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CARLSON'S TROPHIC STATE INDEX (CTSI) OF LAKE JUNONA OF CHANDRAPUR, MAHARASHTRA (INDIA)

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Abstract:
Trophic State index of Carlson (1977) is frequently used biomass related trophic state. It is relatively simple to use, requires a minimum of data and is generally easy to understand. Carlson's trophic state index uses three variables, chlorophyll pigment (CHL), secchi disk depth (SD), and total phosphorus (TP), independently estimate algal biomass. The range of the index is from approximately zero to 100. For the current study, Carlson's trophic state index for lake Junona was calculated in October- November 2014. For evaluating Carlson trophic state index, three variables i.e. TSI (SD) for secchi disk, TSI (CHL) for Chlorophyll a and TSI (TP) for total phosphorus were calculated individually. From the results it was found that trophic state index for secchi disk for Lake Junona was found to be 58.7305 which indicate the eutrophic condition of the lake. Trophic state index for chlorophyll a was found to be 93.82545 which indicate the hypereutophic condition. Trophic state index for total phosphorus was found to be 97.76 which again categories the lake into hypereutrophic state. By averaging these three indices Carlson trophic state index was estimated as 83.4386.Thus according to Carlson trophic state index Lake Junona can be categorized into hypereutrophic state.
Keywords: Carlson's Trophic State Index, Lake, Junona, Chandrapur, Maharashtra

Introduction

Water is one of the priceless gifts of nature. Today, water resources have been most exploited due to increasing population, industrialization, urbanization, increasing living standards and broad spheres of human activities. The level of pollution in the natural environment especially water contamination has been of great concern to the scientists, environmentalist and engineers because of its toxic nature and other adverse effects on human beings and other living creatures *(Sinha,D.,K., and Navneet Kumar (2008).* Water is one of the essentials that support all forms of plant and animals (*Vanloon and Duffy, 2005).* Water is generally obtained from two principal natural resources; surface water such as fresh water lakes, rivers, streams, etc. and ground water such as borehole water and well water *(McMurry and Fay, 2004; Mendie, 2005).*

Water is widely distributed on Earth as freshwater and salt water in the oceans. The Earth is often referred to as the "blue planet". This blue color is caused by reflection from the oceans which cover roughly 71% of the area of the Earth. (*Water distribution on Earth).* The vast bulk of the water on Earth is regarded as saline or salt water, with an average salinity of 35%. Though this varies slightly according to the amount of runoff received from surrounding land. In all, water from oceans and marginal seas, saline groundwater and water from saline closed lakes amount to over 97% of the water on Earth. The remainder of the Earth's water constitutes the planet's fresh water resource. Typically, fresh water is defined as water with a salinity of less than 1 percent that of the oceans. Water with salinity between this level and 1% is typically referred to as marginal water because it is marginal for many uses by humans and animals. The ratio of salt water to fresh water on Earth is around 40 to 1. The planet's fresh water is also very unevenly distributed. Although in warm periods such as the Mesozoic and Paleogene when there were no glaciers anywhere on the planet all fresh water was found in rivers and streams, today most fresh water exists in the form of ice, snow, groundwater and soil moisture, with only 0.3% in liquid form on the surface. Of the liquid surface fresh water, 87% is contained in lakes, 11% in swamps, and only 2% in rivers. Small quantities of water also exist in the atmosphere and in living beings (*Water distribution on Earth).*

Freshwater ecosystems are considered as one of the most important natural resources for the survivability of all the living organisms of the biosphere. The alarming rate of deterioration of water quality of fresh water resources like lakes, ponds, rivers etc. is now a global problem. Over exploitation and pollution of water are responsible for making it scarce and unfit for consumption. For sustainable utilization of the water resources, periodic examinations of the freshwater bodies are very much essential ***(****Ahmed Shah J. and Pandit A.K., 2012****)***.

There is no specific definition for Lakes in India. The word "Lake" is used loosely to describe many types of water bodies – natural, manmade and ephemeral including wetlands. Many of them are euphemistically called Lakes more by convention and a desire to be grandiose rather than by application of an accepted definition. Vice versa, many lakes are categorized as wetlands while reporting under Ramsar Convention *(Conservation and Management of Lakes-An Indian perspective-MoEF, 2010).*In India, National Lake Conservation Programme under the Ministry of Environment and forests (MoEF) defines lakes as "standing water bodies which have a minimum water depth of 3m, generally cover a water spread of more than 10 hectares and have no or very little aquatic vegetation", (Ministry of Environment and Forests, 2010).

Lakes are important part of an urban ecosystem. Though relatively small in size, lakes perform significant environmental, social and economic functions, ranging from being a source of drinking water, recharging groundwater, acting as sponges to control flooding, supporting biodiversity and providing livelihoods. Water in lakes is an easily available source of water for the needs of many sectors of economy such as agriculture, domestic and industrial. These water bodies, whether man-made or natural, fresh water or brackish play a very vital role in maintaining environmental sustainability particularly in urban environments especially in today's context when the cities are facing the challenges of unplanned rapid urbanization *(Protection and Management of Urban Lakes in India,CSE,New Delhi).*

Healthy Lakes and their shores not only provided us with a number of environmental benefits but they influence our quality of life and they strengthen our economy. Proper lake function can ease the impact of floods and droughts by storing large amount of water and releasing it during shortages. Lakes also work to replenish groundwater, positively influence water quality of downstream water courses and preserve the biodiversity and habitat of the area. When the ecological puzzle pieces of a lake came together and the lake is able to work as it should the big picture is clear we all stand to benefit from the important resource.

According to the report of Centre for Science and Environment, New Delhi at present, in India, lakes and wetlands are in extremely bad shape and are in varying degrees of Environmental degradation. Despite knowing their environmental, social and economic significance, city planners have willfully neglected and destroyed these water bodies. Today these water bodies are encroached, full of sewage and garbage. Because of unplanned urbanization, much of the landscape around the lakes has been covered by impervious surfaces. As a result, instead of rain water; it is the sewage and effluents that are filling up urban water bodies. Once the sponges of urban area, today urban lakes have turned into hazards that get choked even with low rainfall and overflow into the blocked canals during high rainfall causing floods in the city. It is the disappearance of these sponges of the city that has exacerbated floods and sharpened the pain of droughts *(Churning Still Water, 2012).*

In Delhi in 2010-11 to check the changes in water bodies in last 10 years the status of 44 lakes was ascertained and it was found that 21 out 44lakes were gone dry due to rapid urbanization and falling water tables *(Singh & Bhatnagar, 2012).*Another example exhibiting this increasing loss of urban water bodies is Hyderabad, within last 12 years, Hyderabad has lost 3245 ha. area of its water in the form of lakes and ponds (Times of India, 2012). There are endless examples in India that shows such devastating state of urban water bodies *(Protection and Management of Urban Lakes in India, CSE, New Delhi).* Considering the present bleak water scenario of Indian cities, today we need our urban lakes and wetlands more than ever. Although there is a plethora of policies and acts for the protection and restoration of urban lakes, urban water bodies are in extremely poor condition. Their numbers are declining rapidly. For example at the beginning of 1960s Bangalore had 262 lakes, now only 10 hold water. Similarly, in 2001, 137 lakes were listed in Ahmadabad city, and over 65 were reported being already built over *(Excreta Matters, 2012).*

Trophic state is the total weight of living biological material (biomass) in a water body at a specific location and time. A trophic state index (TSI) condenses water quality data into a single, numerical index. Different eutrophication points are assigned for various water quality concentrations. The index is the sum of individual eutrophy points for a lake. There are two universal system of lake classification. These are physical or thermal classification and the classification by Trophic level *(Chapman, 1992).* The concept of trophic status as a system of classification was introduced by early limnologists such as Naumann (1919) and Vollenwider (1968) and has been subjected to continuous development up to the present time *(Pouriot and Mey beck, 1995)*

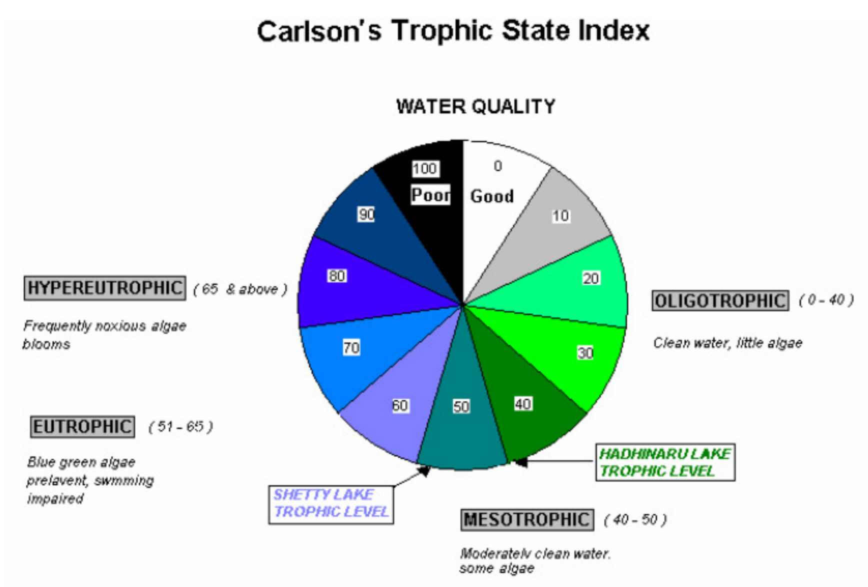
Trophic classification of aquatic environment is necessary for the characterization of water resources that are potentially available for human activities. Eutrophication of aquatic environments, which is both the reason for and the result of their trophic status, depends on a great variety of different process and factors. Therefore, the trophic concept is multidimensional and involves several aspects of lake productivity nutrient loading and concentration faunal and floral quantity and quality, and Lake Morphometry *(Carlson R.E., 1977)*. Indexes that are based on all these indices describe most precisely the trophic status of aquatic environments. However, the high complexity of aquatic environments causes even multi parameter trophic classification to be sometimes unequivocal and limited in application (*Brezonik A.M, Shannon EE, 1971)*.

Carlson's Trophic State Index (TSI)

Trophic state is defined as the biological material that is found in water body. Carlson Trophic State Index (TSI) requires minimum data and uses algal biomass as a basis for classification.

a) Chlorophyll-*a* pigment (CA)
b) Secchi's Depth (SD)
c) Total phosphorus (TP)

1. **TSI <30:** Classic Oligotrophy;Clear water, oxygen through the year in the hypolimnion, salmonid fisheries in deep lakes.
2. **TSI 30-40:** Deeper lakes still exhibit classical oligotraphy, but some shallower lakes will become anoxic in the hypolimnion during the summer.
3. **TS 40-50:** Water moderately clear, but increasing probability of anoxia inhypolimnion during summer.
4. **TS 50-60:** Lower boundary of classical eutrophy: Decreased transparency, anoxic hypolimnion during the summer, macrophyte problems evident, and warm-water fisheries only.
5. **TSI 60-70:** Dominance of blue-green algae, algal scums probable, extensive macrophyte problems.
6. **TSI 70-80:** Heavy algal blooms possible throughout the summer, dense macrophyte beds, but extent limited by light penetration. Often would be classified as hypereutrophic.
7. **TSI >80: Algal scums**, summer fish kills, few macrophytes, dominance of rough fish.



Graphic showing the relative ranking of the average trophic state

Calculating the Trophic State Index (TSI) Of Carlson

a.TSI for Chlorophyll-a (CA) TSI = 9.81In Chlorophyll-a (ug/l)---------------------(1)
b. TSI for Secchi depth (SD) TSI = 60-14.41In Secchidepth (Meters) ---------------------- (2)
c. TSI for Total phosphorus (TP) TSI = 14.42 In Total phosphorous (ug/l) + 4.15-------- (3)
Where TSI is Carlson Trophic State Index and In is Natural logarithm
Carlson's TSI = [TSI (TP) +TSI (CA) +TSI (SD)]/ 3
Where TP and Chlorophyll-a in micrograms/l and SD transparency in meters

Importance of the Index

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a. The index ranges from 0-100 and has the advantage over the use of raw variables (Decimal fractions are converted to units of 10).
b. Any of the three variables can be used to classify the water body.
c. Chlorophyll-a *is*givenhighest priority for classification and is the most accurate of the three at prediction of algal biomass.

Chandrapur District is abundantly endowed with rich flora and fauna, water resources and mineral wealth. Chandrapur district is also gifted with large number of lakes. The larger lakes in the district are Ghodazari, Asola Mandha, Kasarla, Tadoba, Naleshwar, Junona, and Ramala etc. *(MPCB, 2006)*. Due to available minerals and abundant water resources, industries have been set up within and in the surrounding of Chandrapur city *(MPCB, 2006)*. But due to industrial proliferation, rapid population growth, increasing living standards and wide spread human activities these resources, especially water is getting exploited. Surface water resources are becoming polluted due to heavy flux of sewage, industrial effluents and agriculture wastes which consists of substances varying from simple nutrients to toxic hazardous chemicals. Toxic chemicals and human waste products pose threat to aquatic life as well as human health. Surface water resources in Chandrapur District are facing problem of nutrient load which is the root cause of eutrophic condition of water bodies specially the lentic ecosystem.

Materials and Methods

Study area

Chandrapur district is located in the eastern edge of Maharashtra in Nagpur division and forms the eastern part of 'Vidarbha' region. It is the easternmost district of the state of Maharashtra. Chandrapur is located at $19^{0}57'$North latitude and $79^{0}18'$ East longitude. It has an average elevation of 189 meters (620 feet). The city is located on the bank of 'Erai'river. Due to number of coal mines present around the city, the city is also known as city of Black Gold (Environmental Status Report, 2007). Junona talav (lake) and forest is named after the village Junona which is located in jungle are at 8 km from Chandrapur town. Junona Lake is a fresh water and historical lake of Chandrapur district. The lake is surrounded by dense Chichpalli forest and contains rich treasure of flora and fauna. It harbours varieties of birds including migratory birds. This place is known for its scenery lake, where various types of birds visit during different seasons around the year.

Sampling was done from the study area after detailed survey of the sampling sites. Samples were collected from the different sampling sites in 1L thick polyethylene container and were preserved by adding the recommended preservatives and immediately brought to the laboratory and were analyzed for parameters like chlorophyll *a* and Total Phosphorous using the standard methods of APHA, 1992,IS 3025 (Part31) 1988 and Chatwal G.R.,1997. Secchi disk determinations were done on site while sampling.

Secchi Disk

The Secchi Disk created in 1865 by Pietro Angelo Secchi SJ, is a circular disk used to measure water transparency in oceans and lakes. The disk is mounted on a pole or line, and lowered slowly down in the water. The depth at which the pattern on the disk is no longer visible is taken as a measure of the transparency of the water. This measure is known as the Secchi depth and is related to water turbidity.

Total Phosphorous

Phosphorous occurs in natural waters and in waste waters almost solely as phosphates. These are classified as orthophosphates, condensed phosphates (pyro-, meta-, and other polyphosphates), and organically bound phosphates. They occur in solution, in particles or detritus, or in the bodies of aquatic organisms (APHA). These forms of phosphate arise from a variety of sources. Small amount of certain condensed phosphates are added to some water supplies during treatment. Larger quantities of the same compounds may be added when the water is used for laundering or other cleaning preparations. Phosphates are used extensively in the treatment of boiler waters. Orthophosphates applied to agricultural or residential cultivated land as fertilizers are carried into surface waters with storm runoff and to a lesser extent to melting snow. Organic phosphates are formed primarily by biological processes. They are contributed to sewage by body wastes and food residues, and also may be formed from orthophosphates in biological treatment processes or by receiving water biota. Phosphorous is essential to the growth of organisms and can be the nutrient that limits the primary productivity of a body of water. In instances where phosphorous is a growth-limiting nutrient, the discharge of raw or treated waste water, agricultural drainage or certain industrial wastes to that water may stimulate the growth of photosynthetic aquatic micro- and macro organisms in nuisance quantities. Phosphates also occur in both sediments and in biological sludges, both as precipitated inorganic forms and incorporated into organic compounds.

Chorophyll *a*

Chlorophyll is the green molecule in plant cells that carries out the bulk of energy fixation in the process of photosynthesis. Besides its importance in photosynthesis, chlorophyll is probably the most often used estimator of algal biomass in lakes and streams, at least in North America. Its popularity results from several considerations;

- It is a measure of algal biomass that is relatively unaffected by non-algal substances,
- It is a fairly accurate measure of measure of algal weight and volume , and,
- It acts as an empirical link between nutrient concentration and a number of important biological phenomena in lakes and reservoirs.

Chlorophyll itself is actually not a single molecule but a family of related molecules, designated chlorophyll *a, b, c* and *d*. Chlorophyll *a* is the molecule found in all plant cells and therefore its concentration is what is reported during chlorophyll analysis. Chlorophyll *d* is found only in marine red algae, but chlorophyll *b* and *c* are common in fresh water. The molecular structure of chlorophyll *a* and *b* consists like a ring like structure called a porphyrin and a long organic phytol "tail." In the centre of the porphyrin ring is a magnesium molecule. Chlorophyll *c* lacks the phytol chain. The relative concentration within the cell of these chlorophylls varies with the species of algae, but chlorophyll *a* is dominant in all eukaryotic algae and the prokaryotic blue-green algae (Cyanobacteria).

- **Calculating the Trophic State Index (TSI) Of Carlson**

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- where TSI is Carlson Trophic State Index and In is Natural logarithm

Carlson's TSI = [TSI (TP) +TSI (CA) +TSI (SD)]/ 3

- where TP and Chlorophyll-a in micrograms/l and SD transparency in meters

Table: 1 Showing Trophic Status Characteristics

Parameter	Measurement Unit	Test Method	Test Result
Total Phosphorous (as PO_4)	µg/l	IS3025(Part 31) 1988	660
Chlorophyll *a*	µg/l	APHA	630
Secchi disk depth	meter	G.R. Chatwal	1.0922

Table: 2 Showing Carlson Trophic State Index

Parameters	Carlson Trophic State Index Value
Chlophyll *a*	93.82545
Total phosphorous	97.76
Secchi disk	58.7305

Results and Discussion

Carlson's trophic state index uses three variables, chlorophyll pigment (CHL), secchi depth (SD), and total phosphorus (TP), independently estimate algal biomass. For evaluating Carlson›s trophic state index of Junona lake, three variables i.e. secchi disk, Chlorophyll *a* and total phosphorus were calculated individually. From the values Carlson's trophic state index for each variable was calculated. The range of the index is from approximately zero to 100. Carlson›s trophic state index from zero to 40 represent the oligotrophic state (clean water, little algae), from 40 to 50 indicate mesotrophic state (moderately clean water, some algae),from 51 to 65 indicate eutrophic state (blue green algae prevalent, swimming impaired) and from 65 and above hypereutrophic state(frequently noxious algae blooms). From the results it was found that trophic state index for secchi disk for Lake Junona was found to be 58.7305 which indicate the eutrophic condition of the lake. Trophic state index for chlorophyll *a* was found to be 93.82545 which indicate the hypereutophic condition. Trophic state index for total phosphorus was found to 97.76 which again categories the lake into hypereutrophic state. By averaging these three indices Carlson trophic state index was estimated to be 83.43865 which indicate hypereutrophic state i.e. poor water quality and frequently noxious algae blooms.

Conclusion

Junona Lake is a fresh water and historical lake of Chandrapur district. The lake is surrounded by dense Chichpalli forest and contains rich treasure of flora and fauna. It harbours varieties of birds including migratory birds. This place is known for its scenery lake, where various types of birds visit during different seasons around the year. The lake is affected by various activities like sewage discharge, encroachment, cultural misuse and daily manmade activities. Higher values of chlophyll *a and* total phosphorous and lower values of secchi disk categorizes the lake into hypereutrophic condition. The available nutrient supply is very high with high productivity. Carlson›s trophic state index categorizes the lake into hypereutrophic condition.

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