Influence of physicochemical water quality on aquatic macrophyte diversity in seasonal wetlands

S. Rameshkumar^{1,2} · Kalidoss Radhakrishnan³ · S. Aanand³ · R. Rajaram²

Received: 1 June 2016 / Accepted: 27 December 2018 / Published online: 3 January 2019
© The Author(s) 2019

Abstract

The present study aims to assess the physicochemical parameters and distribution of aquatic macrophytes of seasonal wetlands flowing into the coast of Palk Bay, southeast coast of India. We tested the hypothesis whether there is any statistically significant difference in physicochemical parameters and macrophyte communities among study location. Water quality parameters such as temperature, pH, salinity, TDS, DO, turbidity and electrical conductivity, and the aquatic macrophyte diversity were estimated in all three stations. One-way analysis of variance (ANOVA) and Pearson correlation were employed to assess the relationship between water quality parameters, and the water quality index (WQI) was computed to assess the status of water conditions. The ANOVA revealed that there is no statistically significant difference ($p > 0.05$) in water quality parameters among the three stations. The lowest f value 0.180 was recorded for pH and highest of 2.478 for TDS. A total of 7 submerged macrophytes, namely *Ceratophyllum demersum* L., *Egeria densa* Planch., *Lemna minor* L., *Marsilea quadrifolia* L., *Sagittaria guayanensis* and *Isoetes riparia*; 6 rooted floating weeds, namely *Potamogeton nodosus* Poir., *Nymphaea odorata* Aiton., *Nelumbo nucifera* Gaertn., *Myriophyllum spicatum* L. and *Hydrilla verticillata*; 1 floating, namely *Eichhornia crassipes* Kunth; and 1 rooted macrophyte, namely *Najas minor*, were recorded in Tharavai wetland. A deplorable water quality condition was found in the selected study area, which was evidenced from WQI ($> 76\%$). Of this, submerged aquatic vegetation is used as the water quality key indicator, and it exists where there is a better water quality condition. The EC, TDS and turbidity negatively influenced the aquatic macrophytes. Therefore, there is a need for some adaptation measure to maintain the water quality for more extended period for domestic use.

Keywords Seasonal wetland · Physicochemical parameters · Water quality index · Macrophytes · Wetland ecosystem

Introduction

Wetlands are essential element in biological diversity and ecosystem function. This utility performance varied by the hydrological and ecosystem functions (Banner and MacKenzie 2000). This is a most productive system which carried out critical regulatory functions of hydrological process within the watershed (Banner et al.

1988). In natural condition, wetlands provide essential habitat for many wildlife such as fish species, animals, birds, amphibians and mammals, plant species (macrophytes, plankton diversity) and focal ecosystem for many other (Hernandez and Mitsch 2007; Palit and Mukherjee 2012). Aquatic plants can act as measurable indicators of the ecological conditions of surface waters. Notably, the submerged species strongly dependent on water quality have proved to be vulnerable to changes in the aquatic environment (Robach et al. 1996; Dawson et al. 1999). The light transmission decreased by an increase in water turbidity, which leads to changes in community structure and reduction in vegetation diversity and depth (Middleboe and Markager 1997; Duarte et al. 1986; Chambers and Kalff 1985). Thus, submerged macrophytes are considered to be suitable eutrophication indicators and are sensitive to local environmental conditions (Dennison et al. 1993; Lacoul and Freedman 2006; Sondergaard

✉ S. Rameshkumar
rameshkumarbotany@gmail.com

¹ Department of Environmental Sciences, Madurai Kamaraj University, Madurai, Tamil Nadu 625 021, India

² Present Address: Department of Marine Science, Bharathidasan University, Tiruchirapalli, Tamil Nadu 620 024, India

³ Fisheries College and Research Institute, Thoothukudi, Tamil Nadu 628 008, India

et al. 2010). Aquatic vegetation can also influence the abiotic conditions (Flessa 1994; Moore et al. 1994; Barko et al. 1991) and influence wetland biota across multiple trophic levels (Norlin et al. 2005) by providing both habitat and food. The hydrodynamics of the ecosystem varied with soils, topography, climate, hydrology, water chemistry, vegetation and other factors including human disturbance. The fast development of industrial, urban and agricultural activities contributes to the significant alteration and destruction of wetland (Banner and MacKenzie 2000). Present day, the importance of wetlands has focused considerably due to rich potential production, untapped resources and productive nourishment resources for many other organisms (Williams 1990; Secmen and Leblebici 1996). However, the aquatic macrophytes also influence the water quality changes and being used as bio-indicator of pollution (Tripathi and Shukla 1991). The present study aims to investigate the status of the physiochemical parameters and its influences of aquatic macrophytes in seasonal wetland ecosystem in the south-east coast of India.

Materials and methods

Description of the study area

Tharavai wetland is one of the essential and largest freshwater seasonal wetland ecosystems in Ramanathapuram district of Tamil Nadu, southeast coast of India (Fig. 1), which receives water mainly from precipitation. Water is available throughout the year and is mainly used for bathing, washing clothes, sheep grazing, irrigation and fishing by local folks. This wetland originates from Regunathapuram village near to Ramanathapuram town, and it has a length of 35–40 km and breadth of 100–200 m up to Pirappanvalasai village. Then it flows in the small channel (30–40 m breadth) and finally ends in Palk Bay coast. The total area of wetland ecosystem is 2425.6 ha (245.5 sq. km)—a total stretch of 15 km of Tharavai wetland located along the coastal villages like Thamaraiikulam, Ammapattinam, Pudumadam, Nariyurani, Katukkavalasai, Notchiyurani and Manankudi. Of this, three sites were selected for sampling, namely Thamaraiikulam, Pudumadam and Manankudi.

Station 1 is the Thamaraiikulam site located 2.5 km away from Pudumadam village. The breadth is 100–200 m, and

Fig. 1 Sampling stations in Tharavai wetland, Ramanathapuram district of India

the depth is 5–10 feet. The northern part of this station is occupied by agricultural lands mainly paddy field, cereals and coconut cultivation. Station 2 is Manankudi village is situated in the eastern side of Pudumadam village and ending in Pirappanvalasai village. The length of this station is 4 km long, and breadth is 100–200 m. The depth varies between 5 and 10 feet. However, the northern part of the Manankudi is also covered by agricultural lands, mostly paddy fields. Station 3 is situated in Pudumadam: The breadth varies from 100 to 200 m, and the depth varies between 5 and 10 feet. This station is situated in the southern part of wetland, and the agricultural lands cover the northern part. The bank of this wetland is maximum covered by *Acacia* sp. and *Cyperus* sp., and some other varieties of grasses (Poaceae family members) were also present.

Physicochemical parameters analysis

To estimate the physicochemical water quality, the samples were collected from the selected study area (north and south direction) fortnightly from February 2010 to January 2011. Temperature, pH and salinity were observed in situ using a mercury-in-glass thermometer, portable pH meter (Eutech, Japan) and refractometer (ATAGO, Japan), respectively. The dissolved oxygen (DO) was determined by using Winkler's method (APHA 1998). Turbidity (NTU) and conductivity were measured using a TN-100 turbid meter by Eutech Instruments, Singapore, and conductivity meter, model 1601, respectively. Total dissolved solid was described using the method by Goel and Trivedy (1987).

Identification of wetland flora

The aquatic plants were collected from the study area; it was preserved by using formalin in polythene bags. All the aquatic hydrophytes were identified using standard protocols published in books and literature (Nair and Henry 1983; Henry et al. 1987, 1989; Matthew 1991; Saini et al. 2010).

Statistical analysis

The statistical tools such as ANOVA, correlation and water quality index (WQI) of physicochemical parameters were used. Pearson correlation (r) test was carried out to identify the association between pairs of variables for sampling stations and the number of species. The water quality index is a fundamental mathematical tool for calculating a single value from multiple test results. The results of an index represent the level of water quality in a given water basin such as lake, river, stream and ponds too (Akkaraboyina and Raju 2012). WQI attempts to provide a mechanism for presenting a cumulatively derived, numerical expression defining a certain level of water quality (Miller et al. 1986). In this

study, seven parameters were chosen to calculate the water quality index, using the standards of drinking water quality recommended by BIS (1993) and ICMR (1975).

Water quality index of wetland water is calculated by adopting Chatterjee and Razuddin (2002) method, and the formula is given below.

$$WQI = \frac{\sum_{n=1}^n q_n w_n}{\sum_{n=1}^n w_n}$$

where $q_n = 100 [V_n - V_{io}] / (S_n - V_{io})$, q_n quality rating for the i th water quality parameter; V_n estimated value of the i th parameter at a given sampling station; S_n standard permissible value of i th parameter; V_{io} ideal value of i th parameter in pure water (pH 7, DO = 14 mg/l and for other parameter = 0); w_n unit weight for i th parameter; S_n standard value for i th parameter; K constant for proportionality.

Results and discussion

Physicochemical parameters are considered as one of the most important factors that are capable of influencing the aquatic environment and have shown wide temporal and spatial differences. The statistical variations in the water quality parameters for the seasonal wetlands are presented in Table 1. Temperature is one of the controlling factors, which alter the functions of the aquatic ecosystem, and it influences the growth and distribution of flora and fauna (Dwivedi and Pandey 2002; Singh and Mathur 2005; Jalal and Sanalkumar 2012; Tank and Chippa 2013). Temperature has been determined using the pattern of distribution of macrophytes, thereby influencing the productivity and species composition, and this is varied with depth, season and geographical location. The temperatures were consistent between the wetland to wetland; it was ranged from 30.78 ± 0.45 to 31.57 ± 0.32 °C with this minimum and maximum being recorded in station 2 and station 1, respectively. It is not easy to discriminate the difference between the effects of environmental variables on the distribution of aquatic macrophytes. Human effect on the environment and natural activities switches the structure of aquatic macrophytes. Eutrophication affects the concentration of distribution, diversity and density and productivity of macrophytes. The pH, which regulates the acidic or basic characteristics, is a vital property of any aquatic ecosystem since all the biochemical functions and retention of physicochemical attributes of the water are greatly depending on pH of the surrounding environments (Jalal and Sanalkumar 2013). Most of the similar studies recommended that water samples are slightly alkaline due to the presence of carbonates and bicarbonates (Tank and Chippa 2013; Gopalkrushna 2011;

Table 1 Physicochemical characteristics of Tharavai wetland at selected sampling stations

Parameters	Station 1			Station 2			Station 3			F value	P value
	Min	Max	(Mean $\pm$ SD)	Min	Max	(Mean $\pm$ SD)	Min	Max	(Mean $\pm$ SD)		
Temperature ($^{\circ}$ C)	30.5	32.7	31.57 $\pm$ 0.32 ^a	29.5	32.5	30.78 $\pm$ 0.45 ^b	30.0	32.0	31.00 $\pm$ 0.34 ^a	1.106	0.041
pH	7.0	7.7	7.32 $\pm$ 0.11 ^a	7.2	7.6	7.43 $\pm$ 0.07 ^a	7.1	7.6	7.33 $\pm$ 0.09 ^a	0.180	0.065
Salinity (ppt)	0.7	1.6	1.13 $\pm$ 0.15 ^a	0.8	0.9	0.82 $\pm$ 0.02 ^{ab}	0.8	1.0	0.88 $\pm$ 0.03 ^{ab}	1.181	0.074
Conductivity (ms/cm)	355.0	586.0	435.33 $\pm$ 43.88 ^a	348.0	372	355.75 $\pm$ 4.4 ^{ab}	350.0	378	361.75 $\pm$ 4.15 ^b	1.129	0.046
TDS (mg/l)	249.0	320.0	275.42 $\pm$ 12.77 ^a	214.0	254.5.0	230 $\pm$ 7.56 ^{ab}	223.0	250.0	238.17 $\pm$ 4.53 ^{ab}	1.004	0.056
DO (mg/l)	7.8	8.4	8.05 $\pm$ 0.1 ^a	7.7	8.4	7.97 $\pm$ 0.1 ^a	7.4	8.1	7.88 $\pm$ 0.1 ^a	2.478	0.092
Turbidity (NTU)	3.7	6.6	5.38 $\pm$ 0.53 ^a	3.7	6.0	4.57 $\pm$ 0.4 ^b	3.9	6.0	4.63 $\pm$ 0.37 ^b	0.370	0.086

Different letters in a row have statistical significance at 0.05 level

Verma et al. 2012). This can be toxic when it is more than the desirable limit and can influence the ammonia, hydrogen sulfide and heavy metals (Klontz 1993). The higher level of pH can affect the aquatic life at a certain level; however, an optimum level of 7–8.5 was recommended by BIS (2003). In the present study, the pH was ranged from 7.32 $\pm$ 0.11 to 7.43 $\pm$ 0.07 with lowest and highest being recorded in station 1 and station 2, respectively. This finding was supported by Bala and Mukherjee (2010) who observed the pH 5.34–8.67 in Nadia wetlands of West Bengal. The minimum concentration of salinity 0.82 $\pm$ 0.02‰ was recorded in station 2, and the maximum of 1.13 $\pm$ 0.15‰ was recorded in station 1. The salinity is the main physical parameter that can be attributed to the biological diversity, which acts as a limiting factor and influences the distribution of aquatic organisms (Kouwenberg 1994; Neelam and Nair 1997; Chandramohan and Sreenivas 1998; Balasubramanian and Kannan 2005; Sridhar et al. 2006). Electrical conductivity is the measure of the ability of an aqueous solution to transmit an electric current in the aquatic environments (Lodh et al. 2014). It was found to be lowest of 355.75 $\pm$ 4.4 ms/cm in station 2 and highest of 435.33 $\pm$ 43.88 ms/cm in station 1. Bala and Mukherjee (2010) supported this study results. Total dissolved solids (TDS) are the materials dissolved in water

like bicarbonate, sulfate, phosphate, nitrate, calcium, magnesium, sodium and organic ions. In the present study, TDS ranged from 230 $\pm$ 7.56 to 275.42 $\pm$ 12.77 ms/cm with the minimum in station 2 and maximum recorded in station 1, which is influenced mainly by the urbanization, fertilization runoff (agricultural) and domestic effluents. Present findings correlated with the earlier reports (Bala and Mukherjee 2010). Dissolve oxygen (DO) regulates that health of the ecosystems refers to the volume of oxygen present in the water body. It is an important water quality parameter to maintain because of its significant biological and physicochemical property of surrounding water. Oxygen enters into the water by aerial diffusion and as a photosynthetic by-product of aquatic plants (Kotadiya Nikesh and Acharya 2014). The DO depends upon the temperature, salinity and pressure of the water. The DO level indicates the degree of pollution in the water bodies (Gopalkrushna 2011). A minimum DO of 5 mg/l is recommended (BIS/ICMR). In the present study, a minimum of 7.88 $\pm$ 0.1 mg/l was recorded in station 3, whereas a maximum of 8.05 $\pm$ 0.1 mg/l was recorded at station 1. However, in the present study, the dissolved oxygen was found to be more than the required limit and has negative influences toward these wetland ecosystems. Turbidity is the expression of optical property by

Table 2 Pearson correlation coefficients matrix between the physicochemical parameters of study area

Parameters	Temperature ($^{\circ}$ C)	pH	Salinity (ppt)	DO (mg/l)	Conductivity (ms/cm)	TDS (mg/l)	Turbidity (NTU)	Species nos.
Temperature ($^{\circ}$ C)	1							
pH	−0.325	1						
Salinity (ppt)	0.628	−0.64	1					
DO (mg/l)	−0.04	−0.139	0.433	1				
Conductivity (ms/cm)	0.58	−0.575	.987**	0.526	1			
TDS (mg/l)	0.638	−0.654	.987**	0.513	.989**	1		
Turbidity (NTU)	0.475	−0.574	.975**	0.474	.984**	.956**	1	
Species nos.	−0.482	0.211	−0.803	−0.515	−.877*	−.824*	−.858*	1

**Correlation is significant at the 0.01 level (two-tailed)

*Correlation is significant at the 0.05 level (two-tailed)

which light is scattered by the colloidal particles present in the water. Phytoplankton, microscopic organisms, clay and other organic matter make a lake turbid (Das and Shrivastva 2003). In the present study, the minimum concentration of 4.57 ± 0.4 NTU was recorded in station 2 and the maximum of 5.38 ± 0.53 NTU was recorded in station 1, which was supported by Bala and Mukherjee (2010).

The correlation matrix of mean water quality parameters was computed to assess the relationship between the stations. The salinity was strongly positively correlated with electrical conductivity ($r=0.987$), total dissolved solids ($r=0.987$) and turbidity ($r=0.975$) at $p<0.01$ level. The conductivity was strongly positively correlated with TDS ($r=0.989$) and turbidity ($r=0.984$) with a statistical significance level of 0.01, whereas electrical conductivity was negatively correlated with the distribution of species ($r=-0.877$) at $p<0.05$ level. Total dissolved solids were strongly correlated with turbidity ($r=0.956$) at $p<0.01$ level and negatively correlated with the distribution of species numbers ($r=-0.824$) with a statistical significance level of 0.05 level. Turbidity was also negatively correlated with the number of species ($r=-0.858$) with statistically significant at the 0.05 level (Table 2). One-way analysis of variance (ANOVA) was

conducted to explore the relationship of water quality in the different study areas. The statistically significant difference at a $p<0.05$ level was noted in temperature, conductivity and total dissolved solids for the three stations, whereas no significant difference at the $p>0.05$ level was observed for the parameters such as pH, salinity, dissolved solids and turbidity at all stations (Table 1).

Our results highlight that there is considerable variability in the aquatic habitat of seasonal wetlands. Physicochemical factors that alter the habitat structures differences among wetland classes are recognized, as are biogeographic factors significant that structuring wetland communities on broad spatial scales (Brazner and Beals 1997; Loughheed et al. 2001). The strong relations between common plant species and water properties potentially impact the changes in aquatic ecosystems (Naiman et al. 1993), and we made comparisons only among the water parameters and aquatic vegetations of the seasonal wetlands. In the present study, a total of 15 aquatic plant species were recorded; these species belong to 7 classes, 9 orders and 12 families. A total of 7 submerged macrophytes, namely *Ceratophyllum demersum* L., *Egeria densa* Planch., *Lemna minor* L., *Marsilea quadrifolia* L.,

Table 3 List of aquatic plants species that were recorded in the seasonal wetlands

S. no	Scientific name	Family	Common name	IUCN red list	Type	St-1	St-2	St-3
1	<i>Ceratophyllum demersum</i> L.	Ceratophyllaceae	Rigid hornwort	Least concern (stable)	Submerged	✓	✓	✓
2	<i>Egeria densa</i> Planch.	Hydrocharitaceae	Egeria	–	Submerged	✓	✓	✓
3	<i>Lemna minor</i> L.	Araceae	Common duckweed	Least concern (un known)	Submerged	×	✓	×
4	<i>Marsilea quadrifolia</i> L.	Marsileaceae	Water shamrock	Least concern (unknown)	Submerged	×	✓	×
5	<i>Potamogeton nodosus</i> Poir.	Potamogetonaceae	Loddon pondweed	Least concern (un known)	Rooted and floating	×	✓	×
6	<i>Nymphaea nouchali</i> Burm. f	Nymphaeaceae	Red or blue water lily	Least concern (un known)	Submerged	×	×	✓
7	<i>Nymphaea odorata</i> Aiton.	Nymphaeaceae	Indian lotus	–	Rooted and floating	×	×	✓
8	<i>Nelumbo nucifera</i> Gaertn.	Nelumbonaceae	White water lily	–	Rooted and floating	×	×	✓
9	<i>Myriophyllum spicatum</i> L.	Haloragidaceae	Spiked watermilfoil	Least concern (un known)	Rooted and floating	✓	✓	✓
10	<i>Hydrilla verticillata</i>	Hydrocharitaceae	Indian star grass	Least concern (unknown)	Rooted and floating	✓	✓	✓
11	<i>Chara globularis</i>	Characeae	Muskgrass or skunweed	–	Rooted and floating	✓	✓	✓
12	<i>Sagittaria guayanensis</i>	Alismataceae	Arrowhead	–	Submerged	×	✓	✓
13	<i>Isoetes riparia</i>	Isoetaceae	Quillwort	–	Submerged	✓	×	✓
14	<i>Eichhornia crassipes</i> Kunth	Pontederiaceae	Water hyacinth	–	Floating	×	×	✓
15	<i>Najas minor</i>	Hydrocharitaceae	Slender naiad	Least concern (un known)	Rooted	✓	✓	✓
Total number of species in each stations						7	10	12

Table 4 Water quality index (WQI) and status of water quality status

Water quality index	Water quality status
0–25	Excellent water quality
26–50	Good water quality
51–75	Poor water quality
76–100	Very poor water quality
> 100	Unsuitable for drinking

Sagittaria guayanensis and *Isoetes riparia*; 6 rooted floating weeds, namely *Potamogeton nodosus* Poir., *Nymphaea odorata* Aiton., *Nelumbo nucifera* Gaertn., *Myriophyllum spicatum* L. and *Hydrilla verticillata*; 1 floating, namely *Eichhornia crassipes* Kunth; and 1 rooted macrophyte, namely *Najas minor*, were recorded in Tharavai wetland (Table 3). Adhishwar and Choudhary (2013) observed 137 macrophytes belong to 50 families in Gogabil lake wetland, Bihar, India. The submerged and free-floating hydrophytes have a higher capacity to remove large concentrations of nutrients (Sooknah and Wilkie 2004; Greenway 1997). Water hyacinth can be used to remove the higher amount of nitrogen concentration per square meter of growing area and is the fastest growing plant in the wastewater (Rakocy and Allison 1981). Free-floating macrophyte of *Eichhornia crassipes* Kunth was present in Thamaraikulam station. It has positive and negative impacts on the ecosystem and water quality. It affects the diminished flow of water, degrades the water quality by air water interface and greatly reduces the dissolved oxygen concentration in the water bodies (Penfound and Earle 1948). This also reduces the biological diversity, eliminating the native submerged species by obstructive sunlight and eliminating the underwater species like fishes (Gowanloch 1944). Water quality index is used to evaluate the status of characteristics of water table, the range of the quality index and their status presented in Table 4. Water parameters regulates the distribution of aquatic plants; the temperature ranged from 30.5 to 32.7 °C; pH 7.0–7.7; salinity 0.7–1.6 ppt; conductivity 355–586 ms/cm; TDS 249–320 ms/cm; DO 7.8–8.4 mg/l; and turbidity 3.7–6.6 NTU with minimum of 7 species were recorded at station 1 due to the very poor water quality status and this evidenced from the results of WQI 86.25 (Table 5). This may be attributed due to increased suspended solids and algal blooms (Ruttner 1953; Wetzel 1966); this is conformed from the results of turbidity which was found to be higher in station 1 than that of other stations. This finding was also supported by Dennison et al. (1993) who studied the water quality by using aquatic submerged weeds in the Chesapeake Bay. Ten species were recorded in station 2, with the temperature ranged from 29.5 to 32.5 °C; pH 7.2–7.6; salinity 0.8–0.9 ppt; conductivity 348–372 ms/

Table 5 Water quality index of the seasonal wetlands

Sl. no	Parameters	Standard value (s_n)	Unit weight (w_n)	Station 1			Station 2			Station 3		
				Observed value	Quality rating (q_n)	$W_n q_n$	Observed value	Quality rating (q_n)	$W_n q_n$	Observed value	Quality rating (q_n)	$W_n q_n$
1.	pH	6.5–8.5	0.2190	7.32	21.33	4.67	7.43	28.89	6.33	7.33	22.22	4.87
2.	DO (mg/l)	5.0	0.3723	8.05	66.11	24.61	7.97	67.04	24.96	7.88	67.96	25.30
3.	Conductivity (ms/cm)	300	0.3710	435.33	145.11	53.84	355.75	118.58	43.99	361.75	120.58	44.74
4.	TDS (ms/cm)	500	0.0037	275.42	55.08	0.20	230.00	46.00	0.17	238.17	47.63	0.18
	Total		0.9660			83.32			75.45			75.08
	WQI					86.26			78.10			77.72

cm; TDS 214–254.5 ms/cm; DO 7.7–8.4 mg/l; and turbidity 3.7–6 NTU. However, 12 plant species were observed in station 3 due to irregular conditions with temperature ranged from 30 to 32 °C; pH 7.1–7.6; salinity 0.8–1.0 ppt; conductivity 350–378 (ms/cm); TDS 223–250 (ms/cm); DO 7.4–8.1 mg/l; and turbidity 3.9–6.0 NTU. The estimated WQI was around 78.10 and 77.72 for stations 2 and 3, respectively (Table 5), which means it has very poor water quality. This finding was conformed by other observation of Thakor et al. (2011) Jena et al. (2013) and Korgaonkar et al. (2014). Besides, WQI variation has been attained due to the presence of additional submerged vegetation which means it has 5 submerged aquatic vegetation out of 7 submerged vegetation in stations 2 and 3. Dennison et al. (1993) reported the submerged aquatic vegetation as an indicator of water clarity and nutrient level of the water.

Conclusion

The water quality characteristics directly affect the aquatic macrovegetation, which was evidenced from the water quality index of the wetland. Also, the status of water quality varied due to usage and topography. Moreover, this study concludes that submerged aquatic vegetation is an indicator of the water quality parameter, despite the needed to take some adaptation measure to maintain the water quality for more extended domestic use.

Open Access This article is distributed under the terms of the Creative Commons Attribution 4.0 International License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made.

References

- Adhishwar AK, Choudhary SK (2013) Diversity of macrophytic species of gogabil lake wetland in Katihar, Bihar, India. *Ecol Environ Conserv* 19(4):1165–1172
- Akkaraboyina MK, Raju BSN (2012) A Comparative study of water quality indices of river Godavari. *Int J Eng Res Dev* 2(3):29–34
- APHA (1998) Standard methods for the examination of water and wastewater, 20th edn. American Public Health Association, Washington, DC
- Bala G, Mukherjee A (2010) Water quality index of some wetland in Nadia district, West Bengal, India. *Int J Lake Rivers* 4(1):21–26
- Balasubramanian R, Kannan L (2005) Physico-chemical characteristics of the coral reef environs of the Gulf of Mannar biosphere reserve, India. *Int J Ecol Environ Sci* 31:265–271
- Banner A, MacKenzie W (2000) The ecology of wetland ecosystem. 45 extension note. Ministry of Forest Research Program, Victoria, BC
- Banner A, Hebda RJ, Oswald ET, Pojar J, Trowbridge R (1988) Wetlands of Pacific Canada. In: National Wetlands Working Group, Wetlands of Canada (eds) Ecological land classification series no 24, Environment Canada, Ottawa, pp 306–341
- Barko JW, Gunnison D, Carpenter SR (1991) Sediment interactions with submersed macrophyte growth and community dynamics. *Aquat Bot* 41:41–65
- BIS (1993) Standards of water for drinking and other purposes. Bureau of Indian Standards, New Delhi
- BIS (2003) Indian Standard drinking water-specification. Manak Bhavan, New Delhi
- Brazner JC, Beals EW (1997) Patterns in fish assemblages from coastal wetland and beach habitats in Green Bay, Lake Michigan: a multivariate analysis of abiotic and biotic forcing factors. *Can J Fish Aquat Sci* 54(8):1743–1761
- Chambers PA, Kalff J (1985) Depth distribution and biomass of submerged aquatic macrophyte communities in relation to Secchi disc. *Can J Fish Aquat Sci* 42:701–709
- Chandramohan P, Sreenivas N (1998) Diel variations in zooplankton population in mangrove ecosystem at Gaderu canal, south-east coast of India. *Indian J Mar Sci* 27:486–488
- Chatterjee C, Razuddin M (2002) Determination of water quality index (W.Q.I.) of a degraded river in Asanil industrial area, Ranigunj, Burdwan, West Bengal. *Nat Environ Pollut Technol* 1(2):181–189
- Das AK, Shrivastva NP (2003) Ecology of Sarny Reservoir (M.P.) in the context of fisheries. *Pollut Res* 22(4):533–539
- Dawson FH, Newman JR, Gravelle MJ, Rouen KJ, Henville P (1999) Assessment of the tropic status of rivers using macrophytes. Evolution of the Mean Tropic Rank. Research and development. Technical report E39, Environment Agency, Bristol
- Dennison WC, Orth RJ, Moore KA, Stevenson JC, Carter V, Kollar S, Bergstrom PW, Batiuk RA (1993) Assessing water-quality with submersed aquatic vegetation. *Bioscience* 43:86–94
- Duarte CM, Kalff J, Peters H (1986) Patterns in biomass and cover of aquatic macrophytes in lakes. *Can J Fish Aquat Sci* 43:1900–1908
- Dwivedi BK, Pandey GC (2002) Physico-chemical factors and algal diversity of two ponds Gurijakund and Maqubara pond Faizabad. *Pollut Res* 21:361–370
- Flessa H (1994) Plant-induced changes in the redox potential of the rhizospheres of the submerged vascular macrophytes *Myriophyllum verticillatum* L. and *Ranunculus circinatus* L. *Aquat Bot* 47:119–129
- Goel PK, Trivedy RK (1987) Chemical and biological methods for water pollution studies. Environmental Publications, Karad, pp 1–34
- Gopalkrushna MH (2011) Determination of physico-chemical parameters of surface water samples in and around Akot city. *Int J Res Chem Environ* 1(2):183–187
- Gowanloch JN (1944) The economic status of water hyacinth in Louisiana. *La Conserv* 2:3–8
- Greenway M (1997) Nutrient content of wetland plants in constructed wetland receiving municipal effluent in tropical Australia. *Water Sci Technol* 35:135–142
- Henry AN, Kumari GR, Chitra V (1987) Flora of Tamil Nadu, India, vol 2. Series I: analysis. Botanical Survey of India, Coimbatore
- Henry AN, Chitra V, Balakrishnan NP (1989) Flora of Tamil Nadu, India, vol 3. Series II: analysis. Botanical Survey of India, Coimbatore
- Hernandez ME, Mitsch WJ (2007) De-nitrification in created riverine wetlands: influence of hydrology and season. *Ecol Eng* 30:78–88

- ICMR (1975) Manual of standards of quality for drinking water supplies. Indian Council of Medical Research. Special report no. 44: 27
- Jalal FN, Sanalkumar MG (2012) Hydrology and water quality assessment of Achencovil river in relation to pilgrimage season. *Int J Sci Res Publ* 2(12):1–5
- Jalal FN, Sanalkumar MG (2013) Water quality assessment of Pampa river in relation to pilgrimage season. *Int J Res Chem Environ* 3(1):341–347
- Jena V, Dixit S, Gupta S (2013) Assessment of water quality index of industrial area surface water samples. *Int J Chem Res* 5(1):278–283
- Klontz GW (1993) Environmental requirements and environmental diseases of salmonids. In: Stoskopf MK (ed) *Fish medicine*. W. B. Saunders Company, Philadelphia, pp 333–342
- Korgaonkar DS, Bharamal DL, Koli YJ (2014) Determination of water quality index in Annapurna river in Devgad Taluka, district Sindhudurg, Maharashtra. *Int Q J BioLife Sci* 2(4):1268–1273
- Kotadiya Nikesh G, Acharya CA (2014) An assessment of lake water quality index of Manipu lake of district Ahmedabad. Gujarat. *Int J Sci Res* 3(4):448–450
- Kouwenberg JHM (1994) Copepod distribution in relation to seasonal hydrographic and spatial structure in the north-western Mediterranean (Gulf du Lion). *Estuar Coast Shelf Sci* 38:69–90
- Lacoul P, Freedman B (2006) Environmental influences on aquatic plants in freshwater ecosystems. *Environ Rev* 14:89–136
- Lodh R, Paul R, Karmakar B, Das MK (2014) Physico chemical studies of water quality with special reference to ancient lakes Udaipur city, Tripura, India. *Int J Sci Res Publ* 4(6):1–9
- Lougheed VL, Crosbie B, Chow-Fraser P (2001) Primary determinants of macrophyte community structure in 62 marshes across the Great Lakes basin: latitude, land use, and water quality effects. *Can J Fish Aquat Sci* 58(8):1603–1612
- Matthew KM (1991) An excursion Flora of Central Tamil Nadu. Rapi-nat Herbarium, Thiruchirappalli, p 682
- Middleboe AL, Markager S (1997) Depth limits and minimum light requirements of freshwater macrophytes. *Freshw Biol* 37:553–568
- Miller WW, Joung HM, Mahannah CN, Garrett JR (1986) Identification of water quality differences Nevada through index application. *J Environ Qual* 15(3):265–272
- Moore BC, Lafer JE, Funk WH (1994) Influence of aquatic macrophytes on phosphorus and sediment porewater chemistry in a freshwater wetland. *Aquat Bot* 49:137–148
- Naiman RJ, Decamps H, Pollock M (1993) The role of riparian corridors in maintaining regional biodiversity. *Ecol Appl* 3(2):209–212
- Nair NC, Henry AN (1983) Flora of Tamil Nadu, India, vol 1. Series I: analysis. Botanical Survey of India, Coimbatore
- Neelam R, Nair V (1997) Distribution and abundance of copepods in the pollution gradient zones of Bombay harbour-Thane creek-Basin creek, West coast of India. *Indian J Mar Sci* 26:20–25
- Norlin JJ, Bayley SE, Ross LCM (2005) Submerged macrophytes, zooplankton and the predominance of low-over high-chlorophyll states in western boreal, shallow-water wetlands. *Freshw Biol* 50:868–881
- Palit D, Mukherjee A (2012) Studies on the water quality and macrophytes composition in wetlands of Bankura district, West Bengal India. *Indian J Plant Sci* 1:221–228
- Penfound WT, Earle TT (1948) The biology of the water hyacinth. *Ecol Monogr* 18:449–472
- Rakocy JE, Allison R (1981) Evaluation of a closed re circulating system for the culture of Tilapia and aquatic macrophytes. In: Allen LJ, Kinney EC (eds) *Proceedings of bio-engineering symposium for fish culture*. American Fisheries Society, Publ. No. 1, Washington, pp 296–307
- Robach F, Thiebaud G, Tremolieres M, Muller S (1996) A reference system for continental running waters: plant communities as bioindicators of increasing eutrophication in alkaline and acidic water in northeast France. *Hydrobiologia* 340:67–76
- Ruttner F (1953) *Fundamentals of limnology*. University of Toronto Press, Toronto
- Saini DC, Singh SK, Raj K (2010) Biodiversity of aquatic and semi-aquatic plants of Uttar Pradesh (with special reference to eastern Uttar Pradesh). Uttar Pradesh State Biodiversity Board, Lucknow
- Secmen O, Leblebici E (1996) The vegetation cover of Marmara region wetlands. *Turk J Bot* 20:171–187
- Singh RP, Mathur P (2005) Investigation of physico-chemical characteristics of freshwater reservoir of Ajmer city Rajasthan. *Indian J Environ Sci* 19:179–186
- Sondergaard M, Johansson LS, Lauridsen TL, Jorgensen TB, Liboriusen L, Jeppesen E (2010) Submerged macrophytes as indicators of the ecological quality of lakes. *Freshw Biol* 55:893–908
- Sooknah RD, Wilkie AC (2004) Nutrient removal by floating aquatic macrophytes cultured in anaerobically flushed dairy manure wastewater. *Ecol Eng* 22:27–42
- Sridhar R, Thangaradjou T, Senthil Kumar S (2006) Water quality and phytoplankton characteristics in the Palk Bay, southeast coast of India. *J Environ Biol* 27:561–566
- Tank SK, Chippa RC (2013) Analysis of water quality of Halena block in Bharatpur area. *Int J Sci Res Publ* 3(3):1–6
- Thakor FJ, Bhol DK, Pandya SN, Chauhan NB (2011) Water quality index (W.Q.I.) of Periyar lake district, Kheda-Gujarat. *Curr World Environ* 6(2):225–231
- Tripathi BD, Shukla SC (1991) Biological treatment of wastewater by selected aquatic plants. *Environ Pollut* 69(1):69–78
- Verma P, Chandawat D, Gupta U, Solanki H (2012) Water quality analysis of an organically polluted lake by investigating different physical and chemical parameters. *Int J Res Chem Environ* 2(1):105–111
- Wetzel RG (1966) Variations in productivity of Goose and hypereutrophic Sylvan lakes, Indiana. *Invest Indiana Lakes Streams* 7:147–184
- Williams M (1990) *Wetlands: a threatened landscape*. B. Blackwell, Oxford

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.