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Ecological Health Assessment of Surha Lake, India

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Abstract
Surha Lake, located in district Ballia ofstate Uttar Pradesh in India,is the source of livelihood for the local human population and habitatofa large number of birds and other species. The present study aims to assess the ecological health of the lake during wet and dry season in year 2014-15 using EHI, NSFWQI, CTSI, and SDI. The result indicates that the lake is in eutrophic state as during wet and dry season average CTSI was 76.30 and 79.49respectively,and average NSFWQI was reported in medium water quality range, which is not suitable for human use. The SDI was found to be 0.67 and 0.65 in wet and dry season i.e. poor diversity. The ecological health of the lake was also found to be in the medium category indicated by EHI of 2.5 in both seasons. Therefore, suitable conservative measures need to be adopted to recover the good ecological health of the lake.

Keywords: Surha Lake, NSFWQI, CTSI, SDI, EHI.

1. Introduction
Water is essential for the existence of life on earth. The availability of freshwater resources is important to meet the different water demands of rapidly growing population and economic activities of any country. India is naturally supported by a large number of freshwater bodies like rivers, lakes and wetland. In recent years, due to rapid industrialization and urbanization, the pressure on the water bodies has reached to a level, where their revival becomes difficult due to the significant reduction in their carrying capacity[1-2]. The assessment of ecological health and carrying capacity of such water bodies is, therefore, becoming important, not only for developing countries, but also for developing ones[3-5].In orderto restore the ecological health of such polluted water bodies a number of legislations and methodologiesare developed to classify the water bodies on the basis of ecological quality or integrity[6]. These legislative measures address the ecological health and define environmental water quality in an integrative approach using physico-chemical and biological parameters [7-8]. Thenecessity for such integrative methods to assess ecosystem quality is very essential for both scientific and stakeholders point of view[9]. Tofulfill the requirements, anecological health assessment index (EHI) has been developed based on water quality parameters and riparian vegetation [10], facilitatingthe better assessment of the effects of environmental alterations on a water body[7 & 11], and also assisting thepossible explanation to improve and understand the ecosystem functioning. The Surha Lake,located in district Ballia of U.P, is one of the important fresh water bodies in India and supports a large local population for their livelihood, fisheries and agriculture etc.The studies are available for identification of zooplanktons, molluscan fauna, diversity of aquatic insects [12-13], aqua status [14]and diversity of fishes [15] in catchment of Surha Lake. The biodiversity around the lake is reported to be in decline phase [15]. However, a comprehensive study is not available on the assessment of ecological health of Surha Lake. The present paper reports the results of EHI usingnational

sanitation foundation index (NSFWQI)[16], Carlson's trophic state index (CTSI)[17]andSimpson diversity index (SDI)[9].

2. Materials and Methods

2.1. Details of Study site

Surha Lake is located in theIndo-gangetic plain, in the area of Jai Prakash Narayan Bird Sanctuary of district Ballia in U.P, India (Figure 1). It is an ox-bow lake at latitude 26°40' to 26°42' E and longitude 84°11' to 84°14' Nwithin a catchment area of about 34.33 km^2 in the rainy seasonwhich shrinks to about 11.23 km^2in summer. It receives major water supply through three small streams Gararai, Madha and Kateharnalawhich carry water from Ganga and Saryu River (Ghaghra River). The average annual rainfall in this area is about 1000 mm withminimum temperature of4°C in the winter and maximum of 43°C in summer. The lake is surrounded by extensive agricultural land. The main source of income for thelarge local population of the district Ballia is fisheries in this lake. The physiochemical analysis of the Surha Lake has been carried out at eleven sampling locations during pre and the post monsoon season (2014–2015).A location map of the Surha Lake along with sampling locations is shown in Figure 1 and the details are given in Table 1.

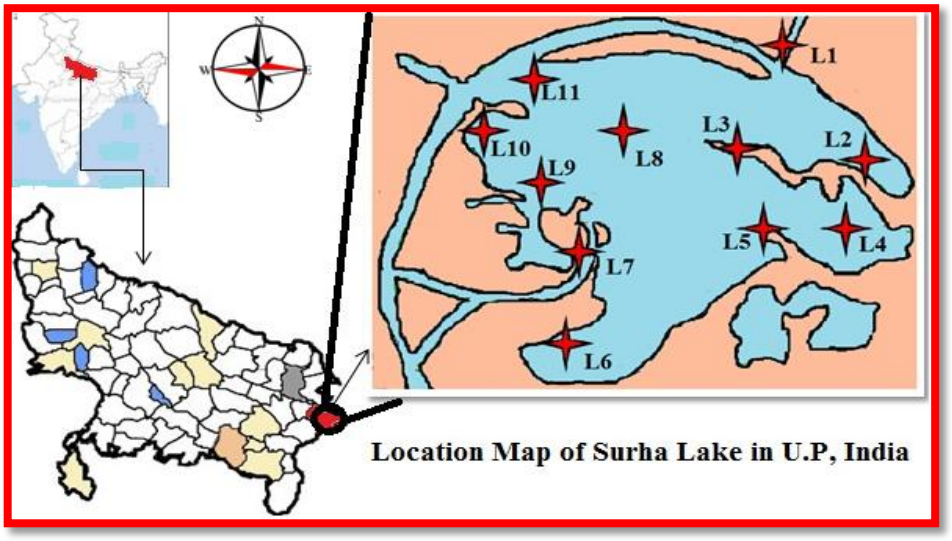

Figure 1: Map of sampling locations in Surha Lake of U.P, India

Table 1. Details of sampling locations

S. code.	Sampling locations	Latitude	Longitude
L1	Maritar	84°19'11″	25°86′11″
L2	Rajpur	84°20′30″	25°84′80″
L3	Katharnala merge point 1	84°18′20″	25°85′11″
L4	Narayanpur	84°20′31″	25°83′81″
L5	Katharnala merge point 2	84°18′90″	25°83′70″
L6	Fulwaria	84°16′50″	25°82′41″
L7	BhikampurMedhanala merge point	84°16′81″	25°85′31″
L8	Middle of lake	84°17′10″	25°85′30″
L9	Basantpur	84°16′11″	25°84′51″
L10	Shivpur	84°15′30″	25°85′21″
L11	Kaithauli	84°15′91″	25°85′90″

2.2. Data collection and analysis

For the assessment of ecological health of Surha Lake, collection of water samples and assessment of riparian vegetation was carried out during wet and dry season in the year 2014-15. At each sampling site secchi disc, pH, dissolve oxygen (DO) and surface water temperature (WT) was directly measured with portable equipments. The sub surface water samples were collected and preserved at 4^{o}Cfor laboratory analysis of water quality parameters like turbidity, chlorophyll (CA), total solid (TS), nitrate (NO_3), biochemical oxygen demand (BOD), and total coli form as per the APHA [18] methods and the results are shown in Table 2 in terms of the mean concentration and standard deviation (SD), of lake water quality.

Table 2. Mean, standard deviation, units and analysis methodology of water quality parameters

S. No.	Parameters	Units	Concentration Mean ± SD (Wet season)	Concentration Mean ± SD (Dry season)	Analytical methods
1.	CA	µg/l	56.79±5.45	68.12±4.87	Acetone Extraction Spectrophotometric
2.	Secchi disk	m	0.55±0.08	0.40±0.11	Using a Secchi Disk
3.	WT	^{0}C	17.69±0.91	25.18±1.09	Thermometric
4.	TS	mg/l	218.56±34.32	230.56± 41.61	Filtration and Gravimetric
5.	pH	−	7.69±0.22	7.62±0.31	pH meter
6.	NO_3	mg/l	3.77±0.32	4.77±0.32	Hach Spectrophotometric
7.	DO	mg/l	7.86±0.34	7.24±0.50	Electrometric DO meter
8.	BOD	mg/l	5.73±0.53	5.79±0.48	5 days incubation, 20°C
9.	Phosphate	mg/l	0.31±0.03	0.48± 0.03	Hach Spectrophotometric
10.	Turbidity	NTU	3.64±1.12	6.91±1.38	Nephelometric
11.	Total coliform	MPN/100 ml index	14.82±1.40	17.00±0.00	Elevated Temperature Fermentation

For assessment of riparian vegetation,a total 80 plots, each of 1m*1m were selected at a distance of 40 m, from the four sides of the lake and different types of vegetation plants were counted. The riparian vegetation includes trees, climbers, herbs, shrubs and grasses as shown in Table 3.The plants were identified with the help of literature [19-21].

2.3. Ecological health Assessment Methodology

It consists of evaluation of different indices like NSFWQI, CTSI and SDI, which are used to compute the overall EHI. The water quality data obtained during laboratory testing were used to evaluate NSFWQI and CTSI while the data of riparian vegetations were converted into a sub-index i.e. SDI, shown in Table 5. The methodology to evaluate overall EHI and its sub-indices (i.e. NSFWQI, CTSI and SDI) are discussed as below:

2.3.1. National sanitation foundation water quality index (NSFWQI)

It is an excellent management and general administrative tool, widely applied to different water bodies all over the world for the classification of water quality [16, 22-23] and is mathematically expressed as:

$$NSFWQI = \sum_{i=1}^{p} W_i I_i \quad \text{Equation 1}$$

Where, W_i is the weightage factor of the i^{th} water quality parameter;I_i is the sub-index for i^{th} water quality parameter; and p is the total number of water quality parameters. The NSFWQI that ranges from 0-100 classify water quality as: very bad (0-30); bad (30-50); medium (50-70); good (70-90); best (90-100).

Table 3. Biodiversity of riparian vegetation

S. No.	Non Woody plants	Abundance ratio		Woody plants	Abundance ratio	
		Wet	Dry		Wet	Dry
1.	*Dhaturastamonium*	0.09	0.09	*Dalbergiasissoo*	0.05	0.05
2.	*Calotropisprocera*	0.09	0.11	*Zizypusjujuba*	0.09	0.09
3.	*Occimum sanctum*	0.18	0.11	*Mangiferaindica*	0.53	0.53
4.	*Ipomoea fistulosa*	0.20	0.54	*Acacia nilotica*	0.11	0.11
5.	*Solanum nigrum*	0.44	0.14	*Prosopisjuliflora*	0.09	0.09
6.	*Hibiscus rosasinenesis*	–	0.02	*Ficusreligiosa*	0.02	0.02
7.	*Loffaaccutangula*	0.25	0.10	*Azzadirectaindica*	0.07	0.07
8.	*Memordicacharantia*	0.04	0.10	*Ficusinfectoria*	0.02	0.02
9.	*Vicia sativa*	0.60	0.65	*Ficusbengaliensis*	0.02	0.02
10.	*Basellarubra*	–	0.10	*Polyalthialongitolia*	0.02	0.02
11.	*Cuscutareflexa*	0.10	0.05	–	–	–
12.	*Cynodondectylon*	0.45	0.33	–	–	–
13.	*Sacchrummunja*	0.03	0.03	–	–	–
14.	*Mollingocerviaha*	0.25	0.11	–	–	–
15.	*Iseilemalaxum*	0.14	0.04	–	–	–
16.	*Saccharumsponitaneum*	0.05	0.05	–	–	–
17.	*Orizarupipogan*	0.12	0.28	–	–	–
18.	*Aristidaadescenionis*	–	0.09	–	–	–
19.	*Brachiariaremosa*	–	0.07	–	–	–
20.	*Chenapodium album*	0.57	0.67	–	–	–
21.	*Melilotusindica*	0.19	0.20	–	–	–
22.	*Acyranthesaspera*	0.05	–	–	–	–
23.	*Amaranthustricolour*	0.05	–	–	–	–
24.	*Rumexdentatus*	0.14	0.13	–	–	–

- Total numbers of non woody species during wet and dry season were 350 and 226 respectively; and total number of woody species during both seasons was 57.
- Wet season: SDI is 0.67; SI is 0.33; and SRI is 3.10
- Dry season: SDI is 0.65; SI is 0.35; and SRI is 3.11

2.3.2. Carlson's Trophic state index (CTSI)

The trophic state of SurhaLake was determined by evaluating the CTSI[17] using the following mathematical equations based on data of CA, SD and TP:

TSI (CA) = 9.81ln CA (ug/L) +30.6……. Equation 2
TSI (SD) = 60-14.41ln SD (m) …… Equation 3
TSI (TP) = 14.42 In TP (ug/l) + 4.15…….... Equation 4
CTSI = [TSI (TP) +TSI (CA) +TSI (SD)]/3……. Equation 5

Where, the TSI (CA) is Carlson sub trophic index of chlorophyll; TSI (SD) is Carlson sub trophic index of secchi disc; and CTSI (TP) is Carlson sub trophic index of total phosphate.The CTSI ranges from 0-100 and classifies trophic state of the water body as: oligotrophic (0-40); mesotrophic (40-50); eutrophic (50-80); and hypereutrophic (80-100).

2.3.3. Simpson Diversity index (SDI)

SDI is measure of species biodiversityand is evaluatedto quantify the species diversity of a habitatin a geographical area[24]. It is mathematically expressed as 1-D, where D is evaluated by the equation:

$D = \frac{\sum n(n-1)}{N(N-1)}$ ..... Equation 6

Where, D is diversity index or Simpson index (SI); n is the total number of individuals of a species; and N is the total number of all species collected. The SDI range from 0-1 andclassifies diversity as: highest or rich diversity (1); and poor diversity (0). The SI range from 0-1and classifies diversity as poor diversity (1); highest or rich diversity (0). In addition, biodiversity has also been defined by Simpson reciprocal index (SRI) which can be evaluated as 1/D. The maximum range of SRI that defines the rich diversity is the maximum number of species considered in the study and lowest is zero for poor diversity.

2.3.4. Overall Ecological health index (EHI)

EHI was proposed by Joshi [25], to assess the ecological health of a water bodybased on NSFWQIand CTSI. Thereafter, the EHI equation was modified andSDI was added to WQI & CTSI,as reported by Yadav et al. [9].The results of WQI & CTSI were converted into EHI scores as shown in Table 4.

Table 4. EHI based on WQI & CTSI [9]

NSFWQI	Carlson's TSI	EHI score	EHI Range	Status
0-25	10-30	1	0-1	Excellent
25-50	30-50	2	1-2	Good
50-70	50-70	3	2-3	Medium
70-90	70-90	4	3-4	Poor
90-100	90-100	5	4-5	Very poor

The resulting scores **(**EHI of NSFWQI & CTSI scores) and SDI were used to evaluate EHI mathematically as shown:

EHI = [EHI (CTSI) + EHI (WQI) + 1/ SDI]/3..... Equation 7

Where, EHI (CTSI) is the score for CTSI; EHI (WQI) is the score for WQI. The EHI range from 0-5 and classifies ecological health of a water body as: excellent (0-1); good (1-2); average (2-3); poor (3-4); and very poor (4-5).

3. Results and Discussions

The average SDI during wet and dry season was found as 0.67 and 0.65 respectively, shown in Table 3. The NSFWQI, CTSI and EHI at all locations in wet and dry season, 2014-15 for Surha Lake are given in Table 5 andEHI has been graphicallyshown in Figure 2. The NSFWQI at all sampling location during wet season was found in the range of 50-70 i.e. medium water quality. While the similar results were obtained during the dry season except at L3, L5 and L7 locations which were found of bad water quality (range 30-50). Further, the CTSI at all locations during wet and dry season was found in the range 60-80i.e. eutrophic.While CTSI at L3, L5 and L7 locations were found to bein eutrophic range in the wet season and hypereutrophic range in dry season.However, the average NSFWQI in wet and dry season were 55.90 and 51.71,and CTSI was 76.3 and 79.49, respectively. The EHI at all sampling locations during wet season was found in range of 2-3 i.e. medium ecological health, while in the dry season, it was also in the same range except, at L3, L5 and L7 locations having poor ecological health.The overall EHI of the lake during the entire season was found to be inmedium ecological health.It has also been observed that the higher value of NSFWQI and CTSI in the dry season than in the wet season. The reason behind the increase in pollution level might be due to dilution of the lake during the monsoon season with the addition of agricultural runoff and water supply through the various nallas carrying waste from residential areas in Ballia district. Therefore, the sampling location L3, L5 and L7 which are at merge site of nallas show more variation in water pollution.

Table 5. Results of NSFWQI, CTSI and EHI at all sampling locations in Surha Lake

Sampling locations	NSFWQI		EHI of NSFWQI score		CTSI		EHI of CTSI score		SDI		EHI		Health status	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
L1	57.40	52.93	3	3	75.34	79.23	3	3	0.67	0.65	2.50	2.51	Medium	Medium
L2	56.97	52.94	3	3	75.33	79.32	3	3	0.67	0.65	2.50	2.51	Medium	Medium
L3	53.22	49.68	3	4	78.63	81.84	3	4	0.67	0.65	2.50	3.18	Medium	Poor
L4	57.08	52.51	3	3	76.51	78.52	3	3	0.67	0.65	2.50	2.51	Medium	Medium
L5	53.26	49.25	3	4	78.82	82.77	3	4	0.67	0.65	2.50	3.18	Medium	Poor
L6	56.64	52.77	3	3	76.25	78.53	3	3	0.67	0.65	2.50	2.51	Medium	Medium
L7	52.41	49.40	3	4	76.95	81.71	3	4	0.67	0.65	2.50	3.18	Medium	Poor
L8	57.00	51.29	3	3	75.33	76.58	3	3	0.67	0.65	2.50	2.51	Medium	Medium
L9	56.78	52.80	3	3	75.38	78.42	3	3	0.67	0.65	2.50	2.51	Medium	Medium
L10	56.74	52.55	3	3	75.47	78.58	3	3	0.67	0.65	2.50	2.51	Medium	Medium
L11	57.43	52.65	3	3	75.34	78.83	3	3	0.67	0.65	2.50	2.51	Medium	Medium
Average	55.90	51.71	3	3	76.30	79.49	3	3	0.67	0.65	2.50	2.50	Medium	Medium

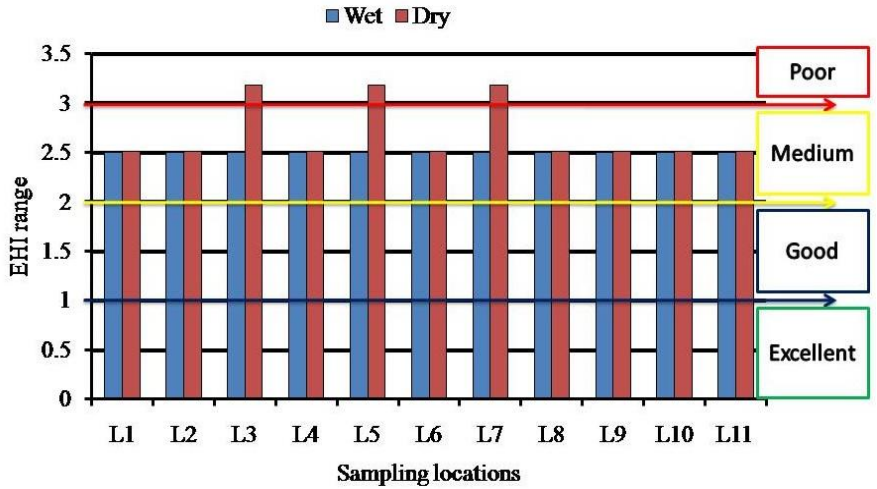

Figure 2: EHI at all sampling locations

On the basis of results obtained, it has been observed that the biodiversity of riparian vegetation around the lake is poor, which is supported by the water quality of the lake i.e. in the medium range [9]. The water quality cannot be used for drinking. Being in eutrophic state, the lake is largely supported by exotic species and not the useful life supporting vegetation, providing poor services to human kind. So, it is recommended that the suitable conservation measures like desilting, dredging, dewatering etc. could be adopted to bring the ecological health of lake in good state.

Conclusions

The study area, Surha Lake has been selected to assess the ecological health during wet and dry season due to its significance for the local public and tourists. The water quality of the lake was found to be not suitable for drinking and bathing as the average NSFWQI evaluated were in the range 55.90 and 51.71 in wet and dry season respectively. Also, the average CTSI was in the range of 60-80 i.e. eutrophic state which indicates the high productivity and increased algal biomass. The SDI for riparian vegetation was found as 0.67 and 0.65 i.e. biodiversity around the lake is poor. The ecological health of the lake was found to be as 2.50 in both seasons, i.e. in the medium category of EHI. Therefore, the suitable conservative measures are required to restore its health. It has been recommended that the concerned authority is suggested to prepare and implement a proper conservation plan, including the measures like desilting, dredging, dewatering and direct flow of nutrients as runoff from the catchment should be checked by constructing a channel so that wastescould be prevented to reach directly to the lake. The present study would be valuable for stakeholders and policy makers to stage-manage the conservative measure to recover the good ecological health of the Surha Lake. The study also illustrates the use of EHI as a valuable methodology for assessment of ecological health of a water body.

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