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Research Article

Assessment of Trophic Status of Bellandur Lake, Bangalore, India by using USEPA Technique

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Abstract

Due to rapid growth of population coupled with urbanization, the water bodies, especially, rivers, lakes, ponds, reservoirs etc are deteriorating due to heavy pollutational stresses resulting in the scarcity of drinking water resources. 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 present paper attempts to work done on the development of Trophic State Index (TSI) for assessment of trophic state of Bellandur Lake in Bangalore city. This index requires the determination of Chlorophyll a (CA), Total phosphorus (TP), Secchi disc depth (SD) transparency and Total Nitrogen(TN). The index values ranging from 0 to 100 can be used for classification of trophic state of the lake. The results of the study showed that the TSI of Bellandur Lake found 85, indicating that Bellandur Lake found in hypereutrophic Stage. 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.

Keywords:*Eutrophication, Trophic State Index, Total Phosphorus, Secchi depth, Chlorophyll 'a', Total Nitrogen*.

1. Introduction

Lakes are important feature of the Earth's landscape which are not only the source of precious water, but provide valuable habitats to plants and animals, moderate hydrological cycles, influence microclimate, enhance the aesthetic beauty of the landscape and extend many recreational opportunities to humankind. The lakes are also used for drinking, irrigation, fishing, eco-toursim etc apart from the above advantages. The different problems of the lake include excessive influx of sediments from the lake catchment, discharge of untreated or partially treated sewage and industrial waste waters/ solid waste, entry of diffused nutrients source from agricultural and forestry, improper management of storm water, over abstraction, over-exploitation of lake for activities like recreation, fishing, encroachments, land reclamation etc causing lake water shrinkage, shoreline erosion and impacting the lake hydrology, deteriorating water quality, impacting bio diversity, bringing climate changes etc. There is an immediate need to know the pollution status of a lake at given time so that necessary conservation activities may be undertaken to regain/improve the health of water body. This can be done by measuring trophic state index (TSI) to know its trophic state; this method is adopted and applied to the Indian lakes (M.P. Sharma *et al*. 2010). Trophic state index involves new methods both of defining trophic status and of determining that status in lakes (Robert E. Carlson1977).

Various methods have been employed for the classification of lakes and to indicate their trophic status. The most commonly and widely used method is based on productivity, and the frequently used biomass related trophic state index is that of Carlson. The trophic status refers to the level of productivity in a lake as measured by phosphorous, algae abundance and depth of light penetration (M.P. Sharma *et al*. 2010). The range of the index is from approximately zero to 100, although the index theoretically has no lower or upper bounds (Carlson, R.E. *et al*. 1996). The concept of trophic status as a system of classification was introduced by early limnologists such as Nauman. Eutrophication is the process by which lakes are enriched with nutrients, increasing the production of rooted aquatic plants and algae to levels those are considered to be an interference with desirable water uses such as recreation fish maintenance and water supply. Eutrophication can also result in detrimental effects on the biological stability of lake and reservoir ecosystem, affecting virtually all the biological populations and their interactions in the water body (Noha Donia *et al*. 2004).

Eutrophication is a term used to describe a directional movement over time towards the eutrophic trophic state from a lower trophic state (USEPA, 2000). The lake does not have to reach the eutrophic state to undergo

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eutrophication; rather, use of the term indicates a trend toward a more eutrophic state (e.g., higher phosphorus, nitrogen, and chlorophyll Concentrations and lower Secchi depth readings over time) (Ted Brown *et al*. 1998). The Carlson Trophic State Index (TSI) is the widely used. It was developed to compare determinations of chlorophyll a, Secchi transparency and total phosphorus concentration. Higher index numbers indicate a degree of eutrophy while low numbers indicate a degree of oligotrophy (low nutrient and algal concentrations and high transparency)(USEPA, 1990).

Excess nutrients, specifically phosphorus and nitrogen, have long been recognized as the primary pollutants that contribute to the cultural eutrophication of lakes. However, even though they are a significant pollutant, as of 2000, there were no Federal (and few State) water quality criteria for nutrients for the purposes of protecting waters from eutrophication. As a part of the Clean Water Action (CWAP) in 1997, nutrients were identified as a significant national problem and USEPA was requested to develop a National Nutrient Strategy. One aspect of this strategy recommended that states develop eco region-based criteria for total phosphorus, total nitrogen, chlorophyll-a and Secchi transparency. Complete details and background on this strategy can be found in several USEPA publications (USEPA 1998). Nitrogen (N), while not considered the limiting nutrient in most cases for freshwater lakes, is nonetheless an essential nutrient for algal and rooted plant growth and EPA has requested states to consider development of N criteria, Total nitrogen (TN), is essentially equal to total Kjeldahl nitrogen (TKN) as nitrite + nitrate N (and of this most is in nitrate form) (USEPA, 2005).

Eutrophication is a severe problem in America, Europe, and Asia. It is expected that global warming will accelerate lake degradation. A trophic status classification provides information on which government and watershed organizations base eutrophication control programs, such as watershed restoration plans.

The most important negative impacts associated with anthropogenic eutrophication are:

- Excessive algal and macrophyte growth (loss of open water);
- Presence of noxious algae (scums; red, blue, or greens blooms; taste and odour; and nonaesthetic);
- Loss of water clarity (small Secchi depths);
- Possible loss of macrophytes (via light limitation by algae and periphyton);
- Low dissolved oxygen (loss of habitat for fish and fish food);
- Excessive organic matter production (smothering eggs and macroinvertebrates);
- Blue-green algae inedible by some zooplankton (reduced food chain efficiency);
- “Toxic” gases formation (e.g., ammonia, hydrogen sulphide) in bottom water (more loss of fish habitat);
- Presence of toxins from noxious species of cyanobacteria;
- Increase in costs of water treatment;
- Loss of sport-fish species (e.g., trout) and associated negative economical impact (Rosa Galvez-Cloutier *et al*. 2007).

Carlson’s Index has largely been used to assess the trophic status of lakes in almost all the countries including India. As such no reports are available on the development of TSI system for Indian lakes but Carlson’s TSI is presently used to assess the status of lakes in India (M.P. Sharma *et al*. 2010).

The objective of this study is to assessment of trophic status of Bellandur Lake in Bangalore city,Karnataka, India by using USEPA technique.

2. Study Area

Bangalore, the capital of Karnataka, has a history of over 400 years. The origin of Bangalore city can be traced back to 1537 when it was founded by Late Magadi Kempegowda. Bangalore is the principal administrative, cultural, commercial and industrial centre of the state of Karnataka. The city of Bangalore is situated at an altitude of 920 meters above mean sea level. Geographically it is located on 12.95º N latitude and 77.57º E longitude. The population of Bangalore as per the 2001 census was 56, 86,844 while it was 1, 63,091 in the beginning of the last century (1901). As per provisional reports of census of India, population of Bangalore in 2011 is 84, 25,970 and is the third densely populated city in India having density of 11,000 per square kilometers(Ramesh. N *et al*. 2014).

The earliest history of creation of lakes in and around the city is traced to the founders of Bangalore–the KempeGowdas –by damming the natural valley systems by constructing bunds. Most of the lakes and tanks were manmade for purposes of drinking water, irrigation and fishing needs and they have also favorably influenced microclimate of the city(Ramesh. N *et al*. 2013).

Bellandur Lake, the largest in Bangalore city spreads across an area of 892 acres. It is located at latitude of 12°58′ N and longitude of 77°35′ E at an altitude of 921 m above mean sea level and has a catchment area of 110.94 sq.miles or 287.33 sqm. The water storing capacity of Bellandur lake is 17.66 million cubic feet, being 3km in length and 2.75km in Width. It is one of the largest man-made lakes in Southeast Asia, located about 20 km from the city towards the south-east of Bangalore city. The tank is a receptor from three chains of tanks. One chain, originates in the north, from Jayamahal, covers the eastern portion and has been referred to as the eastern stream. Another chain originates from the central part of the city, from around the K.R.Market area and covers the central portion and is called the central stream. The other chain, that reaches the tank is through the southwestern region and is called the western stream. Due to urbanization in 1980s, there was breakage of chains of tanks feeding the lake. The breakage in chains, unchecked industrial, residential as well as commercial development, resulted in insufficient rainwater reaching the tank and excess untreated sewerage and effluents laden water flow to the tank (Ramesh. N *et al*. 2013).

Satellite view of Bellandur tank and its surrounding shown in Figure 1. Research work has been carried out to

Fig 1: Satellite view of Bellandur Lake and its surrounding

assessment of trophic status of Bellandur Lake in Bangalore city.

3. Trophic State Index (TSI)

The trophic status refers to the level of productivity in a lake as measured by phosphorous, algae abundance and depth of light penetration. TSI rates individual lakes, ponds and reservoirs based on the amount of biological productivity occurring in the water. Using the index, one can get a quick idea about the extent of productivity of a lake. TSI values can be used to rank lakes within a region and between the regions. This ranking enables the water managers to target lakes that may require restoration or conservation activities(M.P. Sharma *et al*. 2010).

3.1 Method to Determine the TSI

Numerous methods have been developed to measure the trophic state (TS) of lakes. The most popular TSI method Carlson's Trophic Status Index selected for the present study are given below (M.P. Sharma *et al*. 2010). The classical and most commonly used method is based on the productivity of the water body is the biomass related trophic state index developed by Carlson (1977). Carlson's Trophic State Index (TSI) is a common method for characterizing a lake's trophic state or overall health (A.G. Devi Prasad *et al*. 2012).

Trophic state variables are those variables that can be used to predict the trophic state of a water body. Trophic state variables include measures of nutrient concentration (e.g., TP, soluble reactive phosphorus, TN, total Kjeldahl nitrogen), plant (macrophyte or algal) biomass (e.g., organic carbon, chlorophyll a, Secchi depth), and watershed attributes (e.g., land use). All could be used for establishing criteria to address eutrophication concerns, but only a few are viable candidates for early warning variables. Based on the Proceedings of the National Nutrient Assessment Workshop (U.S. EPA, 1996), the most likely trophic state candidates are TP, TN, chlorophyll, Secchi transparency, and dissolved oxygen. In addition, one watershed metric—land use and the associated phosphorus loading—was recommended as an early warning variable. EPA presently requires only TP, TN, chlorophyll a, and Secchi depth be used, but this set of criteria variables may be augmented by other measurements if the State or Tribe prefers(USEPA, 2000).

In this study, the Carlson trophic State Index (TSI) is used to provide a single quantitative index for the purpose of classifying and ranking lakes, most often from the standpoint of assessing the trophic state of the lake. In recent years the Carlson Index appears to have attained general acceptance in the limnological community as a reasonable approach to this problem. This is a measure of the trophic status of a body of water using several measures of water quality including: transparency or turbidity (using Secchi disk depth (SD) recordings, chlorophyll-a (CHLA) concentrations (algal biomass), and total phosphorus (TP) levels (usually the nutrient in shortest supply for algal growth) (Noha Donia *et al*. 2004). Other indices have been constructed to be used with the basic three. Since nitrogen limitation still classifies a lake along Naumann's nutrient axis, the effect of nitrogen limitation can be estimated by having a companion index to the Total Phosphorus TSI. Such an index was constructed by Kratzer and Brezonik (1981) using data from the National Eutrophication Survey on Florida lakes (Carlson, R.E. *et al*. 1996). The more sophisticated approaches to assessing trophic state require analysis of key variables such as phosphorus, nitrogen, chlorophyll, and Secchi depth (T. Brown *et al*. 1998). TSI ranges along a scale from 0-100 that is based upon relationships between secchi depth and surface water concentrations of algal chlorophyll, and total phosphorus. Its major assumptions is that suspended particulate material in the water controls secchi depth and that algal biomass is the major source of particulates; values below 40 generally considered to represent oligotrophic condition and values above 60 representing eutrophic condition. The values between 40 and 50 represent mesotrophic condition, the values between 50 and 60 represent moderately eutrophic and the values above 70 represent hypereutrophic. The classification scheme of TSI Carlson Index is illustrated in Table 1.(Noha Donia *et al*. 2004).

Table 1: Carlson's Classification based on Trophic State Index (TSI)(Carlson, R.E. *et al*. 1996),(Rosa Galvez-Cloutier *et al*. 2007)

TSI	Classification	Description
< 30	Oligotrophic	Clear water, dissolved oxygen throughout the year in the hypolimnion
30-40	Oligotrophic	Deep lakes still exhibit classical oligotrophy, but some shallower lakes become anoxic in the hypolimnion during the summer.
40-50	Mesotrophic	Water moderately clear, but increasing probability of anoxic in hypolimnion during summer.
50-60	Eutrophic	Lower boundary of classical eutrophic; decreased transparency, anoxic hypolimnion during the summer, macrophyte problems evident and warm-water fisheries only.
60-70	Eutrophic	Dominance of blue-green algae, algal scum probable, extensive macrophyte problems.
70-80	Hypereutrophic	Heavy algal blooms possible throughout the summer, dense macrophyte beds, but extent limited light penetration.
> 80	Hypereutrophic	Algal scum, summer fish kills, few macrophytes, dominance of rough fish.

The following equations can be used to compute the Carlson's TSI.

TSI (SD) = 60 - 14.41 ln(SD) (in meters)

TSI (CHL) = 9.81 ln(CHL) + 30.6(in ug/L)

TSI (TP) = 14.42 ln(TP) + 4.15(in ug/L)

TSI (TN) = 54.45 +14.43 In(TN) (in mg/L)

Where SD the sechhi depth, CHL is chlorophyll, TP is total phosphorus and TN is total nitrogen.

4. Materials and Methods

Surface water samples for investigations were collected from six different locations selected which covered the whole area of the lake during March 2013. Six sampling locations are shown in Figure 2. The water samples were collected for the analysis of three parameters, total phosphorus, chlorophyll and total nitrogen. Transparency of the water was measured by Secchi's disc of 20cms in diameter and the values are expressed in meters. The maximum depth at which the disc can be seen when lowered in to the water is marked and measured. Total phosphorus and total nitrogen was analysed by the method prescribed in BIS (IS 3025-2. 2004), (IS 3025-34 .1998) and Chlorophyll was estimated by Spectrophotometric method (APHA, 1999).

5. Results and discussions

The analytical results of the various stations and Trophic State Index (TSI) are shown in Table 2. The average values of Trophic State Index (TSI) of Bellandur Lake were found to be 85. Average value of Trophic State Index Secchi Depth, Total Nitrogen, Total Phosphorous and Chlorophyll-a were used to calculate the Trophic State Indices (TSI) which are shown in the Table 2. The obtained TSI values were compared with Carlson's trophic state classification criteria as given in Table 1. Results of TSI clearly indicate that Bellandur Lake was found in hypereutrophic Stage.

The resulting index values generally range between 0 and 100 with increasing values indicating more eutrophic conditions (with the exception that due to some very high TP measurements some of the TSIP values will exceed 100) (USEPA, 2005). From the study found that Bellandur Lake, values of TSIP exceeds 100.

Limnologists and lake managers have developed a general consensus about freshwater lake responses to nutrient additions, that essentially an ambient total phosphorus (TP) concentration of greater than about 0.01 mg/L and or a total nitrogen (TN) of about 0.15 mg/L is likely to predict blue-green algal bloom problems during the growing season. Similarly, chronic over enrichment leads to lake quality degradation manifested in low dissolved oxygen, fish kills, algal blooms, expanded macrophytes, likely increased sediment accumulation rates, and species shifts of both flora and fauna (USEPA, 2000). From the study found that Bellandur Lake, concentration of TP and TN obtained are greater than about 0.01 mg/l and 0.15 mg/l respectively.

Eutrophication is the progressive directional change of a lake out of one type and into another. Once in a type, the lake takes on certain characteristics by which it can be recognized and therefore, classified. Such classifications are easily recognized from lists of characteristics typical for each trophic state heading Table 1.

TN:TP ratios have been used as a basis for estimating which nutrient limits algal growth (e.g., Smith, 1982). Low TN:TP ratios (less than about 7:1) are indicative of nitrogen limitation, whereas ratios greater than 10:1 are increasingly indicative of phosphorus limitation. Based on data from Minnesota, low ratios occur in some shallow hypereutrophic lakes in the northern glaciated plains. However, these low ratios are typically the result of very high TP loads from point or nonpoint sources in the watershed rather than a shortage of nitrogen. Low TN:TP ratios also are found in lakes receiving significant amounts of sewage effluent (USEPA, 2000). In case of Bellandur Lake from the study found that Low TN:TP ratios.

The nutrients may enter in to lakes as agricultural runoff, sewage or waste water and also by cattle ranching. This causes over enrichment of nutrients in the water bodies leading to the algal blooms. The decaying process of dead algal biomass may also result in the depletion of dissolved oxygen in the lakes causing anoxic environment.

TSI as an important aspect in lake survey, water quality and this can be used as a tool to measure trophic state where the biomass is involved. Sharma *et al*., have applied Carlson's TSI for the assessment of trophic status of lake and found that the systems can be very well used for the assessment of TSI of the lake.

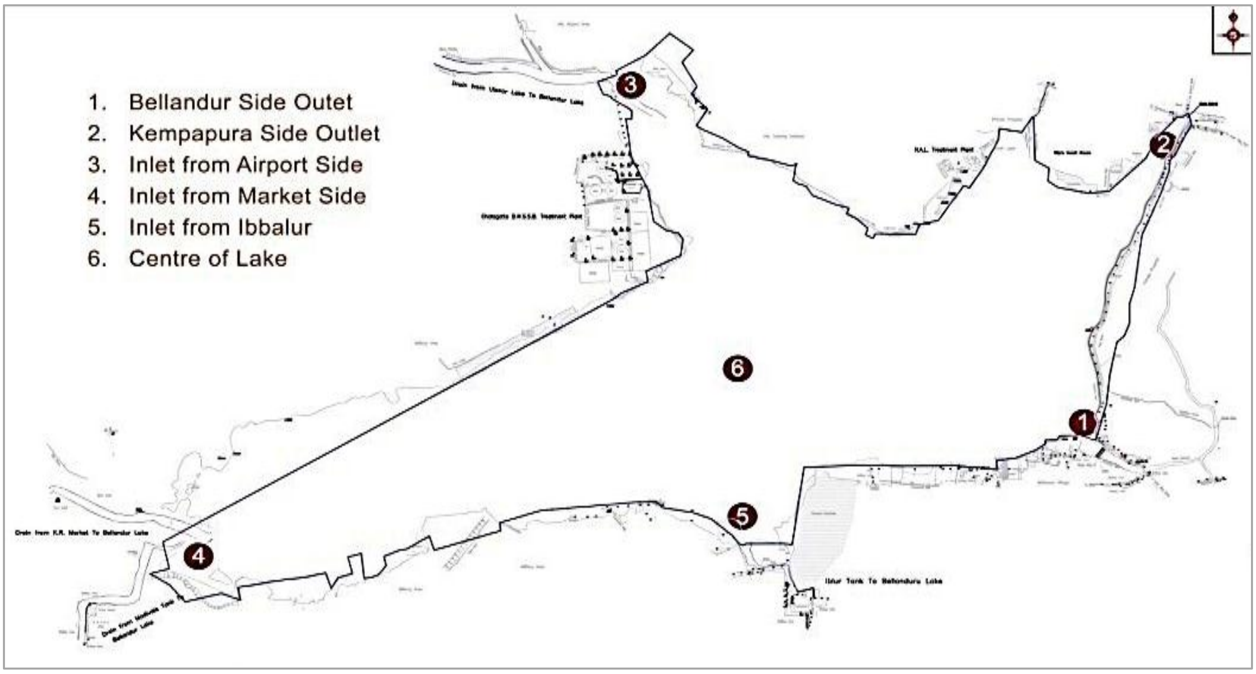

Fig 2: Sampling locations of Bellandur Lake

Table 2: Analytical results of the various stations and Trophic State Index (TSI)

Sampling points	Secchi disk depth in meter		Chlorophyll µg/l		Total Phosphorus µg/l		Total Nitrogrn mg/l	
	SD	TSI	Chl 'a'	TSI	TP	TSI	TN	TSI
S1	0.19	80.93	50	68.97	2100	114.15	2.5	67.67
S2	0.25	79.97	ND	-	6500	130.75	2.8	69.30
S3	0.13	89.39	ND	-	7100	132.02	2.4	67.08
S4	0.08	96.39	10	53.08	7900	133.56	1.0	54.45
S5	0.07	98.31	10	53.08	12400	140.06	2.3	66.47
S6	0.21	82.48	ND	-	7100	132.02	1.0	54.45
Average		87.91		58.37		130.42		63.23

Note: ND = Not detected

Average value of Trophic State Index (TSI) of Bellandur Lake = 85

Conclusions

The progression of lake from oligotrophy to hypereutrophic state is a gradual process in nature. The conversion from one life stage to another is based on the changes in the degree of nutrient inflow and the productivity in the lake. The cultural eutrophication can significantly alter the rate of the natural process and shorten the life expectancy of the affected aquatic body. This can be avoided by adopting suitable conservation measures.

In view of growing pollutional stresses in Bellandur lake, the TSI of a lake can be assessed using Carlson's TSI methods. The results of sampling at six locations indicated that the lake has 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.

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