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Environmental factors drive phytoplankton primary productivity in a shallow Lake

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ABSTRACT

Monitoring of phytoplankton primary productivity in the lake was of great importance to support the life of different aquatic organisms and fill the gap in the information concerning the most important factors that drive primary productivity. The current study investigates the phytoplankton primary productivity in Baghdad Island Tourist Lake and physicochemical parameters from November 2021 to May 2022. Monthly water samples were collected from November 2021 to May 2022 ،and the results were presented along wet and dry seasons. The results revealed that primary productivity ranged from 140.6 mg C/cm^3/hr to 346.8 mg C/cm^3/hr. The Principal Component Analysis (PCA) showed three environmental factors that drive phytoplankton primary productivity, these were light penetration (LP), pH, and dissolved oxygen (DO) in the dry season. While only two factors (water temperature (WT) and DO) were found to be important in the wet season. Sensitivity analysis showed three models, the first model included eight factors (WT, pH, EC, LP, DO, TOC, DOC, and TCO), and the second model included seven factors (WT, pH, EC, LP, DO, TOC, and DOC). While the third model included six factors (WT, pH, EC, LP, DO, and TOC). The trophic level of Baghdad Island Tourist Lake, according to primary productivity, is considered oligotrophic- mesotrophic.

INTRODUCTION

Primary productivity is the process where organisms utilize inorganic substances to produce simple organic materials. It typically occurs through photosynthesis. Phytoplankton has a big role in removing carbon dioxide from an aquatic ecosystem (**Badger *et al*., 1998; Hamdan *et al*., 2018**). Earth's primary productivity is attributed to photoautotrophs (**Zhang *et al*., 2017**). The total biological productivity of a region or ecosystem is referred to as gross primary production. In a food chain, producers (or autotrophs) use a specific amount of organic material to sustain their lives, leaving only the net primary productivity for consumers to use (or heterotrophs, which are made up of herbivores and carnivores in each environment). Primary productivity is generally measured by carbon dioxide or oxygen intake. Production rates are defined as grams of organic carbon per unit area per unit of time (**Cloern *et al*., 2014).** Studying primary production in an ecosystem gives fundamental knowledge about the energy available in the environment and how it is transmitted within that system.

As a result, primary production is the foundation for ecosystem food chains. The food chains in aquatic environments will be aided by increased phytoplankton productivity (**Talib *et al*., 2022**). Monitoring different freshwater systems is important for environmental sustainability (**Li *et al*., 2018; Bakaeva *et al*., 2021**). **Hassan *et al*. (2011)** and **Talib (2017**) studied the phytoplankton primary production, chlorophyll-a, and physicochemical factors in restored Mesopotamian marshes and revealed that the marshes are ranked as oligotrophic-mesotrophic. **Albueajee *et al.* (2020)** used the diversity of phytoplankton to assist the trophic states of the Auda marsh, and the results showed that the marsh was mesotrophic according to the phytoplankton species composition.

The action of photosynthesis by phytoplankton is responsible for primary productivity. As the primary productivity of any ecosystem refers to the system's adequacy and suitability for the survival of aquatic species, this is reflected in the most economically important of these neighborhoods, the fish wealth. Being one of the most important sources of human food, a source of livelihood for the majority, and a source of economic wealth, the researchers researched the primary productivity of phytoplankton in order to boost this fish wealth because it gives an applied benefit in fish farming programs) **Blanchard *et al*., 2012**). Most aquatic animals, such as pinwheels that graze on phytoplankton, and fish, in turn, feed on these aquatic species, especially juvenile fish, and large fish eat small fish. Increasing the productivity of phytoplankton will positively impact the expansion of aquatic food chains (**Bronmark and Hansson, 2017**). As a result, primary productivity has been the subject of numerous worldwide and local studies, and primary productivity in Iraqi aquatic environments has been studied.

The physicochemical and biological parameters of the Al-Tharthar, Al-Habbaniyah, and Al-Razzazah lakes were investigated, reported that a Romanian company measured primary productivity in some Iraqi lakes in 1983 by Romanian company (**Wahhab and Hassan, 2022**) using the oxygen method for only two months, with the following results: Al-Tharthar 37-150 mg C/ m3/ day in August and November, Habbaniyah 37-637 mg C/m3/ day in September and November, and Al-Razzazah 37 in September and November and 187 mg carbon / m3/ day in August and October. The biomass of phytoplankton was calculated throughout a six-month period in 1982 to complete the study. It was mentioned that the biomass in Lake Habbaniyah (1.04-9.37 mg/L) is higher than in Lake Tharthar and Al-Razzaza (0.03-0.08 and 0.04-0.73 mg/L, respectively), and that when using the initial productivity values, each of the Tharthar and Al-Razzaza lakes can be classified as Oligotrophic lakes, whereas the Habbaniyah Lake is classified as Mesotrophic to Eutrophic (**Al Saadi *et al*., 2002**).

Al-Tamimi and Al-Mersomy (2018) used light-dark bottle methods to determine primary productivity in Al-Habbaniyah Lake and found an average of 61.24 mg carbon/m3/hr. The lake is classified as mesotrophic (**Wetzel (1983**) based on the findings of **Al-Tamimi (1992**). **Maulood and Hassan (2021**) explained that the phytoplankton primary production study used different types of methods, such as the light-dark method, chlorophyll-a concentration, and phytoplankton biomass in Iraq lotic systems

Wahhab and Hassan (2021) reviewed all studies concerning the primary production in Iraqi lake and concluded that a big gab noticed in the aforementioned issue.

Based on our information, there are absences of an environmental study to measure the phytoplankton primary productivity of Baghdad Island Tourist Lake. Therefore, determining the primary productivity of phytoplankton on the tourist island of Baghdad is important to maintain a certain extent of productivity without reaching the state of eutrophication. This research aimed to identify the trophic status of the Baghdad Island Tourist Lake and to measure the phytoplankton primary productivity. In addition, to determine the environmental factors drive it.

MATERIALS AND METHODS

Baghdad Island Tourist Lake (BITL) is a tourist area in the city of Baghdad, located in the Al-Fahama area north of the city of Baghdad, about 20 km from the center of Baghdad on the right side of the Tigris River (Fig. 1).

The physicochemical parameters of water measured during the investigation included water temperature (WT), Light penetration (LP), Electric conductivity (EC), salinity (S ‰), pH, Total Alkalinity (TA), Total Hardness (TH), Calcium (Ca^{++}), Magnesium (Mg^{++}), Sodium (Na^{+}), Potassium (K^{+}), Total dissolved solids (TDS), Dissolved oxygen (DO), Total Phosphorus (TP), Total Nitrogen (TN). All physicochemical parameters were measured according to APHA (2017).

Three sites were selected for this study. The first site represented the entry of river water into lake, while the second site represented the middle of the Lake at the Tower area. The third site is located on the lake's southern side (Table 1). Sites 2 and 3 were selected for measuring phytoplankton primary productivity.

Table 1. Global Position System (GPS) of the study sites

Site	Longitude (eastwards)	Latitude (northwards)
S1	44°20'32.4 E	33°46'39.6 N
S2	44° 09’25.2 E	33 °12’247 N
S3	44 °19’47.4 E	33° 22’366 N

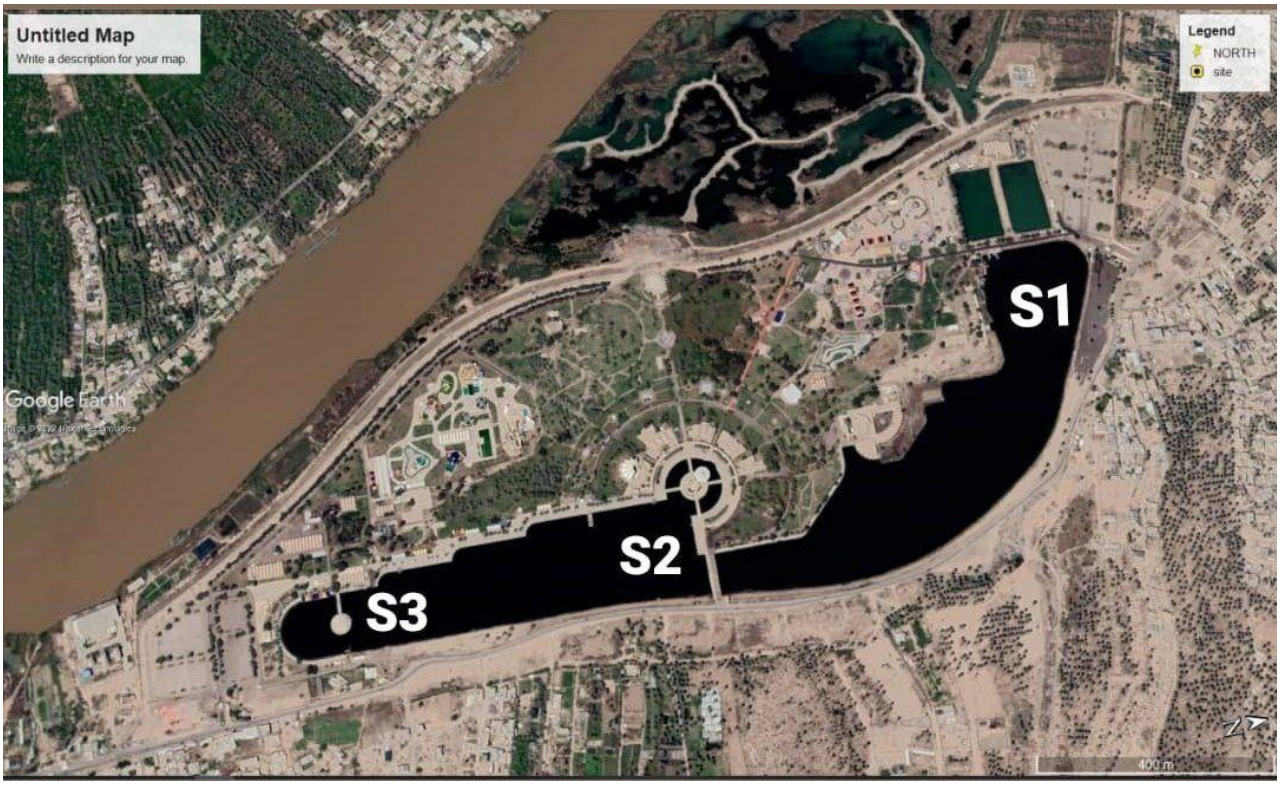

Fig. 1. Map of the study area (S= site)

The phytoplankton primary productivity was measured in this study according to light/ dark methods. The sampling was taken from one-meter depth. Three bottles were used for each of light (L), and dark (D) in two sites to measure phytoplankton primary productivity, and they were incubated for 4 hours in the field. The following equation is used to determine primary productivity:

$$P.P\ mg\ C\ m^{-3}.\ hr^{-1} = (L - D\ /\ incubation\ hours) * 0.375 * 1000$$

Where:

P.P = Primary Productivity

L = light bottles

D= dark bottle

0.375= from conversion Oxygen to Carbon 12/32

Dissolved oxygen in both bottles was determined according to Azide modification.

Statistical analysis: the backward linear regression method was used to determine the factors affecting the primary productivity, as well as the principle components analysis (PCA) method, and for finding a Pearson correlation coefficient (r) to determine the correlation between the factors. ANOVA and post Hoc comparison analysis were used to determine the significant differences between the factors affecting water quality. Sensitivity analysis used the linear backward regression (LBR) to identify which environmental factor(s) influences primary productivity.

RESULTS AND DISCUSSION

The primary productivity of aquatic ecosystem can be studied to provide information about energy and the nature of its transportation in benthic and planktonic communities (**Hassan *et al*., 2011**). Primary productivity is used in this study to monitor the lake's trophic status based on calculating the PP via the oxygen method (light/dark bottles). The value of phytoplankton primary productivity (PP) ranged from 140.6 mg C cm^{-3} hr^{-1} to 290.6 in the wet season, while their values in the dry season ranged from 281.2 mg C cm^{-3} hr^{-1} to 346.8 mg C cm^{-3} hr^{-1} A temporal variation of productivity noticed where productivity was higher in the dry season than in the wet season, as the rise in temperature increases the metabolic rate and algae productivity. The monthly variations of PP in the present study showed two peaks in the sites S1, S2 (Fig. 2) . Whereas one lower peak was detected in November 2021 in S2, and a higher peak was observed in April 2022 (S2)(Fig. 2). Some physicochemical parameters were determined in the lake during the two seasons (Table 2).

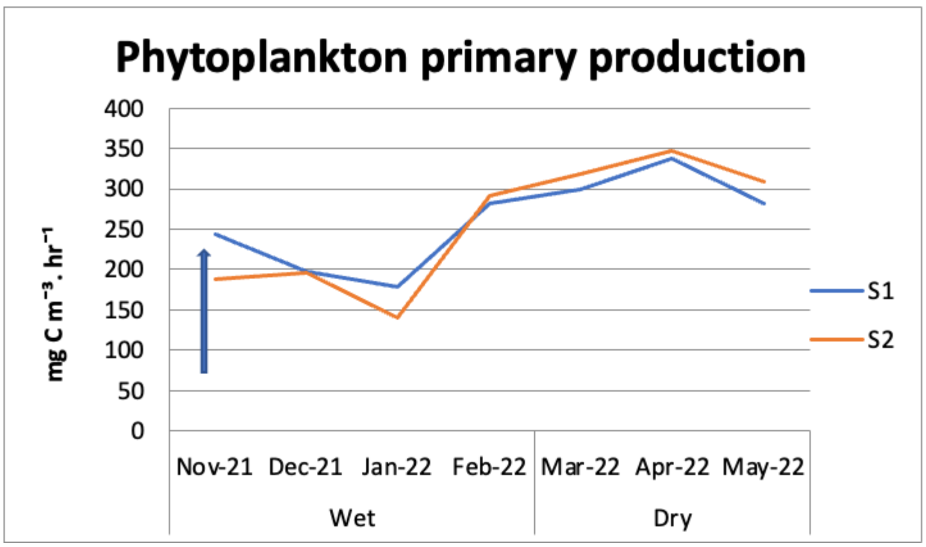

Fig. 2. Monthly variation in primary productivity during the study period. Note: S= site

Table 2. Physicochemical parameters during the study period in Baghdad Tourist Island Lake

Parameters	Code	Dry Mean ±SD	Wet Mean ±SD
Water temp. °C	WT	22.343 ±4.513	15.08 ±1.615
light penetration	LP	159.25 ±41.06	158.583 ±57.25
Electric Conductivity µS/cm	EC	906.807 ±40.357	993.499 ±109.595
Salinity ‰	S‰	0.552 ±0.023	0.613 ±0.067
pH	pH	7.759 ±0.312	7.478 ±0.199
Total Alkalinity (mg $CaCO_3$/L)	TA	153.61 ±13.291	172.502 ±23.317
Total Hardness(mg $CaCO_3$/L)	TH	345.193 ±31.406	341.368 ±19.425
Calcium (mg $CaCO_3$/L)	Ca	74.614 ±10.425	73.719 ±7.327
Magnesium (mg $CaCO_3$/L)	Mg	64.881 ±6.995	66.136 ±5.105
Sodium (mg/L)	Na	59.722 ±6.189	56.473 ±7.157
Potassium (mg/L)	K	7.667 ±0.833	6.735 ±0.728
Total dissolved solids (mg/L)	TDS	630.293 ±25.299	704.866 ±94.305
Dissolved oxygen (mg/L)	DO	7.82 ±0.808	8.139 ±0.715
Total Phosphorus (mg/L)	TP	0.486 ±0.104	0.359 ±0.178
Total Nitrogen (mg/L)	TN	0.992 ±0.681	1.262 ±1.135

The Principal Component Analysis (PCA) results showed that there wrer three significant factors (RC1, RC2, RC3) that affect productivity in the dry season, RC1 was included with LP, DO and pH with Eigenvalue 2.818, While RC2 in conjunction with EC, TCO and TOC with Eigenvalue 1.948 and RC3 was in relation with TOC, WT, and DOC with Eigenvalue of 1.742 (Fig. 3).

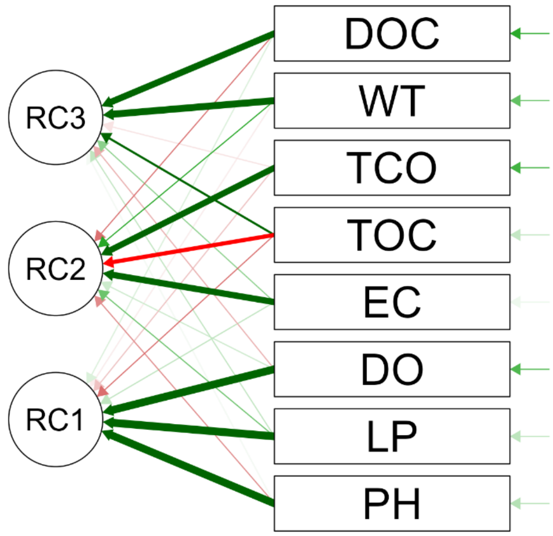

Fig. 3. Path Diagram of Principal Component Analysis results in dry season

The RC1 showed a strong positive correlation between PP and the RC1 factor LP (r= 0.953), DO (0.941), and pH (0.929) at P<0.05. RC2 revealed a strong positive correlation between PP and EC(r= 0.825), TCO (0.810) at P<0.05, and a negative correlation with TOC (r= -0.645 at P<0.05). While RC3 has a strong positive correlation between PP and WT, and DOC (r= 0.876, 0.838 at P<0.05), respectively, and a weak positive correlation with TOC(r= 0.485 at P<0.05). In the wet season, PCA results showed three factors (RC1, RC2, RC3) that affect pp (RC1, RC2, RC3). RC1 the most important factors, these factors were included WT, TCO and DO with Eigenvalue 3.336, While RC2 were LP and EC with Eigenvalue 1.993, and RC3 were TOC and DOC with Eigenvalue 1.026 love *et al*. (2019) (Fig. 4).

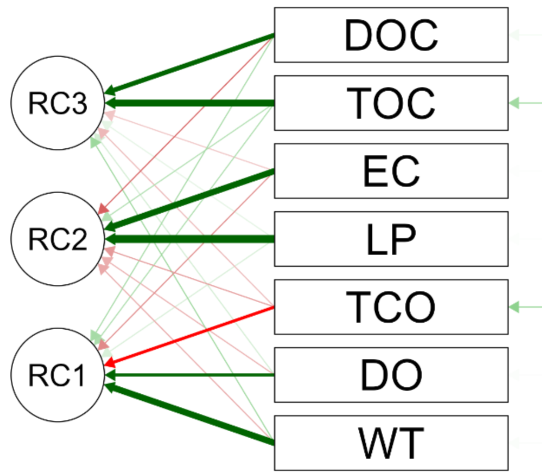

Fig. 4. Path Diagram of Principal Component Analysis results in wet season

The RC1 showed a strong positive correlation between PP and the RC1 factor WT (r= 0.992), DO (0.787), and a negative correlation with TCO (-0.789) at P<0.05. RC2 revealed a strong positive correlation between PP and LP(r= 0.985) and EC (0.914) at P<0.05. While RC3 has a strong positive correlation between PP and TOC, and DOC (r= 0.945, 0.856 at P<0.05), respectively.

In the current study, sensitivity analysis of PP used the linear backward regression (LBR) to identify which environmental factor was more impact on PP. **Namugize and Jewitt (2018)** used the LBR to identify the most important factors affected on water quality. **Kohberger *et al*. (1978**) used sensitivity analysis for environmental factors by using the backward elimination regression model and eigenvalues-eigenvector analyses. In the current study, the LBR was used to determine the most important factors affecting on PP in the study area. **Daggers (2021**) and **Daggers *et al*. (2018)** used sensitivity analysis to determine the impact of environmental factors on the primary production of microphytobenthic, and the studies revealed the impact of emersion duration, mud content, Chl-a ambient light and photosynthesis parameters determine most of PP in the study area.

In dry season, the sensitivity analysis revealed three models. The first model included eight factors; WT, pH, EC, LP, DO, TOC, DOC and TCO. The second model only TCO was excluded, and the model was included only seven factors; WT, pH, EC, LP, DO, TOC, and DOC. The model three showed the most important factors effected the PP in the study lake, these factors were; WT, pH, EC, LP, DO, and TOC.

Table 3. Three models illustrated by sensitivity analysis after standardized the values of the environmental parameters in dry season

Model		Unstandardized	Standard Error	Standardized	t	P
1	WT	0.291	0.213	0.815	1.366	0.402
	PH	-0.534	0.333	-0.656	-1.606	0.355
	EC	-1.037	0.322	-1.590	-3.226	0.191
	LP	0.718	0.540	1.999	1.329	0.411
	DO	-0.429	0.414	-1.363	-1.038	0.488
	TOC	-0.533	0.155	-1.206	-3.443	0.180
	DOC	-0.081	0.287	-0.213	-0.283	0.824
	TCO	0.035	0.323	0.056	0.108	0.931
2	WT	0.312	0.059	0.874	5.257	0.034
	PH	-0.552	0.205	-0.677	-2.689	0.115
	EC	-1.063	0.151	-1.630	-7.048	0.020
	LP	0.762	0.249	2.123	3.066	0.092
	DO	-0.462	0.198	-1.468	-2.333	0.145
	TOC	-0.544	0.084	-1.231	-6.477	0.023
	DOC	-0.109	0.095	-0.285	-1.147	0.370
3	WT	0.291	0.059	0.816	4.902	0.016
	PH	-0.576	0.215	-0.707	-2.683	0.075
	EC	-0.999	0.147	-1.531	-6.786	0.007
	LP	0.543	0.168	1.513	3.243	0.048
	DO	-0.271	0.113	-0.862	-2.400	0.096
	TOC	-0.579	0.082	-1.312	-7.075	0.006

In wet seasons, also three models were determined. The first model with six factors; WT, DO, TOC, DOC, TCO, and LP. The second model excluded only TCO from the aforementioned factors. While the third model included only WT, DO, DOC, and LP, considered the most important factors that affected the PP in wet seasons.

Table 4. Three models illustrated by sensitivity analysis after standardized the values of the environmental parameters in wet season

Model		Unstandardized	Standard Error	Standardized	t	P
1	WT	0.690	0.806	0.871	0.856	0.482
	DO	-0.022	0.701	-0.030	-0.032	0.078
	TOC	0.377	0.379	0.321	0.995	0.125
	DOC	-0.849	0.239	-1.169	-3.546	0.071
	TCO	0.435	0.173	0.485	2.519	0.428
	LP	0.531	0.251	0.549	2.112	0.169
2	DO	-0.022	0.701	-0.030	-0.032	0.078
	WT	0.666	0.203	0.841	3.282	0.046
	TOC	0.382	0.280	0.325	1.362	0.266
	DOC	-0.848	0.195	-1.168	-4.345	0.023
	LP	0.535	0.181	0.553	2.955	0.060
3	DO	-0.022	0.701	-0.030	-0.032	0.078
	WT	0.754	0.212	0.951	3.555	0.024
	DOC	-0.834	0.215	-1.148	-3.882	0.018
	LP	0.655	0.174	0.678	3.773	0.020

CONCLUSION

According to primary productivity, the trophic status of Baghdad Island Tourist Lake is considered as oligotrophic- mesotrophic level. The Principal Component Analysis (PCA) showed three environmental factors that drive phytoplankton primary productivity, where the LP, pH, and DO were found to be the most important factors in the dry season, while WT and DO were significantly affected the primary productivity in the wet season.The sensitivity analysis revealed three models, the first model included eight factors (WT, pH, EC, LP, DO, TOC, DOC, and TCO), and the second model included seven factors (WT, pH, EC, LP, DO, TOC, and DOC), while the third model included six factors (WT, pH, EC, LP, DO, and TOC). In wet seasons, also three models were determined, the first model with six factors (WT, DO, TOC, DOC, TCO, and LP), and the second model excluded only TCO from the aforementioned factors. While the third model included only WT, DO, DOC, and LP.

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