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Measurement of Some Biodiversity Indices for Phytoplankton Community in Sawa Lake, Southern Iraq

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ABSTRACT

Sawa Lake is located at the eastern edge of Iraq's southern desert. It is a habitat for a variety of phytoplankton communities with limited knowledge about their diversity patterns and organization in literature. Thus, seasonal samples were collected from three sites (S1: south of the lake, St 2: in the middle, and St 3: north of the lake) during a period extending from autumn 2020 to summer 2021. Samples were subjected to a comprehensive study using different diversity indices, such as the Shannon diversity index, Simpson index, evenness index, richness index, and Jaccard index, to examine the organization and distribution of phytoplankton communities. A dominance of Bacillariophyceae was detected in the lake under study, followed by Cyanophyceae, Chlorophyceae, and Pyrrophyceae. The Simpson index values ranged from 0.86 to 0.64 during summer. The evenness diversity index was 0.021 in autumn and 0.011 in winter. The Shannon index was 2.31 in summer and 1.55 in autumn. Based on the Jaccard index results, the greatest degree of similarity (66.66%) was recorded between sites 1 and 3, while the lowest (58%) was between sites 1 and 2. The richness index varied from 1.594 - 0.987 in winter and autumn, respectively. A positive correlation between the Shannon Index and the Sampson Index (r = 0.82) was detected at a significance level of $P \leq 0.01$ based on statistical analysis. Result indices were correlated with phytoplankton density, and it was found that the richness index represents the diversity better than other indices.

INTRODUCTION

Natural lakes are flat, ocean-like pools of water that are immobile and do not directly interact with other bodies of water **(Hammer, 1986)**. The physical, chemical, and biological characteristics of the water bodies that lakes contain in arid regions can combine to generate lake ecosystems **(Bhateria & Jain, 2016)**. Lakes supply water and they represent an essential component of the hydrological budget, offering radical habitats for a variety of biological species **(Al-Haidarey*et al.*, 2018)**.

Although water makes approximately 70% of the Earth's surface, limited information is available about the diversity patterns of marine phytoplacton compared to terrestrial plant species. It is commonly known that variety increases production and stability in communities of higher creatures, but little is known about how these relationships apply to communities of unicellular organisms, such as phytoplankton, which account for over 50% of the world's primary productivity **(Motwani*et al.*, 2014).**

Algae are the major food source and oxygen source for consumer creatures in aquatic habitats, and since they are at the base of the food chain, they have a direct impact on primary production. Additionally, algae play a significant part in determining the level of water contamination and in cleaning wastewater. Since they have short life spans, quick response to toxins, and relative easiness to count, algae are one of the more significant biological indicators of changes in water quality. Several techniques were employed to categorize the lakes and establish their trophic status, with the most popular method depending on productivity and employing algae connected to the trophic state index **(Toma, 2019)**.

Phytoplankton offers more data on alterations in water quality than increased concentrations of nutrients or chlorophyll a concentration. The physical, chemical, and biological properties of a given body of water are put together to form its water quality. It is crucial to understand how species variety is maintained because phytoplankton is the primary source of organic matter supporting food webs in the aquatic ecosystem **(Al-Taee, 2017)**.

Aquatic ecosystems have higher biodiversity than terrestrial systems, and marine biodiversity is being lost at a rate that is noticeably quicker than that of terrestrial biodiversity as a result of human activity and climate change. Moreover, a decline in marine biodiversity has been linked to the loss or deterioration of some services and functions provided by the ocean or coastal ecosystem**(Feiyang, *et al.*,2022).**

A diversity index is a measure of species diversity within a community that consists of co-occurring populations of several (two or more) species. Richness and evenness are two of its elements. Richness is a metric for how many different species there are in a sample, with more species in a community indicating higher diversity or greater richness. The relative abundance of the various species within a community is gauged by its evenness **(Dhar & Nikhil, 2017)**. **Al-Saeedi and Al-Salman, (2022)** studied some biodiversity indices that were used to assess water quality, the relationship between sites, seasons, and the qualitative and quantitative presence of phytoplanktons in the lake of the tourist island of Baghdad. Simpson and Shannon indices are a relevant tool to characterize the trophic states, especially in the rainy season, and phytoplankton diversity indices are an effective tool that can be used to assess the trophic states in barrier lakes like Jingpo Lake **(Cai*et al.*,2022)**. An aquatic ecosystem's health should be assessed by considering both the species diversity indices and the levels of water pollution. An ecological portrait of the research region can be obtained through quantitative and qualitative comparisons of phytoplankton abundance and composition over different study locations and times. When assessing the health of an aquatic environment, one should consider the species diversity indices and the levels of water pollution. An ecological portrait of the research region can be obtained through quantitative and qualitative comparisons of phytoplankton abundance and composition over different study locations and times **(Das & Jolly, 2023)**.

The goal of the current study was detrmined to examine the organization of phytoplankton communities using a variety of diversity indices, including the richness, evenness, Shannon, Simpsons and Jaccard indices.

MATERIALS AND METHODS

Study site

In Iraq, Sawa Lake is the only natural lake located at 31º18' N, 45º00' E. It is situated in the eastern border of Iraq's southern desert, 276 kilometers south of Baghdad, 23 kilometers west of the Euphrates River (Fig. 1), and entirely encircled by an arid desert at an elevation of 18.6 meters above sea level. The lake's depth varies from 3 to 5.5 meters. The main source of water for the lake is subterranean springs that run through the center of it; there are no rivers that empty into it. It has been discovered that the lake receives its water from the Euphrates aquifer via a network of fractures and cracks. Due to considerable evaporation, the salinity of the lake water is significantly higher than that of the Euphrates River. A gypsum-dominated rising salt barrier forms the lake margins.(**Al-Husseni*et al.*, 2021**).Three sites were selected for the present study, the first site (St 1) is located in the south of the lake, it is close to the resort buildings, and most visitors are present in it and it is less wide, the second site (St 2) is in the middle of the lake, where it begins to expand and the third site (St 3) is located north of the lake and is more extensive and near the water springs of the lake, and the distance between one site and other about 2 km.

Fig. 1. A map showing Sawa Lake and the 3 study sites

Sampling collection

Sample of phytoplankton were collected using a conical net made of fastening nylon with a mouth ring diameter of 35cm and a mesh width of 20μm.For surface hauls, the net was towed for 10 minutes, and a flow meter attached to it measured the amount of water that passed through it. To prevent mesh clogging, the net was backwashed in between sites. A few drops of 1% Lugol's iodine solution were used to fix and preserve the filtered samples. Samples were concentrated approximately (5-10) ml by siphoning the top layer of the sample carefully with a tube. The algae were identified based on the information reported in the studies of **Martinez *et al.* (1975)** and **Hadi (1981)**.

Diversity indices

The following formulas were used to compute species diversity indices, including the Shannon diversity index, Simpson diversity index, evenness index, richness index, and Jaccard index.

Simpson index

Simpson (1949) derived this diversity index. The Simpson index values (Δ) range from 0 to 1. However, in order to fix the inverse proportion, the final result of the calculation is subtracted from 1.

$1 - \Delta = [\Sigma\ ni\ (ni - 1)] / N\ (N-1)$

Δ: Simpson diversity index; ni: Number of individuals belonging to **i** species, and **N**: Total number of individuals.

Evenees index

This index was seasonally calculated for phytoplankton according to the following formula **(Flöder & Sommer 1999)**.

$J = H / Ln\ S$

H=Shannon weaver diversity; **S**= species richness

Shannon index

This indicator is frequently used to calculate diversity in biological systems. It came from a Shannon mathematical formula **(Shannon & Weaver (1949)**.

$H' = -\Sigma\ [(ni / N) \times \ln\ (ni / N)]$

H': Shannon diversity index ; ni: Number of individuals belonging to **i**species **N**: Total number of individuals.

Richness index

This index was calculated using the following formula given below (**Stiling, 1999**).

$D = n-1 / \ln N$

D: Richness index, and **N**: Total number of individuals in the sample.

Jaccard Index

Jaccard's similarity index computes similarity among the sites according to the following equation of **Magurran (2004)**.

JSI = a/(a+b+c) ×100

a = Total number of species at site a

b = Total number of species at site b

c = Total number of species present at sites a and b

RESULTS

1. Seasonal variation of phytoplankton density

The results showed that the highest mean value of phytoplankton density was recorded in winter at site 3 (495.03×10^3 Indiv/ L). Conversely, in the summer, site 2 showed the lowest overall density of phytoplankton (89.50×10^3 Indiv/L) (Fig. 2).

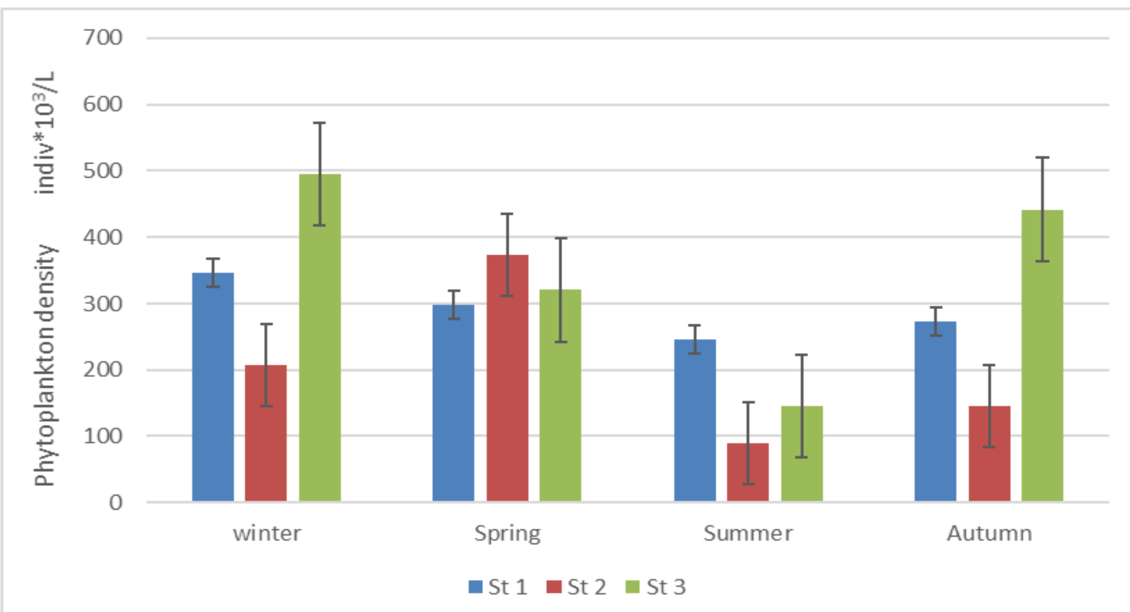

Fig. 2. Seasonal variation in phytoplankton density (Indiv*10^3/l) mean value in Sawa Lake during study period

2.Diversity indices

Table (1) lists the several phytoplankton community diversity indicators (Simpson, Evenness Shannon, and Richness Indexes).

Table 1. Range of diversity indices in all the sites

Parameter (A)	Site (B)	Winter	Spring	Summer	Autumn	LSD(0.05) A*B
Simpson	**S1**	**0.816**	**0.803**	**0.640**	**0.820**	**0.152**
	S2	**0.819**	**0.786**	**0.867**	**0.682**	
	S3	**0.753**	**0.829**	**0.663**	**0.834**	
Eveness	**S1**	**0.011**	**0.013**	**0.015**	**0.013**	**0.0083 (N.S)**
	S2	**0.015**	**0.014**	**0.019**	**0.021**	
	S3	**0.014**	**0.015**	**0.017**	**0.012**	
Shannon	**S1**	**2.189**	**1.971**	**1.615**	**2.192**	**0.481**
	S2	**2.067**	**1.909**	**2.315**	**1.550**	
	S3	**1.767**	**2.028**	**1.783**	**2.125**	
Richness	**S1**	**1.594**	**1.543**	**1.291**	**1.417**	**0.725**
	S2	**1.306**	**1.255**	**1.195**	**0.987**	
	S3	**1.168**	**1.202**	**1.198**	**1.242**	

N.S.: non-significant

2.1. Simpson index

Simpson index is used to measure habitat biodiversity. It reflects the dominance of a particular species in a community by taking into consideration the number and abundance of species. The highest value (0.867) was recorded at site 2 during autumn, while the lowest was (0.640) at site 1 during summer (Table 1). Statistical analysis showed no significant differences ($P \leq 0.05$) between seasons.

2.2. Evenness index

According to the current study's results, the phytoplankton evenness index value varied from 0.011 at site 1 in winter to 0.021 at site 2 in autumn (Table 1). There were no statistically significant differences ($P \leq 0.05$) between seasons and sites.

2.3. Shannon index

Shannon diversity index varied between the lowest value (1.55) at site 2 in summer and the highest value (2.31) at site 2 in autumn (Table 1). There were no statistically significant differences ($p \leq 0.05$) between the sites and seasons.

2.4. Richness index

The results of the richness index showed that the phytoplankton richness index's highest mean value was 1.594 during winter and its lowest mean value was 0.987 in autumn (Table 1). Seasons and sites differed significantly (*P*≤ 0.05) according to the statistical study.

2.5. Jaccard index

The Jaccard index revealed that, in terms of the seasonal similarity of phytoplankton species distribution, sites 1 and 3 had the highest percentage of similarity (66.66%), whereas sites 1 and 2 had the lowest proportion (58%), as displayed in Table (2).

Table 2. Jaccard index for phytoplankton species identified at the study's sites

Sites	Jaccard index
S 1 –S 2	58 %
S 1 – S 3	66.66 %
S 2- S 3	65.11 %

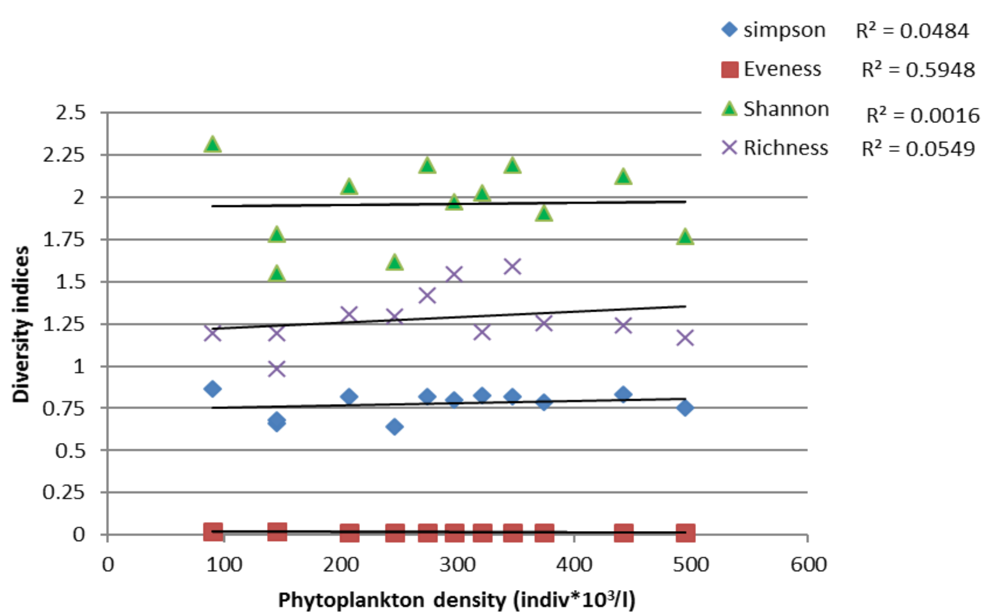

Fig. 3. Correlation between different diversity indices and phytoplankton density

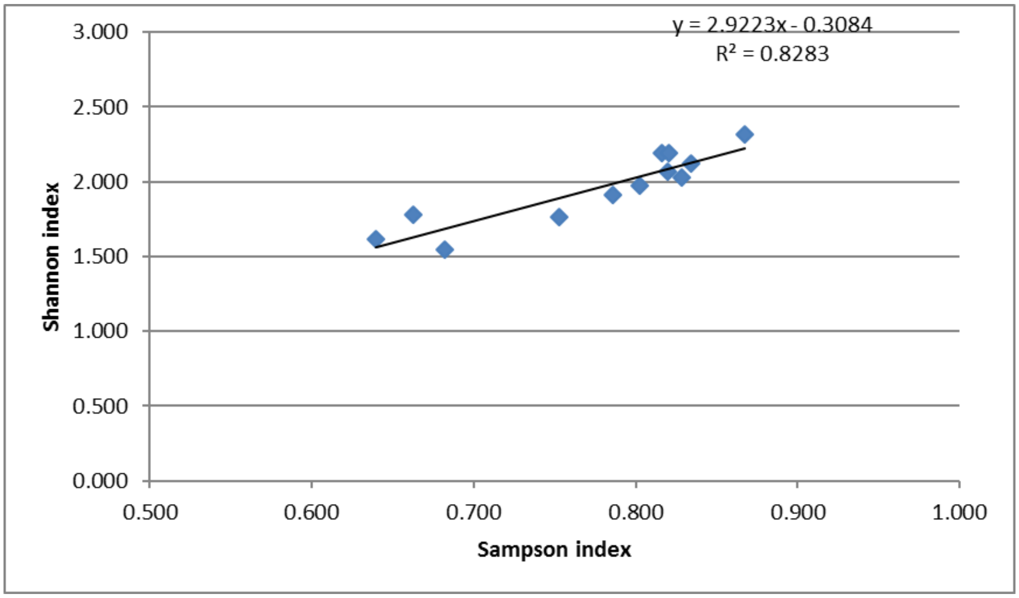

Fig. 4. Correlation between Shannon index and Sampson index

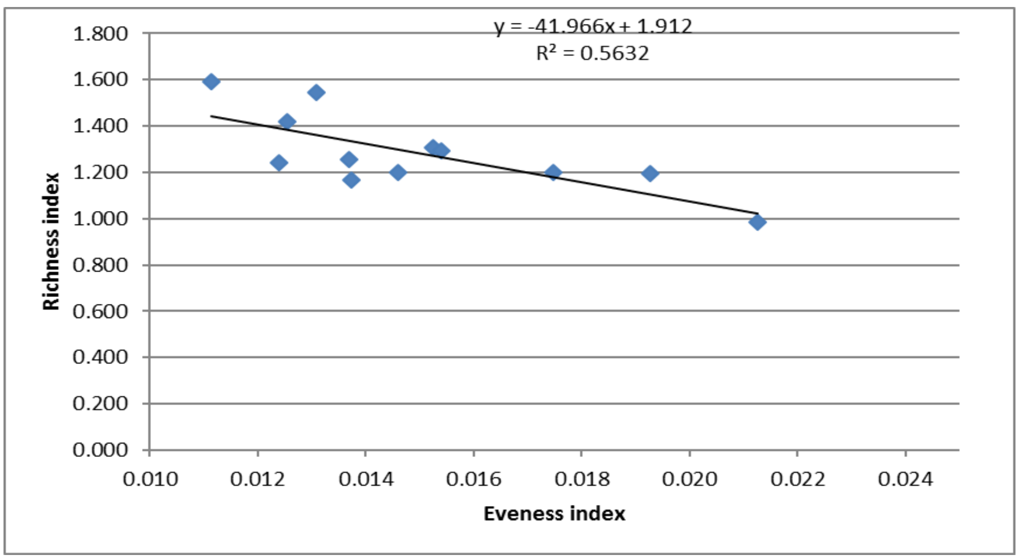

Fig. 5. Correlation between richness index and evenness index

DISCUSSION

Seasonal variation of phytoplankton density and diversity indices

The decrease in density values might be brought on by variations in winter and summer temperatures, which would affect the rate at which algae develop; this might be ascribed to the right environmental factors that are present for growth, such as dissolved oxygen, nutrients, and a suitable level of light intensity **(Kassim *et al.*, 2006; Merhoon *et al.*, 2017; Albueajee *et al.*, 2020)**.

Simpson index results showed that there is no dominant species and that species are distributed uniformly **(Kostryukova *et al.*, 2018)**. The highest recorded Simpson index value was assessed in the present study compared to the results of Massa-lagoon estuary of Morocco. According to a previous study, Simpson index varied between 0.014 and 0.99, and diversity showed a large heterogeneity of the phytoplankton composition **(Badsi *et al.*, 2012)**. According to Simpson's index, species are not evenly distributed.

The reduction of an evenness index in the present study indicates that a small number of highly densely populated species predominate, which is indicative of environmental pressure **(Dhar & Nikhil, 2017)**. The Evenness index results are less than those of previous studies **(Brraich & Kaur, 2015; Al Taee, 2017; Ali *et al.*, 2018)**.

Shannon diversity index ranges from 0 for communities with only one taxon to high values for communities with numerous taxa each with few individuals. Additionally, it establishes the usual value range for water body contamination, which is 0 to 4. Clean water is indicated by an index greater than 3; moderate pollution is indicated by a range between 1-3, and heavy pollution is indicated by a number less than 1 **(Ajayan & Ajitkumar, 2015; Anyanwu *et al.*,2023)**. Results showed that all sites had modest levels of pollution, as the Shannon index values were more than 1. These results revealed a high diversity in the study area and the non-dominance of certain types of phytoplankton **(Cahyonugroho *et al.*, 2022)**. The results showed that there was a great deal of diversity in the study area, and that some phytoplankton species were not dominant.

The richness index characterizes the species composition, range of diffusion, and representation in a given area; the higher index value indicates the greater species richness across the study area **(Al-Hassany *et al.*, 2012)**. As the number of species increases, so does the richness index. Higher values for the richness index in the current study suggest a high degree of diversity, whereas low values show the dominance of specific types of algae, which in turn lowers the index values **(Al Taee, 2017)**. Results showed that there was a large diversity of all species of phytoplankton because there was less pollution and less zooplankton grazing **(Ghosh*et al.*,2012)**.The results of Jaccard index may be related to the similarity of some physicochemical properties between study sites, which is the expected result since they all have the same main source of water **(Albueajee *et al.*, 2020)**.

Comparing different diversity indices

Based on the phytoplankton density found in the samples, the diversity indices were computed to determine which index best represents diversity. The phytoplankton diversity in Sawa Lake was represented by each diversity index. The phytoplankton density was associated with the diversity indices (Eveness, Richness, Shannon, and Simpson indices). The correlation's results, as illustrated in Fig. (3), made it abundantly evident that the evenness index and density have a stronger relationship. Therefore, when compared to other indices, it most accurately depicts the diversity of phytoplankton. High biodiversity indices are found in eutrophic and mesotrophic water bodies where one or two dominant species dominate the phytoplankton community. Nonetheless, the low Shannon index values of Lake's phytoplankton suggest that the water body is in a higher trophic state **(Jekatierynczuk-Rudczyk*et al.*, 2014; Cai, *et al.*, 2022)**.

According to correlation analysis, there was a strong positive correlation between the Simpson index with Shannon index & eveness index with richness index in all samples. (r = 0.82, r = 0.56) as shown in Fig. (4, 5). The statistical analysis revealed that hydrological connectivity strongly influenced the phytoplankton diversity indices and phytoplankton community, which agrees with the result indicating that hydrological connectivity is a key factor influencing phytoplankton community assembly of the Songhua River in China **(Meng *et al.*, 2020)**.

CONCLUSION

The results show that each index has different functions on evaluating the diversity of a phytoplankton community, both the indices of Richness index species and Shannon index showed that the Sawa Lake considering the study sites has a high diversity of diatoms. Following a correlation between indices and phytoplankton density, it was discovered that, the richness index more accurately reflects the diversity than the other indices.

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