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The Critical Changes in Composition of Diatoms Community in East Hammar Marsh, Southern Iraq

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Abstract: Diatoms have dominance in most Iraqi aquatic environments, such as in the Al-Hammar Marsh in southern Iraq, thus they are reflecting the quality of water and environmental factors prevailing in their places of residence. The East Hammar marsh in southern Iraq has experienced substantial environmental changes especially the high temperature and salinity during the last decades. Water quality has deteriorated which has impacted the living species that reside there, the most important of which are diatoms. During August 2018 to April 2019, qualitative and quantitative characteristics of the planktonic and epiphytic diatoms were studied in the East Hammar marsh at three sites, Al-Sadda, Al-Salal, and Al-Burka. During this investigation, 69 taxa belonging to 37 genera were identified and documented. Diatom assemblages contained 30% of brackish water forms, 21 % of marine-brackish water species, 16 % of fresh species, 10% of marine water species, and the remaining 23% had varied ecological preferences ranging from fresh to marine forms. Marine-brackish water species predominate during the summer, whereas freshwater species predominate during the winter.

Keywords: Bacillariophyta, Environmental influence, Epiphyte Plankton, Marshland.

Introduction

The famed marshes of southern Iraq (Mesopotamian marshland) comprise a vast network of canals, shallow ponds and lakes. These marshes are the largest wetlands in Southwest Asia and the Middle East and are of great historical and environmental importance. They enclosed about 15,000-20,000 km^2 across the lower reaches of the Tigris and Euphrates rivers (Chatelard & Abulhawa, 2015; Al-Handal & Al-Shaheen, 2019). These marshes support a wide range of wildlife, including diverse algae, plants, and animals. They also provide nesting and spawning grounds for many migratory birds and fish (Chatelard & Abulhawa, 2015; Jawad, 2021). However, algae are essential since they are the first component of the food webs and contain species that are imperative as bioindicator taxa in the assessment of water quality (Lobo *et al*., 2016; Al-Handal & Al-Shaheen, 2019; Saki & Al-Shaheen, 2025).

The East Al-Hammar Marsh is unique among Iraqi marshes due to its tidal nature, resulting from its connection to the Shatt Al-Arab River. This link allows brackish and saline water to enter the marsh, particularly during periods of reduced inflow from the Tigris and Karun rivers.

Bacillariophyta (Diatoms) are a major group of photosynthetic microscopic algae, unicellular or colonies of eukaryotic microscopic algae. They inhabit diverse environments and possess a unique silica-based cell wall, known as the frustule made of silica, and they can be found as planktonic or attached to different materials (Kociolek, *et al*., 2015; Letáková *et al*., 2018; Poulsen, *et al*., 2022). They are a widely diverse group with an estimated 100,000-200,000 species classified across hundreds of genera (Mann & Vanormelingen, 2013; Falciatore & Mock, 2022; Wang *et al*., 2022), Diatoms are extremely sensitive to environmental changes, they also have specific environmental preferences that allow indicator values to be set for a variety of important environmental variables, including light, temperature, salinity, pH, and nutrients (Hu *et al*., 2012; Bere, 2014; Levkov *et al*., 2017).

In general, many studies and reports confirmed that diatoms are the dominant group of microalgae in Iraqi water including its marshlands (Habeeb *et al*., 2023; Jaffer *et al*., 2023). Despite their ecological importance, comprehensive data on the occurrence and distribution of diatoms in the Al-Hammar marsh remain limited. Most existing diatom records in this region stem from general algal surveys, including those conducted by IMRP (2018), Habeeb *et al.* (2023) and Jaffer *et al*. (2023).

Therefore, the current study aimed to identify the diatom species structure and their relative abundance of both planktonic and epiphytic forms in east Hammar marsh and the influence of environmental variations and salinity intrusion on their composition.

Materials & Methods

Study area

The East Hammar marsh is located south of the Euphrates River in Basrah Province. It is considered the major water body on the lower Euphrates in southern Iraq, with an area of around 3000 km^2, a length of 120 km, and a width of 25 km, with a maximum water depth of 1.8 - 3 meters (Al-Handal & Al-Shaheen 2019; Jawad 2021). It receives most of its waters from Shatt Al-Arab River by Garmat Ali Canal. As a result, the East Hammar marsh was distinguished by the fluctuation of its water's salinity concentration due to the phenomenon of tides coming from the Arabian Gulf through the Shatt Al-Arab River.

Three sites were chosen to study diatoms at various regions of the East Hammar Marsh (Fig. 1, Table 1). The first site is Al-Sadda, which is a muddy cliff, this location marks the beginning of the East Hammar Marsh's limits, with rapid water running in channels, a limitation of plants and animals, and the activity of anglers' boats characterizing the banks.

The second site is Al-Salal, this site is characterized by the continuous movement of boats and subjected to complete drying operations, and the water was returned to it after 2003. Several fish farming and agriculture are found with few houses, and the people depend on buffaloes and fishing in their lives.

The third site is Al-Baraka; it is located north of the Marsh in an open water body that is almost devoid of residents. It is distinguished by its shallow waters, which have aided in spreading prominent and submerged aquatic plants and it spreads the fishing for fish and birds.

Table (1): Localities of the study sites and their GPS coordinates.

Site name		Location	
		Latitude (N)	Latitude (E)
St.1	Al-Sadda	30° 36′ 36″	47° 40′ 17″
St.2	Al-Salal	30° 39′ 31″	47° 38′ 17″
St.3	Al-Burka	30° 41′ 27″	47° 34′ 41″

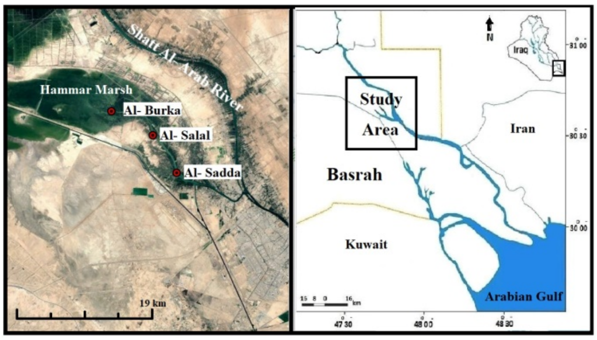

Fig. (1): Map showing the location of study sites at East Hammar marsh.

Sampling and parameters measurement

Water and diatom samples were collected seasonally from three sites in the East Hammar Marsh between August 2018 and April 2019, during the low tide period. Several ecological factors were measured, including water temperature, pH, salinity, electrical conductivity, dissolved oxygen, nitrate, phosphate, and silicate.

Planktonic diatoms were collected using a phytoplankton net with a 20 µm mesh size, towed for 15 minutes by a motorboat. Epiphytic diatoms were collected, both samples were stored in plastic bottles, labeled, and fixed with 4% formalin (Al-Handal *et al*., 2014; Al-Handal & Al-Shaheen, 2019).

There are numerous species of aquatic macrophytes at all sites, including *Phragmites australis* (Cav) Trib. & Steud., *Typha domingensis* Pres., *Ceratophyllum demersum* L., *Schoenoplectus litoralis* (Schrad) Palla. and *Potamogeton pectinatus* L. as well as macroalgae *Cladophora glomerata* (Linnaeus) Kützing. Selected plant specimens were carefully cleaned to ensure they were free from mud and extraneous algal filaments prior to sampling. At least five stems of emergent aquatic plants were taken by sampled 5 to 10 cm sections of the submerged portions. Epiphytic diatoms were scraped and rinsed from an equal number of stems and branches of submerged aquatic plants, as well as from floating macrophytes and macroalgae. To dislodge attached diatoms plant materials were placed in plastic bags and shaken vigorously with water. The suspension was stored in labeled containers and fixed with 4% formalin.

Preparation of diatoms slides for light microscope

Before microscopic examination, the hot hydrogen peroxide technique was used for diatom cleaning (Al-Handal & Wulff, 2008; Al-Handal & Al-Shaheen, 2019). Several milliliters of diatom suspension were boiled with 35% H_2O_2 for approximately one hour and then allowed to cool to room temperature. The cleaned suspension was washed several times with distilled water using filter paper to remove residual reagents. One milliliter of the cleaned diatom suspension was dried on a coverslip to make permanent diatom slides, then mounted on a clean slide containing 0.5 ml of Nephrax (Brunel Microscope Ltd. UK).

Microscopic examination was conducted using a KRUSS microscope (Germany) equipped with an OMAX A35180U3 camera (China). Several references were consulted for species identification, including Patrick & Reimer (1966), Witkowski *et al*., (2000), Hofmann *et al*. (2013) Cantonati *et al*., (2017) and Al-Handal & Al-Shaheen (2019). The qualitative abundances of recorded diatom taxa were estimated according to Al-Handal & Wulff (2008).

Results & Discussion

The results of environmental parameters measured in the present study are shown in table (2). The results of parameters, except conductivity and salinity, were within the range of most previous studies over the past two decades.

The pH values remained on the alkaline side throughout the study period, a common a characteristic of Iraqi marshes (Jawad, 2021). Dissolved oxygen is a key indicator of river biological health, it is influenced by water temperature; however, this dependence changes due to changing climate conditions and the intensity of biological processes such as photosynthesis, respiration, and organic matter decomposition (Rajwa-Kuligiewicz *et al.*, 2015). Moreover, in the current study, DO levels did not fall below the critical threshold of 4 $mg.l^{-1}$ and did not exceed 8.9 $mg.l^{-1}$, whereas Jaffer *et al.*, (2023) have reported values as high as 13.0 $mg.l^{-1}$. The observed low oxygen concentrations during summer can be attributed to high water temperatures, given the well-established inverse relationship between the two (Rajwa-Kuligiewicz *et al.*, 2015).

Electrical conductivity and salinity values in this study were generally higher than those reported in previous studies, except for IMRP (2018), which recorded a peak salinity of 16.1 ppt. In contrast, Jaffer *et al.*, (2023) reported a lower value of 7.6 ppt. Regarding the salinity, the water in this study area is considered oligohaline (0.5-5 ppt) to mesohaline (5-18 ppt) (Reid, 1961). A significant decline in freshwater inflow to the Shatt Al-Arab River has facilitated the intrusion of saline water from the Arabian Gulf. This saltwater intrusion has reached as far as the East Hammar Marsh, resulting in a noticeable increase in salinity during the study period. Global climate change, coupled with dam construction in upstream countries, has intensified saline water intrusion from the Arabian Gulf into the central and northern parts of the Shatt Al-Arab River—ultimately affecting the Al-Hammar Marsh and significantly impacting its biota (IMRP, 2018).

Nitrate values in this study were moderate relative to most previous findings. However, Jaffer (2010) reported a significantly higher value of 23.1 $mg.\ l^{-1}$, whereas our results were more consistent with those of Jaffer *et al.* (2023). The observed decrease in nitrite and nitrate concentrations may result from high nutrient uptake by algae and aquatic plants (Fernandez-Going *et al.*, 2013; Taziki *et al.*, 2015; Mebane *et al.*, 2021). Additionally, when DO levels are relatively high, the conversion of nitrite to nitrate tends to increase (Ishizu & Richards, 2013). This may explain the relatively low nitrate concentrations observed during periods of reduced dissolved oxygen.

The variations in phosphorus concentrations may be attributed to the surrounding soil characteristics, population density, organic pollution, and agricultural runoff (Berg *et al.*, 2018). A noticeable decrease in reactive phosphate was observed during late winter and spring. This may be attributed to phosphorus adsorption onto clay and silt particles, increased turbidity, and uptake by aquatic plants and phytoplankton (Faragallah *et al.*, 2009; Ansari & Singh, 2017).

Table (2): Some hydrographic environmental parameters of all sites during the present study.

Parameters	Range of values	Average of values
Water temperature	18.5-29.9 °C	22.89° C
pH	7.2-8.5	7.69
Salinity	3.1-14.9 ppt	9.43 ppt
EC	5.6-23.0 $mS.cm^{-1}$	14.81 $mS.cm^{-1}$
Dissolved oxygen	4.2-8.9 $mg.l^{-1}$	6.5 $mg.l^{-1}$
Reactive Nitrate	6.0-12.7 $mg.l^{-1}$	7.97 $mg.l^{-1}$
Reactive phosphate	0.41-1.01 $mg.l^{-1}$	0.63 $mg.l^{-1}$
Reactive silicate	52.5-85.0 $mg.l^{-1}$	71.30 $mg.l^{-1}$

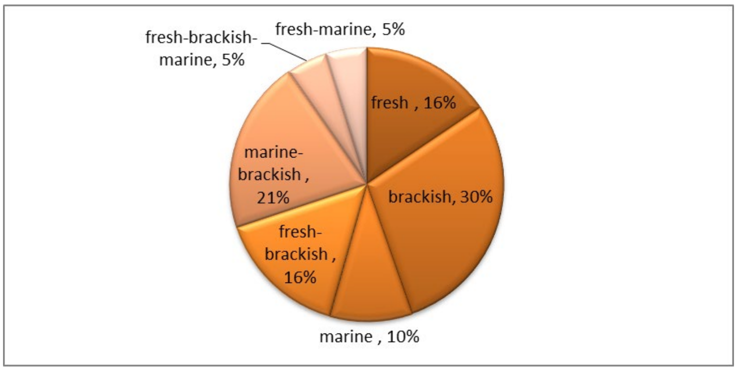

Fig. (2): Environmental preference of all diatom species encountered during study period.

Silica is one of the major components of diatoms frustules. After very low silicate concentrations, the diatoms production may be stopped (McNair *et al*., 2018), the current findings show a relatively high silica concentration, which is consistent with previous research, but a very high concentration reached 198.6 $mg.l^{-1}$ was recorded by Jaffer *et al*. (2023). Despite nutrients being necessary for the diatom's growth, in high concentrations they become toxic (Giri *et al*., 2022). In total, 69 diatom taxa belonging to 37 genera were identified. Their qualitative abundance and occurrence in the East Hammar Marsh are listed alphabetically in table (3). These included 30% brackish-water forms, 21% marine-brackish species, 16% freshwater species, 10% marine species, and 23% with variable or uncertain ecological preferences ranging from freshwater to marine (Fig. 2). Centric diatoms made up 7% of the total taxa (4 genera), while the rest (93%) were pennate diatoms from 31 different genera (Figs. 3-11).

The number of diatom taxa in the current study exceeds those reported by Al-Farhan (2010) and Habeeb *et al*. (2023). Conversely, the number of taxa identified in this study is lower than those reported by Jaffer (2010) and Jaffer *et al*., (2023). These variations in diatom species richness likely reflect local environmental conditions—particularly elevated temperature and salinity—which are known to influence diatom assemblages.

The marine and brackish origin species constituted a considerable part of diatom communities in the current study, where they replaced freshwater species, which constituted only 16% of all identified diatoms. This shift may be attributed to significant changes in environmental conditions that eliminated habitats favorable to freshwater diatoms. Freshwater diatoms dominate in five Egyptian lakes followed by marine-brackish species except in Bardawil Lake where marine origin diatoms are more prevalent (Khairy *et al*., 2017).

Table (3): Ecology and relative occurrence of diatoms taxa in the present study (e: epiphytic, p: plankton, f: freshwater, b: brackish, m: marine, un: unknown). Relative abundance (%) vr: very rare, found only once on a slide, r: rare (5%), f: frequent (5–20%), c: common (20%). (Al-Handal & Wulff, 2008).

Species	Occurrence	Habitat	St.1	St.2	St.3
Amphora mexicana A. Schmidt	e	f	-	-	r
Anomoeoneis sphaerophra Pfitzer	e	f,m	-	-	vr
*Bacillaria paxillifera (*O.F.Müller) T.Marsson	e, p	m,b	f	f	f
Caloneis amphisbaena var. *subsalina (*Donkin) Van der Werff& Hulls	e, p	b	-	f	f
Caloneis cf. *latiuscula* (Kützing) Cleve	e, p	f	vr	-	-
Campylodiscus cf. *bicostatus* W.Smith ex Roper	p	b	r	f	r
Campylodiscus daemelianus Grunow	e	f,m	r	f	f
Cocconeis placentula Ehrenberg	e, p	f,b	f	f	r
Cocconeis euglypta Ehrenberg	e, p	f,b	f	f	f
Craticula cuspidata (Kutzing) D.G.Mann	e, p	b	-	f	f
Ctenophora pulchella (Kützing) D.M.Williams & Round	e, p	b	-	-	f
Cyclotella straita (Kützing) Grunow	e, p	b,m	r	f	f
Diploneis cf. *coffeiformis* (A.W.F.Shmidt) Cleve	e, p	b	r	f	f
Diploneis smithii (Brébisson) Cleve	e, p	b	-	r	r
(Ehrenberg) Ehrenberg *Entomoneis alata*	e, p	b	r	f	f
(Giffen) Witkowski, *Entomoneis corrugata* Lange-Bertalot & Metzeltin	e, p	b	r	f	f
(W.Smith) Reimer *Entomoneis paludosa*	e, p	m	-	f	f
Epithemia gibba (Ehrenberg) Kützing	e	f	r	r	-
Frickea lewisiana (Greville) Heiden	e, p	b	f	f	f
(Grunow) Round & *Giffenia cocconeiformis* Basson	e, p	m	r	-	r
Gyrosigma acuminatum (Kützing) Rabenhorst	e, p	f,b	f	f	f
Gyrosigma attenuatum (Kützing) Rabenhorst	e, p	f,b	f	f	f
Gyrosigma fasciola (Ehrenberg) J.W.Griffith & Henfrey	e, p	b,m	-	r	r
Gyrosigma macrum (W.Smith) J.W.Griffith & Henfrey	e, p	b,m	-	r	r
Gyrosigma wormleyi (Sullivant) Boyer	p	f,b	vr	-	-
Gyrosigma scalproides (Rabenhorst) Cleve	P	f	f	r	-
Gyrosigma sinense (Ehrenberg) Desikachary	e, p	m	r	f	f
Halamphora ghanensis Levkov	e	f,b	f	r	r
Halamphora holsatica (Hustedt) Levkov	e, p	m	r	-	f
Iconella tenera (W.Gregory) Ruck & Nakov	e, p	f	-	-	vr
luticola ventricosa (Kützing) D.G.Mann	e	f	-	vr	-
Mastogloia cf. *elliptica* (C.Agardh) Cleve	e, p	m,f	-	r	r
(Gregory) Ralfs *Navicula digitoradiata*	e	b	f	f	f
Navicula metareichardtiana Lange-Bertalot & Kusber	e	b	-	r	r
Nitzschia bicapitata Cleve	E	m	-	r	r
Nitzschia bilobata W.Smith	e, p	m	r	r	f

Nitzschia cf. *prolongata* Hustedt	e, p	m	r	f	f
Nitzschia dissipata (Kützing) Rabenhorst	e	f	vr	-	-
Nitzschia fusuformis Grunow	e, p	m	r	f	f
Nitzschia hybrida Grunow	e, p	b	r	f	r
Nitzschia microcephala Grunow	e	f	r	-	f
(Kützing) W.Smith *Nitzschia sigma*	e, p	f,b,m	r	f	f
Nitzschia subcohaerens var. *scotica* (Grunow) Van Heurck	e, p	b	r	r	r
Nitzschia sp1.	e	un	r	-	r
Nitzschia sp2.	e	un	r	r	r
Pinnularia furatensis Al-Handal	e	b	f	r	r
Prestauroneis crucicula (W.Smith) Genkal & Yarushina	e, p	b,m	r	f	r
Petrodictyon gemma (Ehrenberg) D.G.Mann	e, p	m	r	f	f
Plagiotropis lepidoptera (W.Gregory) Kuntze	e, p	b	f	f	f
Planothidium delicatulum (Kützing) Round & Bukhtiyarova	e, p	b,m	-	-	vr
Pleurosira laevis (Ehrenberg) Compère	e	b	-	r	r
Pseudofallacia occulta (Krasske) Y.Liu, Kociolek & Q.X.Wang	e, p	b	f	f	f
(Kützing) Otto Müller *Rhopalodia musculus*	e	b,m	-	r	r
Sieminskia wohlenbergii (Brockmann) D.Metzeltin & Lange-Bertalot	e, p	b	f	f	f
Stephanocyclus meneghinianus (Kützing) Kulikovskiy, Genkal & Kociolek	e, p	f,b	f	f	f
Stephanodiscus cf. *neoastraea* Hakansson & Hickel	p	f	-	r	r
Surirella librile (Ehrenberg) Ehrenberg	e, p	f	r	r	-
Surirella ovalis Brébisson	e, p	b	r	r	r
Surirella striatula Turpin	e, p	b	-	-	r
Tabularia fasciculata (C.Agardh) D.M.Williams & Round	e	b,m	f	f	f
Tabularia tabulata (C.Agardh) Snoeijs	e, p	b,m	f	f	f
Tabularia sp.	e, p	un	f	f	f
Thalassiosira sp.	p	un	f	f	f
Gregory *Tryblionella apiculata*	e, p	m	-	-	vr
(Grunow) D.G.Mann *Tryblionella* cf. *coarctata*	e	b,m	f	f	f
Tryblionella compressa (Bailey) Poulin	e	b,m	r	r	r
(Grunow) D.G.Mann *Tryblionella granulata*	e	m	r	r	f
Ulnaria danica (Kützing) Compère & Bukhtiyarova	e, p	f,b	r	r	r
Ulnaria ulna (Nitzsch) P.Compère	e, p	f,b	r	r	r
Total count of species			**49**	**55**	**62**

This pattern is expected due to seawater intrusion in the region. The high representation of marine and brackish diatoms in the East Hammar marsh clearly reflects a shift in diatom assemblage structure in comparison to previous studies where freshwater diatoms prevailed. This can be attributed to the remarkable rise in water salinity during the last two decades, which provided suitable environmental conditions for such diatoms to survive and reproduce. Such conditions can be held responsible for the appearance of several taxa not previously reported from East Hammar marsh or the

Iraq's inland waters. Brackish diatom distributions and abundance are related to tidal gradients which variables such as salinity, electrical conductivity, intensity of light, and grain size of sediment vary with rise, also differences in freshwater inflows can lead to changes in salinity, pH, and plant communities (Sawai *et al*., 2017).

On the other hand, the increase in the salinity of the marsh water led to the disappearance of most of the aquatic plants, especially the floating and submerged, so this was reflected in the number and diversity of diatom species due to the disappearance of the surfaces they preferred to live on, this is the same result that appeared in Habeeb *et al*., (2023). In addition, the salinity and some other abiotic factors such as temperature, pH, heavy metals and nutrients can cause changes in the valve shape of some diatoms which leads to difficulty in identification (Su *et al*., 2018; Falciatore *et al*., 2021; Kamakura *et al*., 2022; Soleimani *et al*., 2022).

Around 56% (39 species) of totally identified diatom species encountered in the current study were found almost at all sites in different occurrence frequencies. Some of them were frequent or common at most of the sites such as *Cocconeis euglypta, Stephanocyclus meneghinianus*, *Gyrosigma attenuatum, Tryblionella* cf. *coarctata*, *Navicula digitoradiata*, *Sieminskia wohlenbergii*, *Tabularia tabulata* and *Tabularia fasciculata,* most of these species are marine-brackish and marine species. The current study found that environmental factors such as salinity influenced the composition of diatoms.

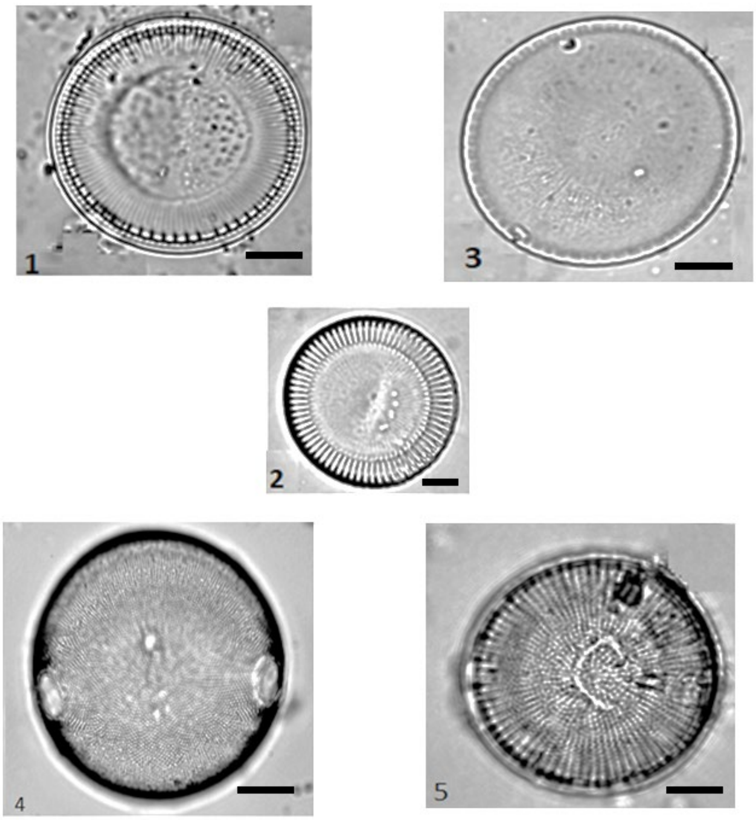

Fig. (3): 1- *Cyclotella straita*, 2- *Stephanocyclus meneghinianus*, 3- *Thalassiosira* sp., 4- *Pleurosira laevis*, 5- *Stephanodiscus* cf. *Neoastraea* (Scale bar: 10 µm (all images)).

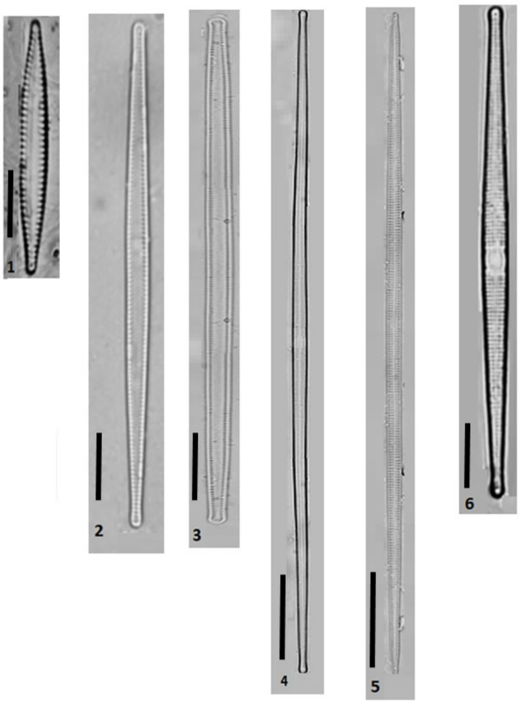

Fig. (4): 1- *Tabularia tabulata*, 2- *Tabularia fasciculata,* 3- *Tabularia* sp., 4- *Ulnaria danica*, 5- *Ulnaria ulna*, 6- *Ctenophora pulchella* (Scale bars: 10 µm (images. 1–3, 6); 50 µm (images. 4, 5).

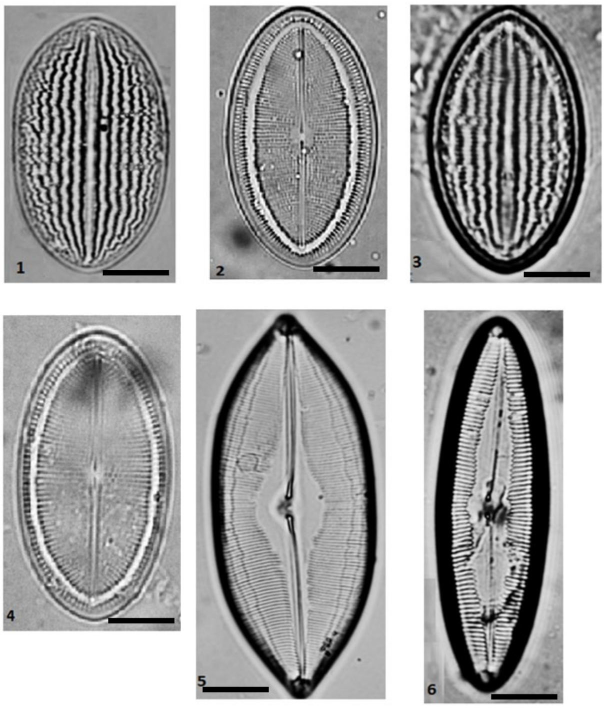

Fig. (5): 1- *Cocconeis placentula* (sternum valve), 2- *Cocconeis placentula* (raphe valve), 3- *Cocconeis euglypta* (sternum valve), 4- *Cocconeis euglypta* (raphe valve), 5- *Caloneis amphisbaena* var. *subsalina*, 6- *Caloneis latiuscula*. (Scale bar: 10 µm (all images)).

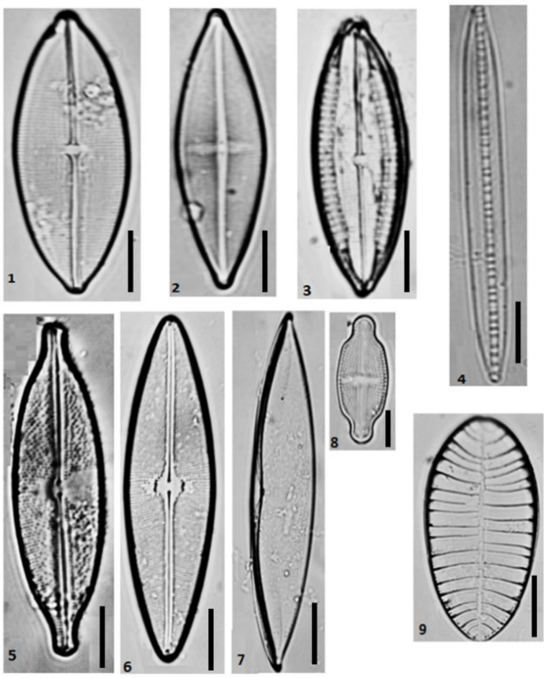

Fig. (6): 1- *Craticula cuspidate,* 2- *Prestauroneis crucicula,* 3- *Mastogloia* cf. *elliptica* 4- *Bacillaria paxillifera,* 5- *Anomoeoneis sphaerophra,* 6- *Sieminskia wohlenbergii,* 7- *Plagiotropis lepidoptera* 8- *Luticola ventricosa,* 9-*Petrodictyon gemma* (Scale bar: 10 µm (all images)).

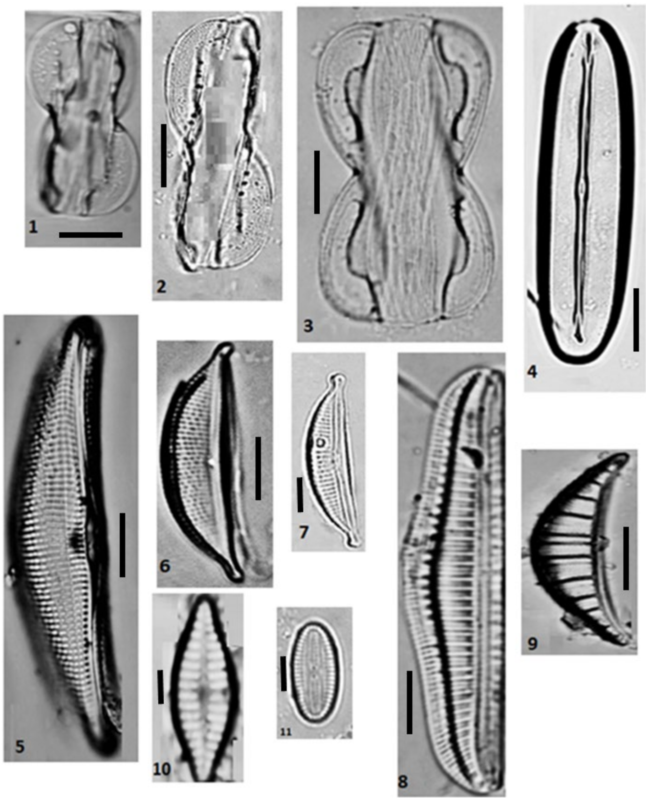

Fig. (7): 1- *Entomoneis corrugata*, 2- *Entomoneis alata*, 3- *Entomoneis paladosa* 4- *Frickea lewisiana*, 5- *Amphora mexicana*, 6- *Halamphora* cf. *holsatica*, 7- *Halamphora ghanensis*, 8- *Rhopalodia gibba*, 9- *Rhopalodia musculus*, 10- *Planothidium delicatulum*, 11- *Pseudofallacia occulta* (Scale bar: 10 µm (all images)).

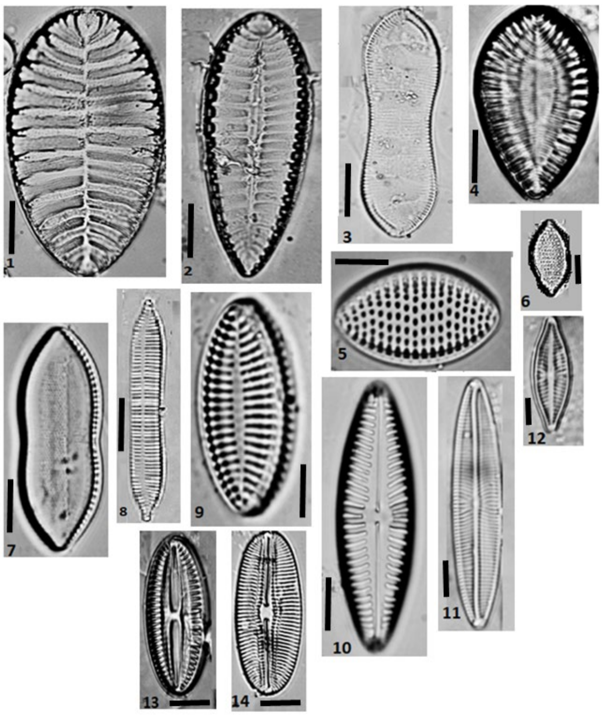

Fig. (8): 1-*Surirella striatula*, 2- *Iconella tenera*, 3- *Surirella librile*, 4- *Surirella ovalis*, Fig.5.*Tryblionella granulata*, 6.*Tryblionella compressa,* 7.*Tryblionella* cf. *coarctata*, 8.*Tryblionella apiculata*, 9. *Giffen cocconeiformis*, 10. *Pinnularia furatensis*, 11.*Navicula digitoradiata*, 12.*Navicula metareichardtiana*, 13. *Diploneis* cf. *coffeiformis,* 14. *Diploneis smithii* (Scale bar: 10 µm (all images)).

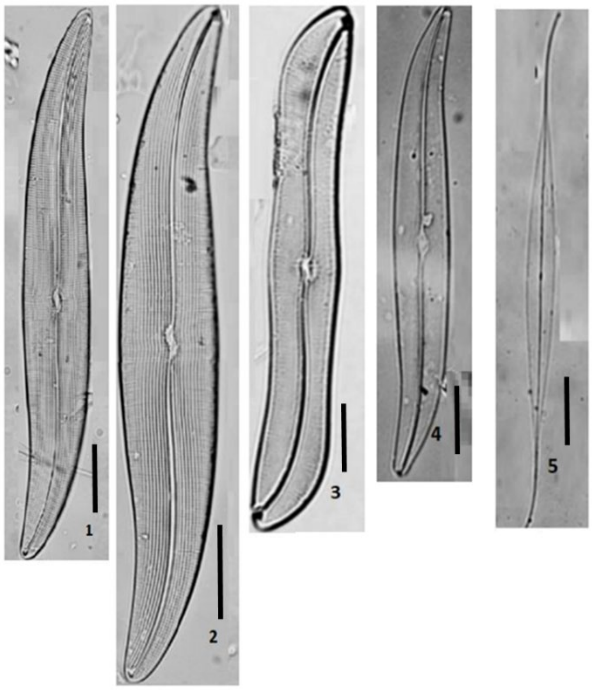

Fig. (9): 1. *Gyrosigma acuminatum*, 2. *Gyrosigma attenuatum* 3. *Gyrosigma sinense*, 4. *Gyrosigma scalproides*, 5. *Gyrosigma macrum* (Scale bar: 25 µm (all images)).

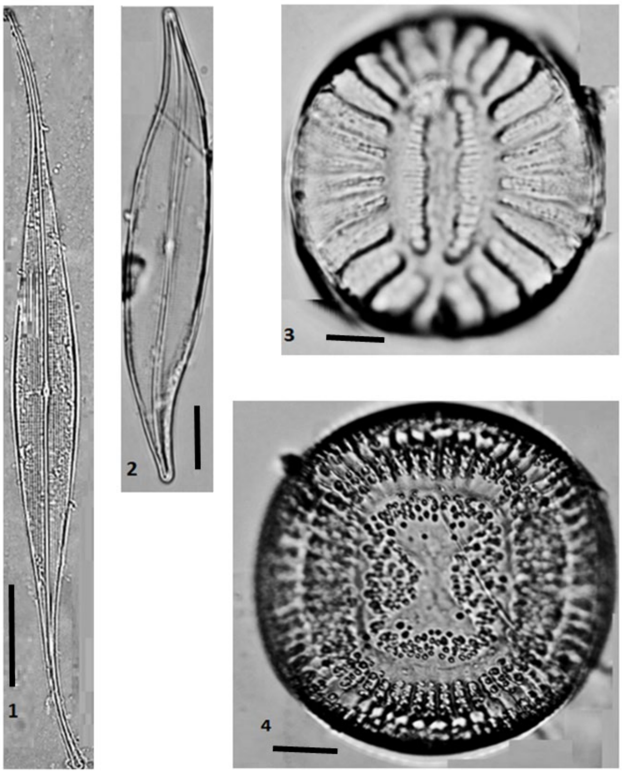

Fig. (10): 1. *Gyrosigma fasciola*, 2. *Gyrosigma* cf. *wormleyi,* 3. *Campylodiscus* cf. *bicostatus*, 4. *Campylodiscus daemelianus* (Scale bar: 25 µm (images 1,2); 10 µm (images 3); 50 µm (images 4)).

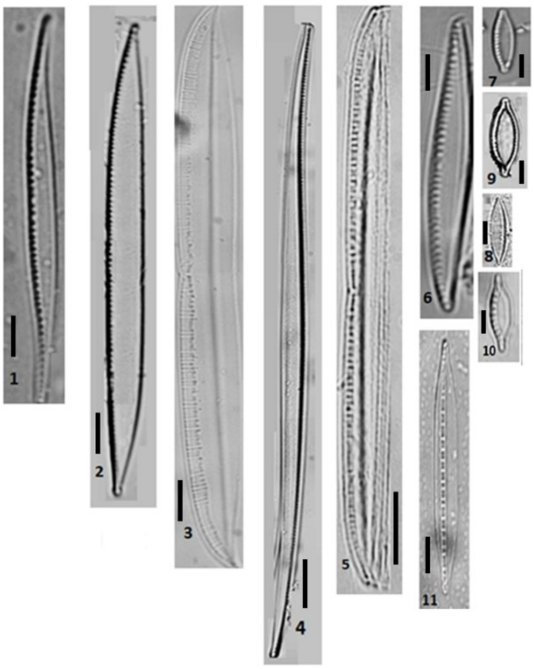

Fig. (11): 1. *Nitzschia fusiformis*, 2. *Nitzschia sigma*, 3. *Nitzschia bilobata*, 4. *Nitzschia* cf. *prolongata*, 5. *Nitzschia hybrid*, 6. *Nitzschia subcohaerens* var. *scotica*, 7.*Nitzschia* sp. 1, 8. *Nitzschia* sp. 2, 9. *Nitzschia bicapitata*, 10. *Nitzschia microcephala,* 11. *Nitzschia dissipata* (Scale bar: 10 µm (all images except 25 µm (images 4,5)

On the other hand, 11% (8 species) of the total species were recorded only at one site, these include *Caloneis latiuscula, Planothidium delicatulum, Iconella tenera, Gyrosigma wormleyi, Anomoeneis sphaerophra, Nitzschia dissipata, Luticola ventricosa*, and *Tryblionella apiculata*. Some of the encountered species 22 species (33%) appeared almost all year round at sites (Table 3). Sawai *et al*., (2017) recorded *P. delicatulum* as one of dominant species in salt marshes. Due to differences in the concentrations of large and small species, Sawai *et al*., (2016) hypothesized that the likelihood of encountering relatively large species (e.g., *Gyrosigma*) may be low. The marine diatom species consist 10% (11 species, table 3) of diatom assemblages in current study, all of them are recording for the first time in the marsh, were previously recorded in Shatt Al-Arab river (Al-Handal & Al-Shaheen, 2019).

Nitzschia was the most abundant genus, with 10 species found at nearly every site. This genus has many important species as an indicator in biological monitoring because it indicates organic pollution and high tolerance to pollutants (Cantonati *et al*., 2017; Simsek, 2018; Wang *et al*., 2020). The dominance of this species was previously recorded in the majority studies in Iraq and Egypt (Jaffer, 2010; Al-Handal *et al*., 2014; Khairy *et al*., 2017; Al-Handal & Al-Shaheen, 2019; Mohamad *et al*., 2024). The species *N. dissipata* has frequent observation in samples, which is considered moderate salinity levels among diatoms species (Herbst & Blinn, 1998).

The second dominant genus is *Gyrosigma* which included seven species, then *Surirella* and *Tryblionella* with four species each, *Tabularia*, *Entomoneis* and *Navicula* with three species each.

Cocconeis euglypta is very common in Iraqi inland water with a wide habitat range and environmental distribution. The wide distribution of this species on the mud, aquatic plants and in the plankton was previously recorded (Al-Handal *et al*., 2014; Al-Handal & Al-Shaeen, 2019). Diatom species that have narrow or distinctive, elevation tolerances can be used as indicators for specific environments such as marsh including freshwater and brackish (Desianti *et al*., 2019; Hong *et al*., 2021). *Pleurosira laevis* can be found in a variety of salinity environments, including rivers and the coast, primarily found in fresh and brackish water (Kamakura *et al*., 2022). The current study identified one species for the rare genus in the region is called *Pinnularia furatensis* which has recently described as new species in the world of brackish habitat in epipelic sample of Euphrates River at Samawah City also it is noticed in Huwaiza marsh (Al-Handal, 2022). The genus *Pinnularia* has become rare and disappeared in Shatt Al-Arab River and Hammar Marsh in recent years.

Al-Burka site observed a larger number of diatom species in spring 2019, which could be attributable to increased aquatic plant growth due to higher nutrient and lower salinity values. On the other hand, owing to the variation in climatic conditions during the study period, reduced species numbers were reported for all sites in autumn 2018.

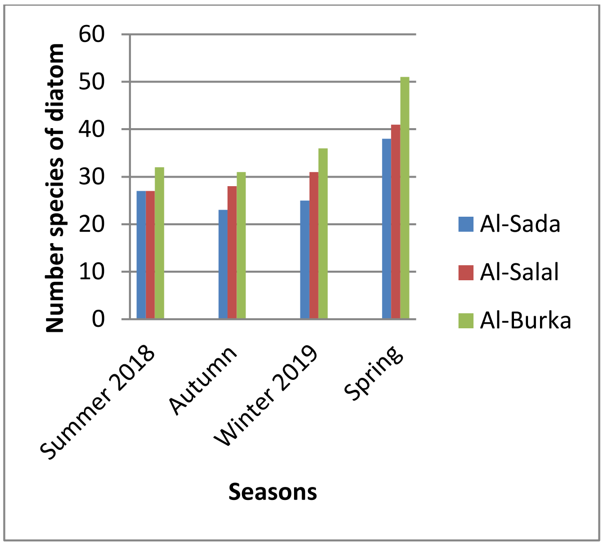

Fig. (2): Number species of diatom during the seasons.

Order Pennate contains 64 species occupied by epiphytic diatoms, while the centric order represents five species for planktonic diatoms, this fact was reported previously (Al-Handal & Al-Shaheen, 2019). This result was not surprising as aquatic macrophytes are widespread in the study region. Furthermore, aquatic macrophytes are considered as live substrates where they form a preferable choice for diatoms than other substrates (Bere & Tundisi, 2011), and this may be because the living substrates provide food derivatives or release organic matter and nutrients during the life cycle. Site 3 had a higher number of diatom species (62 species) than the site 1 (49 species) and site 2 (55 species) due to the huge number of aquatic plants at this site than the other sites.

Because of the apparent change in East Hammar marsh water quality, many diatom species previously here have vanished and been replaced by others that can withstand rising levels of salt content and pollution. The occurrence of marine-derived species has increased. The marine to brackish water origin of 31% of the total number of identified diatoms, which were frequent at most sites, was discovered. These have reached distances far from the Gulf, indicating a significant change in the marsh's environment. Variations in environmental conditions have a greater impact on the quality and density of diatom species matter than the types of substrates.

Conclusion

A total of 69 taxa belonging to 35 genera of both planktonic and epiphytic diatoms were identified and documented in the East Hammar Marsh. Pennate diatoms accounted for approximately 93% of the recorded taxa, while centric diatoms made up the remaining 7%. The highest species richness was observed at the Al-Burka site during spring, whereas the lowest diversity was recorded at the Al-Sadda site in autumn. Diatom assemblages comprised 30% brackish-water forms, 21% marine-brackish forms, 16% freshwater species, 10% marine forms, and the remaining 23% exhibited varied ecological preferences ranging from freshwater to marine environments. The findings of the current study indicate that environmental factors—particularly salinity—played a key role in shaping the composition of diatom communities.

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Contributions of authors

M.A.A: Sample collection and laboratory methodology include isolated diatoms, digested, prepared slides and diagnosed the diatoms, as well as writing-review and editing.

D.A.A: Suggest a title of the research, laboratory methodology, writing and reviewed the final manuscript.

S.S.A.: Laboratory methodology include examined, measured, diagnosed the diatoms, as well writing the manuscript.

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Conflicts of interest

The authors declare that they have no conflicts of interest relevant to this study.

References

Al-Handal, A. Y. (2022). *Pinnularia furatensis* sp. nov. (Bacillariophyceae): a new brackish water diatom from the Euphrates River, Southern Iraq. *Fundamental and Applied Limnology, 196*(1), 75-81. https://doi.org/10.1127/fal/2022/1462.

Al-Handal, A. Y., & Al-Shaheen, M. A. (2019). *Diatoms in the wetlands of Southern Iraq*. Bibliotheca Diatomologica, 67. Gebr. Schweizerbart and Borntraeger science publishers, Stuttgart, 252pp. https://www.schweizerbart.de/publications/detail/isbn/9783443570583.

Al-Handal, A. Y. & Wulff, A. (2008). Marine epiphytic diatoms from the shallow sublittoral zone in Potter Cove, King George Island, Antarctica. *Botanica Marina*, *51*(5), 411-435. https://doi.org/10.1515/BOT.2008.053.

Al-Handal, A. Y., Abdullah, D. S., Wulff, A. & Abdulwahab, M. T. (2014). Epiphytic diatoms of the Mesopotamian wetland: Huwaiza marsh, South Iraq. *Diatom*, *30*, 1-15. https://doi.org/10.11464/diatom.30.164.

Al-Farhan, S. R. N. (2010). *An ecological study of the benthic algae in some aquatic ecosystems of Basrah*. M. Sc. Thesis, College of Science, University of Basrah, 212pp.

Ansari, S. & Singh, S. K. (2017). Limnological Studies with reference to Phytoplankton Diversity in Ponds of Semiarid zone of Western Uttar Pradesh. *Biological Forum – An International Journal*, *9*(2), 129-147.

Banerjee, A., Chakrabarty, M., Rakshit, N., Bhowmick, AR. & Ray, S. (2019). Environmental factors as indicators of dissolved oxygen concentration and zooplankton abundance: deep learning versus traditional regression approach. *Ecological Indicators*, *100*, 99–117. https://doi.org/10.1016/j.ecolind.2018.09.051.

Bere, T., & Tundisi, J. G. (2011). The Effects of Substrate Type on Diatom-Based Multivariate Water Quality Assessment in a Tropical River (Monjolinho), São Carlos, SP, Brazil. *Water, Air, and Soil Pollution*, *216*, 391-409. https://doi.org/10.1007/s11270-010-0540-8.

Bere, T. (2014). Ecological preferences of benthic diatoms in a tropical river system in São Carlos-SP, Brazil. *Tropical Ecology*, *55*, 47-61. https://www.researchgate.net/publication/235944013_Ecological_preferences_of_benthic_diatoms_in_tropical_river_system_Sao_Carlos-SP_Brazil.

Berg, M., Meehan, M., Keena, M., Franzen, D. & Scherer, D. (2018). Phosphorus behavior in the environment. ndsu extension, NM1298, North Dakota State University, Fargo, 4pp.

Cantonati, M., Kelly, M. G., & Lang-Bertalot, H. (eds.) (2017). *Freshwater benthic diatoms of central Europe: over 800 Common species used in ecological assessments*. English edition with updated taxonomy and added species. Schmitten-oberreifenberg: Koeltz Botanical Books, 942pp.

Chatelard, G. & Abulhawa, T. (2015). *The World Heritage Nomination of The Ahwar of Southern Iraq: Refuge of Biodiversity and Relict Landscape of the Mesopotamian Cities*. Arab Regional Centre for World Heritage, Manama, Kingdom of Bahrain, 81pp.

Desianti, N., Enache, M. D., Griffiths, M., Biskup, K., Dege, A., DaSilva, M., Millermann, D., Lippincott, L., Watson, E., Gray, A., Nikitina, D., & Potapova, M. (2019). The Potential and Limitations of Diatoms as Environmental Indicators in MidAtlantic Coastal Wetlands. *Estuaries and Coasts*, *42*, 1440–1458. https://doi.org/10.1007/s12237-019-00603-4.

Falasco, E., Ector, L., Wetzel, C. E., Badino, G., & Bona, F. (2021). Looking back, looking forward: a review of the new literature on diatom teratological forms (2010–2020). *Hydrobiologia*, *848*, 1675–1753. https://doi.org/10.1007/s10750-021-04540-x.

Falciatore, A. & Mock, T. (2022). *The Molecular Life of Diatoms*. Springer Nature Switzerland A. G., Gewerbestrasse 11, 6330 Cham, Switzerland. 831pp. https://doi.org/10.1007/978-3-030-92499-7.

Faragallah, H. M., Askar, A. I., Okbah, M. A., & Moustafa, H. M. (2009). Physico-chemical characteristics of the open Mediterranean Sea water far about 60 Km from Damietta harbor, Egypt. *Journal of Ecology and The Natural Environment*, *1*(5), 106-119. https://doi.org/10.5897/JENE.9000080.

Fernandez-Going, B., Even, T. & Simpson, J. (2013). The Effect of Different Nutrient Concentrations on the Growth Rate and Nitrogen Storage of Watercress (*Nasturtium officinale* R. Br.). *Hydrobiologia*, *705*(1), 63–74. https://doi.org/10.1007/s10750-012-1380-x.

Giri, T., Goutam, U., Arya, A., & Gautam, S. (2022). Effect of Nutrients on Diatom Growth: A Review. *Trends in Sciences*, *19*(2), 1752. https://doi.org/10.48048/tis.2022.1752.

Habeeb, M. K., Al-Shaheen, M. A., Abbas, A. F., Hamza, H. A., Okash, A. N., Hussain, N. A. and Reiss, P. (2023). The fragile ecology in Iraq's Mesopotamian marshlands endangered and restructured by a sharp increase in salinity. *GSC Advanced Research and Reviews, 16*(1), 7-18. https://doi.org/10.30574/gscarr.2023.16.1.0298.

Herbst, D. B., & Blinn, D. W. (1998). Experimental mesocosm studies of salinity effects on the benthic algal community of a saline lake. *Journal of Phycology*, *34*, 772–778. https://doi.org/10.1046/j.1529-8817.1998.340772.x.

Hu, C., Ou, Y., Zhang, D., Zhang, H., Yan, C., Zhao, Y. & Zheng, Z. (2012). Phytoremediation of the polluted Waigang River and general survey on variation of phytoplankton population. *Environmental Science and Pollution Research*, *19*, 4168-4175. https://doi.org/10.1007/s11356-012-0931-z.

Hustedt, F. (1959). Die Diatomeenflora des Neusiedler Sees in osterreichischen Burgenland. *Osterreichischen Botanischen Zeitschrift*, *106*,390-430.

Hofmann, G., Werum, M. & Lange-Bertalot, H. (2013). *Diatomeen im Süßwasser Benthos von Mitteleuropa: Bestimmungsflora Kieselalgen für die ökologische Praxis*, Koeltz Scientific Books, Königstein, Germany, 908pp.

Hong, I., Horton, B. P., Hawkes, A. D., O'Donnell III, R. J., Padgett, J. S., Dura, T. & Engelhart, S. E. (2021). Diatoms of the intertidal environments of Willapa Bay, Washington, USA as a sea-level indicator. *Marine Micropaleontology*, *167*, 102033. https://doi.org/10.1016/j.marmicro.2021.102033.

IMRP. (2018). *Exploring Program Sustainability and Impact Twelve Years Later. USAID Iraq Marshlands Restoration Program (IMRP).* Reiss, P. & Hussain, N. A. (Editors). DAI for the U.S. Agency for International Development, Bethesda, Maryland, 122pp.

Ishizu, M. & Richards. K. J. (2013). Relationship between oxygen, nitrate, and phosphate in the world ocean based on potential temperature. *Journal of Geophysical Research: Oceans*, *118*, 3586-3594, https://doi.org/10.1002/jgrc.20249.

Jaffer, E. M. (2010). *Qualitative and quantitative study of the phytoplankton in some water bodies of Southern Iraq.* M.Sc. Thesis, University of Basrah, 142pp. https://doi.org 10.13140/RG.2.2.29007.41120. (In Arabic).

Jaffer, E. M., Al-Mousawi, N. J. & Al-Shawi, I. J. M. (2023). Impact of some environmental parameters on phytoplankton diversity in the eastern Al-Hammer marsh / southern Iraq. Baghdad *Science Journal,* *20*(5), 42. https://doi.org/10.21123/bsj.2023.7590.

Jawad, L. A. (2021). *Southern Iraq's Marshes-Their Environment and Conservation*. Coastal Research Library, company Springer Nature Switzerland AG, Gewerbestrasse 11, 6330 Cham, Switzerland, 815pp. https://doi.org/10.1007/978-3-030-66238-7.

Kamakura, S., Ashworth, M. P., Yamada, K., Mikami, D., Kobayashi, A., Idei, M., & Sato, S. (2022). Morphological plasticity in response to salinity change in the euryhaline diatom *Pleurosira laevis* (Bacillariophyta). *Journal of Phycolology*, *58*(5), 631-642. https://doi.org/10.1111/jpy.13277.

Khairy, H. M., Shaltout, K. H., El-Sheekh, M. M. & Eassa, D. I. (2017). A Checklist of diatom species reported from the Egyptian Mediterranean Lakes. *Annual research & Rreview in biology, 19*(4), 1-29. https://doi.org/10.9734/ARRB/2017/36894.

Kociolek, J. P., Spaulding, S. A. & Lowe, R. L. (2015). *Bacillariophyceae: The Raphid Diatoms*. In: Wehr, J. D., Sheath, R. G. and Kociolek, J. P. (Editors). *Freshwater Algae of North America Ecology and*

Classification, 2nd edition, Academic Press, 1050pp (Chapter 16: 709-772).

Levkov, Z., Williams, D.M., Nikolovska, D., Tofilovska, S. & Čakar, Z. (2017). *The Use of Diatoms in Forensic Science: Advantages and limitations of the diatom test in cases of drowning*. In: Williams, M., Hill, T., Boomer, I. & Wilkinson, I. P. (Editors). *The Archaeological and Forensic Applications of Microfossils: A Deeper Understanding of Human History*. The Micropalaeontological Society, Geological Society of London: 261–277. https://doi.org/10.1144/TMS7.14.

Letáková, M., Fránková, M., & Poulíčková, A. (2018). Ecology and applications of freshwater epiphytic diatoms - review. *Cryptogam Algology*, *39*(1), 3-22. https://doi.org/10.7872/crya/v39.iss1.2018.3.

Lobo. E. A., Heinrich, C. G., Schuch, M., Wetzel, C. E., & Ector, L. (2016). Chapter 11: *Diatoms as Bioindicators in Rivers*. Pp, 245-271. In: Necchi, Jr. O. (Editor). *River Algae*. Springer International Publishing, Switzerland. 279pp.

Maulood, B. K., Hassan, F. M., Al-Lami, A. A., Toma, J. J. & Ismail, A. M. (2013). *Checklist of algal flora in Iraq*. Ministry of Environment, Iraq, 94pp.

Mann, D. G. & Vanormelingen, P. (2013). An inordinate fondness? The number, distributions, and origins of diatom species. *The Journal of eukaryotic microbiology*, *60*(4), 414-420. https://doi.org/10.1111/jeu.12047.

McNair, H. M., Brzezinski, M. A., & Krause, J. W. (2018). Diatom populations in an upwelling environment decrease silica content to avoid growth limitation. Environmental microbiology, *20*(11), 4184–4193. https://doi.org/10.1111/1462-2920.14431.

Mebane, C. A., Ray, A. M. & Marcarelli, A. M. (2021). Nutrient limitation of algae and macrophytes in streams: Integrating laboratory bioassays, field experiments, and field data. *Plos one, 16*(6), e0252904. https://doi.org/10.1371/journal.pone.0252904.

Mohamad, H., Schimani, K., Al-Shaheen, M., Abarca, N., Jahn, R., Al-Handal, A., Kusber, W-H. & Zimmermann, J. (2024). Comparison of the biodiversity of epiphytic diatoms in the Euphrates-Tigris rivers using morphological and metabarcoding analyses. *Metabarcoding & Metagenomics, 8*, e135082. https://doi.org/10.3897/mbmg.8.135082.

Patrick, R., & Reimer, C. W. (1966). *The Diatoms of the United States exclusive of Alaska and Hawaii*. Monographs of the Academy of Natural Science 13, Philadelphia, 688pp.

Poulsen, N., Davutoglu, M. G. & Zackova Suchanova, J. (2022). *Diatom Adhesion and Motility*. In: Falciatore A, & Mock T (Editors). *The Molecular Life of Diatoms*. Springer, Cham. 808pp. https://doi.org/10.1007/978-3-030-92499-7_14.

Rajwa-Kuligiewicz, A., Bialik, R. & Rowiński, P. (2015). Dissolved oxygen and water temperature dynamics in lowland rivers over various timescales. *Journal of Hydrology and Hydromechanics*, *63*(4), 353-363. https://doi.org/10.1515/johh-2015-0041.

Reid, G. K. (1961). *Ecology of inland water and estuaries.* Reinhold publishing crop, New York, 375pp.

Saki, S. H., & Al-Shaheen, M. A. (2025). Water quality assessment for the Southern Al-Hawizeh marsh using diatom indicators. *Pollution*, *11*(2), 454-463. https://doi.org/10.22059/poll.2024.380917.2510.

Sawai, Y., Nagumo, T., Namegaya, Y., Cisternas, M. V., Lagos, M., & Shishikura, M. (2017). Diatom (Bacillariophyceae) assemblages in salt marshes of south-central Chile: Relations with tidal inundation time and salinity. *Phycological Research*, *65*(1), 29-37. https://doi.org/10.1111/pre.12156.

Sawai, Y., Horton, B. P., Kemp, A. C., Hawkes A.D., Nagumo, T. & Nelson, A. R. (2016). Relationships between diatoms and tidal environments in Oregon and Washington, USA. *Diatom Research*, 31(1), 17–38. http://doi.org/10.1080/0269249X.2015.1126359.

Simsek, K. (2018). Mixed Wastewater use for Culture of Diatom *Nitzschia umbonata* (Ehrenberg Lange-Bertalot, 1978). *International Journal of Research and Innovations in Earth Science, 5*(6), 131-135. https://www.ijries.org/index.php/issues?view=publication&task=show&id=80.

Soleimani, M., Rutten, L., Maddala, S. P., Wu, H., Eren, E. D., Mezari, B., Schreur-Piet, I., Friedrich, H. & van Benthem, R. A. T. M. (2022). Modifying the thickness, pore size, and composition of diatom frustule in *Craspedostauros* sp. with Al^{3+} ions.

Scientific Reports, *12*(1), 4175. https://doi.org/10.1038/s41598-022-08154-8.

Su, Y., Lundholm, N. & Ellegaard, M. (2018). Effects of abiotic factors on the nanostructure of diatom frustules-ranges and variability. *Applied Microbiology and Biotechnology*, *102*(14), 5889–5899. https://doi.org/10.1007/s00253-018-9087-1.

Taziki, M., Ahmadzadeh, H., Murry, M. A. & Lyon, S. R. (2015). Nitrate and Nitrite Removal from Wastewater Using Algae. *Current Biotechnology*, *4*(4), 426-440. https://doi.org/10.2174/2211550104666150828193607.

Wang, Y., Mu, W., Sun, X., Lu, X., Fan, Y. & Liu, Y. (2020). Physiological response and removal ability of freshwater diatom *Nitzschia palea* to two organophosphorus pesticides. *Chemistry and Ecology*, *36*(9), 881-902. https://doi.org/10.1080/02757540.2020.1784883.

Wang, Y., Liu, S., Wang, J., Yao, Y., Chen, Y., Xu, Q., Zhao, Z. & Chen, N. (2022). Diatom Biodiversity and Speciation Revealed by Comparative Analysis of Mitochondrial Genomes. *Frontiers in plant science*, *13*,749982. https://doi.org/10.3389/fpls.2022.749982.

Witkowski, A., Lange-Bertalot, H. & Metzeltin, D. (2000). *Diatom flora of marine coasts I. – Iconographia Diatomologica. 7*. Publisher: A.R.G. Gantner Verlag K.G. Koeltz Botanical Books, Königstein, 925pp.

التغيرات الحرجة في تركيب مجتمع الدياتومات في هور الحمار الشرقي، جنوب العراق

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المستخلص: تنتشر الدياتومات في معظم البيئات المائية العراقية، كما هو الحال في هور الحمار جنوب العراق، مما يعكس جودة المياه والعوامل البيئية السائدة في أماكن تواجدها. وقد شهد هور الحمار الشرقي جنوب العراق تغيرات بيئية كبيرة، لا سيما ارتفاع درجة الحرارة والملوحة خلال العقود الماضية. وقد تدهورت جودة المياه، مما أثر على الكائنات الحية التي تعيش هناك، وأهمها الدياتومات. خلال الفترة من آب 2018 إلى نيسان 2019، دُرست الخصائص النوعية والكمية للدياتومات الهائمة والملتصقة على النباتات في هور شرق الحمّار في ثلاثة مواقع، هي السدّة، والصلال، والبركة. اثناء الدراسة الحالية، تم تشخيص وتوثيق 69 تصنيفًا تنتمي إلى 37 جنسًا. احتوت تجمعات الدياتومات على 30% من أشكال المياه المويلحة، و21% من أنواع المياه البحرية – المويلحة، و16% من أنواع المياه العذبة، و10% من أنواع المياه البحرية، بينما تميّزت نسبة 23% المتبقية بتفضيلات بيئية متفاوتة تتراوح بين الأنواع العذبة والبحرية. تسود أنواع المياه البحرية – المويلحة خلال فصل الصيف، بينما تسود أنواع المياه العذبة خلال فصل الشتاء.

الكلمات المفتاحية: الطحالب العصوية، التأثير البيئي، الاهوار، الهائمات الملتصقة على النباتات،