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Occurrence of Five Diatom Species in Khor Al-Zubair Lagoon, Southern Iraq with a new record of *Cyclotella litoralis* Lange & Syvertsen, 1989

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Abstract: Khor Al-Zubair lagoon is a vital water body in southern Iraq. Despite the existence of a number of environmental studies in this region, it lacks searches related to the diversity of diatoms especially benthic forms, in light of global climatic changes and their impacts on aquatic ecosystems. Therefore, this research was designed to document diatom species that began to colonize this lagoon. The present study was carried out during the period from January to November 2020 in two selected stations at Khor Al-Zubair lagoon, where five species of diatoms were documented and described, including *Amphora acuta, Biremis ambigua, Cyclotella litoralis, Lyrella lyra* var. *subcarinata*, and *Progonoia musca*. The species, *C. litoralis* is a new record for Iraqi diatom flora.

Key words: *Cyclotella litoralis*, Diatoms, Epilithic, Epipelic, Iraq, Khor Al-Zubair lagoon.

Introduction

Diatoms are a major group of microscopic algae that present ubiquitously and can be planktonic or attached to different substrates (John, 2000; Taylor *et al*., 2007). With more than 100000 registered species, these are either single-celled or colonial that vary in size from 2 µm to 2 mm or can be several millimeters (Armbrust, 2009; Mann & Vanormelingen, 2013). Many studies and reports showed that diatoms are the major group of microalgae in Iraq (Al-Shaheen, 2016).

Due to geological factors including progression of a sand bar or spit, parts of sea split forming natural water bodies which is called lagoon. Every lagoon is considered a unique ecosystem with distinctive ecological features (Kwon *et al*., 2021).

Khor Al-Zubair lagoon is important water body in the North-west of the Arabian Gulf representing the main waterway for the ports of Khor Al-Zubair and Umm Qasr (Al-Ramadhan, 1986a; Hussein *et al*., 2010). Consequently, Khor Al-Zubair lagoon represents as a canal of interface between brackish water discharge of the Shatt Al-Basrah canal and the salty water comes from Arabian Gulf (Al-Shaheen & Abdullah, 2021, Al-Yamani, 2021). Al-Handal *et al*. (1991) and Al-Handal & Al-Rekabi (1994) are the first researchers were studied diatoms in Khor Al-Zubair lagoon, diagnosed

91 and 105 diatoms species respectively. In addition, Al-Zubaidi and his group listed only 23 species in their study (Al-Shaheen, 2016). Hussein *et al*. (2010) recorded 52 diatom species. All of previous study focused on planktonic diatoms. Recently, Al-Shaheen & Abdullah (2021) identified 78 species of diatoms at the Mudflats of Khor Al-Zubair and and Khor Abdullah lagoons, three species recorded for the first time in both lagoons.

Perhaps one of the most important reasons for the lack of diversity in diatoms could be attributed to climate changes. Iraq is located in a region known for its high summer temperatures and lack of rain in winter. Thus, recording changes in the diversity or emergence of previously unrecorded invasive or alien species, could reflect alteration in environmental factors in the studied area.

The purpose of this research was to document the diatom species that began to inhabit several solid substrates as a result of environmental changes in Khor Al-Zubair lagoon.

Materials & Methods

Study site

Khor Al-Zubair lagoon located in southern Iraq, southwest of Basrah province (30° 23′ and 30o 23′ N; 47° 50′ and 48° 10′ E) and connected partly to Shatt Al-Arab river through Shatt Al-Basrah canal (Al-Ramadhan, 1986a; Hussein *et al*., 2010, Al-Shaheen & Abdullah, 2021, Al-Yamani, 2021).

The total length of this lagoon is about 40 km and 1-2 km in width, the depth of the navigation channel at the highest tide is about 20 meters, and the total area at the highest flood tide can reach about 60 km^2 (Al-Ramadhan, 1986a). Due to the connection with the Arabian Gulf, it is affected by the daily semi-diurnal tide with a tidal rise of 5.12 m (Al-Ramadhan, 1986b), and a width intertidal zones on its banks described by a silt and mud (Issa *et al*., 2009).

Two stations in Khor Al-Zubair lagoon were selected that are 6.7 Km apart (Fig. 1). The first station located at West bank next to Khor Al-Zubair oil Port (29° 90′ 54″ N; 48° 50′ 13″ E), while the second station at the East bank near a small platform (30° 15′ 62″ N; 47° 90′ 33″ E). Both stations have a widthspread mudflat during low tide, where a lot of mudskipper fish could be seen and several kind of substrates like stones, wood, metals were submerged in the water.

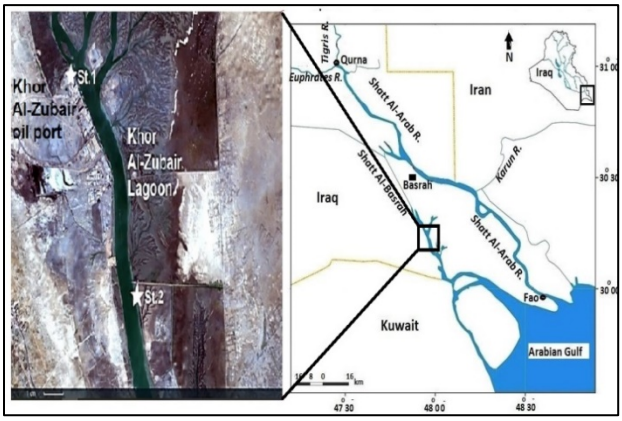


Fig. (1): Map showing studied stations at Khor Al-Zubair lagoon.

Sampling

Samples were collected seasonally between January to November 2020 during low tide level. Some of environmental parameters were measured at field including air and water temperature, salinity and hydrogen ion concentration (Table 1).

Epipelic diatom was collected randomly by scrapping 0.5 cm from the top of sediments.

Epilithic diatoms on stones, standing wood, metals and ropes that were submerged in high tide were also collected by scrapping their surface using sharp tools and toothbrush, while the ropes were cut into small pieces then was shaken vigorously in plastic bags containing distilled water to dislodge attached diatoms (Taylor *et al*., 2007). All diatoms samples were preserved in 4% formalin before transferring to the laboratory for cleaning the diatoms frustules.

Motile epipelic diatoms were trapped by lens tissue that left on the mud surface for one day. Lens tissue were removed and cut into small pieces and put in screw glass tubes, followed by shaking vigorously in distilled water (Al-Shaheen & Abdullah, 2021). The supernatant of epipelic and epilithic diatom were transferred into clean pyrex beakers containing H_2O_2 (35%), heated to clean the diatoms frustules. Finally, they washed with distilled water then mounted by Naphrax® to prepare permanent slide (Al-Handal & Wulff, 2008). Microscopic examination of diatoms was done using Zeiss Axiophot 2 imaging microscope (Carl Zeiss AB) that is supplied with a professional camera for sample imaging. SEM imaging of diatoms was done using Hitachi S-3500N SEM (Hitachi, Tokyo, Japan) operated at 15 kV at the Knight Oceanographic Research Center, College of Marine Science, University of South Florida, Florida, USA. All measurements of diatom species are in micrometres (μm).

Results & Discussion

Values of air and water temperatures, salinity and pH are given in table (1). In general, the results of environmental parameters were similar at both stations. Minimum temperatures in the current study were several degrees higher than what was previously recorded (Al-Handal & Al-Rekabi, 1994; Hussein *et al.*, 2010), but in agreement with Al-Shaheen & Abdullah (2021). Temperature is fluctuating environmental factor in lagoons that plays an important role in controlling the abundance and distribution of organisms in those environments (Mouillote *et al*., 2005; Petihakis *et al*., 1999). Although the results of salinity were close to that measured by Al-Shaheen & Abdullah (2021), it was lower than what was previously recorded by Al-Handal & Al-Rekabi (1994) and Hussein *et al.* (2010). This might be due to the increase of both rainfall and water releases during the period of study. Many researchers confirmed that salinity in the lagoon is subject to large seasonal variations and is an important factor in controlling the abundance and spread of aquatic life. (Mouillote *et al*., 2005; Franco-Herrera & Castro, 2008). The pH values that recorded in this study are similar to those measured previously (Hussein *et al.*, 2010; Al-Shaheen & Abdullah, 2021).

Table (1): Some environmental parameters in Khor Al-Zubair lagoon during January to November 2020.

Parameter	Month			
	Jan.	Apr.	Jul.	Nov.
Air temperature (°C)	15.1	24.5	40.9	19.9
Water temperature (°C)	16.2	19.8	27.5	16.8
Salinity (PSU)	5.9	10.3	21.6	20.8
pH	7.8	8.5	8.4	7.7

To our best acknowledge, this study is the first on the epilithic diatoms at Khor Al-Zubair lagoon, and one of very few studies that deals with epilithic diatoms in Iraq. Most of local studies were focused on planktonic and epiphytic diatoms, as well as epipelic diatoms (Al-Shaheen, 2016; Al-Shaheen & Abdullah, 2021).

Identification results of diatoms showed five species are recorded in Khor Al-Zubair lagoon including *Amphora acuta, Biremis ambigua, Cyclotella litoralis*, *Lyrella lyra* var. s*ubcarinata* and *Progonoia musca*. **(**Figs. 2-6**).**

Floristic list

Amphora acuta W. Gregory, 1857 (Fig. 2)

References: Wachnicka & Gaiser (2007), p. 410, fig. 80; Levkov (2009), pl.80, figs.1-5.

Description: Valves dorsiventral shape, convex in dorsal margin and slightly concave to straight in ventral margin, 75-77 Length and 18-19 width. Apices are acutely or sharply rounded. Raphe eccentric, located very nearer to the ventral margin. Endings of both proximal and distal raphe are strongly dorsally bent. Axial area and central area are narrow. Striae arranged in parallel to slightly radial form, dorsal striae are 15-16 in 10 µm and 18-21 at centre and ends respectively. Ventral striae are hardly observable under light microscope, about 24-25 in 10 µm.

Remarks: Observed specimens have slightly higher striae density (normally 8-11 in 10 µm). This species has been confused with *Amphora decussata* Grunow but the later species is characterized by narrow valve and more concave ventral margin with denser striae of ventral side.

Ecology and Habitat: It is a marine epipelic species.

Distribution: Broadly distributed in marine water. Recently reported in Iraqi coral reef (Al-Handal *et al*., 2018).

Occurrence: At both stations in July and November.

Biremis ambigua (Cleve) D .G. Mann, 1990 (Fig. 3)

References: Witkowski *et al*. (2000), p.158, pl.155, figs.2-6; Hein *et al*. (2008), p. 47, pl. 20, fig. 9 & pl. 21, fig. 6.

Synonym: *Pinnularia ambigua* Cleve 1895; *Schizonema ambiguum* (Cleve) Kuntze 1898.

Description: Frustules rectangular in girdle view, and linear with broadly rounded apices, weakly constricted at the middle in valve view, 103-106 Length and 11-12 broad. Raphe at centre and somewhat undulating shape with widthly sternum. Striae are in parallel arrange-ment on valve surface with short, coarse and marginal transapical striae, 7-9 in 10 µm.

Remarks: The observed specimens were Lengther than those reported in the literatures [e.g. Witkowski *et al.,* 2000 (60-80); Al-Yamani & Saburova 2011 (37-63); Al-Handal *et al*., 2018 (42-60)].

Ecology and Habitat: Ubiquitous marine littoral species (epipelic).

Distribution: This is a global species, previously described from the Arabian Gulf and Iraqi coral reef (Al-Yamani & Saburova, 2011; Al-Handal, *et al*., 2018).

Occurrence: At both stations during study period.

Cyclotella litoralis Lange & Syvertsen, 1989 (Fig. 6)

References: Lange & Syvertsen (1989), p.343, Figs.1-30; Prasad & Nienow (2006), p.139, Figs 35-39; Park *et al*. (2013), p.9, Fig.3; Lee *et al*. (2015), p.587, Figs. 8c-d.

Description: Valves circular 24-27 in diameter, with undulating central area. Marginal chambers absent. Striae in radiated form, every stria consists of 2-3 rows near central area and become 3-4 rows at the mantle edge. Marginal striae 10-11 in 10 µm, with seven valve face fultoportula. Mantle fultoportulae located at the end of each stria or one at every two striae ends.

Remarks: *C. litoralis* can be distinguished from *C. baltica* by two features, spacing of the mantle fultoportulae and number of central fultoportula. Mantle fultoportulae in *C. baltica* positioned on second, third and some time on fourth interstria, while in *C. litoralis* it is located on every second interstria. The number of fultoportula is one to several in a hemispherical position in *C. baltica*, in contrast, 2 to 20 of fultoportula in arc positioned in *C. litoralis* (Lange & Syvertsen, 1989; Håkansson, 2002; Park, *et al*., 2013). Moreover, absent of marginal chambers from *C. litoralis* have been the main distinguished feature from *C. striata* and *C. stylorum.* Also, *C. litoralis* can be separated from *C. striata* based on the lack of fultoportula from the valve face, and from *C. stylorum* depending on spacing of mantle fultoportula (Lange & Syvertsen, 1989 Håkansson, 2002; Prasad & Nienow, 2006; Park, *et al*., 2013).

Ecology and Habitat: This is a marine to brackish water species, mainly planktonic neritic form (Håkansson, 2002; Prasad & Nienow, 2006).

Distribution: This species is a new record for Iraq's diatom flora, which has not previously reported from the Arabian Gulf, but mainly reported in marine water including Northern and Southern temperate regions (Hasle & Syvertsen, 1996).

Occurrence: At station 2 in July and November.

Lyrella lyra var**. *subcarinata*** (Grunow ex A. W. F. Schmidt) Moreno, 1996 (Fig. 4)

References: Moreno *et al*. (1996), p.88, pl.24, fig.1.

Synonym: *Navicula lyra* var. *subcarinata* Grunow ex A. W. F. Schmidt 1874; *Navicula lyra* f. *subcarinata* (Grunow in Schmidt, *et al*.) Cleve 1901; *Navicula subcarinata* (Grunow ex A. W. F. Schmidt) Hendey 1951.

Description: Valves broadly elliptic in shape with broadly to sub-rostrate apices, 76-79 Length, 31-32 broad. Raphe is straight with narrow axial area, rounded central area which extended transversely and connected with lateral extensions to produce distinct lyre-shaped hyaline area. Striae are punctate, parallel at the middle then become slightly radiate forward the apices, all striae are interrupted by lyre-shaped area, 11-13 in 10 µm with 18-20 in 10 µm puncta.

Remarks: Our specimens slightly smaller than those reported by Al-Handal *et al*., (2018) (Length 80-140, width 40-52).

Ecology and Habitat: This is a cosmopolitan marine species.

Distribution: Previously described from the Arabian Gulf and Iraqi coral reef (Al-Yamani & Saburova, 2011; Al-Handal, *et al*., 2018).

Occurrence: At both stations aLength the study period.

Progonoia musca (W.Gregory) H. -J. Schrader, 1971 (Fig. 5)

References: Schrader (1971), pl.1, figs.1-3, pl.2, figs.1-4; Lobban (2015), p. 247, Figs. 1-4.

Synonym: *Navicula musca* W. Gregory 1857; *Caloneis musca* (W. Gregory) Cleve 1894; *Schizonema musca* (Gregory) Kuntze 1898; *Oestrupia musca* (W. Gregory) Hustedt 1935.

Description: Valves have broadly elliptical to lanceolate shape, obvious compression in the middle, broadly cuneate shape of apices, 70-73 Length, 17-18 width. Raphe straight at centre of valve, with broadly lanceolate axial area. Coarsely transapical striae, parallel in the centre of valve and weakly radiate at the ends, 7-8 in 10 µm. Striae divided into two Lengthitudinal rows by Lengthitudinal hyaline line located parallel to margin of the valve.

Remarks: Observed specimens slightly Lengther than those previously described [e.g. Al-Yamani & Saburova, 2011 (40-57); Al-Handal, *et al*., 2018, (46-58)]. This species has been commonly reported as *Oestrupia musca* (Gregory) Hustedt.

Ecology and Habitat: It is a marine epipelic species.

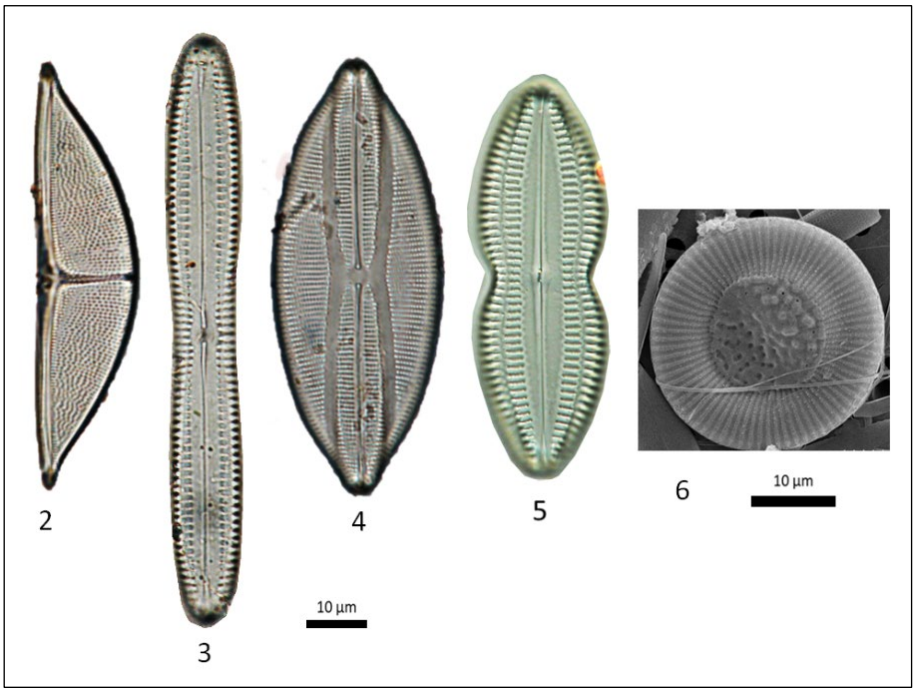
Distribution: Widthly spread in marine water. Previously reported at the Arabian Gulf and Iraqi coral reef (Al-Yamani & Saburova, 2011; Al-Handal, *et al*., 2018).

Occurrence: At both stations during study period.

The species *C. litoralis* is new record for the diatom flora of Iraq (Maulood *et al*., 2013; Al-Saedy *et al*., 2020). *C. litoralis* was discovered for first time in south western Atlantic by Lange & Syvertsen (1989). Although this species has been recorded in various locations around the world, and recently been documented for the first time in Korea and India (Park, *et al.,* 2013; Samanta & Bhadury, 2018), but its distribution is still limited in comparison to other species nearby, particularly the *C. striata* complex. However, no report or study found this species in either the Arabian Gulf or the Iraqi aquatic environment.

Recording diatom species in Khor Al-Zubair lagoon could indicate the appropriateness of the environmental conditions, for their living and settlement. Presence of these species in the lagoon may be due to drifting, carried by tidal water and/or transported by ships. New environmental conditions may be attributed to climate changes and anthropogenic influence such as higher temperature, extreme warm seasons, untreated domestic and industrial wastes (Mohamed & Abood, 2017; Al-Handal & Al-Shaheen, 2019). However, most of these taxa are rare in the study area and will require extensive research to fully understand their diversity in this region.

Diatoms are one of the most important organisms used as a bioindicator in various water bodies, their presence reflects the environmental status of the water. So, it is necessary to continue monitoring the qualitative composition of diatoms in Iraqi waters in order to detect environmental changes.



Figs. (2-7): LM and SEM images of recorded diatoms species at Khor Al-Zubair lagoon, Southern Iraq. LM images: Fig. (2): *Amphora acuta*, Fig. (3): *Biremis ambigua*, Fig. (4): *Lyrella lyra* var. *subcarinata*, Fig. (5): *Progonoia musca*, SEM image: Fig. (6): *Cyclotella litoralis*, (scale bar: 10 µm).

Conclusion

Occurrence of five diatom species have been documented in Khor Al-Zubair lagoon including *A. acuta, B. ambigua, C. litoralis, L. lyra* var. *subcarinata*, and *P. musca*. The species, *C. litoralis* is a new record for Iraqi diatom flora.

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Conflict of interest

The authors declared that they have no conflict of interest.

Contributions of Authors

D.S.A.: Suggest a title of the research, sample collection, and Laboratory methodology include isolated diatoms, digested, and prepared slides.

M.A.A.: Laboratory methodology include examined, measured, diagnosed the diatoms, as well writing and reviewed the final manuscript.

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تواجد خمسة انواع من الدياتومات في خور الزبير جنوبي العراق، مع تسجيل جديد للنوع *Cyclotella litoralis* Lange & Syvertsen, 1989

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المستخلص: يعتبر خور الزبير احد المسطحات المائية المهمة في جنوبي العراق، وعلى الرغم من وجود عدد من الدراسات البيئية في هذه المنطقة، إلا أنها تفتقر إلى الابحاث المتعلقة بتنوع الدياتومات فيها، خاصة القاعية منها، في ضوء التغيرات المناخية العالمية وتأثيراتها المختلفة على النظم البيئية. لذلك تم تصميم هذا البحث لتوثيق انواع الدياتومات التي بدأت في استعمار مياه وضفاف هذا الخور. أجريت الدراسة الحالية خلال الفترة من كانون الثاني ولغاية تشرين الثاني 2020 في محطتين مختارتين في خور الزبير، أذ تم توثيق ووصف خمسة أنواع من الدياتومات والتي تضمنت *Amphora acuta* و *Biremis ambigua* و *Cyclotella litoralis* و *Lyrella lyra* var. *subcarinata* و *Progonoia musca*. ان النوع *C. litoralis* يعد تسجيلا جديدا يضاف إلى قائمة الدياتومات العراقية.

الكلمات المفتاحية: *Cyclotella litoralis*، دياتومات، ملتصقة بالصخور، ملتصقة بالطين، خور الزبير، العراق.