Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 28(2): 1119 – 1135 (2024)
www.ejabf.journals.ekb.eg

Evaluation of the Water Quality of the Shatt al-Basra Canal Using the (TSI) Trophic Status Index

Ali M. Galo*, Amjed K. Resen
Department of Fisheries and Marine Resources, Agriculture College, Basrah University, Iraq
*Corresponding author: 8888mlynam@gmail.com

ARTICLE INFO
Article History:
Received: March 25, 2024
Accepted: April 19, 2024
Online: April 30, 2024

Keywords:
Shatt al- Basra Canal,
Nutritional State index,
Eutrophication

ABSTRACT

As a result of the changes in characteristics and vitality caused by human inventions, and due to the difficulty of understanding the motives for these changes, the study aimed to link the nutritional state of the Shatt al-Basra Canal to the main reasons for its production for the period from October 2022 to September 2023. Water samples were collected monthly from two stations in the water canal, then the physical, chemical and biological parameters were analyzed including water temperature, dissolved oxygen, salinity, total phosphorus (TP), total Chlorophyll-a (Chl a), and light transmittance (secchi disc depth (SD) in addition to temperature. For water temperature, values fluctuated between 11 & 36^{0}C in January and August, whereas the dissolved oxygen was recorded between 4.5 & 11.5mg/ L in June and January. The values of salinity ranged between 48.9 & 20.3 parts per thousand in March and July, and the water light penetration was between 23-55cm in March and August, while a range between 3.5 and 0.6g/ L was recorded for the total phosphorus in March and December. For chlorophyll-a, values ranged from 20.57 to 118.79µg/ L in February and September, while a value range from 46.76-57.89 was assessed for the nutritional state index (TSI) in November and December. Thus, it was deduced that the canal was experiencing a high state of dimerization. Based on the results of the statistical analysis, significant differences were detected between the studied plants at a level of $P \geq 0.05$ in the second station, where a higher TSI concentration was recorded compared to the first study site.

INTRODUCTION

The environment is an important element for humanity, as human life and the natural world are built on a variety of balances, and the human relationship with the environment is one of these main balances **(Yang, 2022)**.

Any external impact on the boundaries of the chain forming this natural balance causes this balance to be negatively affected, leading to environmental problems **(Genc, 2018)**.

As a result of multiple human activities, rivers have become a reservoir of flows, including industrial and agricultural activities. The current state of the rivers shows that there is great concern regarding the quality of water in these aquatic ecosystems as a result of their exposure to the process of eutrophication **(Klippel *et al.*, 2020)**. The process of enriching water with plant nutrients, primarily nitrogen and phosphorus, is called eutrophication, which stimulates primary aquatic production, leading to the proliferation of visible algae and phytoplankton, and promoting the growth of algae attached to aquatic plants **(UNEP, 2003)**. The trophic state reflects the human impact on water quality and the environmental performance of rivers and is an important characteristic of aquatic ecosystems, as nutritional state indexes show a clear picture of how the availability of nutrients and light control the development of phytoplankton **(Cunha *et al.*, 2013)**.

The trophic state index is also considered to be the best for assessing the trophic state of rivers since it reduces the assessment of water penetration, which is associated with inorganic turbidity rather than phytoplankton biomass **(Klippel *et al*., 2020)**. Notably, the trophic state of a river reflects its productivity, water quality, and biological integrity **(USEPA, 1994)**. The concept of trophic state depends on the lake production and is measured by estimating the biomass of algae due to its impact on the biological structure of the lake **(Naumann, 1919)**. The trophic state index (TSI) is widely used to assess the trophic state of aquatic environments, being an index that combines chlorophyll-a, light transmittance, and total phosphorus **(Li *et al.*, 2022)**.

The trophic state index helps guide decision-making and aids in water resource management by collecting and organizing data **(Carlson & Simpson, 1996)**. By applying this index, the productive state of the aquatic environment can be described, and it is expressed by a number whose value ranges from 0- 100 **(Carlson, 1977)**. The aquatic environment is also classified according to the trophic state index Trophic into four sections (Table 1), oligotrophic, mycotrophic, mycotrophic, eutrophic, and hypertrophic **(Rajashekar & Vijay Kumar, 2008)**.The trophic state index is the total weight of biomass in a water body and is the biological response to nutrient supply into the water bodies **(Devi Prasad & Siddaraju, 2012)**.

Water depth affects the estimation of the TSI (SD) of water bodies, as it is not preferable to use TSI (SD) and TSI (TP) in shallow water bodies with depths less than 2m. On the other hand, total nitrogen (TSI) (TN) must be excluded from eutrophication in bodies with depths more than 5m, as water depth is the main internal regional factor affecting the accuracy of these factors in indicating algal biomass **(Zhang *et al.*, 2023)**. This research aimed to evaluate the trophic state index of the aquatic environment in the Shatt al-Basra Canal by linking the nutritional state of the canal to the main causes of its productivity, which is a complex response to the interaction between various physical, chemical, and biological factors.

MATERIALS AND METHODS

Study and sampling area

The Shatt al-Basra Canal is an artificial drainage canal and is a waterway linking the southern marshes to the Arabian Gulf **(Hassan *et al.*, 2018)**. It is used to transport floodwater from the Hammar Marsh to Khor Al-Zubair and then to the Arabian Gulf via Khor Abdullah **(UNEP, 2001)**. It starts from the north of Basra and extends toward the southeast. It covers about 37,157km^2 located within the lands of the Basra Alluvial Plain. It is located between latitudes 30 27-30 28 in the North and 47 50-47 49 in the East. Samples were collected from two stations. The first station is near the Shatt al-Basra gas power station and is located northwest of Basra (N: 47 44 42.5 E: 30 28 31.1), while the second station is near the Shatt al-Basra regulator and is located in the southwestern part of the city of Basra (E: 30 24 40.1 N: 47 46 22.6) (Fig. 1).

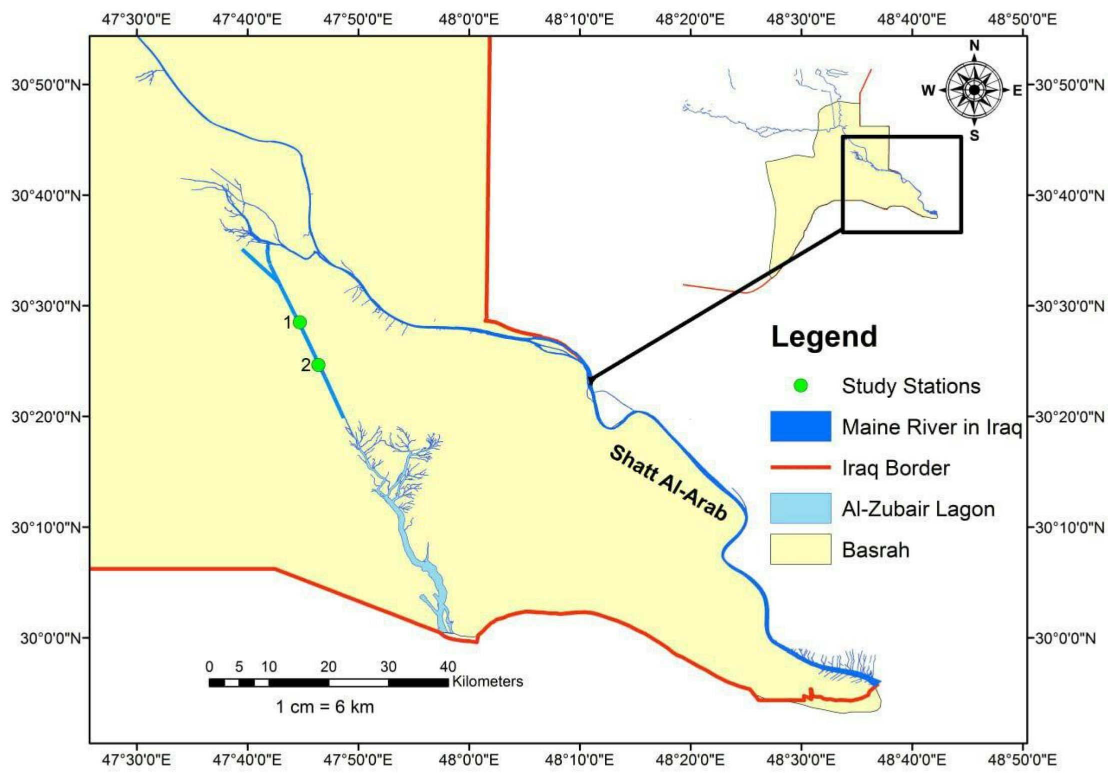

Fig. 1. Map of collection site from Shatt Al-Basrah Canal

Sample collection

Samples were collected from two stations for the period from October 2022 to September 2023 during the low tide period. A mercury thermometer graduated from 0- 100 and a light penetration were used to measure water temperature (°C) and light transmittance by a Secchi disk, with a diameter of 30cm. The values (cm/s) are expressed as Secchi depth.

These variables were measured during real-time sampling in the field. Dissolved oxygen (mg/L) was determined according to the modified Winkler method (Azide modification) described in **APHA (2005)**. Salinity (parts per thousand ppt) was also measured using a Cond3L5i type wTw device. Plastic bottles, made of polyethylene with a capacity of 500mm, were used to collect water samples. They were preserved in 4% formalin immediately after being withdrawn from a depth of 15- 25cm below the surface of the water, and the samples were preserved in refrigerated containers with crushed ice and transported to the laboratory for further analysis. Total phosphorus (TP) was determined according to **APHA (2005)**. and chlorophyll-a was evaluated according to **Lorenzen (1967)**. The nutritional state index was calculated according to **Carlson(1977)** by applying the formula:

TSI (SD) =60-14.41 Ln [Secchi disc depth (meter)]

TSI (Chl a) =9.81 Ln [Chlorophyll a(µg/l)]+30.6

TSI (TP) = 14.41 Ln [Total phosphor(µg/l)]+4.15

Average TSI = [TSI (TP) + TSI (Chl)a+ TSI (SD)]/3

Statistical analysis

The statistical analysis of the data was performed by using SPSS 20 software (Statistical Package for Social Sciences). In addition, the L.S.D. test was used to determine those differences under the significance level of $P<0.05$ through the ANOVA test in the current study sites.

On what basis were the two sites chosen? Their results are very close.

Fig. (2) August on X-axes is written dad.

RESULTS

Water temperature

Monthly changes in water temperature IN the stations varied over time. Temperatures ranged between 11 & 36°C in January and August (Fig. 2).

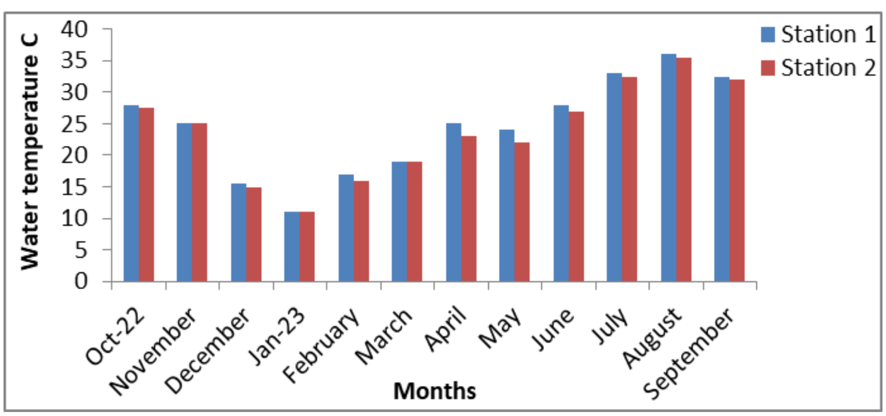

Fig. 2. Monthly variations of the temperature °C at the study sites

Dissolved oxygen

DO concentrations ranged from 4.5 to 11.5 mg/L in June and January (Fig. 3).

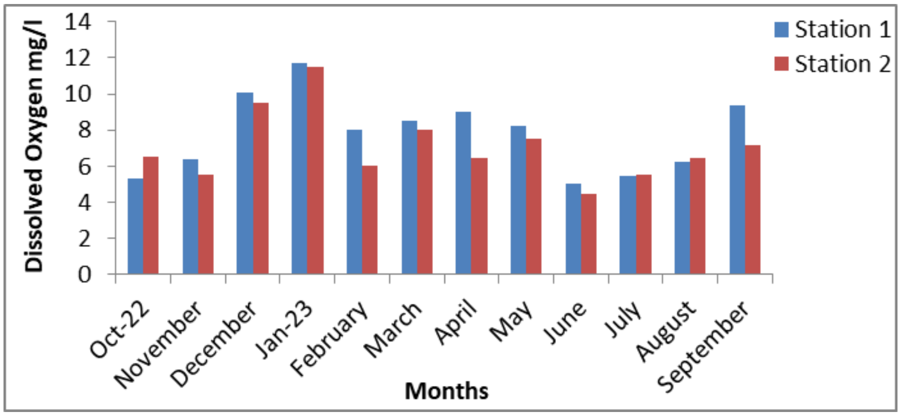

Fig. 3. Monthly changes in dissolved oxygen concentration at the study sites

Salinity

Salinity concentrations ranged monthly between the lowest and highest (48.9-20.3) ppt in March and July, respectively (Fig. 4).

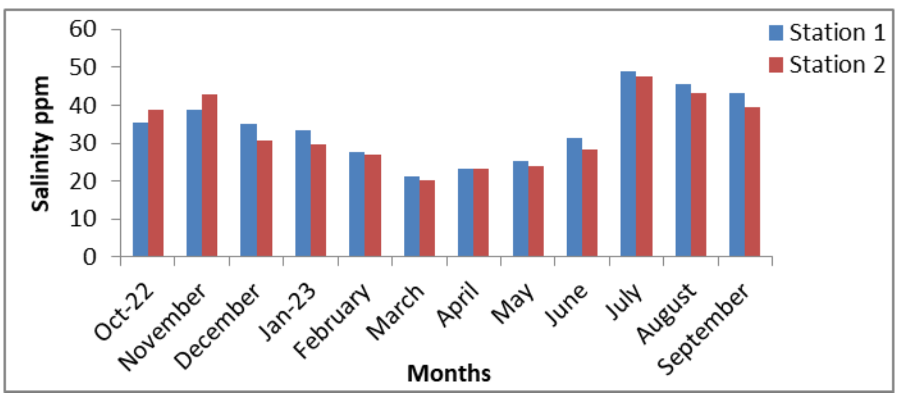

Fig. 4. Monthly changes in salinity concentration at the study sites

Total phosphorus

The lowest and highest TP concentrations ranged between 3.5 and 0.6μg/ L in March and December, respectively (Fig. 5). Statistical analysis showed significant differences between the study stations at the probability level of $P \leq 0.05$.

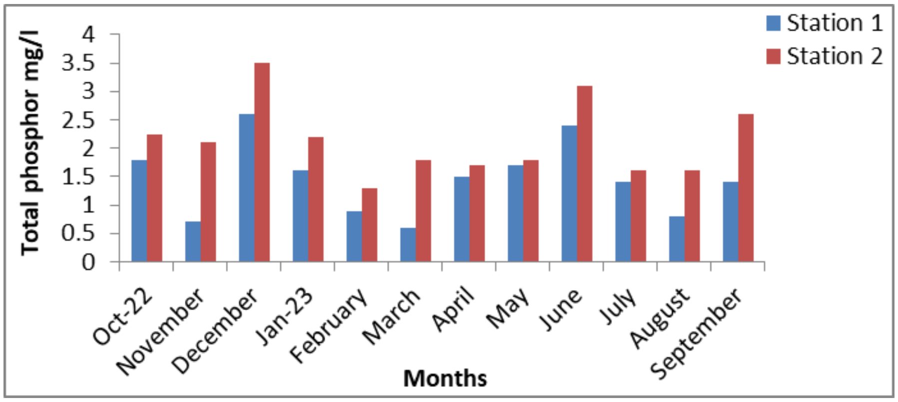

Fig. 5. Monthly changes in total phosphorus concentration at the study sites

Chlorophyll-a

Chlorophyll-a (Fig**.** 6) shows that the highest value of Chl-a (118.79µg/ L) was recorded in September, while the lowest (20.57µg/ L) was in February. Statistical analysiss exhibited significant differences between the study stations at the level of $P \leq 0.05$.

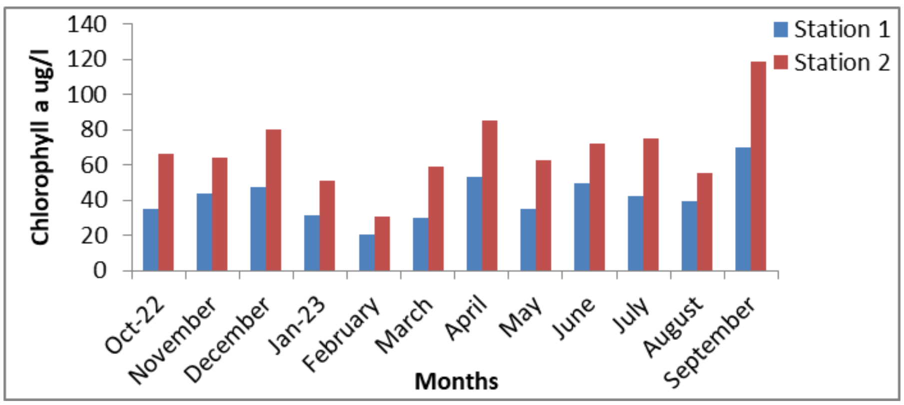

Fig. 6. Monthly variations of Chlorophyll-a at the study sites

Light penetration

Fig. (7) shows the monthly changes in light penetration. The highest value was 55cm recorded in August, while the lowest was in March, with a value of 23cm.

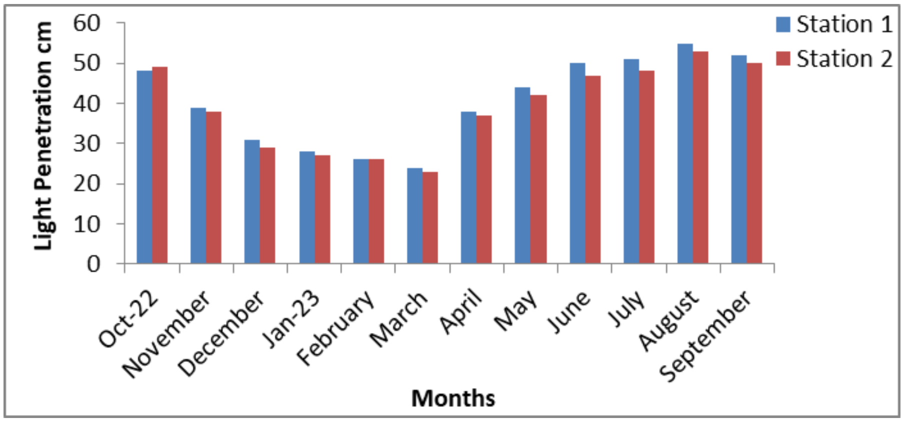

Fig. 7. Monthly light penetration/cm variations at the study sites

Trophic state index

The trophic state index (Fig. 8) showed that the highest value (57.89) was registered in December, and the lowest (46.76) was in November.

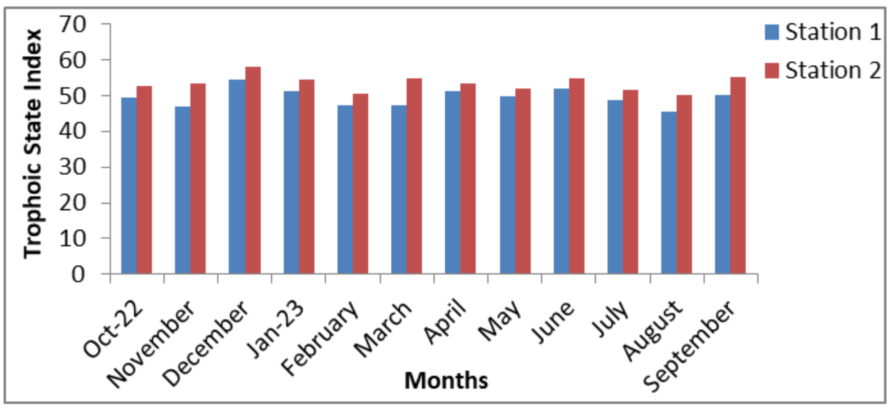

Fig. 8. Monthly changes in the trophic state index at the study sites

Table 1. TSI grade and their ecological attributes **(Carlson & Simpson, 1996)**.

Ecological attributes	TSI	Class
Oligotrophic -low productivity	< 40	1
Mesotrophic moderate productivity	40-50	2
Eutrophic -high productivity	51-70	3
Hypereutrophic very high productivity	>70	4

DISCUSSION

Water temperature is one of the most important factors affecting the environment of water bodies through its effect on several chemical and physical factors, viz. gases dissolved in water, pH, conductivity, specific density, and viscosity **(Banana *et al.*, 2016)**. The highest and lowest values were recorded during August and January, respectively. The decrease in water temperature in winter and its increase in summer in the ecosystem follow the temperature of the surrounding air **(Fouzia & Amir, 2013)**. During summer, the study area is affected by the long hours of daylight and the resulting brightness of sunlight affecting the surface of the water.

The river's shallowness, due to reduced flow during summer, increases its vulnerability to air temperatures **(Galo, 2023)**. This differs from the winter season, which is characterized by short daylight hours, weak sunlight, and varying levels of water depth. The reason for the difference may also be attributed to changes in climate, being hot and dry during summer and cold and rainy during winter **(Al-Hejuje, 2014)**. This was reflected in the water temperature, giving clear differences between months. For the difference between the two study stations, it may be due to the sampling times and the depth of the water from which they were taken, taking into account the high heat capacity of the water **(Lampert & Sommer, 1997)**.

Given that placing an earthen dam on the Karma Ali River (the confluence of the Tigris and Euphrates rivers) to prevent the high salt tide, causes a decrease in freshwater discharge. It is worthy to mention that, salinity affects the size of the biological community and its quantitative and qualitative representation **(Power *et al*., 2000)**, and that the strong tidal currents from the Gulf increase the salinity concentrations in the water **(Galo *et al*., 2022)**. In this context, the current study recorded salinity concentrations that are higher than what was reported in previous studies in the waters of the Shatt al-Basra Canal in the first station during July.

The lowest salinity concentrations were also recorded in the second station during March. The reason for the high concentrations may be ascribed to the evaporation process in the season of summer owing to the high temperature and the length of the day. The lower part of the canal is also affected by marine tidal phenomena, which shows the effect of the salt water of the Arabian Gulf on the Shatt al-Basra Canal. The water of the Shatt Basra Canal can be classified as marine water. In addition to this, there is a continuous increase in salts resulting from human activities and untreated wastewater **(Galo *et al.*, 2023)**. The decrease in salt concentrations during the cold months may be due to the reduction in rainfall and the increase in Shatt al-Basra Canal discharges during those months of the year.

Dissolved oxygen in water plays an effective role in regulating the vital processes of several aquatic organisms. It is not possible to dispense with it, even if its concentrations are reduced below the level of sustaining the lives of these organisms **(Abowei, 2010)**. The results showed a decrease in oxygen concentrations during summer and an increase during winter and spring in the two study stations. The reason for the decrease in dissolved oxygen concentrations during the summer, especially in June, may be attributed to the increase in the rate of decomposition of organic materials and the consumption of oxygen by aquatic organisms owing to the increase in water temperature **(Moyel, 2014)**.

The reason for the high concentrations of dissolved oxygen during winter, especially in January, may be traced back to the presence of an inverse proportion between the solubility of gases and temperature **(Durmishi *et al.*, 2008)**. In addition, the results of the current study showed that dissolved oxygen concentrations in the second station are lower than those recorded in the first station, and this may be due to household waste and untreated wastewater **(Charles *et al.*, 2019)** in the Shatt Basra Canal.

Notably, total phosphorus is one of the main variables that control the nutritional index and is directly related to its values. Phosphorus accumulates in plants and animals in the aquatic environment, leading to sedimentary materials entering the bottom of the water body upon death.

When organic compounds decompose, they regain their movement in the water column under the influence of the movement of water currents **(Li *et al.*, 2018)**. It is worth noting that orthophosphate represents the factor that determines the growth of algae in the freshwater environment; however, its presence in high concentrations causes the phenomenon of eutrophication **(Camargo & Alons, 2006)**. The increase in concentrations, especially in December, may be attributed to the lack of consumption by phytoplankton and aquatic plants of the factor that determines algal growth, orthophosphate.

The dissolution of phosphorus compounds in the Earth's crust is a result of rainfall and washing of agricultural lands **(Rasan, 2001)** in addition to the domestic wastewater that the canal containing phosphate compounds receives without treatment **(Hassan *et al.*, 2018)**. With respect to the low concentrations during November and March, it may be traced back to the consumption of orthophosphate by phytoplankton and aquatic plants to flourish in spring and fall. This proves that TSI values depend mainly on an increase in nutrients (nitrogen and phosphorus) **(Rahul *et al.*, 2013)**.

This reflects the pressure exerted by the increasing discharge of untreated wastewater loaded with phosphate compounds, such as household detergents and agricultural fertilizers **(Al-Asadi & Al-Hejuje, 2019)**. The increase in nutrient values led to an increase in the values of chlorophyll a, which is an important pigment for the process of photosynthesis by converting the solar energy into a chemical energy, adding to its significance in estimating primary productivity in the water bodies **(Kim *et al.*, 2021)**.

The current study recorded two peaks of chlorophyll values, the first during the month of April, which is the lowest, while the highest peak was recorded during the month of September. The reason for this may be attributed to the moderate temperature and increase in nutrient concentration leading to the growth of types of algae, which are considered to have a high content of chlorophyll. Chlorophyll a in all lakes and rivers responds to changes in the concentrations of total nitrogen or total phosphate **(Zhang *et al.*, 2023)**. Light penetration is a physical factor with an impact on the abundance and distribution of algae due to the effect of light on the photosynthesis process **(Swatland, 2020)**. The results of the current study indicate that light penetration values decreased during the winter months until they reached the lowest value in March. The reason for this may be related to the difference in the photoperiod and high productivity, which causes an increase in the concentrations of suspended materials, reducing the light penetration, while light penetration values were high during the summer months. It reached its peak in August, which may be due to the difference in the density of phytoplankton and the low speed of the current, leading to the sedimentation of suspended materials **(Abdullah, 2015)**. The results showed that the second station recorded the least penetration to light during the study period, and this may be due to the movement of fishing boats, household waste, and sewage **(Charles *et al.*, 2019)**. The angle of incidence of the sun's rays, the clarity of the air, the movement of boats, mixing processes, and tides also affect the penetration of light **(Hussein & Fahad, 2008)**.

Eutrophication is a natural process accelerated by eutrophication in aquatic ecosystems and is caused by fertilizers, industrial products, sewage, and household waste **(Lopes *et al.*, 2019)**. This causes algae growth to flourish and results in a decrease in dissolved oxygen concentrations because of its consumption through the decomposition process of these algae after their death, causing habitat pollution and the death of aquatic organisms **(Liang *et al*., 2021)**.

The values of the trophic state index (TSI) in the first station were within the medium nutritional status category, while the second station was in the high trophic state, especially in December. This may be attributed to the discharge of untreated local sewage and industrial wastewater loaded with phosphate compounds, such as household detergents and agricultural fertilizers **(Al-Asadi & Al-Hejuje, 2019)**. Heavy rains also contributed to the deposition from the air and the emission of phosphate from sediments, as a result of increased mixing processes since the rate of recycling nutrients from sediments is better in the absence of plants **(Horppila & Nurminen, 2003)**.

The study indicates that the Shatt al-Basra Canal is full of nutrients. Although no previous studies related to TSI in the Shatt al-Basra Canal were followed, comparisons were made with local and international studies (Table 2). In general, the higher TIS values in the second station compared to the first station are due to the release of untreated domestic wastewater and agricultural wastewater coming with the general downstream water.

The PCA analysis (Fig. 9) showed that the value of the TSI index was directly related to total phosphorus, chlorophyll a, and light penetration. The direct correlation showed the effect of these factors on the value of the index. This can be mainly due to the apparent increase in salinity, which led to the death of aquatic plants and phytoplankton, as elucidated in the study of **El-Serehy *et al*. (2018)**.

The temperature and length of the lighting period also affected the growth of phytoplankton, given that the concentrations of pollutants in aquatic systems increase with an increase in chlorophyll a, through which the living mass of phytoplankton is estimated. In terms of locational changes, the current study recorded the highest concentrations of TSI values in the second station, which are higher than those of the 1st station.

The reason for this may be attributed to the large quantities of untreated sewage and industrial wastewater released from pollutant discharge pipes, rich in organic matter, resulting from nearby population centers **(Hassan *et al.*, 2018)**. The TSI evaluation value (53.38) in the current study was compared with values of local and international studies (Table 2). Noticeably, it is highly eutrophic and does not agree with the study of **Al Amri (2021)** in the Shatt al-Arab, where he evaluated TSI value at 36.30, which is mesotrophic. Moreover, this difference in the TSI values is obvious in the study of **AL-Shamary (2022)** on the Shatt al-Arab estuary and Iraqi marine waters, who evaluated it at 36, which is mesotrophic as a result of the lack of vegetation in Iraqi marine waters, this may be due to continuous mixing processes due to tidal processes, the nature of the estuary, and sea levels. On the other hand, high levels of salinity, decrease in total phosphorus, and low levels of light penetration cause a decrease in the TSL index. The present study agrees with that of **Shawi (2010)** in Khor Al-Zubair, as the TSI of his study was evaluated at 54.98, which is highly nutritious. Globally, the current study coincides with the study of **El-Serehy *et al.* (2018)**. In Egypt's Crocodile Lake, the TSI is rated at 60 and is highly eutrophic, This may be attributed to the state of eutrophication in the lake's water as a result of the formation and abundance of phytoplankton with the dominance of diatoms and the increase in population density, reflecting the state of eutrophication in the lake. On the other hand, the lake receives water with high salinity, very low light pentration, and high total phosphorus values, causing an increase in the TSL index.

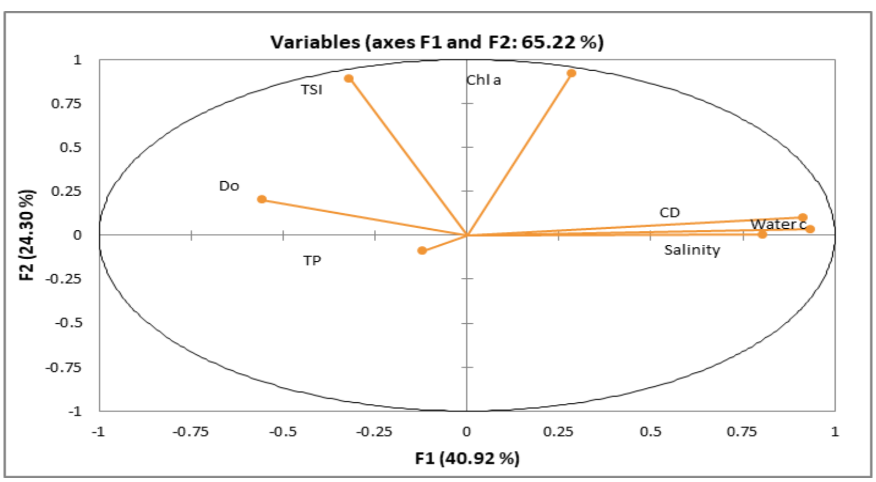

Fig. 9. PCA analysis between TSI and input variables in Shatt al-Basra Canal

Table 2. TSI evaluation in the present study and around the world

Evaluation (TSI)	Country	Place	Reference
Mesotrophic	Cyprus	Limassol Coastal	Papoutsa and Hadjimitsis (2014)
Oligotrophic	Romania	Adriatic Sea	Fiori *et al*. (2016)
Hypertrophic	Brazil	Patos lagoon Estuary	Marrero *et al*. (2017)
Eutrophic	Egypt	Like Timsah	El-Serehy *et al.* (2018)
Eutrophic	Iraq	Khor Al Zubair	Shawi (2010)
Oligotrophic	Iraq	Shatt al-Arab	Al Amri (2021)
Mesotrophic	Iraq	Shatt al-Arab Estuary and Iraqi marine water	AL-SHAMARY (2022)
Eutrophic	Iraq	Shatt al-Basrah Canal	Present study

The author is grateful to the authorities of both the Department of Fish and Marine Resources and the laboratories of the Marine Science Center.

CONCLUSION

The study showed that the TSL INDEX in the Shatt al-Basra can be largely inferred by assessing water depth, chlorophyll a concentration, total phosphorus as a result of the discharge of untreated domestic and industrial wastewater, agricultural drainage water from irrigated lands and the movement of fishing boats, which increased the level of organic matter and nutrients within. Other environmental standards are mandatory to be taken into consideration, such as salinity, turbidity, water temperature, dissolved oxygen concentration, and the mutual relationship between these variables.

REFERENCES

Abdullah, A. H. J. (2015). Fish biodiversity and some biological characteristics in the northern part of Shatt Al-Arab river and some of its reaches . Ph. D. Thesis, Coll. Agric., Univ. Basrah: 192pp.(In Arabic).

Abowei, J. F. N. (2010). Salinity, dissolved oxygen, pH and surface water temperature conditions in Nkoro River, Niger Delta, Nigeria. Advance Journal of Food Science and Technology, 2(1): 36-40.

Rahul, U.; Arvind, P. K. and Upadhyay, S. K. (2013). Assessment of lake water quality by using palmer and trophic state index-a case study of Upper Lake, Bhopal, India. International Research Journal of Environment Sciences, 2(5): 1-8.

http://www.isca.in/IJENS/Archive/v2/i5/1.ISCA-IRJEvS-2013-024.php.

Al-Amiri, A. A. (2021). The use of zooplankton and Canadian evidence in assessing water quality in the Shatt al-Arab river. M.Sc . College of Agriculture, University of Basra: 104 pp. (In Arabic).

Al-Asadi, A. A. (2019). Assessment of the impact of sanitation on the level of pollution and environmental pollution in the central marshes / southern Iraq. Master's Thesis, College of Science, University of Basra. 160pp.

Al-Asadi, A. A. and Al-Hejuje, M. M. (2019). Application of Organic Pollution Index (OPI) to assess the water quality of Al-Chibayish marsh, Southern Iraq. Marsh Bulletin, 14(1): 22-30.

Al-Hejuje, M. M. (2014). Application of water quality and pollution indices to evaluate the water and sediments status in the middle part of Shatt Al-Arab River. Ph. D. Thesis, College of Science, University of Basrah, 239pp.

AL-Shamary, A. C. (2022) Assessing of Trophic status for shatt AL-Arab Estuary and Iraqi marine Waters EM International, 41 (3): 912-917.

http://doi.org/10.53550/PR.2022.v41i03.021

Al-Shawi, I. J. M. (2010). Ecological and Taxonomical studies to plankton in Khor Al-Zubair lagoon with determination of the total petroleum hydrocarbons levels. Ph. Dthesis, College of Agriculture, University of Basrah:148 pp. (In Arabic).

Al-Zubaidi, A. J. M.; Abdullah, D. S.; Houriabi, K. K. and Fawzi, M. (2006). Abundance and distribution of phytoplankton in some southern Iraqi waters. Marsh Bull, 1(1): 59-73.

Amjed, K. R. (2001). Comparative study of ecological characteristics and levels of organic pollution in three main canals of the Shatt Al-Arab River, Southern Iraq. M.Sc . College of Agriculture, University of Basra: 58pp. (In Arabic).

APHA (American Public Health Association) (2005). Standard methods for the examination of water and wastewater. 21th ed, Washington, D.C., 1193pp.

Banana Adel, A.; Al-Gheethi, A. A.; RMSR Mohamed; Efaq, A. N. and Gadawi, A. M. S. (2016). Environmental impact assessment for disposal of sewage into seawater at Sabratah, Libya. 3rd International conference on green energy and environmental engineering, GEEE.

Camargo, J. A. and Alonso, Á. (2006). Ecological and toxicological effects of inorganic nitrogen pollution in aquatic ecosystems: A global assessment. Environment International, 32(6): 831-849.

Carlson, R. E. (1977). A trophic state index for lakes: Limnology and Oceanography, 22 (2): 361-369 .

https://doi.org/10.4319/lo.1977.22.2.036

Carlson, R. E. and Simpson, J. (1996). A coordinator’s guide to volunteer lake monitoring methods. North American Lake Management Society, 96 pp.

Charles, D. F.; Tuccillo, A. P. and Belton, T. J. (2019). Use of diatoms for developing nutrient criteria for rivers and streams: A biological condition gradient approach. Ecological Indicators, 96 (1): 258-269.

Cunha, D. G. F.; do Carmo Calijuri, M. and Lamparelli, M. C. (2013). A trophic state index for tropical/subtropical reservoirs (TSItsr). Ecological Engineering, 60: 126-134.

https://doi.org/10.1016/j.ecoleng.2013.07.058

Devi Prasad, A. G. and Siddaraju, S. (2012). Carlson's trophic state index for the assessment of trophic status of two lakes in Mandya district. Advances in Applied Science Research, 3 (5): 2992-2996 .

http://www.pelagiaresearchlibrary.com

Durmishi, B.; Ismaili, M.; Shabani, A.; Jusufi, X. S.; Fejzui, M. X.; Kostovska, M. and Abduli, S. (2008). The physical, physical-chemical and chemical parameters determination of River water Shkumbini (pena) (part A), BALWOIS-Oherd, Republic of Macedonia, 27(31): 1-11.

El-Serehy, H. A.; Abdallah, H. S.; Al-Misned, F. A.; Al-Farraj, S. A. and Al-Rasheid, K. A. (2018). Assessing water quality and classifying trophic status for scientifically based managing the water resources of the Lake Timsah, the lake with salinity stratification along the Suez Canal. Saudi Journal of Biological Sciences, 25(7): 1247-1256.

https://doi.org/10.1016/j.sjbs.2018.05.022

Fadum, J. M. and Hall, E. K. (2022). The interaction of physical structure and nutrient loading drives ecosystem change in a large tropical lake over 40 years. Science of The Total Environment, 830: 154454.

https://doi.org/10.1016/j.scitotenv.2022.154454

Fiori, E.; Zavatarelli, M.; Pinardi, N.; Mazziotti, C. and Ferrari, C. R. (2016). Observed and simulated trophic index (TRIX) values for the Adriatic Sea basin. Natural Hazards and Earth System Sciences, 16(9): 2043-2054.

https://doi.org/10.5194/nhess-16-2043-2016

Fouzia, I. and Amir, K. (2013). Diversity pattern of Macrozoobenthos and their relation with qualitative characteristics of River Yamuna in Doon Valley Uttarakhand. American-Eurasian Journal of Toxicological Sciences (AEJTS), 5(1): 20-29.

http://idosi.org/aejts/5(1)13/4.

Galo, A. M.; Al-Yassein, R. N. and Resen, A. K. (2022). Total petroleum hydrocarbons in water, sediment, and Redbelly tilapia, Coptodon zillii in Shatt Al-Basrah Canal, Iraq. International Journal of Aquatic Biology, 10(6): 504-514.

https://doi.org/10.22034/ijab.v10i6.1782

Galo, A. M.; Resen, A. K. and Alyassein, R. N.(2023) Spatial and Temporal Variation of Total Petroleum Hydrocarbons and Aliphatic Compounds in Muscles of Planiliza subviridis in Shatt Al-Basrah Canal, Southern Iraq. Biological and Applied Environmental Research, 7(1): 78-91.

https://doi.org/10.51304/baer.2023.7.1.78.

Galo, A. M. (2023). Levels of Organic Pollution and Petroleum Hydrocarbons in Some Fish, Water and Sediments of the Shatt Al-Basrah Canal M. Sc. College of Agriculture, University of Basra:225pp. (In Arabic).

Genc, M.; Genc, T. and Rasgele, P.G. (2018). Effects of nature-based environmental education on the attitudes of 7th grade students towards the environment and living organisms and affective tendency. International Research in Geographical and Environmental Education, 27(4): 326-340.

Hassan, A. A.; Dawood, A. S. and AL-Mansori, N. J. (2018). Assessment of water quality of Shatt Al-Basrah Canal using water pollution index. International Journal of Engineering and Technology, 7(4) (4.19): 757-762.

Horppila, J. and Nurminen, L. (2003). Effects of submerged macrophytes on sediment resuspension and internal phosphorus loading in Lake Hiidenvesi (southern Finland). Water research, 37(18): 4468-4474.

https://doi.org/10.1016/S0043-1354(03)00405-6

Hussein, S. A. and Fahad, K. K. (2008). Seasonal variations in abiotic ecological conditions in Al-Garaf Canal one of the main branches to Tigris River Thi Qar province, Iraq. Basrah Journal of Scienec., B, 26(1): 38-47.

Kim, S. and Kim, H. (2021). Assessment of Trophic Responses of a Reservoir to Seasonal and Annual Variations in Monsoon. MDPI, 13(2117):1-24.

Klippel, G.; Macêdo, R. L. and Branco, C. W. (2020). Comparison of different trophic state indices applied to tropical reservoirs. Lakes & Reservoirs: Research & Management, 25(2): 214-229.

https://doi.org/10.1111/lre.12320

Lampert, W. and Sommer, U. (1997). Limnology. The ecology of lake and stream. Oxford Univ. Press. Avenue- New York, 261pp.

Li, S.; Chen, F.;Song, K.; Liu, G.; Tao, H.; Xu, S. and Mu, G. (2022). Mapping the trophic state index of eastern lakes in China using an empirical model and Sentinel-2 imagery data. Journal of Hydrology, 608: 127613.

https://doi.org/10.1016/j.jhydrol.2022.127613

Li, W.; Li, Y.; Zhong, J.; Fu, H.; Tu, J. and Fan, H. (2018). Submerged Macrophytes Exhibit Different Phosphorus Stoichiometric Homeostasis, J. of Frontiers in Plant Science, 9(1207): 1-9.

https://doi.org/10.3389/fpls.2018.01207

Li, Y.; Geng, M.; Yu, J.; Du, Y.; Xu, M.; Zhang, W.; Wang, J.; Su, H.; Wang, R. and Chen, F. (2022). Eutrophication decrease compositional dissimilarity in freshwater plankton communities, J. of Science of The Total Environment, 281: 1-15.

Liang, Z.; Xu, Y.; Qiu, Q.; Liu, Y.; Lu, W. and Wagner, T. (2021). A framework to develop joint nutrient criteria for lake eutrophication management in eutrophic lakes. J. of Hydrolgy. 594: 125883.

https://doi.org/10.1016/j.jhydrol.2020.125883

Lopes, O. F.; Rocha, F. A.; de Sousa, L. F.; da Silva, D. M.; Amorim, A. F.; Gomes, R. L.; Junior, A. L. and De Jesus, R. M. (2019). Influence of land use on trophic state indexes in northeast Brazilian river basins. J. of Environ Monit Assess, 191(77): 1-14.

Lorenzen, C. J. (1967). Determination of chlorophyll and pheopigments: spectrophotometric equations. J. of Limnology Oceanography, 12: 343-346.

Marreto, R. N.; Baumgarten, M. D. G. Z. and Wallner-Kersanach, M. (2017). Trophic quality of waters in the Patos Lagoon estuary: a comparison between its margins and the port channel located in Rio Grande, RS, Brazil. Acta Limnologica Brasiliensia, 29(11): 1-12

https://doi.org/10.1590/S2179-975X10716

Moyel, M. S. (2014). Assessment of water quality of the Shatt Al-Arab River, using multivariate statistical technique. Mesopotomia Environment Journal, 1(1) :39-46.

Naumann, E. (1919). Några synpunkter angående limnoplanktons ökologi med särskild hänsyn till fytoplankton. Svensk Botanisk Tidskrift, 13(6): 129-163.

Nojavan, F.; Kreakie, B. J.; Hollister, J. W. and Qian, S. S. (2019). Rethinking the lake trophic state index. PeerJ, 7: 7936.

https://doi.org/10.7717/peerj.7936

Papoutsa, C.; Akylas, E. and Hadjimitsis, D. (2014). Trophic State Index derivation through the remote sensing of Case-2 water bodies in the Mediterranean region. Open Geosciences, 6(1): 67-78.

https://doi.org/10.2478/s13533-012-0161-4

Power, M.; Attrill, M. J. and Thomas, R. M. (2000). Environmental factors and interactions affecting the temporal abundance of juvenile flatfish in the Thames estuary. Journal of Sea Research, 43(2): 135-149.

Rahul, U.; Arvind, K. P. and Upadhyay, S. K. (2013). Assessment of lake water quality by using Palmer and Trophic state index- a case study of upper lake, Bhopal, India. International Research Journal of Environmental Sciences, 2(5): 1-8.

Rajashekar, M. and Vijaykumar, K. (2008). Trophic index state of Sharanabasaweshwara lake: Gulbarga District, Karnataka, India. The 12th World Lake Conference: pp.1933-1935.

Swatland, H. J. (2020). Light penetration through shallow flowing water, comparing the effects of surface lenses in laminar flow with bubbles added in turbulent flow. Earth and Environment Science Research and Reviews, 3(1): 40-43.

UNEP, H. (2001). The Mesopotamian marshlands: demise of an ecosystem. Division of early warning and assessment, United Nations Environment Program (UNEP) Nairobi, Kenya, 46pp.

UNEP. Eutrophication monitoring strategy of MED POL. (2003). Meeting of the MED POL. National Coordinators (Sangemini, Italy,27-30 May 2003) Mediterranean Action Plan Report. UNEP (DEC) /MEDWG .231/14: 13pp.

USEPA. (1994).Water quality standards handbook Technical Report EPA-823-B-94-005. US Environmental Protection Agency, Office of Water and Office of Research and Development, Washington, D.C.

Yang, Q.; Liu, G.; Agostinho, F.; Giannetti, B. F. and Yang, Z. (2022). Assessment of ecological restoration projects under water limits: Finding a balance between nature and human needs. Journal of Environmental Management, 311: 114849.

https://doi.org/10.1016/j.jenvman.2022.114849

Zhang, F.; Xue, B.; Cai, Y.; Xu, H. and Zou, W. (2023). Utility of Trophic State Index in lakes and reservoirs in the Chinese Eastern Plains ecoregion: The key role of water depth. J. of Ecological Indicators, 148: 110029.

https://doi.org/10.1016/j.ecolind.2023.110029