JOURNAL OF
ENVIRONMENTAL HYDROLOGY
The Open Access Electronic Journal of the International Association for Environmental Hydrology
On the World Wide Web at http://www.hydroweb.com

VOLUME 24 2016

THE TROPHIC STATE INDEX OF BAHR AL-NAJAF DEPRESSION RESERVOIR, IRAQ

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Bahr Al-Najaf Depression Reservoir (BNDR) is located 5 kilometers south-southwest of Najaf city in central Iraq. It covers an area of approximately 360 square kilometers. Carlson's Trophic State Index (CTSI) was applied to the BNDR. To do so, Chlorophyll (A), total phosphorus (TP), Secchi disc depth Transparency (SD) and some physiochemical parameters were measured. The mean value of Chl-a was 1,06 (±1,33), the maximum and minimum values of TSI based on total Chl-a were recorded during summer and spring respectively. The classification of trophic state using TSI (TP) and TSI (SD) was closed, but by using TSI (Chl-a) it was much higher, the value of TSI (Chl-a) > TSI (TP) >TSI (SD), the CTSI value of BNDR was between 35.11-71.33 (r^2 = -27, 53), the highest value of CTSI was in summer while the lowest values were during winter, the average of physiochemical parameters (± standard deviation) were: 26,5 (±1,42), 7,6 (±0,88), 0,1 (±0,16), 71 (±16,57), 10100 (±5591), 1,55 (±2,26), 53350 (±24143), 243299 (±358773), 30752 (±44649), 20 (±13), 2499 (±1819), 2659 (±2561), 0,22 (±0,02), 0,32 (±0,06) for temperature, pH, DO, Ec, HCO^-_3, TN, TH, Cl^- $SO^=_4$, TOC, Na^+, K^+, Fe^+, and Mn^+ respectively. According to CTSI, BNDR can be classified as eutrophic. CTSI results were very close to those of lakes Sawa and Al-Razzazah, while there were some slight differences when compared with Al-Habbanayh and Derbandikhan lakes, where the level of trophic index was decreasing (56, and 52 for Al-Habbanayh lake and Derbandikhan lake respectively).

INTRODUCTION

Lakes are critical part in the hydrological budget, source of water, and provide valuable habitats for biological species (Sarkar et al., 2006). BNDR (also known as the Najaf Sea) is a depressed area, composed of a lake or marsh-like area with limited cultivated orchards beyond and surrounded by vast desert or semi desert areas, located 5 km to the west and south-west of Holy Najaf City (Figure 1) (Mohammed et al., 2013). It extends at north west-south east direction over an area of about 360-750 km^2 (longitude 43˚40 - 44˚25 E and latitude 31˚40 - 32˚10 N) and altitude of about 11 msl. (Benni and Al-Tawash, 2011). It is host for a wide variety of flora and fauna, especially birds, it's also known to recharge the ground water, channelize water flow to prevent water logging and flooding (Mohammed et al., 2013). Immediate attention must be taken to restore, conserve, manage and maintain this resource, because it is an important part of the whole local ecosystem and if ignored could be dangerous in the future (KBA, 2011). Lake Habitat classification schemes have been based upon geography, physical factors, chemical factors, aquatic species and trophic status (Stednick and Hall, 2003).

Trophic state is defined as the total weight of living biological material in the water body at a specific location and time (Naumann, 1929). The traditional classification of reservoirs and lakes divides them into three categories: oligotrophic, mesotrophic and eutrophic (Shapiro, 1979). Typical parameters that are used to determine the TSI are: dissolved oxygen, primary production, TP, TN, chlorophyll-a, transparency and organic matter in sediments (Leach and Herron, 1992). Several of these parameters are combined to develop composite indices.

There are several models for evaluation of TSI such as: National Eutrophication Survey model (EPA 1974), fixed boundaries based upon the results of the National Eutrophication Survey (NES) to oligotrophic, mesotrophic and eutrophic which depend on Chl-a, TP, and SD; Loading plots model (Vollenweider, 1975), based upon a plots of phosphorous loading and mean depth hydraulic residence time; Carlson Trophic state Index model (Carlson, 1977), An index that uses TP, transparency and chlorophyll-a to define the trophic status as a numerical value from 0 to approximately 100; Trophic State Classification probabilities (OECD 1982) based upon probabilities and chlorophyll-a

Figure 1: Location map of Bahr Al-Najaf Depression reservoir (BNDR).

concentration; U.S. Environmental Protection Agency model (EPA, 1988) a probability classification system based upon NES data using TP concentrations in intervals to predict mean chlorophyll-a and Secchi disk depth.

Several studies certified the Carlson's model for evaluation of TSI such as: Brown and Simpson (2001), Goldyn et al., (2003), Stednick and Hall (2003), Murthy et al., (2008), Barki & Sing (2014), Vidovic et al., (2015), Gilbert et al., (2015), Bucci et al., (2015), and Silvino & Barbosa (2015). Carlson's Trophic State Index (TSI) is a common method for characterizing a lake's trophic state or overall health.

In this research, BNDR is to be evaluated from the trophic state of lake perspective, which supports the fauna and flora, as a first step for its conservation because of the trophic state monitoring is an important part in assessing and managing lake ecosystems, and the trophic state measurements serve as benchmarks for measuring the success of a lake management program (Horne and Goldman, 1994; Brown and Simpson, 2001).

MATERIALS AND METHODS

Triplicate samples were collected on monthly bases (February - November 2015) from four sites in BNDR. Three parameters were measured for calculation of Carlson's trophic state index (CTSI); Secchi disc (SD) readings were taken directly in the field, which refers to the water clarity. It is determined by a 20 cm diameter disk, water samples for total phosphorus (TP) and chlorophyll-a (Chll-a) collected by ultra-cleaned 1 liter sampling bottle (method #: 4500E according to: APHA, 1995). TP was analyzed according to APHA (995) (method #: 4500E) by using digestion block followed by the ascorbic acid method. Chlorophyll-a was estimated by the acetone method, and then measured by using a spectrophotometer (APHA, 1995).

The trophic state index (TSI) of Carlson was calculated using the following formulae:

TSI for Chlorophyll-a TSI (Chl-a) = [9.81* In Chlorophyll-a (μg/L)] + 30.6 (1)

TSI for Secchi depth TSI (SD) = 60 – [14.41* In SD (Meters)]. (2)

TSI for Total phosphorus TSI (TP) = [14.42 * In total phosphorous (μg/l)] + 4.15. (3)

Carlson's trophic state index (CTSI) = [TSI (TP)+TSI(CA)+TSI(SD)]/3 (4)

The classification of BNDR and other lakes was carried out according to Carlson and Simpson (1996) (Table 1). All the results for Sawa, Al-Razzazah, Al-Habbanayh, and Derbandikhan lakes that were used in the present data analysis have been published previously. (Hassan et al., 2006 & Al-Saadi et al., 2008). For details of the data, see Hassan (1998), Hassan et al., (2001), & Hassan (2007) for Sawa lake data; Al-Razzazah lake data; AL-Fahdawi et al., (2015) for Al-Habbaniyah Lake; and Rasheed (2010) for Derbandikhan lake.

Water temperature, pH, dissolved oxygen (DO), and electrical conductivity (Ec) were directly measured in the field using WTW portable multimeter (Multi 350i/3500i, Germany); bicarbonate, total nitrogen (TN), total hardness (TH), chloride (Cl^-), sulfate ($SO^{=}_4$), total organic carbon (TOC), sodium (Na^+), potassium (K^+), ferrous (Fe^+), and manganese (Mn^+) were analyzed the procedures given by APHA (1995).

Analysis of variance (ANOVA) test was applied to data for determining the statistical differences. The relationships between the measured environmental variables and the CTSI were analyzed by calculating the Pearson correlation coefficients. Some data were log-transformed prior to the statistical analysis to meet the requirements of normality. Segma Plot was used for creating some graphs.

RESULTS AND DISCUSSION

Carlson (1977) recommends that the trophic state classification should be based on season of mixing (spring and fall data). On the basis of Chl-a, Secchi depth, and total phosphorus, as well as TSI calculated, the results showed that there were seasonal variation (Figure 2-A,B,C,D).

In summer, the increase of temperature causes depletion in oxygen concentration leading to higher phosphorus concentration in the water column (Kangur et al., 2013). According to Sondergaard et al. (2005), the onset of the increasing biological activity in spring triggered the release of some of the P retained during the winter. Accordingly, it was noticed that TP increased during summer and winter while it decreased in the spring because of the fast growing of producers and increasing of productivity (Figure 2-A). So, the highest values of TSI based on total phosphorus were recorded in summer, while the lowest values were in spring (Figure 2). These results agree with those of Goldyn et al. (2003) for inland shallow water. It was also noticed that there was an increase in TP values with decrease in SD (Figure 3), and that is agree with Bergmen (1999).

The mean value of Chl-a was 1,06 (±1,33) (Figure 2-B), the highest values of TSI based on total Chl-a were recorded in summer, while the lowest values were in spring (Figure 4). The results showed that the classification of trophic state using TSI (TP) and TSI (SD) is close, but by using TSI (Chl-a) it becomes much higher. The results of the index for each parameters addressed in Figure 2, the value of TSI (Chl-a) > TSI (TP) >TSI (SD), Carlson trophic state index value of BNDR was between 35.11-71.33 (r^2 = -27, 53), the highest value of CTSI was in summer while the lowest values were during winter, this result agrees with Goldyn et al., (2003). Eutrophication state is closely related to photosynthesis, which is the driving force for seasonal variation of different physiochemical parameters and biotic activity (Ping,2006).

The average of physiochemical parameters (± standard deviation) were: 26,5 (±1,42), 7,6 (±0,88), 0,1 (±0,16), 71 (±16,57), 10100 (±5591), 1,55 (±2,26), 53350 (±24143), 243299 (±358773), 30752 (±44649), 20(±13), 2499 (±1819), 2659 (±2561), 0,22 (±0,02), 0,32 (±0,06) for temperature, pH, DO, Ec, HCO^-_3, TN, TH, Cl^- , $SO^{=}_4$, TOC, Na^+, K^+, Fe^+, and Mn^+ respectively. Figure 5 shows the natural logarithm of measured parameters.

The results showed that the values of CTSI in different seasons were close with standard error and standard deviation each of 0,03 and ±2,6 respectively (Figure 6). The correlation between the CTSI and some physicochemical parameters of water, showed that there were no significant relations (Figure 7), this indicates that the evaluation of BNDR depends on TP, Chlorophyll-a, and SD was exact and typical, with simple significant effects (mean: 0,2167±0,321, and r^2: 0,046).

According to Table 1, the water of BNDR was classified as eutrophic with dominance of blue green algae, algal scum probable, exstensive macrophyte problems. It should be noted that BNDR receives untreated water sewage from the old Al-Najaf City. Comparison of the CTSI results of the present study with those of Sawa and Al-Razzazah lakes, were very close (65, 61, and 64 for BNDR, Sawa, and Razzazah lakes respectively with standard deviation ± 1,875). This might be related to the fact that they have the same geological formation, same sources of water feeding, and same fault depression as the Wadi Abu Jeer Fault (Al Ahmed , 2012). The values of CTSI when compared with Al-Habbanayh Lake (feeding from Euphrates River) and Derbandikhan lake (feeding mainly from Sirwan river) were slightly different in the level of trophic index and lower than those of BNDR (56, and 52 for Al-Habbanayh lake and Derbandikhan lake respectively). This is attributed to the nature of source of water feeding these lakes and the their different geological nature (Figure 8).

Table 1. Carlson's trophic state index values and classification of lakes (Carlson and Simpson, 1996)

TSI	Lake class	Attributes
< 30	Oligotrophic	Clear water, oxygen throughout the year in the hypolimnion
30-40	Oligotrophic	Oligotrophy, but some shallower lakes will become anoxic during the summer
40- 50	Mesotrophic	Water moderately clear, but increasing of anoxia during the summer
50-60	Eutrophic	Decreased transparency, warm-water fisheries only
60-70	Eutrophic	Dominance of blue-green algae, algal scum, extensive macrophyte problems
70-80	Eutrophic	Heavy algal blooms possible throughout the summer, often hypereutrophic
>80	Eutrophic	Algal scum, summer fish kills, few macrophytes

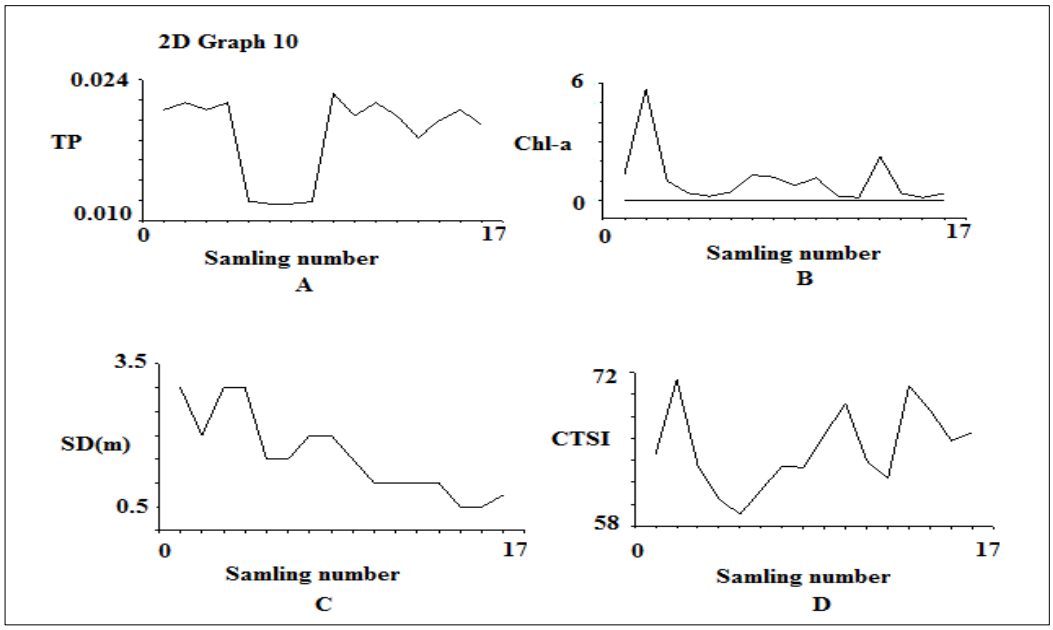

Figure 2. A: Total phosphorus concentration (µmol/l), B: Chlorophyll-a (µg/l), C: Secchi Disc (m), and D: Carlson's Trophic State Index (CTSI).

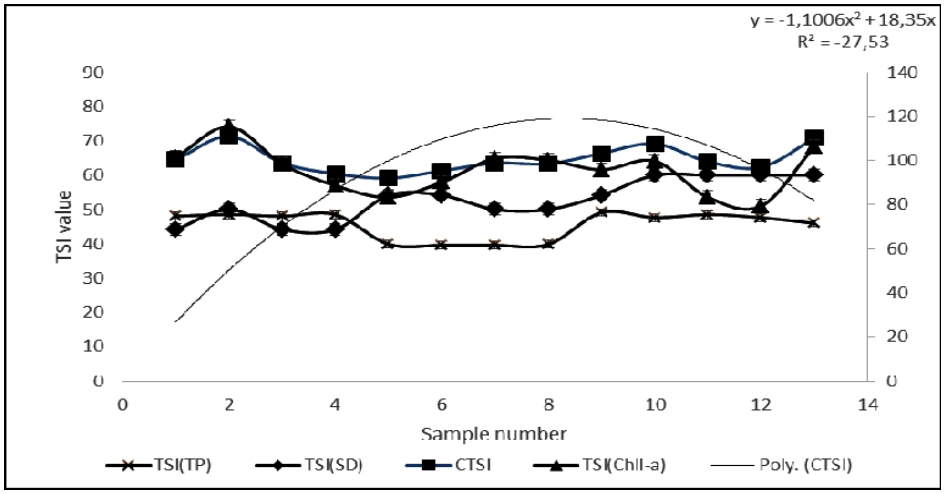

Figure 3. Interaction between TP values and SD values.

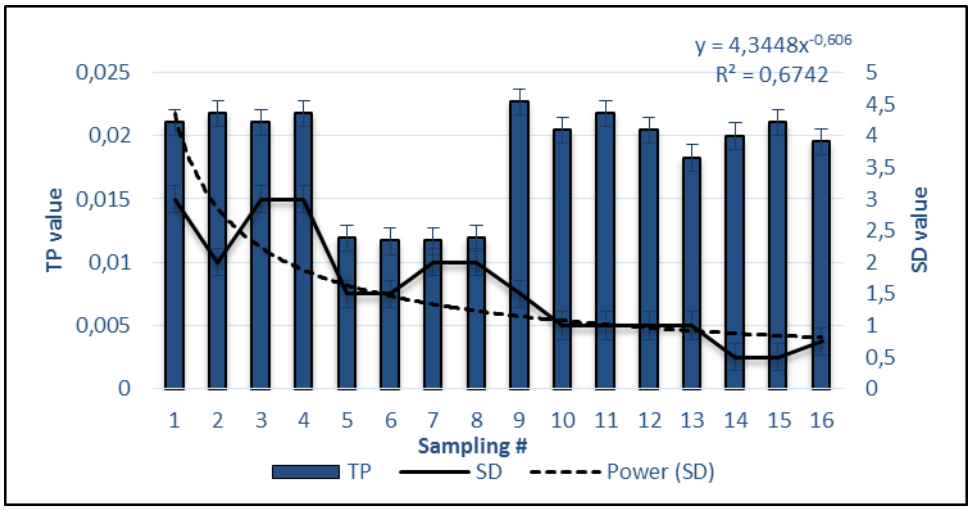

Figure 4. Carlson's trophic state index values and classification of BNDR.

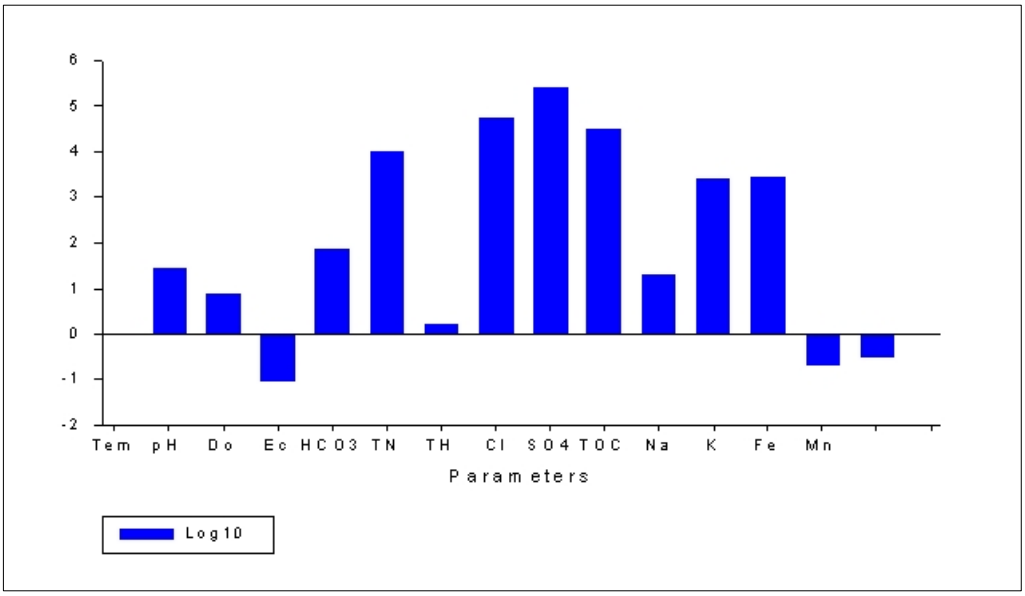

Figure 5. Log[10] of physiochemical parameters mean in period of study.

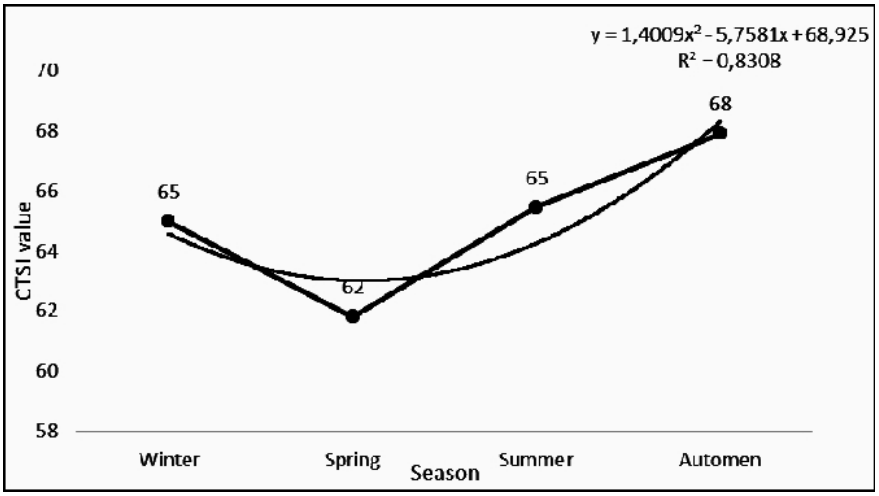

Figure 6. Mean of CTSI values in different season ±SD.

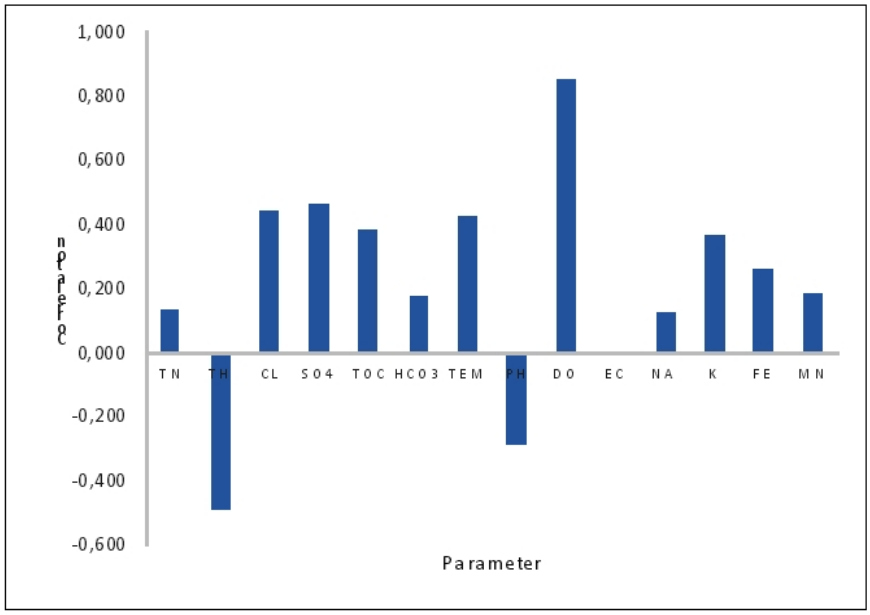

Figure 7. The correlation between CTSI and physiochemical properties of water samples.

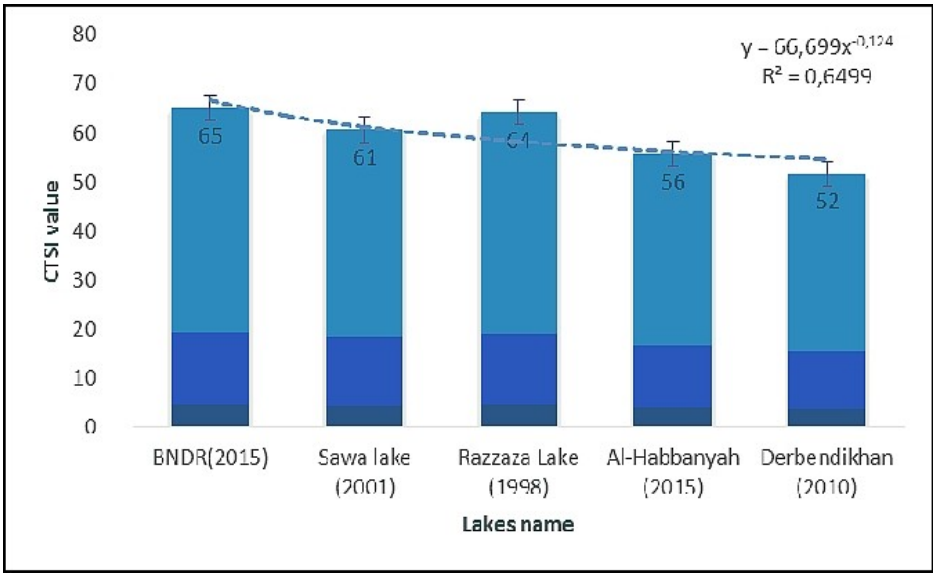

Figure 8. CTSI values for different lakes.

CONCLUSIONS

BNDR is a depressed area, composed of a lake or marsh-like area with limited cultivated orchards beyond and surrounded by vast desert or semi desert areas, located 5 km to the west and south-west of Holy Najaf City. It extends at north west-south east direction over an area of about 360-750 km^2 (longitude 43˚ 40 - 44˚ 25 E and latitude 31˚ 40 - 32˚ 10 N) and altitude elevation of about 11 m a. s. l.. Samples were collected directly in the field on monthly bases to calculate the Carlson's trophic state index (CTSI); Secchi disc (SD) which refers to the water clarity. The results of the analyses showed the following results:

TP increased during summer and winter while it decreased in the spring because of the fast growing of producers and increasing of productivity.

The highest values of TSI based on total phosphorus were recorded in summer, while the lowest values were in spring. It was also noticed that there was an increase in TP values with decrease in SD.

The highest values of TSI based on total Chl-a were recorded in summer, while the lowest values were in spring.

The highest value of CTSI was in summer while the lowest values were during winter.

The water of BNDR was classified as Eutrophic with dominance of blue green algae, algal scum probable, extensive macrophyte problems.

Comparison of the CTSI results in BNDR showed that they were closer to those of Sawa, and Razzazah lakes and relatively higher than those of Al-Habbanayh and Derbandikhan lakes. This is due to the fact that the former have the same geology and water resources of that of BNDR.

ACKNOWLEDGMENTS

The authors would like to thank Professors R. Alkhaddar of Liverpool JM University and M. Alshawi of Salford University and Kadhum Almuqdadi of the Arab Academy in Denmark for their fruitful suggestions and discussions.

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