodology

3.1 Description of the study area

Mysore, city of palaces is an important tourist destination in Karnataka, India. It lies between 11º30' and 12º50' of north latitude 75º45' and 77º 45' east longitudes. Mysore has several large and small water bodies. Some of the major lakes are Kukkarahalli Lake, Lingambudi Lake, Devanoor Lake, Dalvai Lake and Karanji Lake.Though Mysore has developed into a modern city, the city still moves at a gentle, unhurried and leisurely pace. The city has a good green cover and has a few lakes that add to the beauty and calmness of the city. These lakes are popular picnic spots and are frequented by nature lovers as they attract a number of migratory birds, in which Karanji Lake occupies the frontline.

Karanji Lake is spread over 90 hectares, while water spread area is about 55 acres, the foreshore area measures about 35 hectares and is home to more than 90 species of resident and migratory birds (Figure3).The Lake is shallow with a maximum depth of 2.2m and minimum depth of 0.2m

3.2 present scenario analysis

In the past, Karanji Lake was fed with the storm water a drain surrounding the lake in the catchment area. The lake is now managed by Mysore Zoological Garden. The Karanji Lake is facing serious problem of inflow of huge quantity of drainage water from the UGD running from the adjoining residential areas (Siddhartha Layout) and dairy industry.

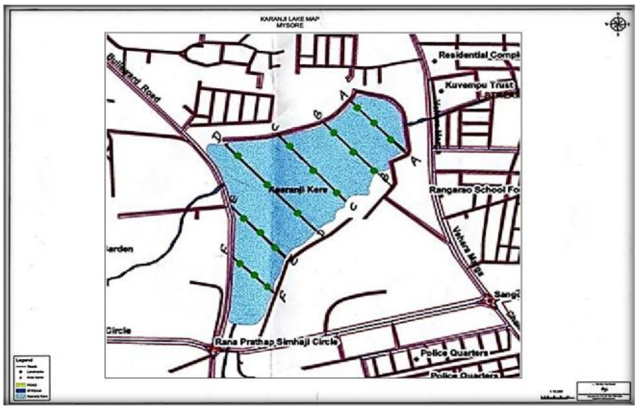

Fig 3: Details of sampling points along with Inlet

Table 5: Methods adopted for analysis of water quality parameters

Parameters	Methods
Nitrate	PDA(UV Spectrophotometer)
Phosphate	(UV Spectrophotometer)
Chemical oxygen demand	Closed Reflux Titrimetric
Biological oxygen demand	Titrimetric method
Turbidity	Digital Nephelo-Turbidity meter
pH	pH meter
Total hardness	EDTA Method
Calcium hardness	EDTA Method
Magnesium hardness	EDTA Method
Sulphate	Turbidimetric
Sodium	Flame photometer
Fluorides	Visual method(Alizarin)
Temperature	pH Meter
Dissolved oxygen	DO Meter
Conductivity	Conductivity Meter

3.3 Lake monitoring

Six transect were selected across the lakes and in each transect three sampling locations were identified (Figure3)Surface water samples were collected once in

Table 6: Summary of water quality of Karanji Lake based on monitoring from February, 2013 to May, 2013.

Sl. No.	Parameter	Transect 1	Transect 2	Transect 3	Transect 4	Transect 5	Transect 6
1	pH	7.88	8.34	8.63	8.59	8.75	8.70
2	Temperature	21.31	26.6	27.6	28.1	28.38	28.33
3	Conductivity	771.35	759.2	761	758	747.2	741.6
4	DO	2.63	5.18	11.36	14.77	16.94	17.51
5	BOD	23.41	22.41	19.92	18.43	16.77	16.13
6	Nitrate	7.23	6.19	5.36	4.56	3.24	2.78
7	Phosphate	0.19	0.17	0.043	0.04	0.01	0.02
8	Sulphate	27.12	26.18	26.08	23.42	19.95	19.31
9	Hardness	232.6	222.1	167.2	209.8	205.5	200.2
10	Calcium hardness	2.16	1.92	1.83	1.69	1.54	1.31
11	Magnesium hardness	2.62	2.53	2.42	2.27	2.12	1.57
12	Ammonia	5.04	4.11	3.27	3.08	2.48	2.26
13	Chloride	89.62	84.53	79.84	77.72	76.64	73.95
14	Fluoride	0.56	0.55	0.53	0.51	0.51	0.51
15	Sodium	3.03	2.76	2.69	2.60	2.53	2.43
16	Turbidity	22.36	21.30	19.60	19.03	17.41	16.48
17	COD	132.24	120.58	117.55	114.87	112.07	110.13

every month from February, 2013 to May2013.Parameters such as color, temperature, conductivity, DO and turbidity was measured insitu. The other physicochemical parameters including hardness, BOD, COD, alkalinity, chloride, nitrate, sulphate, fluoride, phosphate, sodium were determined in the laboratory as per the IS standards. The analytical methods adopted to analyze these water quality parameters are listed in Table 5.

4. Results and discussion

4.1 Water quality of the Lake

The water quality of Karanji Lake as determined by the present study is summarised in Table 6.

It can be noticed from Table 6 that concentrations of these constituents are more at transect 1 and 2 because of the inflow of sewage/effluent from the Siddhartha layout and Mysore milk dairy. The concentration of parameters, in general, decreased from the first transect to subsequent transect. The two main reasons for this patterns could be uptake of nutrient and degradation of biodegradable organics by aquatic flora/fauna and mixing and hence dilution. In case of parameters such as nutrients (N and P) and BOD, there is a clear indication of both uptake/biological degradation and dilution resulting in substantial gradient in the reduction in concentrations at higher transects whereas for the remaining parameters, mixing played a major role.

4.2 Trophic status classification of Karanji Lake

The parameters involved in the estimation of Carlson's TSI are summarised in Table 7, which were then used to calculate the TSI (Table 8).

Table 7: Calculation of Total Phosphorous, Secchi depth and Chl-a conducted from analysis ofKaranji lake

Survey	TP(microgram/l)	Secchi depth (m)	Chl-a (microgram/l)
1	55.245	1.147	$14.6*10^{-3}$
2	41.48	1.019	$16.7*10^{-3}$
3	35.424	1.09	$15.7*10^{-3}$
4	67.58	1.01	$16.9*10^{-3}$

Table 8: Summary table of TP, SD and Chl-a using TSI

Survey	TSI(TP)	TSI(SD)	TSI(Chl-a)
1	61.99	58.023	10.88
2	57.867	59.73	9.57
3	55.59	58.68	10.15
4	64.9	59.92	9.42

Based on the guidelines summarised in Table 2, Table 3 and Table 4, the trophic status of Karanji Lake can be classified as mesotrophicor eutrophic depending on the classification criteria and the associated parameter. The trophic status classification of Karanji Lake is presented in Table 9.

Based on this analysis, it can be concluded that the Karanji Lake was in the Eutrophic condition during the study period. However, this study period being non-monsoon period, does not represent the annual status of the Lake. The Mysore Zoo authority has taken tremendous efforts to improve the lake water quality. Some of the actions undertaken at the receiving end include introduced Fisheries, artificial aeration through man-made fountains, sewage inflow being passed through a constructed wetland. A beautiful park on the bank of the lake, boating in the lake, aviary with an excellent collection of indigenous and exotic birds, a butterfly garden, nesting and other activities of migratory birdsand friendly staff attracts a number of tourists to the lake throughout the year.

Table 9: Trophic status classification of Karanji Lake

Criteria	Chlorophyll-a	Secchi depth	Phosphorous
Carlson	Eutrophic	Mesotrophic	Eutrophic
Dobson	Eutrophic		
U.SEPA-NES	Mesotrophic	Eutrophic	Eutrophic
Academy	Mesotrophic		
Sakamoto	Mesotrophic		

5. Conclusions

The overall conclusions drawn from this case study of Karanji Lake are

- The physico- chemical analysis of the water samples showed that the amount of nutrients (nitrogen and phosphorous) concentration in the inlet (transect 1) is more because of sewage inflow from Siddhartha layout and Mysore milk dairy industry.
- The water quality parameters like pH, temperature, COD and BOD are in the range which supports the aquatic growth in the lake.
- The aquatic plants like water hyacinth and lavancha are seen abundant in the lake which helps in absorbing nutrients thereby reducing the pollutant concentration and aiding in Lake Self-purification.
- Based on trophic status given by the multi-variant indices, it is concluded that the Karanji Lake is in moderate eutrophic condition during this study period. However, with monsoons rains and the excellent attempts from the zoo authority, the lake water quality is bound to improve.
- Thus from overall analysis, the above mentioned indices can be used as predictive tool in lake management programme.

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