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Original Article

Mapping of diatom indices by remote sensing to evaluate the Um El-Naaj Marshes' water quality

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Abstract: This study was conducted to evaluate the water quality of the Um El-Naaj Marshes using the community of diatoms bioindicator and mapping them by remote sensing data. From November 2018 to April 2019, epiphytic diatoms were collected from host aquatic plants of *Zannichllia palustnia* from six sites in the Um El-Naaj Marshes. According to the results, the Diatom Index (DI) ranged from 3.5 in autumn 2018 to 2.4 in summer 2019, i.e in sites 3 and 2, respectively. The index of trophic diatoms (TDI) for the majority of study sites showed the mesotrophic state ranged from 47.5 to 62.5 in all seasons. Except for site 2, which had the lowest value (35) in the summer of 2019, and station 3 which had a greater value than 60 in the Autumn of 2018 and spring of 2019, other sites had oligo-mesotrophic states. The general diatomic index (GDI) values showed the lowest value (9.6) at site 2 in the summer of 2019 and the greatest value (14.4) at site 3 in the spring of 2019. In addition, in the current study, maps were produced using remote sensing methods to visualize the values close to the studied sites to show the quality state of the whole marsh.

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Introduction

The Mesopotamian marshlands are one of the Middle East's most internationally significant wetlands due to their high biodiversity and role as a breeding place for numerous bird species that migrate from North Europe. Because freshwater discharge has decreased over the past three decades, the water quality of these marshes has deteriorated, and the hydrological regime has changed, causing substantial environmental impacts. This has significantly impacted the marshes' vegetation and fauna, reducing their ecological viability and importance (Al-Handal et al., 2016).

Epiphytic algae are residing on submerged aquatic vegetation, including freshwater angiosperms and macroalgae (Dunn et al., 2008). Due to the recurrent process of separating epiphyton from the host plant, these species are the main food supply for small fish and other invertebrates in the littoral zone (Al Ramahi and Al Bahadly, 2017). Recent research has demonstrated their significance as primary producers that remove carbon from the water column and absorb key nutrients, making these vital elements available to other species, such as tiny aquatic habitats in lakes (Fawzy et al., 2016; Neran et al., 2020). Because of being sessile, having rapid production rates, and unique set of environmental tolerances and preferences, epiphytic algae serve as reliable indicators of water quality and environmental conditions (Hassan and Al-Bdulameer, 2014; Naqeeb et al., 2022). They play a significant role in the ecological equilibrium between various types of macrophytes and their associated water bodies in the lotic water system, where they are the dominating species (USGS, 2017). This study aimed to evaluate the water quality of the Um El-Naaj Marshes based on bioindicators for the community of epiphytic diatoms collected

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Table 1. Coordinates and names of sampling sites of Um El Naaj Lake.

Sites (ST)	Sites (E)	x-axis coordinate (UTM)	y-axis coordinate (UTM)
1	Um bzazen	746945	3500950
2	AboAthba 1	750024	3504050
3	AboAthba 2	750046	3502900
4	Alkhabta	743841	3500870
5	Aboliefa 1	753309	3500520
6	Aboliefa 2	753652	3497750

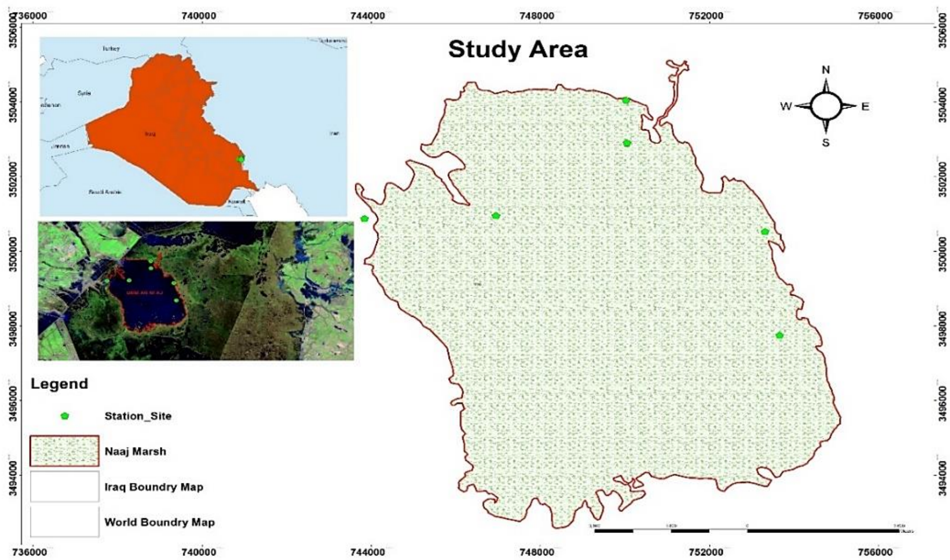

Figure 1. The study area of the, Observation station name in study area Al-Naaj lake include six stations.

from host aquatic plants of *Zannichllia palustnia*.

Materials and Methods

Study Area: Um El-Naaj Lake is located in the Kahala district having two entryways: one is through AL Kahla district in the direction of Bani Hashem, and the other one is through Kahla-Al Mueel-Abo Khasaf village (Table 1). The Um El-Naaj Lake has a 25 km width and a 30 km width along the Iran-Iraq border. Although there were some dried fields, it was a part of the partially dried wetlands. Currently, this marsh receives water through its outlets from both inside and outside of Iraq, including the Al Khala, the Al Mshrah, Al-Dwiridj and Karkheh, Nissan, and Al-Kfagia rivers (Hassan et al., 2012).

Processing of remote sensing (RS): In our investigation, we employed four bands of Landsat-8 OLI terrestrial remote sensing data, which were produced from November 2018 to October 2019. Images were obtained from the WEB at the same time as fieldwork data collection (Muhsin and Foud, 2012). In order to determine the study area's greatest visual clarity, data from Bands 7, 4, and 3 were combined. They were also used to track any changes that resulted from the analysis of parameter samples from the six stations located throughout the study area (Werner, 1977). ArcGIS (10.4) was used to produce prediction maps using the Interpolation Method (IDW). These maps show the circumstances surrounding Um El-Naaj Lake inside Iraqi borders. Inverse Distance Weighted (IDW) (Santos and Ferragut, 2018) was the approach used in this study to spatially interpolate water reflectance during seasonal changes in Um El-Naaj Marshes in 2018-2019.

Six sampling sites were selected in Um El-Naaj Marshes (Hor Al Huweiza) by GPS (Table 1, Fig. 1). Water samples were taken monthly from November

Table 2. The description of the values of the diatom index (DI) (Descy, 1979).

Value of diatom index	Interpretation values
4.5	Optimum biological quality, zero contamination
4-4.5	Almost standard caliber (Slight changes in the community, slight pollution)
3-4	Substantial eutrophication, declines in sensitive species, mild pollution, or community-wide effects that are more significant
2-3	High pollution, dominant species resistance, sensitive species declines or extinctions (reduced biodiversity), and resistant species
1-2	A clear preference for a few numbers of resistant species (many species vanish), and extreme pollution

Table 3. The description of TDI values ranged from 0-100. (Kelly and Whitton, 1995).

Pollution Degree	Value of index
Oligotrophic state	TDI< 35
Oligo-mesotrophic state	TDI 35-50
Mesotrophic state	TDI 50-60
Eutrophic state	TDI 60-75
Hypertrophic state	TDI>75

Table 4. The values of generic diatom index (GDI).

Water Quality	Value of index
High	17.5-20
Good	14-17.5
Moderate	10.5-14
Poor	7-10.5
Bad	< 7

2018 to October 2019. For qualitative study; 10g of host plants were cut into small parts of 2-3 cm and washed with 50-100 ml of environment water and then scrapped by a smooth brush or the blade. The samples were preserved in containers plastic with 1ml of Lugol's solution.

After separating the diatom from the plant, the sample is placed in tubes (100 ml) for 10-15 days with 1ml of Lugol's solution to precipitate, after which the precipitate is taken (20-30 mL) and stored in containers with a few drops of Lugol's solution (Hassany and Al-Bueajee, 2015; Salman et al., 2017; Prescott, 1964). Marked samples in containers with the date and location of the collection. Epiphytic diatoms are prepared on permanent slides for microscopic inspection. Diatoms were identified using the references listed below (Patrick, 1966; Werner, 1977; Hadi, 1984).

Trophic indices: Diatomic index (DI) was calculated according to Descy's list (Descy, 1979) which consists of 155 species using the formula of DI = ΣAj × Ij × Vj/Aj × Vj Aj, that it is the relative abundance of the species j present in the sample. Diatom taxa were chosen for their indicator value (tolerance to inorganic nutrients) and ease of identification which are crucial to measuring of Trophic Diatom Index (Kelly and Whitton, 1995) that was calculated using the formula of TDI = ∑(AjS jVj / AjVj X25)-25, where Aj = the frequency or percentage of species j in the sample, Sj = varies from 1 for sites with extremely low nutrient concentrations to 5 for sites with very high nutrient concentrations i.e. the species nutritional sensitivity of species j in the sample ranges from 1 to 5. (Table 3), and Vj = indicating the index's value (ranging 1-3)

Generic Diatom Index (GDI): This index is measured using equation of *GDI* = (∑ AjSjVJAjVj) × 4 (Lecointe et al., 2003), where Aj = the number or percentage of different species in the sample, Sj = Species that are sensitive to nutrients (1–5) (Table 4), and Vj = Value of index (1-3).

Results and Discussion

Diatom index: The results of the DI showed that the water quality of the El-Naaj Marshes ranged from 3.5 in autumn 2018 to 2.4 in summer 2019. The greatest value was 3.6 in site 3 in Spring 2019 and

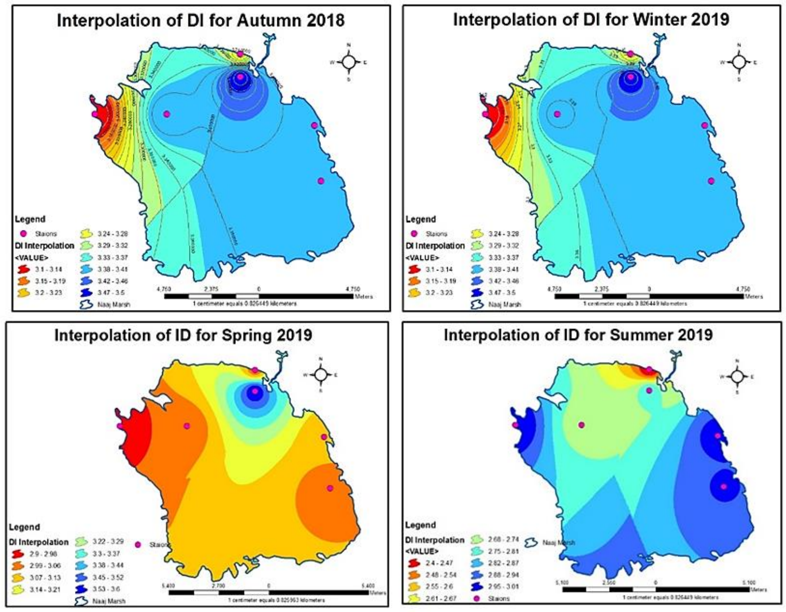

Figure 2. The seasonal variations of diatom index.

the lowest was 2.4 in site 2 in summer 2019 (Fig. 2). According to Descy (1979), the Um El-Naaj Lake's water quality ranged from moderate contamination (more sensitive species have a moderate to good quality) to good quality. Species of *A. minutissima* and *Nitzchia* were prevalent in contaminated water. Both species are tolerant to various pollutants (Todd and Mays, 2004). Reductions of vulnerable species show low pollution or severe eutrophication.

During the study time period, the water quality of Um El-Naaj Lake ranged from moderate water (moderate pollution) to low pollution categories. The high diversity of some species in the Um El-Naaj Lake may be attributable to the river's water quality, which is suited for high diversity due to the wide range of favorable development conditions and when there are challenging conditions, like a shortage of nutrients or an excess of them.

It allows species that were only initially present in a few natural settings to grow while reducing the presence of many species (Kusstatscher et al., 2019) The findings demonstrate that the shape of the host plant and seasonal water level variations influence the temporal variations of epiphytic algae on aquatic macrophyta (*Phragmites australis*).

The range and density of epiphytic algae are restricted by elements including temperature, light intensity, turbidity, and nutrient-rich plants. This study came to the conclusion that the water quality of Um El-Naaj Lake, which has a large diversity of diatoms, is favorable for the survival of many species of creatures (Salman and Hadi, 2015). The *Nitzschia* genus is regarded as a biological indicator that tracks the levels of high pollutant toxins and organic pollutants in sediments due to an abundance of organic materials brought to the river by agricultural runoff and human waste.

Trophic diatom index: Epiphytic diatoms' TDI values indicated that the majority of studied sites in all seasons had mesotrophic states, with values ranging from 47.5 to 62.5. Site 2 in the summer of 2019 recorded the lowest value (35), and site 6 the spring of 2019 had the highest value (62.5.5) showing a eutrophic state (Fig. 3). TDI showed variations in spring and summer at some showing an oligo-mesotrophic state. TDI data showed the level of water quality in the AL Hawaiza Marshes ranging from mesotrophic to eutrophic conditions. Increased bacterial activity to decompose organic materials in the water and promotes the growth of algae can be the cause of the increase in nutrients (CCME, 2007; Köbbing et al., 2013). The Inverse Distance Weighted (IDW) approach results of the current study to spatially interpolate water reflectance

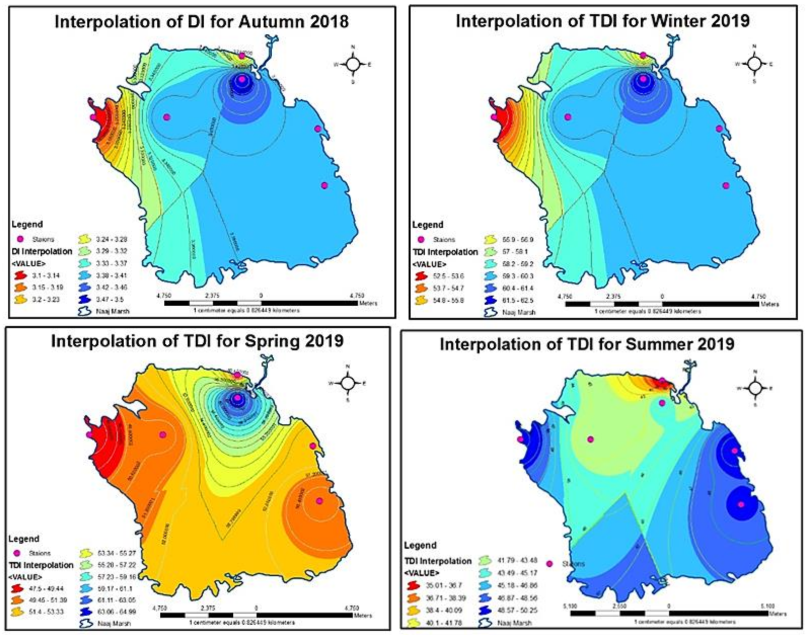

Figure 3. The seasonal variations of trophic diatom index.

during seasonal changes in Um El-Naaj Marshes in 2018-2019 are shown in Figure 3.

Generic diatoms index: According to the results, GDI values were lowest at site 2 in the summer of 2019 and highest at site 3 in the spring of 2019 (Fig. 4). The quality of the Um El-Naaj Lake ranged from mediocre to good based on these values (Hungary Ministry of Environment and Water, 2005) (Table 2). The greater the water quality and appropriateness for living creatures, the higher the GDI indicator

Table 5. Seasonal variations of TDI, GDI, DI in the Um-Al Naaj Lake.

Autumn 2018	TDI	GDI	DI
St1	60	13.66	3.4
St2	55.75	12.94	3.23
St3	62.5	14.04	3.5
St4	52.5	12.79	3.1
St5	60	13.83	3.4
St6	60	13.6	3.4
Winter 2019			
St1	60	13.66	3.4
St2	55.75	12.94	3.23
St3	62.5	14.04	3.5
St4	52.5	12.79	3.1
St5	60	13.83	3.4
St6	60	13.6	3.4
Spring 2019			
St1	50	12.02	3
St2	50	12.16	3
St3	65	14.4	3.6
St4	47.5	11.77	2.9
St5	52.25	12.36	3.09
St6	50	12	3
Summer 2019			
St1	42.5	11.1	2.7
St2	35	9.6	2.4
St3	45	11.2	2.8
St4	50.25	12.07	3.01
St5	49.5	11.94	2.98
St6	48.75	11.8	2.95

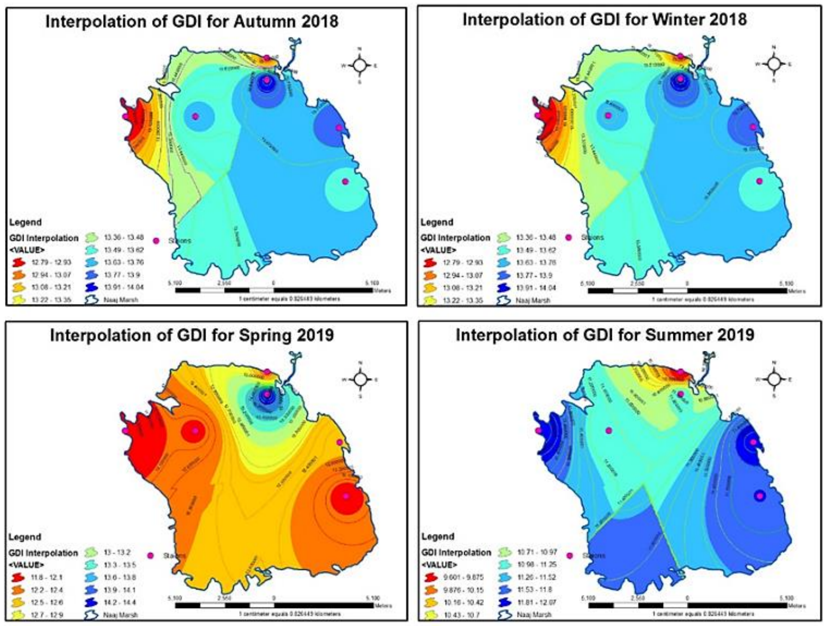

Figure 4. The generic diatoms index seasonal variations.

readings. Additionally, there aren't many nutrients in the water, and poor water quality results from low index values. The Abu-Zirig Marsh has a moderate pollution level, according to the GDI data (Abu-Hadal and Al Hassany, 2020).

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