Poll Res. 40 (3) : 1078-1085 (2021)

ISSN 0257–8050

DIATOMS IN KHOR AL-ZUBAIR MUDFLATS AND KHOR ABDULLAH LAGOONS, SOUTHERN IRAQ

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(Received 10 May, 2021; Accepted 22 June, 2021)

ABSTRACT

Present study considers the first search on the epipelic diatoms at Khor Al-Zubair and Khor Abdullah lagoons, Southern Iraq. In total, 78 taxa belonging to 44 genera were identified during the current study, encountered taxa was dominant by genus *Nitzschia* represented by 10 species followed by *Navicula* which has 8 species and six species for *Gyrosigma*. A few species are a centric form, while the rest are in pennate form. Morever about a half of the encountered species are marine form (52%), followed by brackish to marine species consist of 37%, while the freshwater form comprises just 5%, and finally 6% for other environmental favourites species. Epipelic diatoms encountered in the present study consist more 70% of all identification taxa, whereas the rest consist 21% of planktonic taxa, epiphytic (7%) and few percentages for other habitat. Three new species including *Biremis sigmoidea*, *Cocconeis sawensis*, and *Frickia lewisiana* were recorded first time in both the lagoons.

KEY WORDS : Diatoms, Mudflats, Khor Al-Zubair lagoon, Khor Abdullah lagoon, Southern Iraq

INTRODUCTION

Estuaries are specific environments characterized by its high primary production and diverse communities of flora and fauna (Levinton and Waldman, 2006, Bianchi, 2013). Intertidal mudflats are naturally formed in the sheltered areas of estuaries or when current energy is low and may cover vast areas depending on local conditions. Mudflats are formed of mud fine particles and silt, for this reason, these places are highly productive and can sustain diversified groups of organisms (Underwood and Kromkamp, 1999). Microphytobenthos mainly occur in subtidal shallow and mudflats. This group of microorganisms are considered as a vital source of primary production (Brotas *et al.*, 1995; Guarini *et al*., 1998). Among these, benthic diatoms play a significant role in this primary productivity and responsible for 20% of global carbon fixation (Matheke and Horner, 1974; Mann and Vanormelingen, 2013). Diatoms of mudflats exhibit various modes of life depending on sediment components. The most common taxa are the epipelic. Most of local algal and diatom studies in Basrah governorate water environments have focused on the planktonic and epiphytic forms with few studies have been undertaken to investigate the biological community of epipelic, epilithic and episammic diatoms. Hadi *et al*. (1984) studied diatoms at the middle part of the Shatt Al-Arab River and identified 116 taxa, among which epipelic forms were most frequent. Khor Abdullah coast has many diatom species, the most common species were belonging to the genus *Coscinodiscus, Nitzschia* and *Navicula* respectively as reported by Tynni (1983). The benthic microalgae and their primary productivity were studied in three stations at Shatt Al-Arab River. These studies identified 170 algal taxa including 126 species of diatom, epipelic form were the most frequent species (Al-Shaban, 1996; Al-Farhan, 2010). There were indirect studies at Shatt Al-Arab River and Al-Faw through dealing with food of mudskipper (Pankow and Huq, 1979; Sarker *et al.,* 1980). Recently Al-Shaheen (2016), provide important insights and data covered the taxonomical and ecological factors 49 of diatoms communities within different habitats such as epipelic at the middle and south part of Shatt Al-Arab River. Most of local algal and diatom studies in Khor Al-Zubair lagoon, Khor Abdullah lagoon only focused on planktonic forms with few studies on periphytic forms (Tynni, 1983; Al-Rekabi, 1990; Al-Handal *et al.,* 1991a; Al-Zubaidi, *et al.,* 2006; Al-Shawi, 2010). For this reason, the current study the first search was designed to discover and identify the specific composition of epipelic diatoms in both of Khor Al-Zubair and Khor Abdullah lagoons.

MATERIALS AND METHODS

Study area

Two study stations were selected for this work, Khor Al-Zubair lagoon and Khor Abdullah lagoon, were located in South of Iraq, South west of Basrah governorate and specifically in the North western part of the Arabian Gulf. The first station, Khor Al-Zubair lagoon which is an extension channel of Khor Abdullah, and they are connected together by Khor Shytana (Lafta *et al.,* 2020). Khor Al-Zubair lagoon is a maritime navigation waterway towards two main ports in Iraq, Khor Al-Zubair and Umm Qasr (Al-Ramadhan, 1986a).

The lagoon is 40 Km long and 1 - 2 Km wide with a depth of 10-20 meters during high tide with a mean tidal range exceed 4 m at spring tide (Al-Ramadhan, 1988) (Fig. 1). Moreover, Khor Abdullah lagoon a funnel shape lies between Iraqi Al-Faw peninsula on the east and Kuwaiti Bobian island on the west, with about of 40 km long, 17 km wide, 7-14 m depth, and wide intertidal zones on both banks (Mohamed *et al.*, 2002). Generally, both lagoons have a wide intertidal zone on its banks and their soil characterized by a silty clay nature at shores. The mudflat of Khor Al-Zubair described by a silty clay tend to be a soft sandy clay layer on top and hard clay layer in bottom (Muhammad Ali, 1986). Ecological nature of Khor Al-Zubair lagoon influenced by fresh to brackish waters comes from 73 the north site of Shatt Al-Arab River through Shatt Al-Basrah canal during low tide, and also by the tides of the Arabian Gulf which are of semi-diurnal type. Therefore, Khor Al-Zubair lagoon undergoes increase and decrease in salinity during high and low tide of Arabian Gulf sea (Al-Hassan and Hussain 1985; Al-Ramadhan, 1986; Al-Yamani *et al*., 2007; Al-Shaheen, 2016). On the other hand, Khor Abdullah lagoon effected by brackish waters comes from the north by Khor Al-Zubair and marine water comes from Arabian Gulf.Two stations were selected for current study, both of them are at the at East bank of both lagoons. The first one locates in

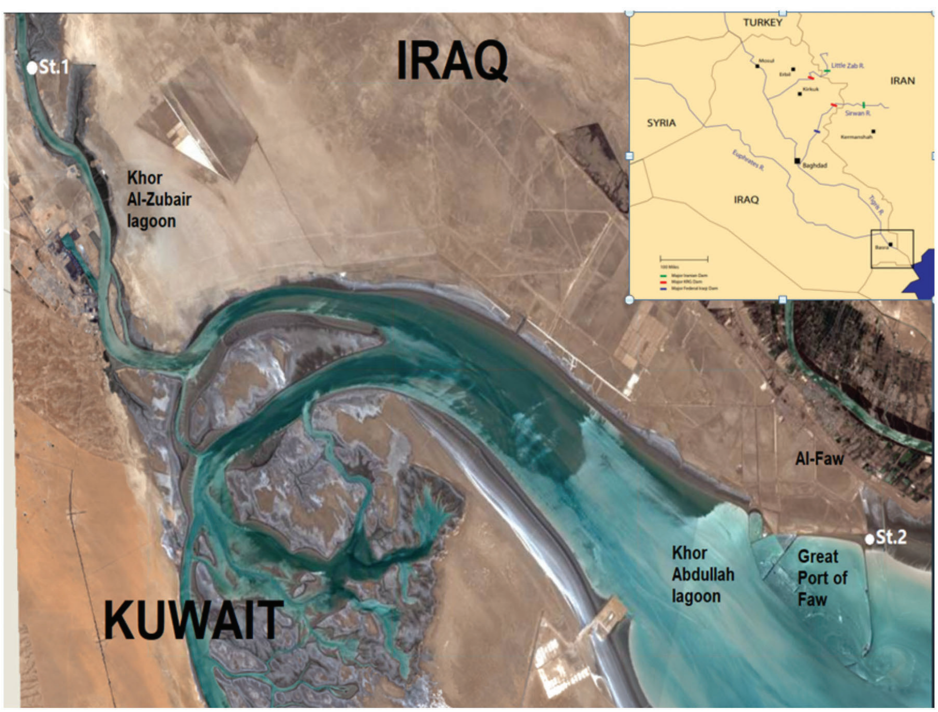

Fig. 1. Map showing study stations at Khor Al-Zubair and Khor Abdullah lagoons

Khor Al-Zubair lagoon where a small platform is found (N: 30o 152 62222; E: 47º 902 33922). The position of second station at Khor Abdullah lagoon next to the eastern breakwater of the Great Port of Faw (N: 29º 902 54622; E: 48o 502 13122). The mudflat coast of both stations has a wide area extends for more than 100 m toward the water side were they completely free of aquatic plants except for a few mangrove bushes and lot of mudskipper fish.

Sampling and parameters measurement

Samples were collected seasonally from March 2018 to December 2019 during the lowest level of low tide. Many parameters were tracked including air and water temperatures, hydrogen ion concentration and salinity. Epipelic diatoms were collected by scrapping the surface of mud around 0.5 cm of the top at each station. Samples were kept in plastic containers and preserved in ice box at the field before transferring to laboratory for analysis. Sediment samples were mixed toughly and immobilized into Petri dish (9.5 cm) with 1 cm depth. To isolate clean diatoms the protocol of Al-Handal and Wulff (2008) was followed with a little modification. To trap all motile epipelic diatoms a lens tissue was left on the top of each samples for next day. The tissue was removed and cut into small pieces then transferred into screw glass tubes that included in distilled water. Tubes were shaken vigorously then the supernatant was transferred into a clean 98 250 ml glass beakers contained H_2O_2 at 35 % in concentration. The samples were heated at 90 C for 1 h. Collected frustules were cleaned via washing with distilled water then a one milliliter of them was left to dry on a cover slip and then mounted in NaphraxR for microscopic examination. For diatoms species identification, the guide of many publications was followed Al-Handal (2009); Al-Kandari *et al*. (2009); Al-Yamani and Saburova (2011); Cantonati *et al.* (2017); Krammer & Lange-Bertalot (1986,1988,1991); Lange-Bertalot (1996); Lavoie *et al*. (2008); Novelo *et al*. (2007); Taylor *et al.* (2007) and Witkowski *et al.,* (2000).

RESULTS

Water Parameters

At the time of collection of samples, the environmental parameters of air temperature, water temperature, pH and salinity are presented in Table 1. The analysis results of identification diatoms showed that there 78 taxa belonging to 44 genera. The details of taxa listed alphabetically in Table 2. The most frequent genus was *Nitzschia* represented by 10 species followed by *Navicula* which has 8 species then *Gyrosigma* by 6 species. Pennate diatoms form were ubiquitous taxa comparing with a centric form diatom. Based on environmental preferences, more than 50% of diatoms related to marine form taxa followed by brackish to marine species (35%), freshwater form (5%) respectively.

Table 1. Some environmental parameters in Khor Al-Zubair and Khor Abdullah lagoons during March 2018 to February 2019.

Parameter	Khor Al-Zubair lagoon	Khor Abdullah lagoon
Air temperature (ºC)	22.1-35.4	21.5-36.8
Water temperature (ºC)	17.6-25.4	16.7-24.6
Salinity (PSU)	4.8-19.5	22.7-45.1
pH	7.5-8.6	7.5-8.8

Regarding to diatoms habitat, more than 70% of all identified taxa were epipelic diatoms, whereas the rest consist 21% of planktonic taxa, epiphytic (7%) and few percentages for other habitat. In the present study, identification most common diatoms species that recognized in both stations showed that *Berkeleya scopulorum* and *Nitzschia clausii* were the predominant species within brackish to marine water. Furthermore, the study spots the occurrence of several brackish to marine water species including 122 *Actinocyclus* cf. *curvatulus*, *Cyclotella striata, Gyrosigma* cf. *balticum, Gyrosigma eximium, Navicula* sp.1, *Nitzschia sigma*, *Nitzschia* sp.2, *Peterodictyon gemma*, *Pleurosigma angulatum*, *Pleurosigma diverse-striatum, Thalassionema nitzschioides* and *Tryblionella littoralis*.

Frustulia interposita, *Gyrosigma scalproides* and *Nitzschia dissipata* of a freshwater species were rarely observed. Furthermore, current study recording three new species including *Biremis sigmoidea, Cocconeis sawensis* and *Frickia lewisiana* were not previously reported at Khor Al-Zubair lagoon.

DISCUSSION

In the present study, we report 78 diatom taxa belonging to 44 genera (Table 2). This finding indicates to a significant increase in diatom species number when comparing with previous studies such as Tynni (1983) 78 species of diatoms at Khor Abdullah lagoon, both of Al-Rekabi (1990) and Al-Shawi (2010) are reported 47 and 19 respectively of

Table 2. Environmental preferences, relative occurrence and dimensions 352 of mudflats diatoms at Khor Al-Zubair and Khor Abdullah lagoons, Southern Iraq.
(f: freshwater, b: brackish water, m: marine, un: unknown, vr= very rare, r= rare, fr= frequent, c: common).

No.	Species	Habitat	Relative occurrence	Longe/ Diameter	Width	Striae in 10 um
1.	*Actinocyclus* cf. *curvatulus* Janisch	m	fr	38- 41		8-10
2.	*Achnanthes brevipes var. intermedia* (Kutzing) Cleve	b	vr	31-55	7-11	8-11
3.	*Achnanthes kuwaitensis* Hendey	m	vr	69-85	9-10	9-11
4.	*Asteromphalus flabellatus* (Brebisson) Greville	m	vr	47-50		12-15
5.	*Ardissonea formosa* (Hantzsch) Grunow	m	vr	141-145	14-16	11-12
6.	*Bacillaria paxillifera* (O.F.Muller) T. Marsson	b,m	r	62-134	5-7	18-24
7.	*Berkeleya scopulorum* (Brebisson ex Kutzing) E.J.Cox	m	c	84-93	11-13	16-18
8.	*Biremis sigmoidea* Al-Handal	m	r	14-17	4-5	12-13
9.	*Caloneis elongata* (Grunow) Boyer	m	vr	95-99	11-14	16-17
10.	*Campylodiscus neofastuosus* Ruck & Nakov	m	vr	25-27	19-21	14-1
11.	*Campylodiscus* cf. *bicostatus* W.Smith ex Roper	b	r	42-63	8-20	
12.	*Cocconeis sawensis* Al-Handal et Riaux-Gobin	b	vr	19-22	17-19	21-22
13.	*Coscinodiscus radiatus* Ehrenberg	m	r 71-76	3-5		
14.	*Coscinodiscus oculus-iridis*	m	r	12-16	4-6	
15.	*Cyclotella striata* (Kutzing) Grunow	m, b	fr	22.6-42.5		11-14
16.	*Cyclotella stylorum* Brightwell	m	r	27-45	11-14	
17.	*Diploneis weissflogii* (Schmidt) Cleve	m	r	35-40	8-11	8-9
18.	*Diploneis* sp.	un	vr	20-21	7-9	13-16
19.	*Encyonema* sp.	un	vr	14	4	20
20.	*Entomoneis* sp.1	un	vr	44	15	14-16
21.	*Entomoneis* sp.2	un	vr	138	13.5	12-13
22.	*Entomoneis* sp.3	un	vr	109-113	10-13.5	12-13
23.	*Entomoneis* sp.4	m	r	90-193	8-10	10-12
24.	*Eucampia zodiacus* Ehrenberg	m	r	43 – 82	16-20	
25.	*Frickea lewisiana* (Greville) Heiden	b	r	97-161	22-25	19-23
26.	*Frustulia interposita* (Lewis) De Toni	f	r	48-69	10-14	18-24
27.	*Frustulia* sp. un vr 58 11.9 25-27					
28.	*Giffenia cocconeiformis* (Grunow) Round & Basson	b,m	r	44-56	15-18	7-8
29.	*Gomphotheca sinensis* (Skvortzov) Hendey & Sims	m	r	212-232	10-12	25-28
30.	*Gyrosigma* cf. *balticum* (Ehrenberg) Rabenhorst	b,m	fr	127-237	18-22	15-20
31.	*Gyrosigma eximium* (Thwaites) Boyer	b	fr	61-67	9-11	20-23
32.	*Gyrosigma fasciola* (Ehrenberg) Griffith & Henfrey	b,m	r	83-136	11-12	18-22
33.	*Gyrosigma scalproides* (Rabenhorst) Cleve	f	r	86-101	11-14	21-22
34.	*Gyrosigma* sp.1	un	r	74-82	9-10	19-24
35.	*Gyrosigma* sp.2	un	r	122-125	18-20	18-19
36.	*Luticola mutica* (Kutzing) D.G.Mann	f, b	vr	18-30	11-13	16-19
37.	*Mastogloia quinquecostata* Grunow	m	r	61-70	22-23	16-18
38.	*Mastogloia* sp.	un	vr	54	18	15-17
39.	*Navicula digitoradiata* (Gregory) Ralfs	b	r	36-59	7-10	13-16
40.	*Navicula directa* (W. Smith) Ralfs	m	vr	52-64	9-11	9-13
41.	*Navicula salinarum* Grunow f,	b	r	23-28	8.12	16-17

Table 2. *Continued ...*

No.	Species	Habit at	Relative occurrence	Longe/ Diameter um	Width	Striaein 10
42.	*Navicula* cf. *schroeterii* Meister	b	r	49-52	10-11	10-13
43.	*Navicula* sp. 1	un	fr	21.4	6.35	13-16
44.	*Navicula* sp. 2	un	r	30.5	7.6	11-13
45.	*Navicula* sp. 3	un	vr	37.88	14.91	9-11
46.	*Navicula* sp. 4	un	vr	26.1	7.47	10-12
47.	*Nitzschia bilobata* W. Smith	m	r	111-221	8-12	20-22
48.	*Nitzschia clausii* Hantzsch	m,	b	c	42-63	4-6
49.	*Nitzschia dissipata* (Kutzing) Rabenhorst	f	r	37-43	4-6	
50.	*Nitzchia hybrid* Grunow	b	r	97-176	6-8	10-12
51.	*Nitzschia lorenziana* Grunow	b	r	77-120	4-5	19-20
52.	*Nitzschia sigma* (Kutzing) W. Smith m,	b,	f	fr	113-141	5-8
53.	*Nitzschia scalpelliformis* Grunow m,	b	r	62-77	56	19-21
54.	*Nitzschia* sp.1	un	r	34.8	7.24	
55.	*Nitzschia* sp.2	un	fr	127-130	6-7	19-21
56.	*Paralia sulcata* (Ehrenberg)	Cleve	m	vr	20-25	
57.	*Peterodictyon gemma* (Ehrenberg) D.G. Mann	m, b	fr	65-85	29-31	16-20
58.	*Petroneis marina* (Ralfs) D.G. Mann	m	vr	65-72	28-31	10-11
59.	*Pleurosigma angulatum* (J.T.Quekett) W.Smith	m, b	fr	122-197	32-35	17-19
60.	*Pleurosigma diverse-striatum* F. Meister	m	fr	57-84	14-15	16-20
61.	*Pleurosigma* cf. *elongatum* W. Smith	b	r	177-200	19-24	19-21
62.	*Podosira* sp. m vr 30-32					
63.	*Scoliopleura basrensis* Al-Handal & Pennesi	b	r	31-43	7-8	25-28
64.	*Seminavis* sp. 1	un	vr	23	4	20
65.	*Seminavis* sp. 2	un	vr	45-46	5-6	13-14
66.	*Stauroneis* sp.	un	vr	42.11	8.96	18-2
67.	*Stephanodiscus* sp.	un	vr	11-12	10-12	
68.	*Surirella recedens* A.W.F. Schmidt	m	r	28-31	20-22	
69.	*Thalassionema nitzschioides* (Grunow) Mereschkowsky	m	fr	25-74	2-3.5	
70.	*Trachyneis aspera* (Ehrenberg) Cleve	m	vr	72-75	12-17	13-15
71.	*Trachyneis debyi* (Leuduger-Fortmorel) Cleve	m	vr	136-141	23-36	8-10
72.	*Triceratium* cf. *favus* Ehrenberg	m	vr	70-75		
73.	*Trieres mobiliensis* (Bailey) Ashworth & Theriot	m	vr	37-52	13-16	
74.	*Tryblionella apiculata* Gregory	m	vr	36-41	5-6	15-17
75.	*Tryblionella* cf. *coarctata* (Grunow) D.G. Mann	m, b	vr	32-36	9-10	20-22
76.	*Tryblionella littoralis* (Grunow) D.G.Mann	m, b	fr	46-73	14-17	16-18
77.	*Tryblionella* sp.	un	vr	22.4	8.7	22
78.	*Tryblioptychus cooconeiformis* (Grunow) Hendey	m	r	17.7		16-18

benthic diatoms species in planktonic samples in the same station in front of Khor Al-Zubair port. Also, Al-Zubaidi *et al.* (2006) reported 23 species in planktonic samples from Khor Al-Zubair lagoon. Al-Handal and his group (1991b) identified 76 planktonic diatoms species at Shatt Al-Basrah canal. Moreover, at Faw city, the same increase of diatom species was reported in this study comparing with Al-Shaban (1996), was identified 62 diatom species, and recently Al-Bidhani (2014) and Al-Shaheen (2016) who listed 52 and 42 diatom taxa respectively at the same city coast. The increasing of the diatoms species number in this study compared to the previous studies might be due to the changes in environmental variables at study area such as rise in temperature and salinity especially after severe decreasing of fresh water drain in Tigris and Euphrates that could directly affected on Shatt Al-Basrah canal parameters and Shatt Al-Arab River quality in the last years especially during Summer 2018 (Al-Handal and Al-Shaheen, 2019). This may explain the highly percentage of marine diatoms recorded 147 in the study area. Meanwhile, Hassan *et al.* (2011), Karim *et al*. (2016), Hassan (2018) and

Hassan *et al.* (2018) reported an increase the nutrients and other polluted chemical compounds in Shatt Al-Basrah canal that will be arriving to Khor Al-Zubair water. These pollutions may cause disappearing of some native diatom species, as well as provide a suitable environment for new diatoms species that not found previously at this area. Another main resource of pollutants come from commercial vessels and oil tankers in rivers and lagoons that play a vital role in changing water quality and compositions which influence the normal structure of microalgal communities. As a result, alien species can occupy the new environmental and pushing other native ones to disappear. Marine navigation could consider another way for bringing marine species into Shatt Al-Arab River, Khor Abdullah and Khor Al-Zubair lagoons. In addition to marine navigation, ship ballast water also has a significant key in providing sources of new organisms. Human mediated disturbance to distributions of species and changing in community structure (Gollasch *et al*., 2000; Ruiz *et al*., 2000; Klein *et al.,* 2010). Also, diatoms can also be transferred by birds, wind and aquatic insects. All these reasons associated with the appearance of new taxa in the Shatt Al-Arab River and other water systems. Current study identified 44 genera where dominant by genus *Nitzschia* represented by 10 species followed by 8 species of *Navicula* and 6 species of *Gyrosigma* as reported in previous literatures at Southern Iraq (Pankow and Hug, 1979; Al-Handal *et al.,* 1991a,b; Al-Handal, 2009; Al-Handal and Abdullah, 2010; Al-Farhan, 2010; Jaffer, 2010; Al-Ankush, 2013; Al-Shaheen, 2016). Dominance of *Nitzschia* spp. may be due to their wide range of environmental tolerance in waters with high organic pollution (Spaulding and Edlund, 2008). Marine species accounted about a halve of identified total species, followed by brackish and brackish-marine species that consist 35% of diatom encountered in present study as reposted in previous studies (Al-Rekabi, 1990; Al-Shawi, 2010; Al-Shaheen, 2016). About 60% of the total encountered diatoms are epipelic form, while other species have different habitat with few 173 percentages for them such as planktonic, epilithic and epiphytic. However, decreasing occurrence of planktonic, epilithic and epiphytic form in present study is due to the study area was characterized by a muddy coast only with absence of rocks, sand and plants. To our acknowledge, three new species including *Biremis sigmoidea*, *Cocconeis sawensis*, and *Frickia lewisiana* were recorded first time at Khor Al-Zubair and Khor Abdullah lagoons. In 2014, Al-Handal and his group was reported *Cocconeis sawensis* in Sawa lake and Al-Handal and Al-Shaheen (2019) reported *Biremis sigmoidea* in mudflats of Shatt Al-Arab estuary. *Frickia lewisiana*, is a very rare species in Iraqi waters, reported in different places in Faw coast southern Iraq (Pankow and Hug, 1979) and in Shatt Al-Arab river by Al-Shaheen (2016) and have not been reported in both lagoons.

ACKNOWLEDGMENT

Authors thank all who help and support in the Ecology Department, College of Science, University of Basrah and the Marine Science Centre, University of Basrah.

REFERENCES

Agatz, M., Asmus, R. M. and Deventer, B. 1999. Structural changes in the benthic diatom community along a eutrophication gradient on a tidal flat. *Helgoland Marine Research.* 53 : 92-101.

Al-Ankush, M.A.T. 2013. Monitoring of Shatt Al-Arab River using water quality environmental modeling and benthic diatoms indices. Ph.D. Thesis, College of Agriculture, University of Basrah, 143pp.

Al-Bidhani, M. F. H. 2014. Qualitative composition of phytoplankton in the Shatt Al-Arab and the impact of environmental factors on the extent of to which some of the production and accumulation of hydrocarbon compounds. Ph.D. Thesis, College of Education for Pure Science, University of Basrah, 165pp. (In Arabic).

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, 212 pp. (In Arabic).

Al-Handal, A.Y. 2009. Littoral diatoms from the Shatt Al-Arab 202 estuary, North West Arabian Gulf. *Cryptogamie Algologie* 30(2) : 153-183.

Al-Handal, A.Y. and Abdullah, D. S. 2010. Diatoms from the restored Mesopotamia marshes, South Iraq. *Algological Studies.* 133 : 65-103.

Al-Handal, A.Y. and Al-Shaheen, M.A. 2019. Diatoms in the wetlands of Southern Iraq. *Bibliotheca Diatomologica.* 67 : 1-252pp.

Al-Handal, A.Y. and Wulff, A. 2008. Marine epiphytic diatoms from the shallow sublittoral zone in Potter Cove, King George Island, Antarctica. *Botanica Marina.* 51 : 411-435.

Al-Handal, A. Y., Ghani, A. A. and Al-Saboonchi, A.A. 1991a. Phytoplankton of Khor Al-Zubair lagoon, Nort-West Arabian Gulf. *Marina Mesopotamica.* 6 (1) : 7 33 pp.

Al-Handal, A.Y., Mohamad, A. R. M. and Abdullah, D. S. 1991b. The diatom flora of the Shatt Al-Basrah canal, South Iraq. *Marina Mesopotamica.* 6 (2): 169-181.

Al-Hassan, L.A.J. and Hussain, N.A. 1985. Hydrological parameters influencing the penetration of Arabian Gulf fishes into the Shatt Al-Arab River, Iraq. *Cybiam.* 9 (1) : 7-16.

Al-Kandari, M.; Al-Yamani, F.Y. and Al-Rifaie, K. 2009. Marine phytoplankton atlas of Kuwait's waters. Kuwait Institute for Scientific Research, Kuwait, Lucky printing Press, 350pp.

Al-Ramadhan, B.M. 1986a. Introduction to Marine Physics in Khor Al Zubair. Khor Al Zubair classification. *Proceedings of the first symposium on the marine nature of Khor Al Zubair. Publications of the Center for Marine Sciences - University of Basrah,* No. (7): 11-20.

Al-Ramadhan, B.M. 1986. Distribution of Salinity in Khor Al Zubair. *Proceedings of the first symposium on the marine nature of Khor Al Zubair.* Publications of the Center for Marine Sciences - University of Basrah, No. (7): 34-53.

Al-Ramadhan, B.M. 1988. Residual fluxes of water in an estuarine lagoon. *Estuar Coast Shelf Sci.* 26(3) : 319-330 .

Al-Rekabi, K.M. 1990. *Study of the diatom flora Khor Al-Zubair lagoon, North West Arabian Gulf*. M.Sc. Thesis. Marine science Center, University of Basrah, 82pp. (In Arabic).

Al-Shaban, A.A.G. 1996. *Primary production of the benthic microalgae in the Shatt Al-Arab River.* Ph.D. Thesis, College of Science, University of Basrah, 104pp. (In Arabic).

Al-Shaheen, M.A.G. 2016. *Taxonomical and ecological study on the diatoms communities of shatt Al-Arab River, Southern Iraq.* Ph.D. Thesis. College of Science, University of Basrah, 308pp.

Al-Shawi, I. J. M. 2010. *Ecological and taxonomical studies to 236 planktons in Khor Al-Zubair lagoon with determination of the total petroleum hydrocarbons levels.* Ph.D. Thesis, College of Agriculture, University of Basrah, 147pp. (In Arabic).

Al-Yamani, F.Y. and Saburova, M.A. 2011. *Illustrated Guide on The Benthic Diatoms of Kuwait's Marine Environment.* Kuwait Institute for Scientific Research, Kuwait, Lucky Press, 352pp.

Al-Yamani , F. Y., Bishop, J. M., Al-Rifaie, K. and Ismail, W. 2007. The effect of the river diversion, Mesopotamian marsh drainage and restoration and river damming on the marine environment of the North-West Arabian Gulf. *Aquatic Ecosystem Health and Management.* 10 (3) : 277-289 pp.

Al-Zubaidi, A. J. M., Abdullah, D.S., Houriabi, K.K. and Fawzi, M. 2006. Abundance and distribution of phytoplankton in some southern Iraqi waters. *Marsh Bulletin.* 1(1): 59-73.

Bianchi, T. S. 2013. *Estuaries: Where the River Meets the Sea.* Nature Education Knowledge, 4(4):12.

Brotas, V., Cabrita, T., Portugal, A., Serodio, J. and Catarino, F. 1995. Spatio-temporal distribution of microphytobenthic biomass in tidal flats of the Tagus Estuary (Portugal). *Hydrobiologia.* 300/301 : 93-104.

Cantonati, M., Kelly, M. G. and Lange-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, 942 pp.

Gollasch, S., Lenz, J., Dammer, M. and Andres, H.G. 2000. Survival of tropical ballast water organisms during a cruise from the Indian Ocean to the North Sea. *Journal of Plankton Research*. 22 : 923-937.

Guarini, J. M., Blanchard, G. F., Bacher, C., Gros, P., Riera, P., Richard, P., Gouleau, D., Galois, R., Prou, J. and Sauriau, P. G. 1998. Dynamics of spatial patterns of microphytobenthic biomass: inferences from a geostatistical analysis of two comprehensive surveys in Marennes-Oleron Bay (France). *Marine Ecology Progress Series.* 166 : 131-141.

Hadi, R. A. M. and Al-Saboonchi, A. A. 1989 . Seasonal variation of phytoplankton, epiphytic and epipelic algae in the Shatt Al-Arab River at Basrah, Iraq. *Marina Mesopotamica.* 4(2) : 211-232.

Hadi, R.A.M., Al-Sabonchi, A.A. and Haroon, A.K.Y. 1984. Diatoms of the Shatt Al-Arab River Iraq. *Nova Hedwigia.* 39 : 513-557.

Hassan, W.F. 2018. Metal Contamination in the Sediments of Tidal Flat for Iraq Costal. International *Journal of Science and Research.* 7(3) : 120-125.

Hassan, A.A., Dawood, A.S. and AL-Mansori, N.J. 2018. Assessment of Water Quality of Shatt Al-Basrah Canal using Water Pollution Index. *International Journal of Engineering & Technology.* 7 (4.19) : 757-762.

Hassan, W.F., Iqbal F. Hassan, I.F. and Jasim, A.H. 2011. The effect of industrial effluents polluting water near their discharging in Basrah Governorate, Iraq. *Journal of Basrah Research (Sciences).* 37(1): 21-32.

Hinton, G.C.F. and Maulood, B. K. 1980. Some diatoms from brackish water habitats in Southern Iraq. Nova *Hedwigia.* 31: 475-486.

Jaffer, E.M. 2010. *Qualitative and quantitative study of the phytoplankton in some water bodies of Southern Iraq.* M.Sc. Thesis, University of Basrah, 142 p. (In Arabic).

Jassim, A.K. 1999. Ecological study for phytoplankton on northern part of Shatt Al- Arab River, Iraq-Basrah. College of Agriculture, University of Basrah, 261pp.

Karim, H.H., Ziboon, A.R.T. and Al-Hemidawi, L.M. 2016. Assessment of Water Quality Indices for Shatt Al-Basrah River in Basrah City, Iraq. *Engineering and Technology Journal*. 34, Part (A), (9): 1804- 1822.

Klein, G., MacIntosh, K.; Kaczmarska, I. and Ehrman, J.M. 2010. Diatom survivorship in ballast water during trans-Pacific crossings. *Biological Invasions.* 12 : 1031-1044.

Krammer, K. and Lange-Bertalot, H. 1986. Bacillariophyceae, Teil 1. Naviculaceae. In : Ettl, H., Gerloff, J., Heyning, H. and Mollenhauer, D. (Eds): *Susswasserflora von Mitteleuropa* 2/1: 1-876. Gustav Fischer Verlag, Heidelberg.

Krammer, K. and Lange-Bertalot, H. 1988. Bacillariophyceae, Teil 2. Bacillariaceae, Epithemiaceae, Surirellaceae. – In: Ettl, H., Gerloff, J., Heyning, H. and Mollenhauer, D. (Eds): Susswasserflora von Mitteleuropa 2/2: 1-876. Gustav Fischer Verlag, Heidelberg.

Krammer, K. and Lange-Bertalot, H. 1991. Bacillariophyceae, Teil 3. Centrales, Fragilariaceae, Eunotiaceae. In: Ettl, H., Gerloff, J., Heyning, H. and Mollenhauer, D. (Eds): Susswasserflora von Mitteleuropa 2/3: 1- 599. Gustav Fischer Verlag, Heidelberg.

Lafta, A. A.; Altaei, S.A. and Al-Hashimi, N.H. 2000. Impacts of Potential Sea-Level Rise on Tidal Dynamics in Khor Abdullah and Khor Al-Zubair, Northwest of Arabian Gulf. *Earth Systems and Environment.* 4 : 93–105.

Lange-Bertalot, H. 1996. Kobayasia bicuneus gen. et spec. nov. In: *Iconographia Diatomologica, Annotated Diatom Micrographs* (H. Lange-Bertalot, ed.), 4, 277-287. (In German).

Lavoie, I., Hamilton, P.B., Campeau, S., Grenier, M. and Dillon, P.J. 2000. Guide 305 d'identification des diatomees des rivieres de l'est du Canada. Presses de l'Universite du Quebec, 241 pp. (In French).

Levinton, J. S. and Waldman, J.R. (eds.). 2006. *The Hudson River 307 Estuary.* Cambridge University Press, Reissue edition, 496 pp.

Mann, D. G. and Vanormelingen, P. 2013. An Inordinate Fondness? The Number, Distributions, and Origins of Diatom Species. *Journal of Eukaryotic Microbiology.* 60(4): 414-420.

Mohamed Ali, E. A. 1988. Some hydraulic phenomena in Khor Al Zubair area. *Proceedings of the first symposium on the marine nature of Khor Al-Zubair.* Publications of the Marine Sciences Center - University of Basrah, No. (7): 23-33.

Mohamed, A.R.M., Ali, T.S. and Hussain, N.A. 2002. The physical oceanography and fisheries of Iraqi marine waters, Northwest Arabian Gulf, pp 47-56. In: *Proceedings on utilization of marine resources regional seminar organized jointly by Islamic Education Scientific and Cultural Organization (ISESCO) and National Institute of Oceanography (NIO),* pp 20-22.

Novelo, E., R. Tavera and C. Ibarra. 2007. Bacillariophyceae from karstic wetlands in Mexico. Bibliotheca Diatomologica, Band 54, J. Cramer, Berlin, Stuttgart. 136 pp.

Pankow, H., Al-Saadi, H.A., Huq, M.F. and Hadi, R.A.M. 1979. On the algal flora of the marshes near Qurna (southern Iraq). *Willdenowisa.* 8(3): 493-506.

Pankow, H. and Huq, M.F. 1979. Diatoms in stomach content of *Pseudapocrytes dentatus* a mud skipper from the Shatt Al -Arab estuary (Iraq). Wissenchaftliche Zeitscherift Der Wilhelm-Pieck-Universitat Rostock, Mathematisch-Naturwissenschaftliche Reihe, Heet 6 Herausgeber: *Der Rektor,* 28:547-554.

Ruiz, G.M.; Fofonoff, P.W.; Carlton, J.T.; Wonham, M.J. and Hines, A.H. 2000. Invasion of coastal marine communities in North America: apparent patterns, processes, and biases. *Annual Review of Ecology, Evolution, and Systematics.* 31 : 481-531.

Sarker, A. L.; Al-Daham, N. K. and Bhatti, M. N. 1980. Food habits of the mudskipper, *Pseudapocryptes dentatus* (Val.). *Journal of Fish Biology.* 17 : 635–639.

Spaulding, S., and Edlund, M. 2008. *Nitzschia, Pleurosira*. In Diatoms of the United States. [online]. http://westerndiatoms.colorado. edu/taxa/genus/

Taylor, J.C.; Harding, W.R. and Archibald, C.G.M. 2007. An illustrated guide to some common diatom species from South Africa. WRC Report TT 282/07, Water Research Commission, Pretoria, South Africa, 215pp.

Tynni, R. 1983. Diatoms from the coast of Khaur Abdullah, Persian Gulf. Geological survey of Finland. Report of investigation No. 60, 42pp.

Underwood, G.J.C. and Kromkamp, J. 1999. Primary Production by Phytoplankton and Microphytobenthos in Estuaries. *Advances in Ecological Research.* 29 : 93-153.

Witkowski, A., Lange-Bertalot, H. and Metzeltin, D. 2000. Diatom flora of marine coasts I. – Iconographia *Diatomologica.* 7: 1-925.