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Littoral diatoms from the Shatt Al-Arab estuary, North West Arabian Gulf

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Abstract – Littoral diatoms were studied in two locations in the Shatt Al-Arab estuary, North West Arabian Gulf, a eutrophic brackish to marine environment whose diatom flora appears to be poorly known. A total of 170 taxa belonging to 70 genera were identified and documented by light microscopy. Large numbers of freshwater taxa washed down from the inland waters of South Iraq were observed. *Cocconeis placentula* and its variety *euglypta*, *Cyclotella meneghiniana*, *Cymbella aspera*, *Gomphonema coronatum*, *G. truncatum*, *Pinnularia divergens* and *Surirella capronii* were the most common freshwater taxa. The majority of the recorded taxa have a cosmopolitan geographic distribution, but some tropical and subtropical ones were also common: *Cyclotella stylorum*, *Tryblioptychus cocconeiformis*, *Trachyneis debyi*, *Trachyneis antillarum*, *Trachyneis* spp. and *Gomphotheca sinensis*. The taxon *Navicula lyra* var. *abnormis* Grunow in A. Schmidt is recombined in the genus *Lyrella* Karajeva and at the same time its taxonomic rank is raised to that of a species, *Lyrella abnormis* (Grunow *in* A . Schmidt) comb. et stat. nov. *Navicula peculiaris* Salah *et* Tamas is proposed as a taxonomic synonym of *Lyrella abnormis*.

Diatoms / Freshwaters / Littoral / Marine-brackish water environments / North West Arabian Gulf / Shatt Al-Arab estuary

Résumé – **Diatomées littorales de l'estuaire du Shatt Al-Arab, Golfe Arabe du Nord-Ouest**. L'auteur a étudié les diatomées littorales présentes dans deux stations situées dans l'estuaire du Shatt Al-Arab, Golfe Arabe du Nord-Ouest, un milieu marin à saumâtre eutrophisé dont la flore à diatomées n'est pas bien connue. Au total, 170 taxons appartenant à 30 genres ont été identifiés et documentés au microscope photonique. Nombre de taxons d'eau douce provenant des eaux continentales de l'Iraq du Sud ont été trouvés. *Cocconeis placentula* et sa variété *euglypta*, *Cyclotella meneghiniana*, *Cymbella aspera*, *Gomphonema coronatum*, *G. truncatum*, *Pinnularia divergens* et *Surirella capronii* étaient les taxons d'eau douce les plus communs. La plupart des taxons trouvés ont une distribution géographique cosmopolite, mais quelques taxons tropicaux et sub-tropicaux étaient aussi présents : *Cyclotella stylorum*, *Tryblioptychus cocconeiformis*, *Trachyneis debyi*, *Trachyneis antillarum*, *Trachyneis* spp. et *Gomphotheca sinensis*. Le taxon *Navicula lyra* var. *abnormis* Grunow *in* A. Schmidt est recombiné dans le genre *Lyrella* Karajeva et élevé au rang d'espèce, *Lyrella abnormis* (Grunow *in* A. Schmidt) comb. et stat. nov. Le *Navicula peculiaris* Salah *et* Tamas est proposé comme synonyme taxinomique du *Lyrella abnormis*.

Diatomées / Eaux douces / Estuaire du Shatt Al-Arab / Golfe Arabe du Nord-Ouest / Littoral / Milieux marins-saumâtres

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INTRODUCTION

The diatom flora of the Arabian Gulf has not been investigated in depth. Hendey (1970) reported on some littoral diatoms in samples collected from the coast of Kuwait in 1954, centering on fouling diatoms attached to purpose-built wooden frames. Simonsen (1974) investigated planktonic diatoms mainly based on samples from the eastern coasts of the central and southern regions of the Gulf during the Indian Ocean Expedition of the Meteor; 247 taxa, of which three genera and 16 taxa were new to science, were identified during that investigation. Tynni (1983) studied benthic diatoms collected from deposits inside dead gastropod shells. Plankton diatoms of the north-western parts of the Gulf were investigated by Al-Handal (1988). Reid & Williams (2002) described two new species of *Climaconeis* Grunow from the coasts of Abu Dhabi, central western Gulf. The scant diatom records remaining are available from a few ecological works (e.g. Al-Saadi *et al.*, 1976; Huq *et al.*, 1977).

The present work aims to provide a floristic list of diatoms from a little-known region where the Indian Ocean surface water mixes with freshwater from the Tigris, Euphrates and Karun rivers. Diatoms of this region are subject not only to salinity fluctuations but also high hydrocarbon pollution from oil platforms, which is mostly concentrated in the sediments (Al-Saad *et al.*, 1998).

STUDY AREA

The Arabian Gulf is a shallow marginal sea of the Indian Ocean which extends northward for a distance of 1000 km to the Shatt Al-Arab estuary, covering an area of 239×10^3 km^2 with an average depth of 50 m. It is largely surrounded by arid areas with a subtropical climate. The lower part of the Gulf is very narrow, separating the region from the Gulf of Oman by the Strait of Hormuz, which is no more than 60 km wide. The Gulf is therefore a semi-enclosed sea. Movement of water masses follows an anticlockwise path, passing from the Strait of Hormuz towards the Iranian coasts, continuing to the north western Arabian coasts and finally out to the Gulf of Oman as undercurrents. The only seawater source to the Gulf is surface water of the Indian Ocean. Owing to the semi-enclosed nature of the Gulf and the long warm periods in the region which cause excessive evaporation, the salinity of the Gulf water is high, reaching 40 Practical Salinity Units (PSU) and sometimes exceeding 50 PSU in some shallow coastal regions (Basson *et al.*, 1974).

The north-western part of the Gulf receives very high amounts of fluvial input through the Shatt Al-Arab river, the nexus of the Tigris and Euphrates rivers, as well as the Karun river which flows through Iran. The freshwater influence has been found to extend up to 5 km off the Shatt Al-Arab river delta, but the freshwater influx is too small to compensate for the loss of water through evaporation. Precipitation is very low in the region and almost entirely confined to a short winter period. These conditions are responsible for the increasing salinity in the northern parts of the Gulf, but the freshwater inflow also increases considerably the nutrient concentration, particularly in the north- western parts leading to high plankton productivity (Abayechi *et al.*, 1988; Al-Saad *et al.*, 1998).

MATERIAL AND METHODS

Samples were collected from two stations in the North West Arabian Gulf during April and November 1994 (Fig. 1). Station 1 is a mudflat on the western side of the Shatt Al-Arab estuary. A wide area becomes completely exposed when high tides recede and salinity decreases to 22 PSU owing to freshwater discharge from the Shatt Al-Arab river. Samples were obtained by scraping the uppermost 0.5 cm of sediment, and kept in plastic vials to which a few drops of commercial formalin solution were added. Station 2 is located in the open sea, 25 km south of station 1. The bottom is mostly covered with mud and silt, with water depth ranging between 8-12 m depending on the tidal cycle. This locality is hardly subject to freshwater influence and salinity never dropped below 38 PSU. Samples were collected using a grab sampler.

Diatom samples were first washed with distilled water to remove salts and then cleaned with 35% hydrogen peroxide. Excess peroxide was removed by adding a few drops of 50% hydrochloric acid, followed by several rinses with distilled water. Aliquots (1-ml) of the cleaned diatoms suspensions were placed on coverslips and allowed to dry at ambient temperature. Permanent diatom slides were made using Naphrax as inclusion medium . Diatoms were examined and photographed using a Zeiss Axiophot 2 imaging microscope. Taxonomic identifications were based on Hustedt (1930, 1961-1966), Hendey (1964, 1970), Simonsen (1962, 1974), Germain (1981), Krammer & Lange-Bertalot (1986, 1988), Desikachary (1988), Lange-Bertalot (1996) and Witkowski *et al.* (2000). Relative abundance was estimated qualitatively as follows: *very rare*, found only once on a slide; *rare*, a few specimens on a slide; *frequent*, one specimen per microscope field; *common*, several specimens per microscope field. Since the majority of the diatoms found are cosmopolitan in distribution and well known from other geographical locations, species description are not provided here. Taxonomic notes are given on lesser known taxa or those that might be hitherto undescribed.

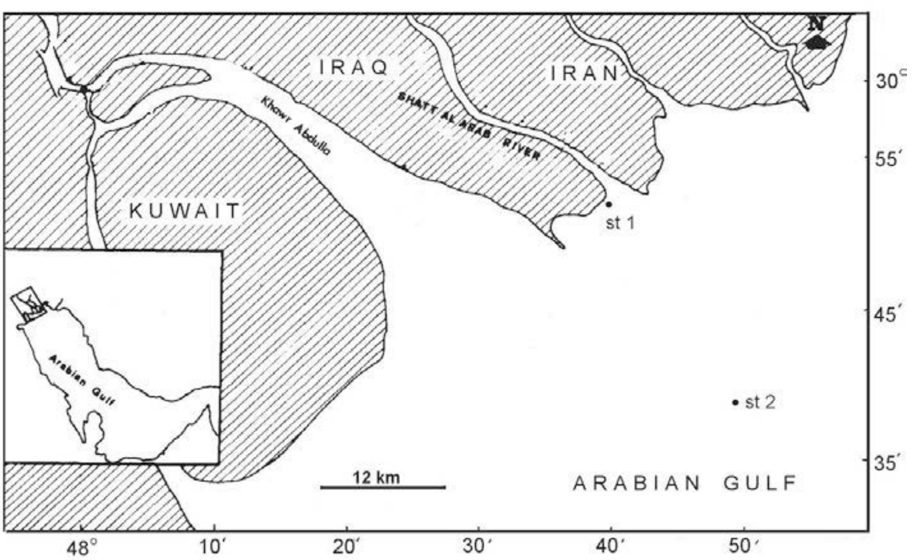

Fig. 1. Location of the sampling sites in the Shatt Al-Arab estuary, North West Arabian Gulf.

Table 1. Some environmental parameters in the North West Arabian Gulf during April and November 1992.

Parameter	*Station 1*		*Station 2*	
	April 1994	*November 1994*	*April 1994*	*November 1994*
Water temperature (°C)	19.2	18.6	19.7	17.9
Salinity (PSU)	22.1	23.2	38.3	38.1
Nitrate (µg at N-NO_3/l)	38.7	28.9	2.3	2.1
Nitrite (µg at N-NO_2/l)	0.65	0.72	0.67	0.53
Phosphate (µg at P-PO_4/l)	0.56	0.68	1.69	1.53
Silicate (µg at SiO_3/l)	33	75	31	54

Concentrations of the major inorganic nutrients in the North West Arabian Gulf during the sampling periods were provided by the Department of Marine Chemistry, Marine Science Centre, Basrah, Iraq (Table 1). Compared to the other parts of the Gulf, the north-western region is remarkably rich in nutrients (Hartman, 1971; Kutonuma, 1974; Abaychi *et al*., 1988). The major source of nutrients and organic matter is the Shatt Al-Arab river, which is rather mineral-rich (Talling, 1980), as can be clearly seen at Station 1 studied here, which receives the river discharge.

RESULTS

A total of 170 diatom taxa belonging to 70 genera were identified (Table 2, which also provides morphometric information). The relative abundance and habitats are given in Table 3.

Station 1

The diatom assemblages at this site are mixture of freshwater, brackish water and marine taxa (Table 3), with a relatively high proportion of freshwater taxa (56 taxa) likely discharged by the Shattt Al-Arab river and deposited on the sediment. Most common among these were *Cocconeis placentula* with its variety *euglypta*, *Cyclotella meneghiniana*, *Cymbella aspera*, *Gomphonema coronatum*, *Pinnularia divergens* and *Surirella capronii*. The diatom flora of this station was dominated by the brackish water taxa *Berkeleya scopulorum*, *Gyrosigma eximium*, *Mastogloia braunii*, *Mastogloia elliptica* var. *dansei*, and to a lesser extent *Achnanthes brevipes*, *Cyclotella striata* and *Gyrosigma acuminatum*. Both *Berkeleya scopulorum* and *Gyrosigma eximium* were most common and found only at this station, indicating their sensitivity to salt concentration. Several marine taxa were also found but were rather rare.

Table 2. Littoral diatoms identified in the North West Arabian Gulf during this investigation. L: valve length (μm), W: valve width (μm), D: valve diameter (μm).

Species	*Figures*	*L*	*W*	*D*	*Striae in 10 μm*
Achnanthes brevipes C. Agardh	59-61	13-70	8-15		8-11
Achnanthes kuwaitensis Hendey	58	55-70	8-12		9-11
Actinocyclus normannii forma *subsalsa* (Juhlin-Dannfelt) Hustedt	21			35-38	
Actinocyclus octonarius Ehrenberg	8			40-70	
Actinocyclus subtilis (Gregory) Ralfs in Pritchard	15			34-50	
Amphora copulata (Kützing) Schoeman et Archibald	167	50-70	15-20		12-14
Amphora cf. *costata* W. Smith	164	65-75	10-15		8-10
Amphora coffeaeformis (C. Agardh) Kützing	166	52-70	10-14		20-24
Amphora exigua Gregory	172	20-28	8-10		13-15
Amphora macilenta Gregory	168	35-55	7-10		14-15
Amphora veneta Kützing	171	20-25	7-9		16-19
Amphora sp. 1	169,170	22-48	11-15		15-19
Amphora sp. 2	165	60-70	11-15		22-24
Ardissonea robusta (Ralfs ex Pritchard) De Notaris	33-35	300-500	20-30		8-9
Asterionella formosa Hassall	39	60-90	3-4		26-29
Asteromphalus brookei Bailey	9			25-40	
Berkeleya scopulorum (Brébisson ex Kützing) Cox	124	90-150	7-12		18-22
Caloneis permagna (Bailey) Cleve	125	80-150	26-35		13-15
Caloneis silicula (Ehrenberg) Cleve	126,131	50-80	13-16		15-18
Campylodiscus demelianus Grunow	217			30	
Campylodiscus intermedius Grunow	218			38-50	
Cocconeis placentula Ehrenberg var. *placentula*	70,72	20-70	10-30		22-24
Cocconeis placentula var *euglypta* (Ehrenberg) Grunow	71,73	15-40	9-24		18-19
Cocconeis convexa Giffen	68,69	12-20	10-18		20
Cocconeis maxima (Grunow) Peragallo	65	38-60	25-30		12-15
Cocconeis pediculus Ehrenberg	66	20-35	12-22		15-16
Cocconeis scutellum Ehrenberg	74	25-40	18-25		6-8
Coscinodiscus marginatus Ehrenberg	13			35-60	
Coscinodiscus oculus-iridis Ehrenberg	3			120-200	
Coscinodiscus cf. *rothii* (Ehrenberg) Grunow	4			35-60	
Coscinodiscus sp.	14			35-40	
Craticula cuspidata (Kützing) D.G.Mann	118	120-180	28-40		12-16
Craticula halophila (Grunow) D.G.Mann	99	25-50	8-16		14-18
Cyclotella meneghiniana Kützing	23,24			10-18	
Cyclotella radiosa Grunow	26			14-28	
Cyclotella striata (Kützing) Grunow	17,18			22-40	
Cyclotella stylorum Brightwell	16			40-60	
Cyclotella sp.	19,20			5-8	
Cymatopleura elliptica (Brébisson) W.Smith	214	58-170	35-60		
Cymatopleura solea (Brébisson) W.Smith var. *solea*	216	150-260	12-28		
Cymatopleura solea var. *apiculata* (W.Smith) Ralfs	215	50-70	24-30		
Cymbella aspera (Ehrenberg) Cleve	88	80-130	18-33		8-10
Cymbopleura sp.	180	40-55	14-16		8-11
Delphineis surirella (Grunow) Andrews	57	30-50	22-30		7-9
Delphineis surirelloides (Simonsen) Andrews	56	40-70	7-11		9-11
Diatoma mesodon (Ehrenberg) Kützing	54	12-18	9-12		18-20
Diatoma tenuis Agardh	40	50-120	4-6		
Diatoma vulgaris Bory	55	30-45	9-15		16-17
Diploneis chersonensis (Grunow) Cleve	204	70-90	20-28		10-11
Diploneis crarbo Ehrenberg	205	65-85	18-24		6-8
Diploneis didyma (Ehrenberg) Cleve	206	60-96	22-30		7-8
Diploneis smithii (Brébisson) Cleve	208	30-50	16-25		9-11
Diploneis suborbicularis (Gregory) Cleve	203	40-50	18-24		8-9
Diploneis sp.	207	23	14		10-11
Encyonema pusilla (Grunow) D.G. Mann	175,176	20-30	7-9		15-16
Encyonema ventricosum Kützing	173	16-28	7-12		12-14
Encyonema sp.	174	18-24	10-14		10-11
Entomoneis corrugata (Giffen) Witkowski, Lange-Bertalot & Metzeltin	181	45-60	22-40		16-18

Table 2. Littoral diatoms identified in the North West Arabian Gulf during this investigation. L: valve length (μm), W: valve width (μm), D: valve diameter (μm). *(suite)*

Species	*Figures*	*L*	*W*	*D*	*Striae in 10 μm*
Eunotia bilunaris (Ehrenberg) Mills	78	50-70	4-5		15-17
Eunotia sp.	77	30-40	6-7		13-15
Fallacia oculiformis (Hustedt) D.G. Mann	179	15-22	9-14		20-22
Fogedia finmarchica (Cleve & Grunow) Witkowski, Medlin & Lange-Bertalot	114	22-30	11-14		10-12
Fragilaria martyi (Héribaud) Lange-Bertalot	45,46	8-20	7-9		8-9
Fragilaria pulchella (Ralfs) Lange-Bertalot	38	50-70	6-9		15-17
Frustulia interposita (Lewis) De Toni	121	60-80	14-18		15-18
Gomphonema affine Kützing	201	60-100	10-15		8-9
Gomphonema clavatum Ehrenberg	200	60-80	9-13		9-11
Gomphonema coronatum Ehrenberg	196	50-90	9-15		8-9
Gomphonema truncatum Ehrenberg	197-199	30-70	11-15		9-12
Gomphonema sp.	202	22-28	4-6		16-19
Gomphotheca sinensis (Skvortzow) Hendey and Sims	50-52	240-860	7-20		26-28
Grammatophora marina (Lyngbye) Kützing	48	20-30	8-12		18-22
Grammatophora oceanica Ehrenberg	49	50-80	6-8		22-25
Gyrosigma acuminatum (Kützing) Rabenhorst	158	90-170	12-18		16-18
Gyrosigma eximium (Thwaites) Bayer	155	55-70	9-11		26-28
Gyrosigma parkeri (Harrison) Elmore	154	68-90	14-20		22-25
Gyrosigma peisonis (Grunow) Hustedt	157	65-110	8-12		24-26
Gyrosigma sinensis (Ehrenberg) Desikachary	156	80-130	10-16		18-20
Hantzschia virgata (Roper) Grunow	140	38-55	7-10		12-15
Hantzschia virgata var. *capitellata* Hustedt	141	40-60	7-9		14-17
Hippodonta capitata (Ehrenberg) Lange-Bertalot, Medlin & Witkowski	102	14-24	8-10		9-11
Lyrella abrupta (Gregory) D.G. Mann	115	35-50	17-22		11-12
Lyrella clavata (Gregory) D.G.Mann	116	40-70	24-30		13-15
Lyrella hennedyi (W.Smith) Stickle & D.G.Mann	112	50-65	26-32		10-15
Lyrella abnormis (Grunow in A. Schmidt) comb. et stat. nov.	113	58-90	20-30		22-24
Lyrella spectabilis (Gregory) D.G. Mann	119,120	40-70	20-35		10-17
Lyrella sp.	111	45-70	24-30		9-14
Mastogloia cf. *apiculata* W. Smith	91	40-55	15-20		19-20
Mastogloia braunii Grunow	92	38-60	14-19		20-22
Mastogloia crucicula (Grunow) Cleve	67	22-30	15-18		8-10
Mastogloia elliptica var *dansei* (Thwaites) Cleve	79-81	60-80	13-18		16-20
Mastogloia fimbriata (Brightwell) Cleve	87	28	22		9
Mastogloia pumila (Grunow) Cleve	85,86	22-30	9-12		25-28
Mastogloia quinquecostata Grunow	90	55-90	20-25		16-20
Mastogloia smithii Thwaites var *smithii*	82,83	30-40	10-12		18-19
Mastogloia smithii var *amphicephala* Grunow	84	35-45	14-18		16-18
Melosira moniliformis (Müller) C. Agardh	42			12-20	
Navicula cf. *arenaria* Donkin	97	35-50	9-12		9-10
Navicula directa (W.Smith) Ralfs	104	70-130	8-12		7-9
Navicula digitoradiata (Gregory) Ralfs	95	60-90	12-15		10-12
Navicula gregaria Donkin	98	28-40	7-9		15-16
Navicula perrhombus Hustedt ex Simonsen	101	22-30	10-14		7-8
Navicula radiosa Kützing	94	70-90	11-15		10-12
Navicula rhynchocephala Kützing	117	30-42	5-9		22-25
Navicula schroeterii Meister	106	45-55	6-8		12-14
Navicula sp1	96	42-65	13-18		9-10
Navicula sp.2	103	40-50	7-10		13-16
Neidium affine (Ehrenberg) Pfizer	129,130	54-90	14-22		20-24
Neidium iridis (Ehrenberg) Cleve	128	130-220	24-32		14-18
Neosynedra provincialis (Grunow) William et Round	41	48-70	5-6		30-31
Nitzschia capitellata Hustedt	149	30-50	4-7		38-40
Nitzschia cf. *coarctata* Grunow	147	16-30	6-8		18-20
Nitzschia elegantula Grunow	145	10-17	2.5-4		26-30
Nitzschia cf. *filiformis* (W.Smith) Van Heurck	148	36-60	4-7		32-36

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Species	*Figures*	*L*	*W*	*D*	*Striae in 10 μm*
Nitzschia cf. *fonticola* (Grunow) Grunow	146	15-25	3-4		28-30
Nitzschia hybrida Grunow	150	45-60	8-11		23-26
Nitzschia ligowskii Witkowski, Lange-Bertalot, Kociolek & Brzezinska	44	15-25	6-7		30-32
Nitzschia sigma (Kützing) W.Smith	143	45-90	6-9		30-34
Nitzschia sp.	151	40-65	6-8		38-40
Paralia sulcata (Ehrenberg) Cleve	22			20-35	
Parlibellus crucicula (W.Smith) Witkowski	105	70-120	25-32		15-17
Petrodictyon gemma (Ehrenberg) D.G.Mann	209	40-70	22-30		22-2
Petroneis granulata (Bailey) D.G.Mann	110	45-70	24-30		9-14
Petroneis marina (Ralfs) D.G.Mann	123	40-65	22-30		11-13
Petroneis monilifera (Cleve) Stickle & D.G.Mann	122	42-70	25-32		6-7
Pinnularia cruciformis (Donkin) Cleve	138	45-72	9-12		11-15
Pinnularia divergens W.Smith	135	55-90	12-18		10-12
Pinnularia gibba Ehrenberg	132	70-120	9-12		9-11
Pinnularia legumen (Ehrenberg) Ehrenberg	134	60-80	13-19		10-12
Pinnularia nobilis (Ehrenberg) Ehrenberg	133	180-300	40-50		4-5
Pinnularia viridis (Nitzsch) Ehrenberg	136,137	50-70	11-18		9-13
Pinnularia sp.	139	140-220	28-35		5-7
Planothidium frequentissima (Lange-Bertalot) Round & Bukhtyarova	62,63	10-16	5-8		10-12
Pleurosigma aestuarii (Brébisson ex Kützing) W.Smith	152	60-85	18-25		22
Pleurosigma diverse-striatum Meister	153	55-80	12-18		14-16
Pleurosigma salinarum (Grunow) Grunow	159,160	100-170	14-18		22-25
Pleurosira minor Metzeltin, Lange-Bertalot & Garcia-Rodriguez	5-7	35-60	28-35		
Podosira stelliger (Bailey) Mann	10,11			35-60	
Psammodictyon panduriformis (Gregory) D.G. Mann	142	50-75	20-30		15-18
Rhoicosphenia abbreviata (Agardh) Lange-Bertalot	47,177,178	20-45	5-9		13-15
Rhopalodia gibba (Ehremberg) O.Müller	184,185	42-120	16-25		
Rhopalodia musculus (Kützing) O.Müller	182,183	28-50	12-18		
Sellaphora pupula (Kützing) Merschkovsky	100	18-40	6-18		18-22
Seminavis ventricosa (Gregory) M. Garcia-Baptista	89	45-60	8-12		14-18
Sieminskia zeta (Cleve) Metzeltin & Lange-Bertalot	107-109	40-70	20-32		15-17
Stauroneis phoenicenteron (Nitzsch) Ehrenberg	161-163	80-290	18-28		14-18
Staurosira construens var. *binodis* (Ehrenberg) Hamilton	43	15	4-5		19-20
Stephanodiscus neoastraea Håkansson & Hickel	28			34	
Surirella brightwellii W.Smith	219	18-40	16-36		15-18
Surirella capronii Brébisson ex Kitton	210	40-80	20-35		
Surirella fastuosa (Ehrenberg) Kützing	213	45-120	28-85		
Surirella ovalis Brébisson	211	35-75	20-30		
Surirella striatula Turpin	212	60-130	30-95		
Symbolophora cf. *trinitatis* Ehrenberg	29	20-24			
Synedra gaillonii (Bory) Ehrenberg	32	60-150	8-14		
Synedra ulna (Nitzsch) Ehrenberg	36,37	60-310	5-8		9-12
Tabellaria fenestrata (Lynbye) Kützing	75,76	24-80	3-8		20-22
Thalassiosira cf. *lacustris* (Grunow) Hasle	27				17-25
Thalassiosira spinosa Simonsen	2			40-70	
Thalassiothrix sp.	64	48-80	2-3		
Trachyneis antillarum Cleve	190	60-120	20-32		12-14
Trachyneis aspera (Ehrenberg) Cleve	194,195	70-240	22-34		8-10
Trachyneis debyi (Leudiger-Fortmorel) Cleve	191-193	150-280	22-38		10
Trachyneis sp. 1	186,187	50-90	12-16		13-15
Trachyneis sp. 2	188,189	40-65	18-28		11-12
Trachysphenia sp.	53	34	8		8
Triceratium dubium Brightwell	30,31	22-40			
Tropidoneis vitrea (W.Smith) Cleve	127	75-120	22-35		
Tryblionella hungarica (Grunow) D.G. Mann	144	65-95	6-9		15-17
Tryblioptychus cocconeiformis (Cleve) Hendey	12	16-23	14-21		6

Table 3. Qualitative relative abundances of the diatom taxa found here. vr: very rare, r: rare, f: frequent, c: common, fr: freshwater, br: brackish water, m: marine.

Species	*Station 1*		*Station 2*		*Habitat*
	Apr. 94	*Nov. 94*	*Apr. 94*	*Nov. 94*	
Achnanthes brevipes C. Agardh	f	r	f	vr	br
Achnanthes kuwaitensis Hendey			r	r	m
Actinocyclus normannii f. *subsalsa* (Juhlin- Dannfelt) Hustedt				r	br,m
Actinocyclus octonarius Ehrenberg			r	r	m
Actinocyclus subtilis (Gregory) Ralfs *in* Pritchard			r		m
Amphora copulata (Kützing) Schoeman *et* Archibald		r			fr
Amphora cf. *costata* W. Smith	vr		r	r	m
Amphora coffeaeformis (C. Agardh) Kützing	f	r	r	r	br
Amphora exigua Gregory			r		br,m
Amphora macilenta Gregory	r	vr			br
Amphora veneta Kützing	r	r			fr
Amphora sp.1		r		r	–
Amphora sp.2		r		r	–
Ardissonea robusta (Ralfs *ex* Pritchard) De Notaris			c	r	m
Asterionella formosa Hassall	r		r		fr,br
Asteromphalus brookei Bailey			r		m
Berkeleya scopulorum (Brébisson ex Kützing) Cox	f	c			br
Caloneis permagna (Bailey) Cleve	f	f	vr		br
Caloneis silicula (Ehrenberg) Cleve	r				fr
Campylodiscus demelianus Grunow		vr			fr,br
Campylodiscus intermedius Grunow			r		m
Cocconeis placentula Ehrenberg var. *placentula*	c	f	vr		fr
Cocconeis placentula var. *euglypta* (Ehrenberg) Grunow	c	f			fr
Cocconeis convexa Giffen	f	f	f	f	fr,br
Cocconeis maxima (Grunow) Peragallo			r	r	m
Cocconeis pediculus Ehrenberg	f	r			fr
Cocconeis scutellum Ehrenberg	r	r	f	f	br,m
Coscinodiscus marginatus Ehrenberg	vr		f	r	m
Coscinodiscus oculus-iridis Ehrenberg	r	r	c	c	m
Coscinodiscus cf. *rothii* (Ehrenberg) Grunow				r	m
Cosciondiscus sp.	vr		f	r	m
Craticula cuspidata (Kützing) D.G.Mann	r	vr			fr
Craticula halophila (Grunow) D.G.Mann		r			fr
Cyclotella meneghiniana Kützing	f	r			fr
Cyclotell radiosa Grunow	r				fr
Cyclotell striata (Kützing) Grunow	f	f			br
Cyclotell stylorum Brightwell	f	f	f	f	m
Cyclotella sp.	r	r			–
Cymatopleura elliptica (Brébisson) W.Smith	r	r	r	r	fr
Cymatopleura solea (Brébisson) W.Smith var. *solea*	r	r	vr		fr
Cymatopleura solea var. *apiculata* (W.Smith) Ralfs	r	r			fr
Cymbella aspera (Ehrenberg) Cleve	f	f			fr
Cymbopleura sp.		vr			fr

Table 3. Qualitative relative abundances of the diatom taxa found here. vr: very rare, r: rare, f: frequent, c: common, fr: freshwater, br: brackish water, m: marine. *(suite)*

Species	*Station 1*		*Station 2*		*Habitat*
	Apr. 94	*Nov. 94*	*Apr. 94*	*Nov. 94*	
Delphineis surirella (Grunow) Andrews			f	r	m
Delphineis surirelloides (Simonsen) Andrews			r	r	m
Diatoma mesodon (Ehrenberg) Kützing		vr			fr
Diatoma tenuis Agardh	r	r			fr,br
Diatoma vulgaris Bory		r		vr	fr,br
Diploneis chersonensis (Grunow) Cleve				r	m
Diploneis crarbo Ehrenberg			r	r	m
Diploneis didyma (Ehrenberg) Cleve				r	m
Diploneis smithii (Brébisson) Cleve	r	r	f	r	br
Diploneis suborbicularis (Gregory) Cleve			r	r	m
Diploneis sp.			r		–
Encyonema pusilla (Grunow) D.G. Mann	f	r			fr,br
Encyonema ventricosum Kützing	r	r	vr	vr	fr,br
Encyonema sp.		r			fr
Entomoneis corrugata (Giffen) Witkowski, Lange-Bertalot *et* Metzeltin	f	r	f	r	br
Eunotia bilunaris (Ehrenberg) Mills		r			fr
Eunotia sp.		r			fr
Fallacia oculiformis (Hustedt) D.G. Mann			r	vr	br,m
Fogedia finmarchica (Cleve *et* Grunow) Witkowski, Medlin *et* Lange-Bertalot			r	r	br,m
Fragilaria martyi (Héribaud) Lange-Bertalot	r	r			fr
Fragilaria pulchella (Ralfs) Lange-Bertalot	f	f	r	r	br
Frustulia interposita (Lewis) De Toni	r		vr		–
Gomphonema affine Kützing	f	r			fr
Gomphonema clavatum Ehrenberg	r		vr		fr
Gomphonema coronatum Ehrenberg	f	f	vr	vr	fr
Gomphonema truncatum Ehrenberg	f	f	vr		fr
Gomphonema sp.			vr		
Gomphotheca sinensis (Skvortzow) Hendey *et* Sims	vr	r	c	c	br
Grammatophora marina (Lyngbye) Kützing			r	r	m
Grammatophora oceanica Ehrenberg			vr	r	m
Gyrosigma acuminatum (Kützing) Rabenhorst	f	f	r		fr,br
Gyrosigma eximium (Thwaites) Bayer	f	c			br
Gyrosigma parkeri (Harrison) Elmore	r	vr			fr
Gyrosigma peisonis (Grunow) Hustedt			vr	r	br
Gyrosigma sinensis (Ehrenberg) Desikachary	r	r	f	f	br
Hantzschia virgata (Roper) Grunow			r	r	m
Hantzschia virgata var. *capitellata* Hustedt			r	r	m
Hippodonta capitata (Ehrenberg) Lange-Bertalot, Medlin & Witkowski	r	r		vr	fr
Lyrella abrupta (Gregory) D.G. Mann			vr	r	m
Lyrella clavata (Gregory) D.G.Mann			r	r	m
Lyrella hennedyi (W.Smith) Stickle *et* D.G.Mann			r	r	m
Lyrella abnormis (Grunow *in* A. Schmidt) comb. et stat. nov.			r	vr	m

Table 3. Qualitative relative abundances of the diatom taxa found here. vr: very rare, r: rare, f: frequent, c: common, fr: freshwater, br: brackish water, m: marine. *(suite)*

Species	*Station 1*		*Station 2*		*Habitat*
	Apr. 94	*Nov. 94*	*Apr. 94*	*Nov. 94*	
Lyrella spectabilis (Gregory) D.G. Mann		vr	r	r	m
Lyrella sp.		vr	f	f	m
Mastogloia cf. *apiculata* W. Smith	r	r	r	r	br
Mastogloia braunii Grunow	c	c	r	r	br
Mastogloia crucicula (Grunow) Cleve				f	br
Mastogloia elliptica var. *dansei* (Thwaites) Cleve	c	c	r	f	br
Mastogloia fimbriata (Brightwell) Cleve	vr		f	r	m
Mastogloia pumila (Grunow) Cleve	vr		r	r	br
Mastogloia quinquecostata Grunow			vr	r	m
Mastogloia smithii Thwaites var. *smithii*	f	r	f	r	br
Mastogloia smithii var. *amphicephala* Grunow	f	f	r	vr	br
Melosira moniliformis (Müller) C. Agardh			r	vr	br,m
Navicula cf. *arenaria* Donkin			f	r	m
Navicula directa (W.Smith) Ralfs			r	r	m
Navicula digitoradiata (Gregory) Ralfs	f	r	f	f	fr,br
Navicula gregaria Donkin	vr		r	r	br,m
Navicula perrhombus Hustedt *ex* Simonsen	vr	r			fr
Navicula radiosa Kützing	f	r			fr
Navicula rhynchocephala Kützing	r				fr
Navicula schroeterii Meister	r	r			br
Navicula sp.1	r	r			
Navicula sp. 2	r	r			
Neidium affine (Ehrenberg) Pfizer	r	r			fr
Neidium iridis (Ehrenberg) Cleve	r	r			fr
Neosynedra provincialis (Grunow) William *et* Round			vr		m
Nitzschia capitellata Hustedt	r	r	f	f	br,m
Nitzschia cf. *coarctata* Grunow	r	f	r	r	fr,br
Nitzschia elegantula Grunow	r	r	f	r	br,m
Nitzschia cf. *filiformis* (W.Smith) Van Heurck			r	r	br
Nitzschia cf. *fonticola* (Grunow) Grunow	vr	vr			fr
Nitzschia hybrida Grunow	r	r	f	r	br
Nitzschia ligowskii Witkowski, Lange-Bertalot, Kociolek *et* Brzezinska	r	r			–
Nitzschia sigma (Kützing) W.Smith	r	r	c	c	m
Nitzschia sp.			r	vr	fr,br
Paralia sulcata (Ehrenberg) Cleve			r	r	m
Parlibellus crucicula (W.Smith) Witkowski	vr		f	f	m
Petrodictyon gemma (Ehrenberg) D.G.Mann	r	r	f	f	br,m
Petroneis granulata (Bailey) D.G.Mann		vr	f	f	m
Petroneis marina (Ralfs) D.G.Mann			r	r	m
Petroneis monilifera (Cleve) Stickle *et* D.G.Mann			r	r	m
Pinnularia cruciformis (Donkin) Cleve			r		m
Pinnularia divergens W.Smith	f	r			fr
Pinnularia gibba Ehrenberg	r	r			fr

Table 3. Qualitative relative abundances of the diatom taxa found here. vr: very rare, r: rare, f: frequent, c: common, fr: freshwater, br: brackish water, m: marine. *(suite)*

Species	*Station 1*		*Station 2*		*Habitat*
	Apr. 94	*Nov. 94*	*Apr. 94*	*Nov. 94*	
Pinnularia legumen (Ehrenberg) Ehrenberg	r	vr			fr
Pinnularia nobilis (Ehrenberg) Ehrenberg	f	r		vr	fr
Pinnularia viridis (Nitzsch) Ehrenberg	r	r			fr
Pinnularia sp.	f	r			fr
Planothidium frequentissima (Lange-Bertalot) Round *et* Bukhtyarova		vr		vr	fr
Pleurosigma aestuarii (Brébisson *ex* Kützing) W.Smith			r	r	m
Pleurosigma diverse-striatum Meister			f	c	m
Pleurosigma salinarum (Grunow) Grunow			r	r	m
Pleurosira minor Metzeltin, Lange-Bertalot *et* Garcia-Rodriguez	r	r	f	f	br
Podosira stelliger (Bailey) Mann	r	r	f	f	m
Psammodictyon panduriformis (Gregory) D.G Mann			f	f	m
Rhoicosphenia abbreviata (Agardh) Lange-Bertalot	r	r	r	r	fr
Rhopalodia gibba (Ehremberg) O.Müller	r	r			fr,br
Rhopalodia musculus (Kützing) O.Müller	r	r	r	r	br,m
Sellaphora pupula (Kützing) Merschkovsky	vr	vr			fr
Seminavis ventricosa (Gregory) M. Garcia-Baptista			vr	r	m
Sieminskia zeta (Cleve) Metzeltin *et* Lange-Bertalot			r	r	m
Stauroneis phoenicenteron (Nitzsch) Ehrenberg	r	r			fr
Staurosira construens var. *binodis* (Ehrenberg) Hamilton	vr	vr			fr
Stephanodiscus neoastraea Håkansson *et* Hickel	r	r	vr		br,m
Surirella brightwellii W.Smith	r		f	f	br
Surirella capronii Brébisson *ex* Kitton	f	f	r	r	fr
Surirella fastuosa (Ehrenberg) Kützing	f	r	f	r	m
Surirella ovalis Brébisson	r	vr	r	r	fr,br
Surirella striatula Turpin	r	f	f	f	br
Symbolophora cf. *trinitatis* Ehrenberg			r	r	m
Synedra gaillonii (Bory) Ehrenberg	r	r			br
Synedra ulna (Nitzsch) Ehrenberg	f	r			fr
Tabellaria fenestrata (Lynbye) Kützing	r	r	vr		fr
Thalassiosira cf. *lacustris* (Grunow) Hasle	r				–
Thalassiosira spinosa Simonsen			r	r	m
Thalassiothrix sp.			r	r	
Trachyneis antillarum Cleve	r	r	c	c	m
Trachyneis aspera (Ehrenberg) Cleve	r	r	f	f	m
Trachyneis debyi (Leudiger-Fortmorel) Cleve	f	f	c	c	m
Trachyneis sp. 1			f	r	m
Trachyneis sp. 2			f	f	m
Trachysphenia sp.			r		m
Triceratium dubium Brightwell			r	r	m
Tropidoneis vitrea (W.Smith) Cleve	vr		r	f	br,m
Tryblionella hungarica (Grunow) D.G.Mann	r	r	f	f	br,m
Tryblioptychus cocconeiformis (Cleve) Hendey	r	r	r	r	m

Station 2

Diatom assemblages were dominated by *Coscinodiscus oculus-iridis*, *Gomphotheca sinensis*, *Nitzschia sigma*, *Trachyneis antillarum*, *Trachyneis aspera* and *Trachyneis debyi*. A large number of brackish water taxa were found but none of these were common (Table 3). Most important of these were *Cocconeis convexa, Diploneis smithii, Gyrosigma sinensis, Navicula digitoradiata, Nitzschia capitellata, Surirella brightwellii, Tropidoneis vitrea* and *Tryblionella hungarica*. Empty frustules of several planktonic species were observed on the sediment at this station. An exception is *Coscinodiscus oculus-iridis* which appeared commonly in every sample examined.

Some interesting taxa

Tryblioptychus cocconeiformis (Cleve) Hendey **Fig. 12**

Hendey 1958, p. 40, pl. 2, fig.10.
Basionym: *Campylodiscus cocconeiformis* Cleve 1883, p. 502, pl. 38, fig. 78.
Synonym: *Cyclotella crassa* Tynni 1983, p. 8, fig. 86.

Valves broadly elliptic, 16-23 µm long, 14-21 wide. Valve surface slightly undulating and apparently divided into two halves which lie in different focal planes. Areolae coarse, arranged in rows of striae, 6 striae in 10 µm. The valve margin has a row of large areolae. Cleve (1883) described this species as *Campylodiscus cocconeiformis* from samples collected by the Vega Expedition. Hendey (1958) found it in material collected from West Africa. He found that Cleve was wrong to refer this species to *Campylodiscus* as it bears no resemblance to that genus. For this reason Hendey established the new genus *Tryblioptychus*. He concluded that Cleve might have written *Campylodiscus* by mistake for *Campyloneis* because, at first sight, *T. cocconeiformis* bears a superficial resemblance to the upper valve of *Campyloneis grevillei* (W.Smith) Grunow. Tynni (1983), on the other hand, found this species in muddy deposits inside gastropods shells in the North West Arabian Gulf, where this taxon occurs for most of the year, but referred to it as a species new to science, *Cyclotella crassa*. However, neither the broadly elliptical valve nor the striation of *T. cocconeiformis* resemble *Cyclotella*. According to Prasad *et al.* (2002), Tynni placed this taxon in *Cyclotella* because the marginal area of the valve has short radial striae, a feature seen in some members of *Cyclotella*.

T. cocconeiformis occurred rarely in the study area but was found in all samples. Its occurrence in both locations suggests that it is a halotolerant species. It has not been recorded from other parts of the Gulf. Biogeographically its distribution is confined to tropical and subtropical regions.

Gomphotheca sinensis (Skvortzow) Hendey *et* Sims **Figs 50-52**

Hendey & Sims, 1982, p. 199, Figs 1-12.

Valves mostly slender, 240-860 µm long. The specimens found in this study differ in valve outline from those described previously. Valves have two distinct flattened areas which appear as undulations in the valve margins. One large flattening lies in the upper quarter of the valve (Fig. 50). The exact position of this area differs between specimens. In some it is located just before the valve margin tapers to form a weakly cuneate and produced upper apex. Another small flattened area lies in the lower quarter of the valve.

Hendey & Sims (1982) mentioned that specimens from Lorenzo Marquez, Mosambique, possessed a valve outline similar to that described above, but considered this a variation in the valve outline. In the Shatt Al-Arab estuary, two morphologically distinct populations of *G. sinensis* were observed. The first had valves identical to the type and was found in the upper, less saline parts of the estuary, while the second, having valves with two flattened areas, was observed in the more saline waters of Station 2. Representatives of the two populations did not co-occur. The second population might represent, perhaps, a new variety of this species.

Lyrella abnormis (Grunow *in* A. Schmidt) **comb. et stat. nov.** **Fig. 113**

Basionym: *Navicula lyra* var. *abnormis* Grunow *in* A. Schmidt 1874, *Atlas der Diatomaceenkunde*, pl. 2, fig. 8.
Nomenclatural (obligate) synonyms: *Navicula robertsiana* var *abnormis* (Grunow *in* A. Schmidt) Amossé 1924, *Bulletin du Muséum national d'Histoire naturelle* 20, p. 111, Hendey 1958, p. 61; *Navicula robertsiana* f. *abnormis* (Grunow *in* A. Schmidt) Hustedt 1964, *Rabenhorst Kryptogamen-Flora* 7 (3), p. 164.
Taxonomic synonym: *Navicula peculiaris* Salah *et* Tamas 1968, *Hydrobiologia* 31, p. 234, pl. 2, figs 1-4, pl. 5, figs 1, 2.

Valves elliptic-lanceolate with obtusely rounded apices, 68-80 µm long, 22-28 µm wide. Raphe straight, external central endings distant, axial area narrow, central area transversely rectangular and connected to parallel lateral areas. Lateral areas relatively broad, hyaline, becoming narrow near valve apices. Transapical striae on both sides of the central area very fine, 44-46 in 10 µm, becoming coarser towards valve apices, 19-22 in 10 µm. Striae punctuate, puncta very fine.

This taxon is transferred to *Lyrella* based on the the presence of two wide hyaline lateral areas on both sides of the axial area which interrept the transapical striae over all valve surface, a characteristic feature of this genus. It can be easily identified based on the very fine striae on both sides of the central area, which are more compact and finer than those over the rest of the valve. It is a tropical to sub-tropical form, but was rather rare in the material from the North West Arabian Gulf.

Salah & Tamas (1968) found this taxon in the Suez Canal and described it as a new species, which they named *Navicula peculiaris*. They compared their specimens to Grunow's original illustration of *Navicula lyra* var. *abnormis* (in A. Schmidt 1874, pl. 2, fig. 8) and stated that "it differs mainly in the details of the markings as well as in the orientation of the striae on the two sides of the valve". Although their specimens differ slightly in the valve dimensions from Grunow's illustration, in the present author's opinion this difference does not warrant a new species, hence the present proposal to consider *Navicula peculiaris* as a taxonomic synonym of *Lyrella abnormis*.

Trachyneis debyi (Leudinger-Fortmorel) Cleve **Figs 191-193**

Simonsen 1974, p. 43, pls. 27, 28, fig. 1.

The unusual valves of *T. debyi* have attracted the attention of several authors. Hendey (1964) followed a comment by Cleve (1894, p. 190) and suggested that each valve is composed of three layers, one inside another. The two inner layers lack a raphe and have less marked striations. In contrast, Simonsen (1974) considered the layers as separate valves, external and internal. He discussed the opinion of Hustedt (1930-66, p. 438) on the presence of a rhombic chamber connected with the internal valve by an opening (foramen), stating that such chamber could not be observed although there is a rhombic marking corresponding to the foramen. However, Simonsen (1974) found one internal valve within one valve of his specimens.

The large high number of specimens found here provided an opportunity to examine the valve structure of this species from different angles, lending support to the interpretation by Simonsen(1974) that these layers are valves constructed inside one other. Three types of internal valves, not necessarily all in the same frustule, were observed here. In some specimens, the first internal valve (just inside the external valve) is similar to that described by Simonsen (p. 43, pl. 27, fig. 3). This form, however, is variable in respect to the axial and central areas. In some cases the axial area is absent or extremely narrow, but it widens at the centre to form a circular central area. The other type of valves, the second internal valve, is identical to the illustration in Schmidt (1874-1957, pl. 48, fig. 23) in which there is a large axial area that widens at the valve centre. The thickness of this valve is greatly reduced towards the apices. The third type of internal valves appears similar to the external one but possesses a less well developed raphe, which appears to be not very marked (Fig. 191). This particular form supports the view of Simonsen (1974) that the layers are in fact other valves. The same structure has also been found in *Trachyneis* sp. 2 described in this work (Fig. 189).

Hustedt (1949) suggested that these structures are formed to accommodate osmotic fluctuations in the surrounding water. Simonsen (1968) believed that they are due to pH and temperature fluctuations. In the North West Arabian Gulf, pH does not vary for most of the year but salinity undergoes remarkable fluctuations owing to freshwater discharge in spring and high evaporation in summer.

Trachyneis **sp.1** **Figs 186, 187**

Frustules rectangular, valves linear-lanceolate with obtuse apices, 50-90 µm long, 12-16 µm wide. Axial area widening towards the middle of the valve, central area rounded or slightly rectangular, on both sides of the central nodule. Raphe slightly eccentric, central pores deflected in the same direction to one side of the central area. Valve surface areolate, alveoli in longitudinal flexuose or in irregularly oblique rows. Transverse rows gently radiate throughout, 13-15 in 10 µm.

This diatom is similar to *T. antillarum* Cleve but differs in the characteristic shape of the central area, which extends on both sides of the central nodule rather than being unilateral as in *T. antillarum*. The raphe central endings are laterally deflected rather than straight. The rows of alveoli are coarser and the valves more linear. These characters are very distinct and may suggest a new species.

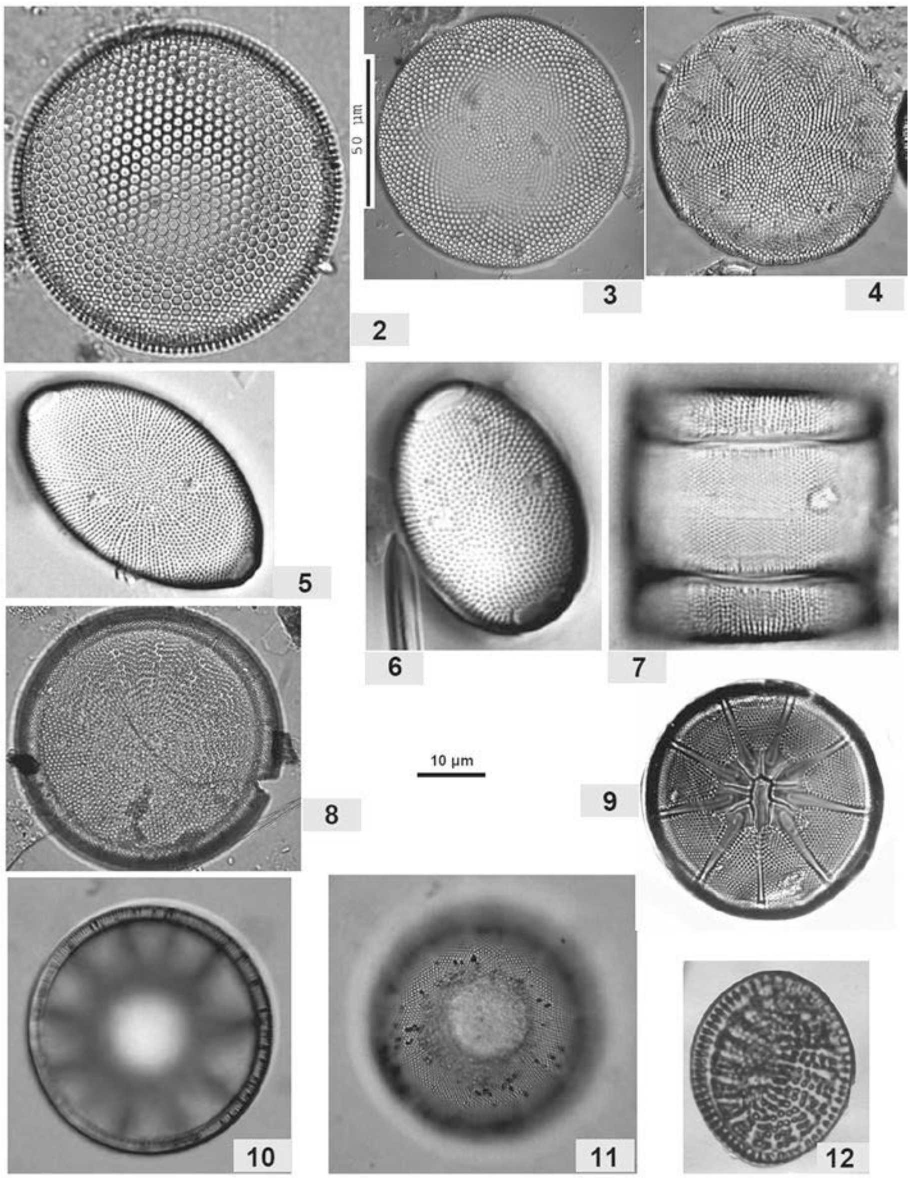
Trachyneis sp.1 was frequent in the material examined.

Trachyneis **sp. 2** **Figs 188, 189**

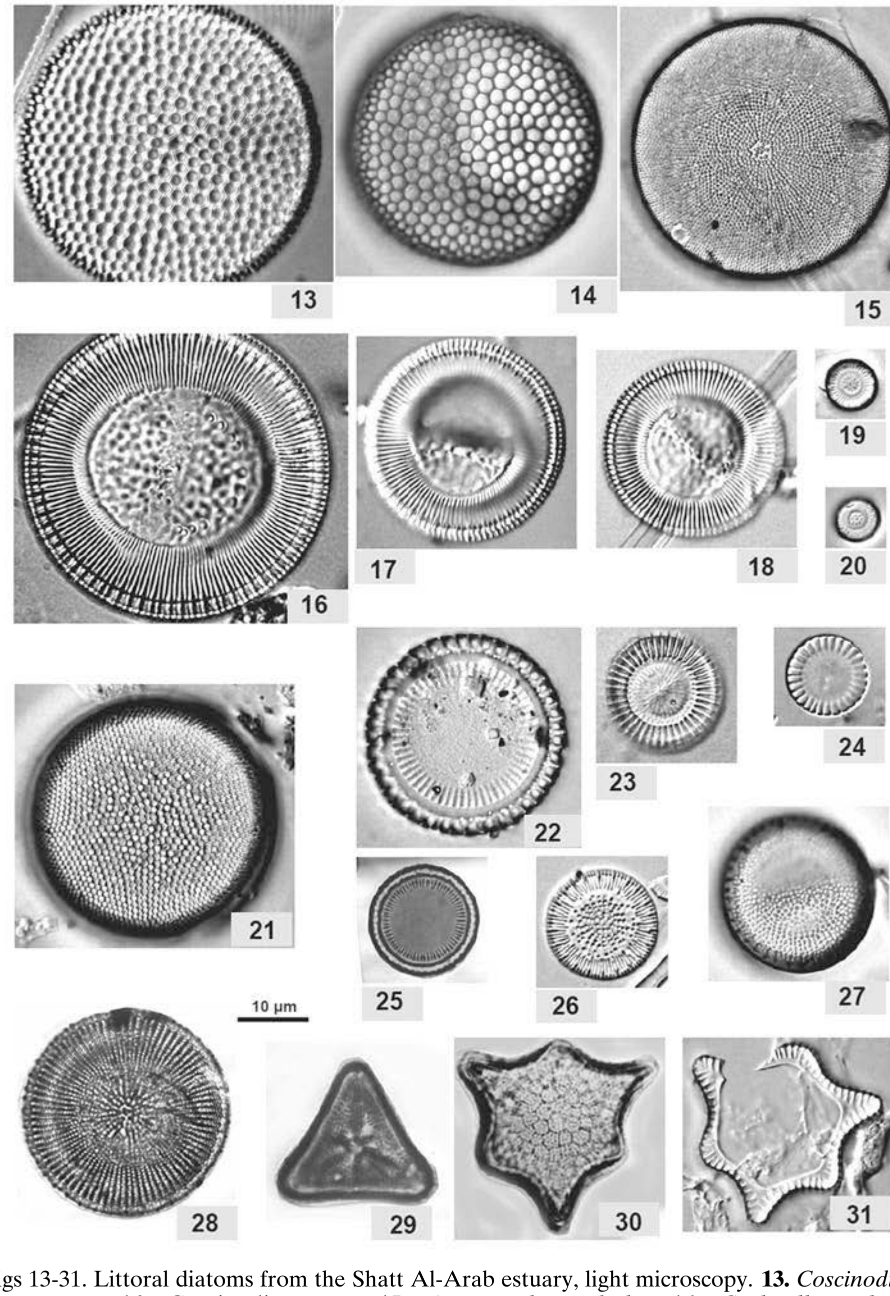
Valves elliptic-lanceolate with obtuse apices, 40-65 µm long, 18-28 µm wide. Raphe slightly eccentric at the middle of the valve, but almost median and straight about halfway between the central area and the poles. Axial area irregularly linear, widening towards the central nodule. The central rows of areoli on one side of the axial area are shortened to form a suborbicular central area. Transapical striae coarse, 11-12 in 10 µm.

This diatom is characterized by the wide elliptical shape of the valve, the curvature of the raphe and the coarse rows of areoli. The central area is less rounded, formed by gradual shortening of the striae over a longer distance.

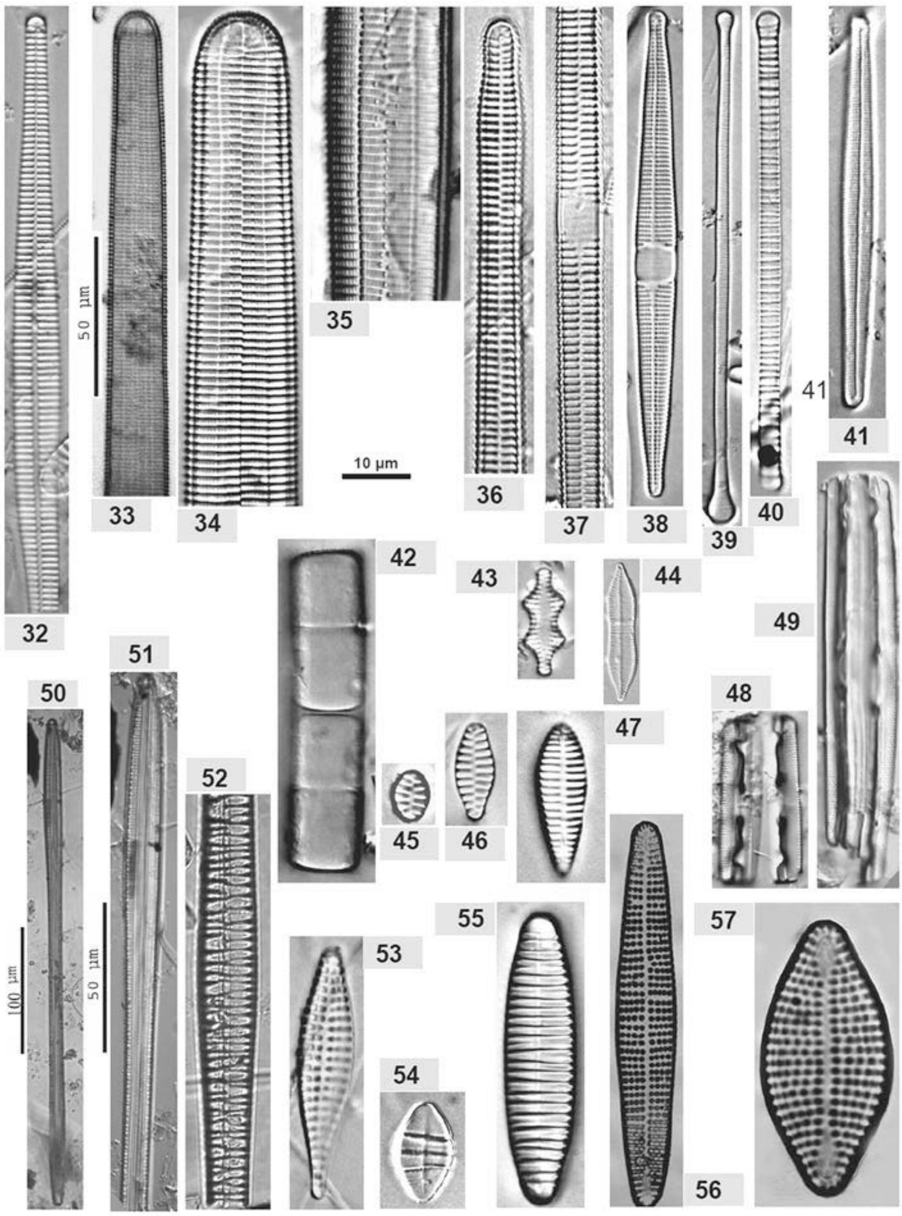
Frequent at Station 2 only.



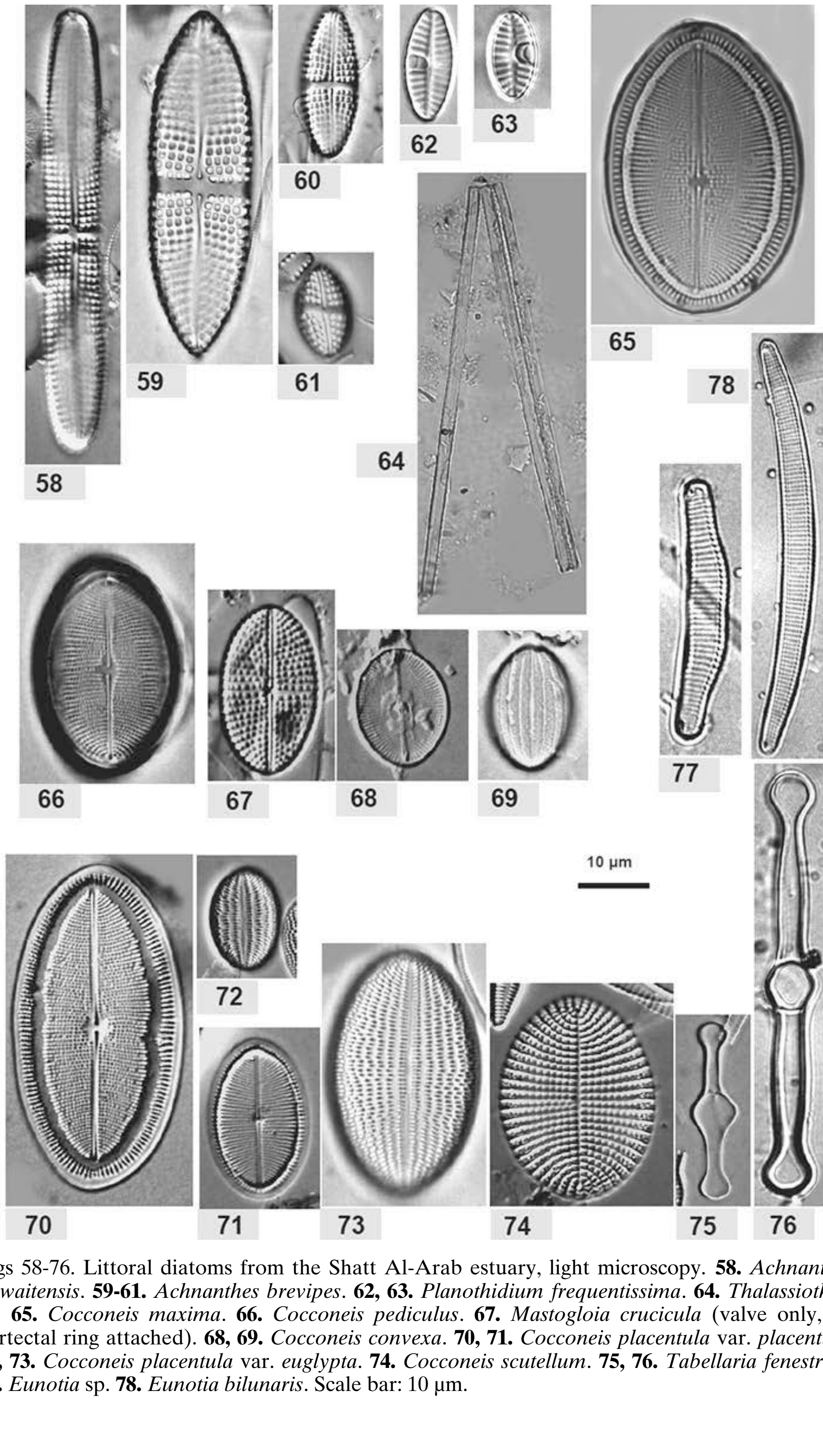
Figs 2-12. Littoral diatoms from the Shatt Al-Arab estuary, light microscopy. **2.** *Thalassiosira spinosa*. **3.** *Coscinodiscus oculus-iridis*. **4.** *Coscinodiscus* cf. *rothii*. **5-7.** *Pleurosira minor*. **8.** *Actinocyclus octonarius*. **9.** *Asteromphalus brookei*. **10, 11.** *Podosira stelliger*. **12.** *Tryblioptychus cocconeiformis*. Scale bars: Fig. 3: 50 µm, all others: 10 µm.



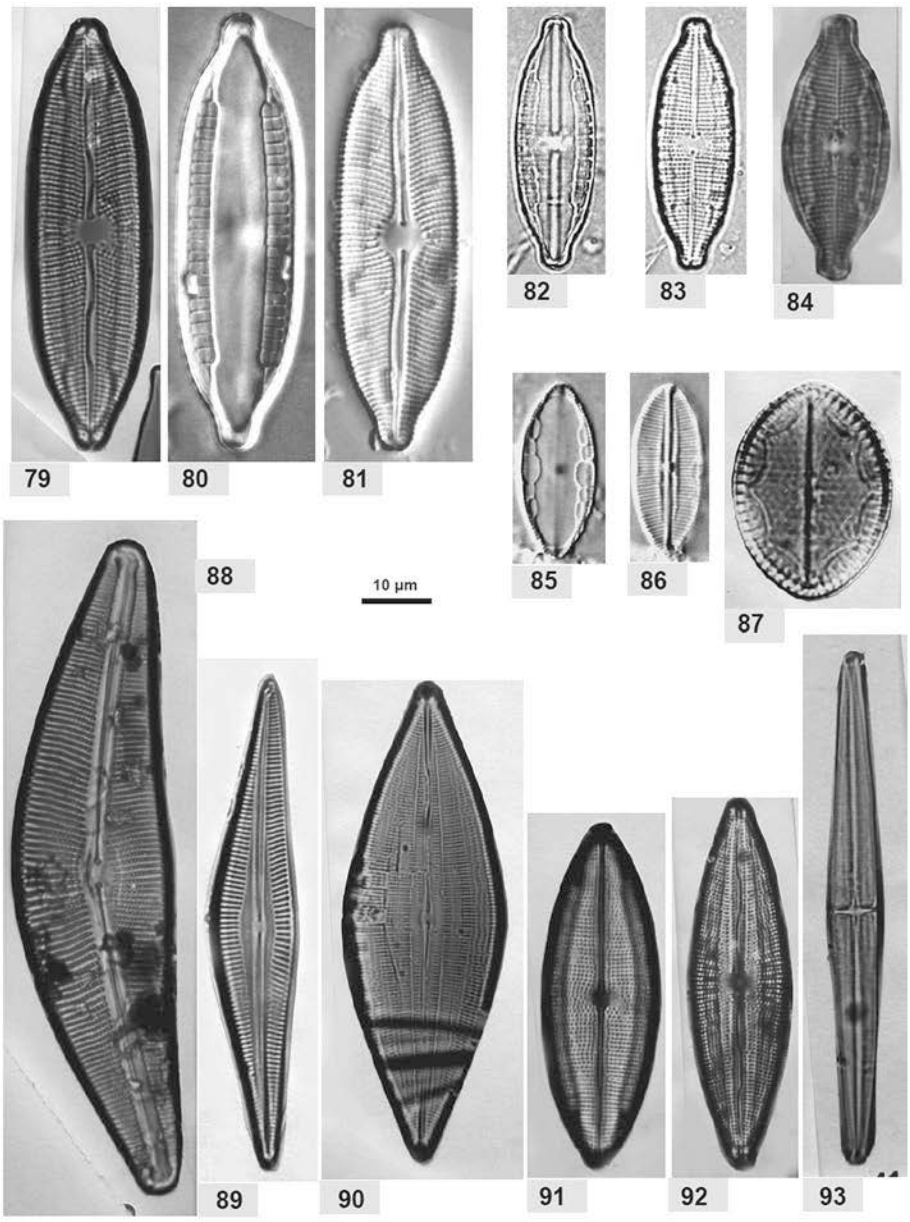
Figs 13-31. Littoral diatoms from the Shatt Al-Arab estuary, light microscopy. **13.** *Coscinodiscus marginatus*. **14.** Coscinodiscus sp. **15.** *Actinocyclus subtilis*. **16**. *Cyclotella stylorum*. **17, 18.** *Cyclotella striata*. **19, 20.** *Cyclotella* sp. **21.** *Actinocylcus normanii* var. *subsalsa*. **22.** *Paralia sulcata*. **23, 24.** *Cyclotella meneghiniana*. **25.** *Melosira* sp. **26.** *Cyclotella radiosa*. **27.** *Thalassiosira* cf. *lacustris*. **28.** *Stephanodiscus neoastraea*. **29.** *Symbolophora* cf. *trinitatis*. **30, 31.** *Triceratium dubium*. Scale bar: 10 µm.



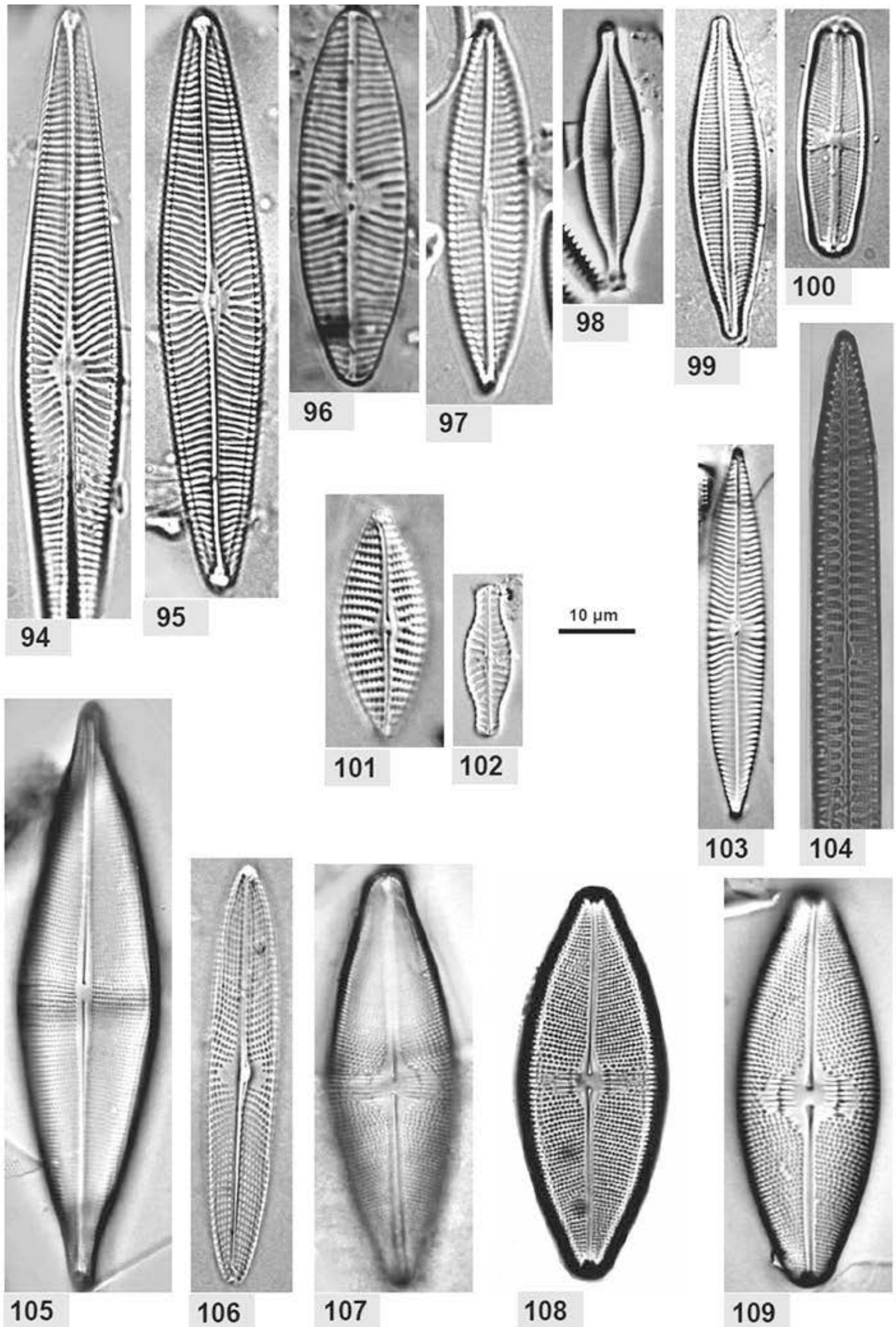
Figs 32-57. Littoral diatoms from the Shatt Al-Arab estuary, light microscopy. **32.** *Synedra gaillonii*. **33-35**. *Ardissonia robusta*. **36, 37**. *Synedra ulna*. **38.** *Fragilaria pulchella*. **39.** *Asterionella formosa*. **40.** *Diatoma tenuis*. **41.** *Neosynedra provincialis*. **42.** *Melosira moniliformis*. **43.** *Staurosira construens* var. *binodis*. **44.** *Nitzschia ligowskii*. **45, 46.** *Fragilaria martyi*. **47.** *Rhoicosphenia abbreviata* (convex valve). **48.** *Grammatophora marina*. **49.** *Grammatophora oceanica*. **50-52.** *Gomphotheca sinensis*. **53.** *Trachysphenia* sp. **54.** *Diatoma mesodon*. **55.** *Diatoma vulgaris*. **56.** *Delphineis surirelloides*. **57.** *Delphineis surirella*. Scale bars: Figs 33, 51:50 µm; Fig. 50:100 µm; all others: 10 µm.



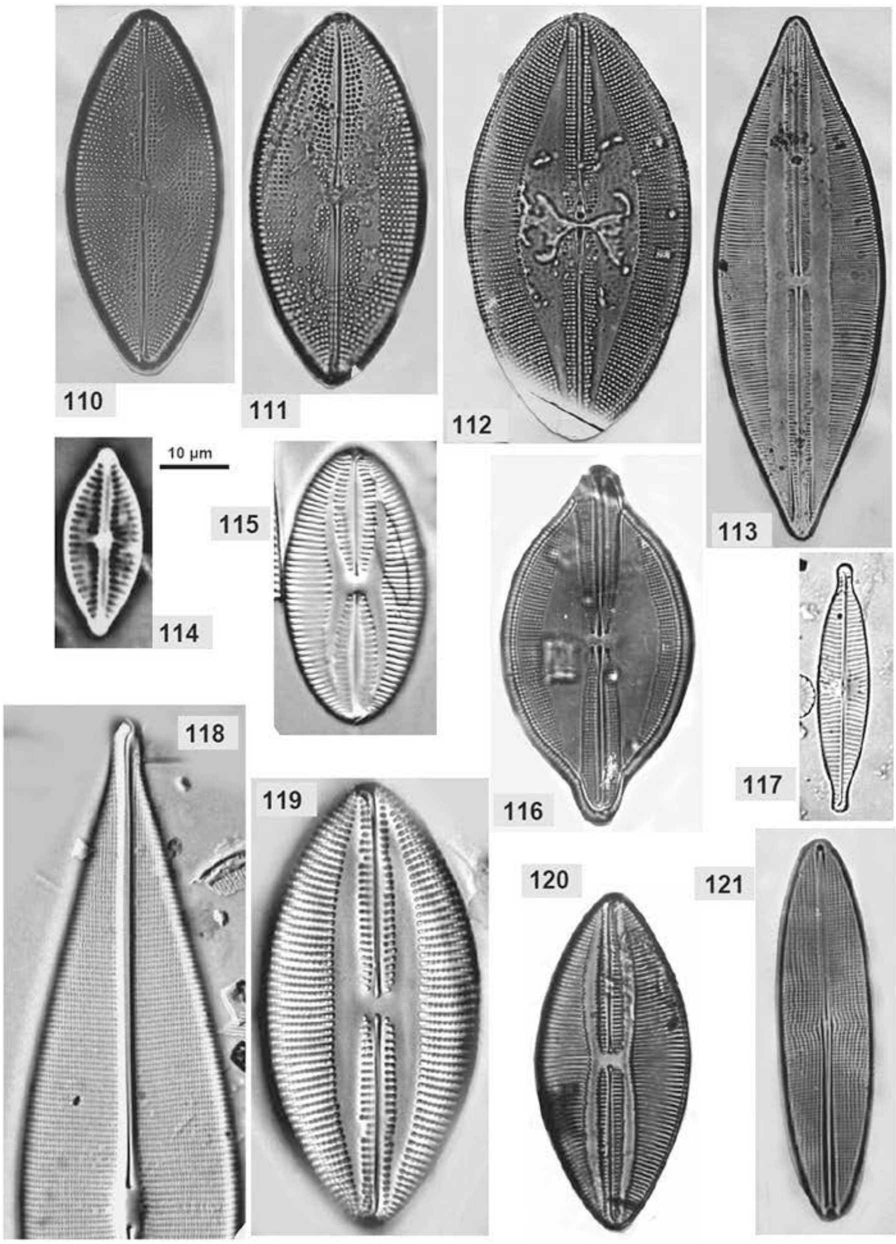
Figs 58-76. Littoral diatoms from the Shatt Al-Arab estuary, light microscopy. **58.** *Achnanthes kuwaitensis*. **59-61.** *Achnanthes brevipes*. **62, 63.** *Planothidium frequentissima*. **64.** *Thalassiothrix* sp. **65.** *Cocconeis maxima*. **66.** *Cocconeis pediculus*. **67.** *Mastogloia crucicula* (valve only, no partectal ring attached). **68, 69.** *Cocconeis convexa*. **70, 71.** *Cocconeis placentula* var. *placentula*. **72, 73.** *Cocconeis placentula* var. *euglypta*. **74.** *Cocconeis scutellum*. **75, 76.** *Tabellaria fenestrata*. **77.** *Eunotia* sp. **78.** *Eunotia bilunaris*. Scale bar: 10 µm.



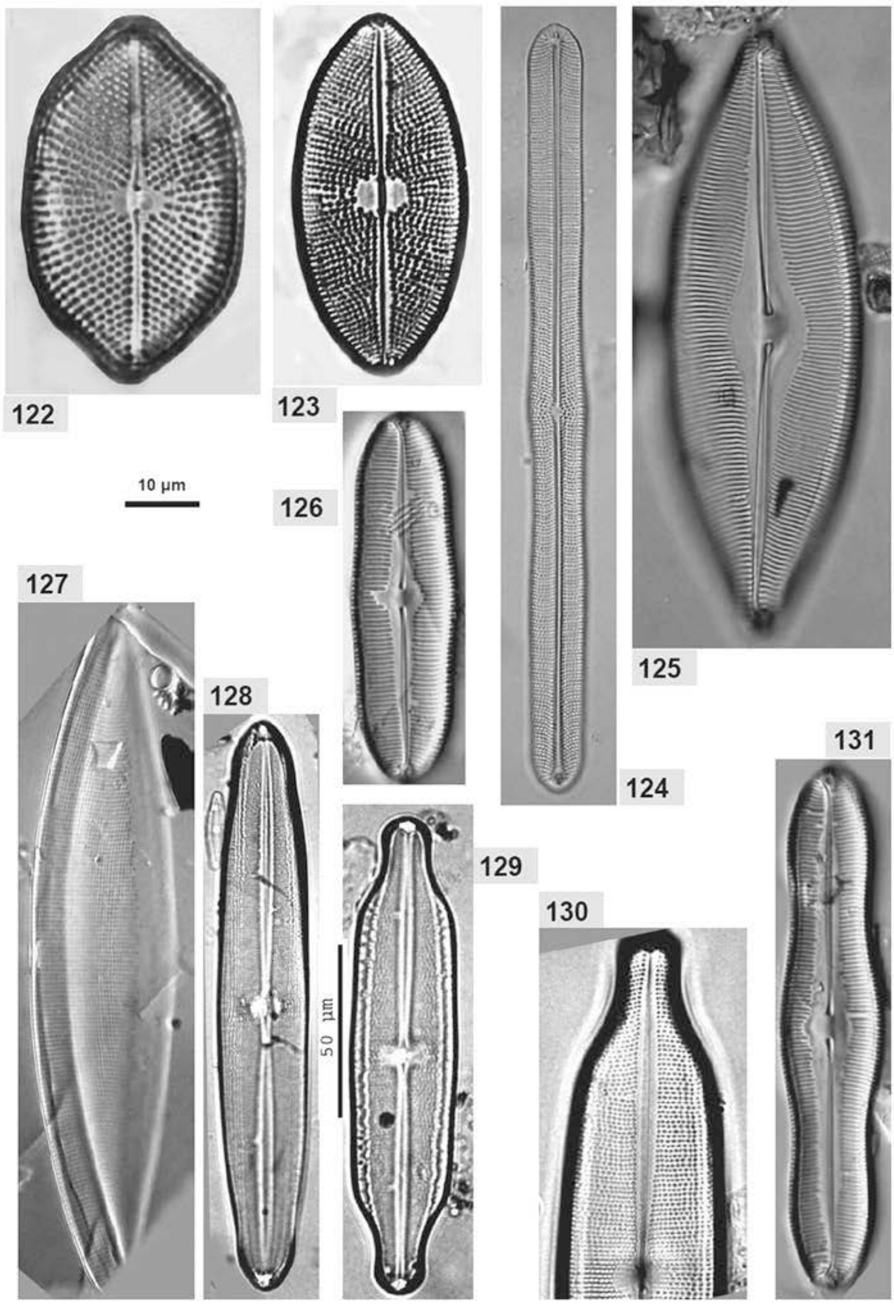
Figs 79-93. Littoral diatoms from the Shatt Al-Arab estuary, light microscopy. **79-81.** *Mastogloia elliptica* var *dansei*. **82, 83.** *Mastogloia smithii*. **84.** *Mastogloia smithii* var. *amphicephala*. **85, 86.** *Mastogloia pumila*. **87.** *Mastogloia fimbriata*. **88.** *Cymbella aspera*. **89.** *Seminavis robusta*. **90.** *Mastogloia quinquecostata*. **91.** *Mastogloia apiculata*. **92. M***astogloia braunii*. **93.** *Stauronella* sp. Scale bar: 10 µm.



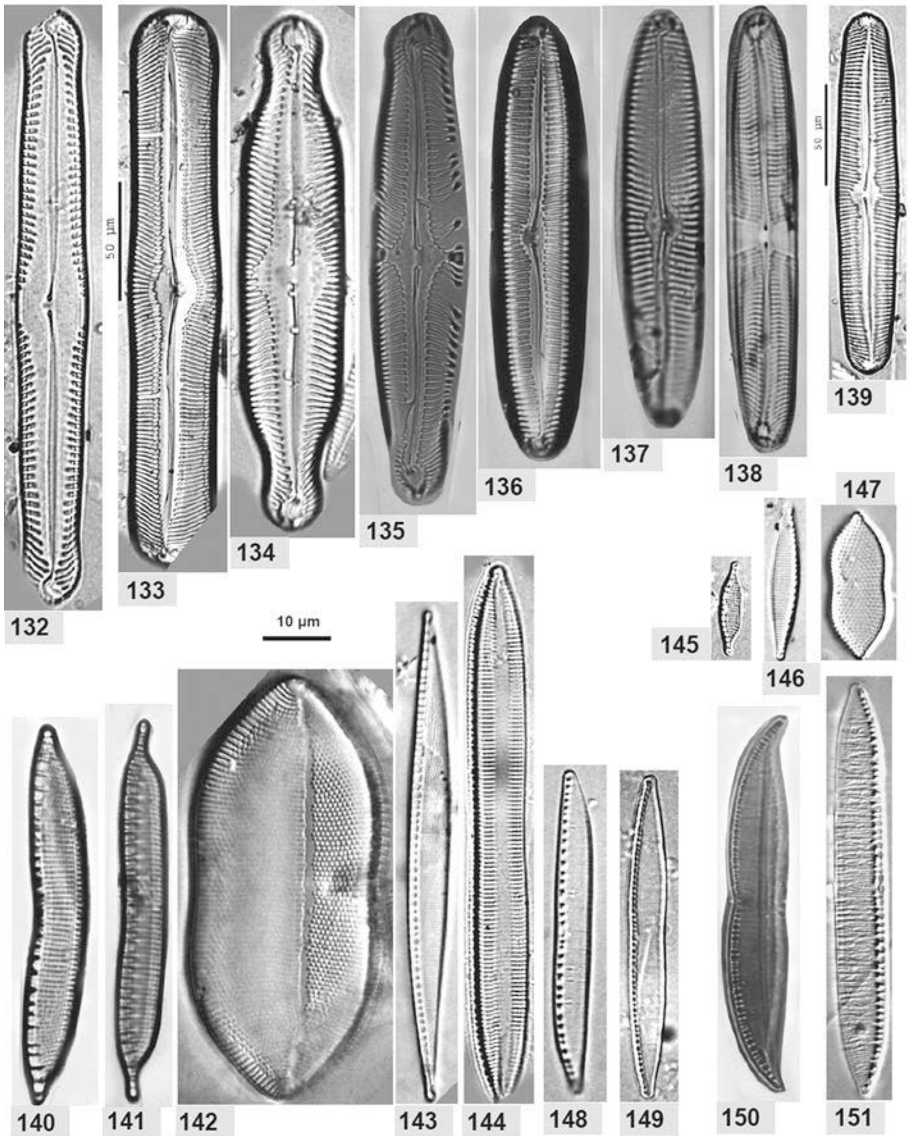
Figs 94-109. Littoral diatoms from the Shatt Al-Arab estuary, light microscopy. **94.** *Navicula radiosa*. **95.** *Navicula digitoradiata*. **96.** *Navicula* sp. 1. **97.** *Navicula* cf. *arenaria*. **98.** *Navicula gregaria*. **99.** *Craticula halophila*. **100.** *Sellaphora pupula*. **101.** *Navicula perrhombus*. **102.** *Hippodonta capitata*. **103.** *Navicula* sp. 2. **104.** *Navicula directa*. **105.** *Parlibellus crucicula*. **106.** *Navicula schroeteri*. **107-109.** *Sieminskia zeta*. Scale bar: 10 μm.



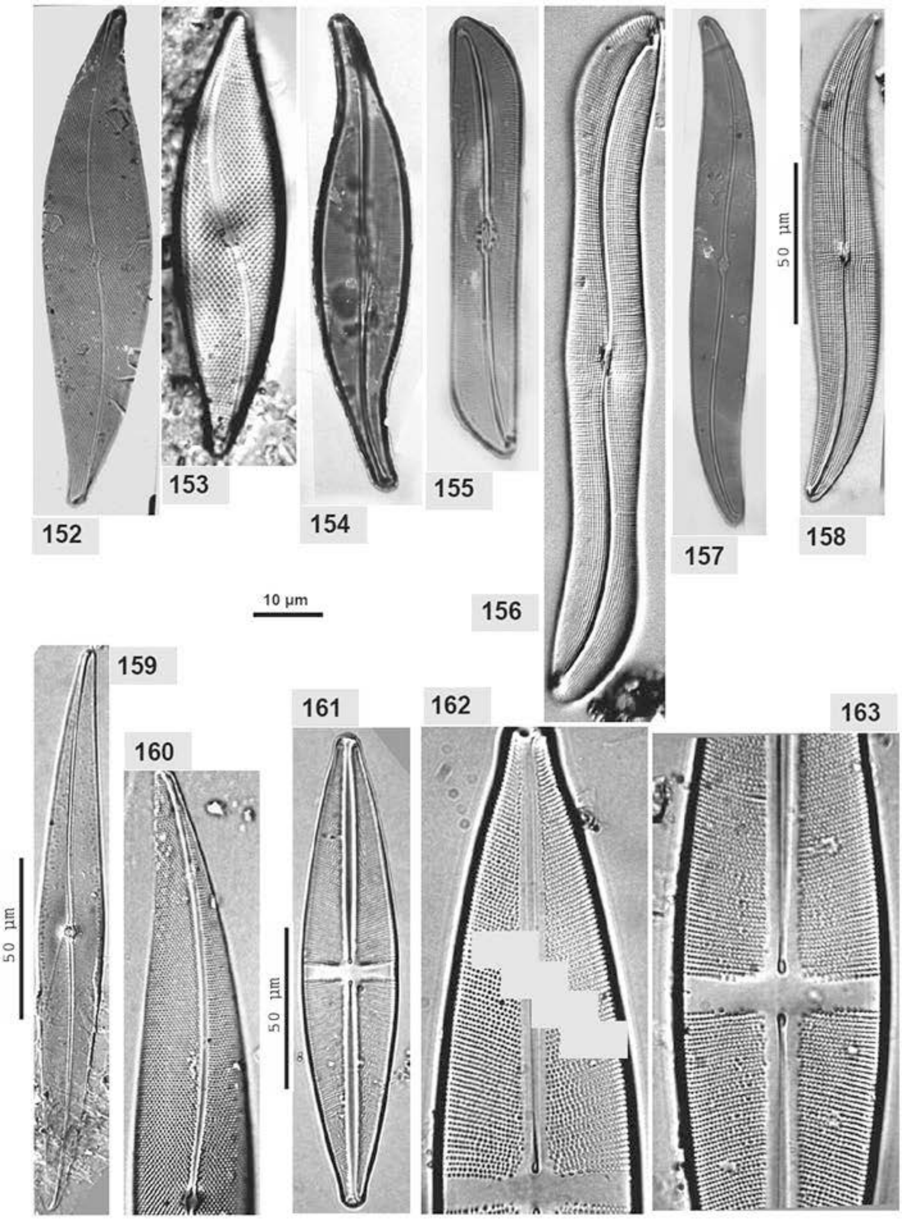
Figs 110-121. Littoral diatoms from the Shatt Al-Arab estuary, light microscopy. **110.** *Petroneis granulata*. **111.** *Lyrella* sp. **112.** *Lyrella hennedyi*. **113.** *Lyrella abnormis*. **114.** *Fogedia finmarchica*. **115.** *Lyrella abrupta*. **116.** *Lyrella clavata*. **117.** *Navicula rhynchocephala*. **118.** *Craticula cuspidata*. **119, 120.** *Lyrella spectabilis*. **121.** *Frustulia interposita*. Scale bar: 10 µm.



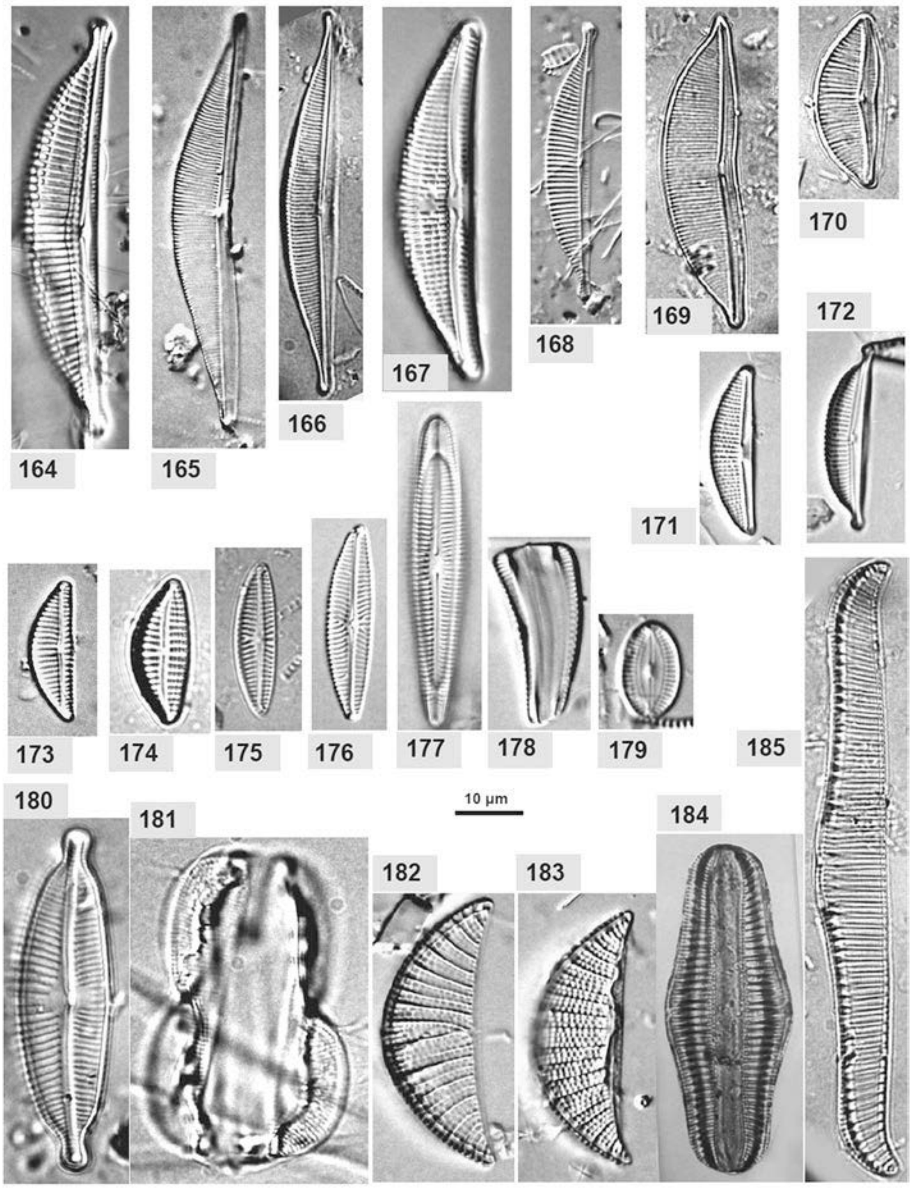
Figs 122-131. Littoral diatoms from the Shatt Al-Arab estuary, light microscopy. **122.** *Petroneis monilifera*. **123.** *Petroneis marina*. **124.** *Berkeleya scopulorum*. **125.** *Caloneis permagna*. **126.** *Caloneis silicula*. **127.** *Tropidoneis vitrea*. **128.** *Neidium iridis*. **129, 130.** *Neidium affine*. **131.** *Caloneis silicula*. Scale bars: Figs 128, 129. 50 µm; all others: 10 µm.



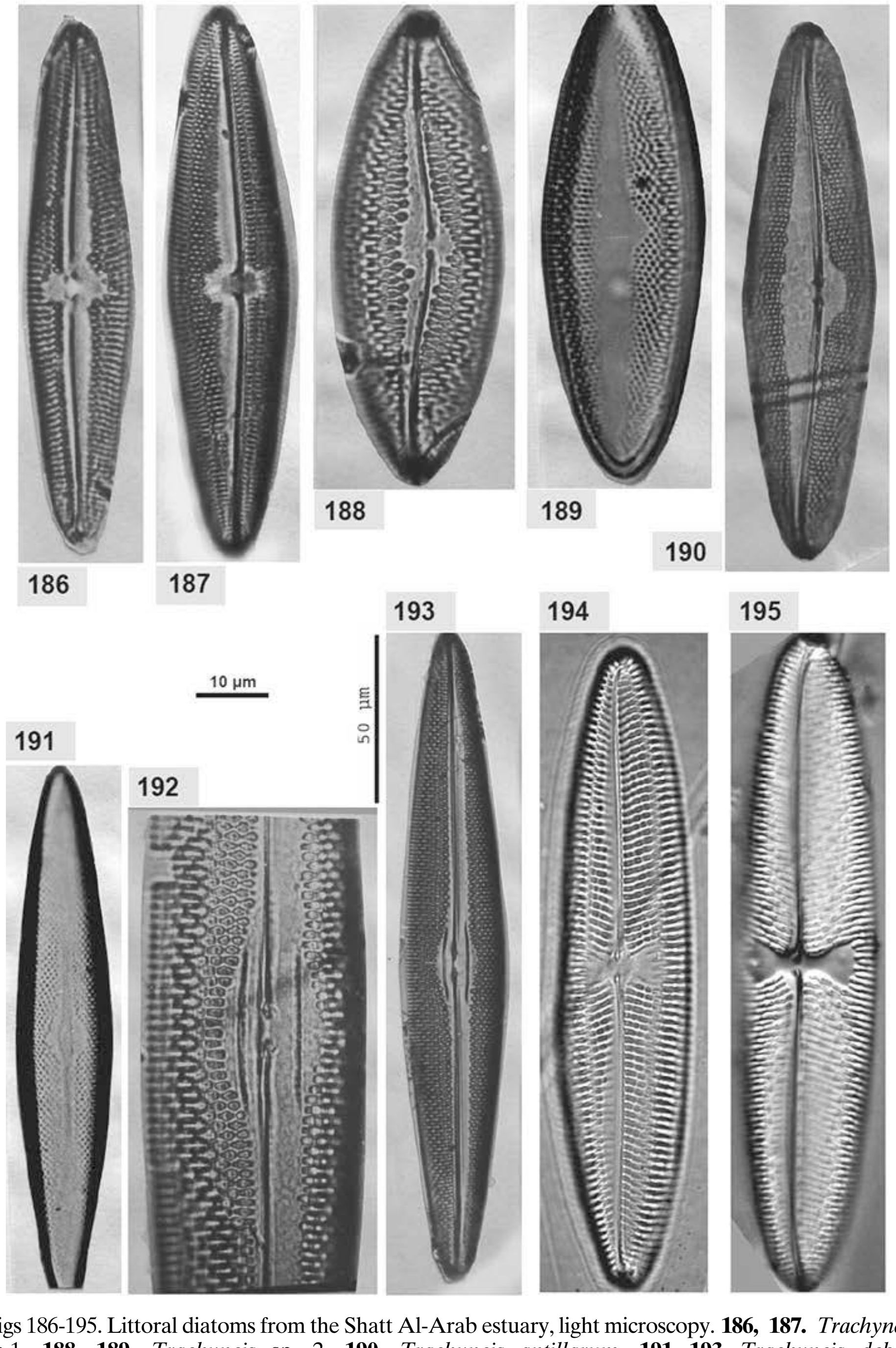
Figs 132-151. Littoral diatoms from the Shatt Al-Arab estuary, light microscopy. **132.** *Pinnularia gibba*. **133.** *Pinnularia nobilis*. **134.** *Pinnularia legumen*. **135.** *Pinnularia divergens*. **136, 137.** *Pinnularia viridis*. **138.** *Pinnularia cruciformis*. **139.** *Pinnularia* sp. **140.** *Hantzschia virgata*. **141.** *Hantzschia virgata* var. *capitellata*. **142.** *Psammodictyon panduriformis.* **143.** *Nitzschia sigma*. **144.** *Tryblionella hungarica*. **145.** *Nitzschia elegantula*. **146.** *Nitzschia cf. fonticola*. **147.** *Nitzschia* cf. *coarctata*. **148.** *Nitzschia* cf. *filiformis*. **149.** *Nitzschia capitellata*. **150.** *Nitzschia hybrida*. **151.** *Nitzschia* sp. Scale bars: Figs 139: 50 µm; all others: 10 µm.



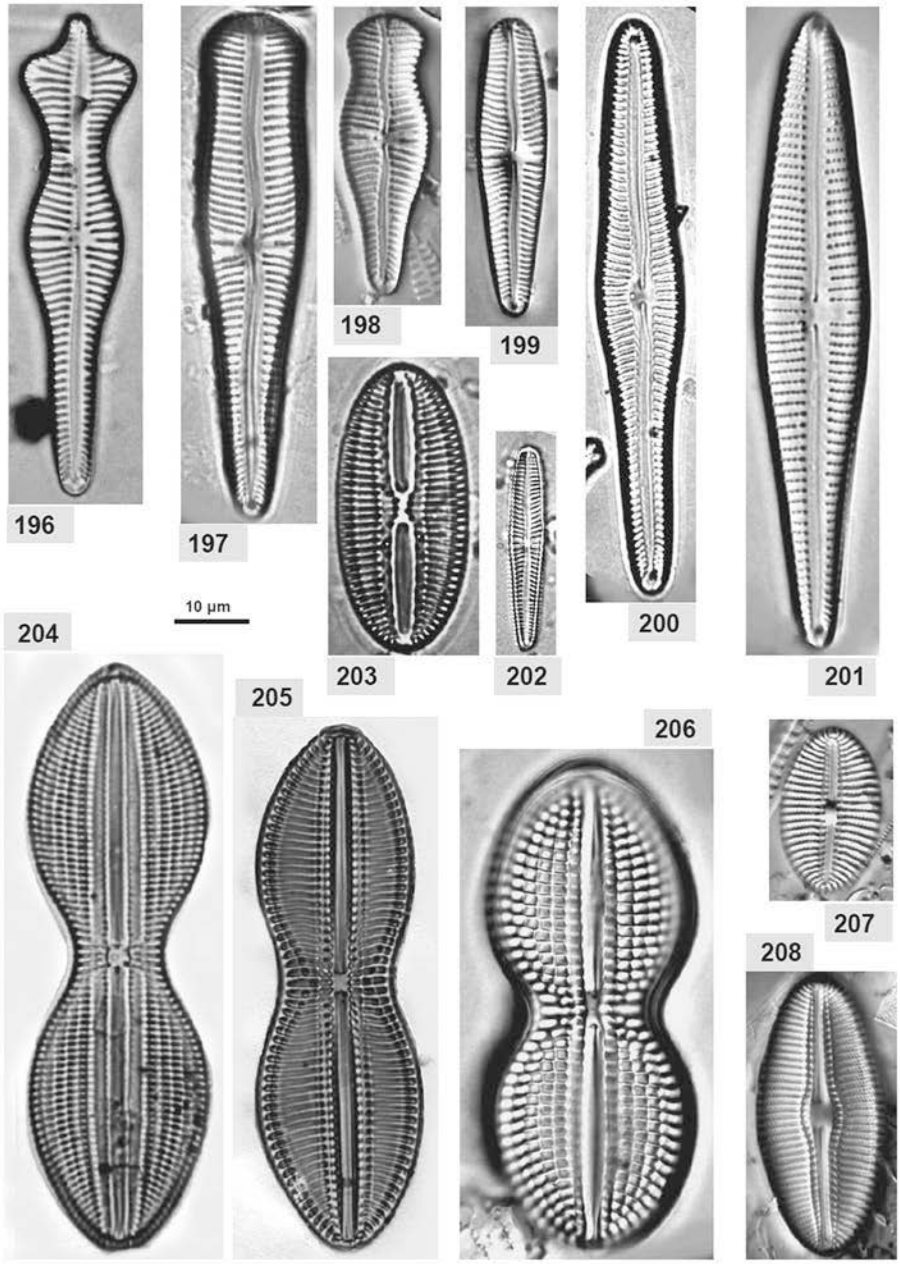
Figs 152-163. Littoral diatoms from the Shatt Al-Arab estuary, light microscopy. **152.** *Pleurosigma aestuarii*. **153.** *Pleurosigma diverse-striatum*. **154.** *Gyrosigma* cf. *parkeri*. **155.** *Gyrosigma eximium*. **156.** *Gyrosigma sinensis*. **157.** *Gyrosigma peisonis*. **158.** *Gyrosigma acuminatum*. **159, 160.** *Pleurosigma salinarum*. **161-163.** *Stauroneis phoenicenteron*. Scale bars: Figs 158, 159, 161: 50 µm; all others: 10 µm.



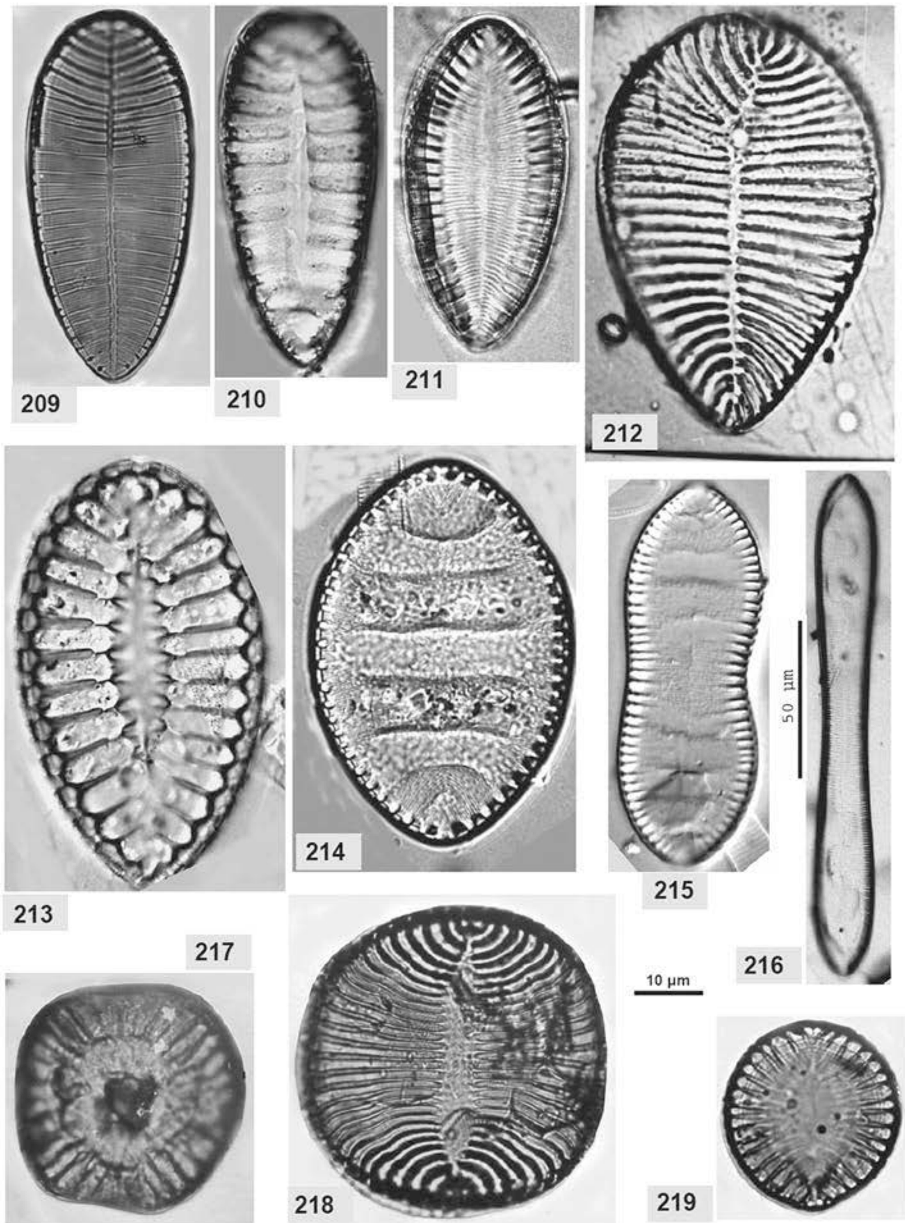
Figs 164-185. Littoral diatoms from the Shatt Al-Arab estuary, light microscopy. **164.** *Amphora* cf. *costata*. **165.** *Amphora* sp. **166.** *Amphora coffeaeformis*. **167.** *Amphora copulata*. **168.** *Amphora macilenta*. **169, 170.** *Amphora* sp. **171.** *Amphora veneta*. **172.** *Amphora exigua*. **173.** *Encyonema ventricosum*. **174.** *Encyonema* sp. **175, 176.** *Encyonema pusilla*. **177, 178.** *Rhoicosphenia abbreviata*. **179.** *Fallacia oculiformis*. **180.** *Cymbopleura* sp. **181.** *Entomoneis corrugata*. **182, 183.** *Rhopalodia musculus*. **184, 185.** *Rhopalodia gibba*. Scale bar: 10 µm.



Figs 186-195. Littoral diatoms from the Shatt Al-Arab estuary, light microscopy. **186, 187.** *Trachyneis* sp.1. **188, 189.** *Trachyneis* sp. 2. **190.** *Trachyneis antillarum*. **191, 193.** *Trachyneis debyi*. **194, 195.** *Trachyneis aspera*. Scale bars: Fig. 193: 50 µm; all others: 10 µm.



Figs 196-208. Littoral diatoms from the Shatt Al-Arab estuary, light microscopy. **196.** *Gomphonema coronatum*. **197-199.** *Gomphonema truncatum*. **200.** *Gomphonema clavatum*. **201.** *Gomphonema affine*. **202.** *Gomphonema* sp. **203.** *Diploneis suborbicularis*. **204.** *Diploneis chersonensis*. **205.** *Diploneis crarbo*. **206.** *Diploneis didyma*. **207.** *Diploneis* sp. **208.** *Diploneis smithii*. Scale bar: 10 µm.



Figs 209-219. Littoral diatoms from the Shatt Al-Arab estuary, light microscopy. **209.** *Petrodictyon gemma*. **210.** *Surirella capronii*. **211.** *Surirella ovalis*. **212.** *Surirella striatula*. **213.** *Surirella fastousa*. **214.** *Cymatopleura elliptica*. **215.** *Cymatopleura solea* var. *apiculata*. **216.** *Cymatopleura solea* var. *solea*. **217.** *Campylodiscus demelianus*. **218.** *Campylodiscus intermedius*. **219.** *Surirella brightwellii*. Scale bars: 216, 50 µm; all other, 10 µm.

DISCUSSION

The diatom assemblages found here varied considerably between the two investigated stations, reflecting different environmental conditions. At Station 1 a large number of allochthonous freshwater taxa were observed in assemblages otherwise dominated by brackish water taxa. Most of these were dead cells likely discharged by the Shatt Al-Arab river, as suggested by the fact that they were previously recorded from fresh- and brackish water habitats in southern Iraq (Hinton & Maulood, 1983; Hadi *et al*., 1984; Al-Handal & Abdullah, 1994).

Some taxa appeared to have variable environmental preferences. The occurrence of living cells of *Cocconeis placentula* var. *euglypta* in large numbers in untreated sediment material collected from a location with relatively high salinity (> 22 PSU) suggests that it may be a halotolerant taxon. By contrast, it is normally considered as oligohalobious (indifferent), alkaliphilic and epiphytic (Patrick & Reimer, 1966; Gale *et al*., 1979), although it has also been reported from waters with a salinity range of 17-20 PSU (Simonsen, 1962). *Pinnularia divergens*, *Pinnularia major* and *Pinnularia nobilis* also occurred frequently on the mudflats. These taxa are said to be acidophilic and prefer water of low mineral content (Hustedt, 1930; Patrick & Reimer, 1966; Gaiser & Johansen, 2000). Their occurrence in a truly alkaline habitat suggests a wider ecological spectrum. It is likely that the specimens found here drifted from the freshwaters of South Iraq which is characterized by high alkalinity (pH > 8.0) and high mineral content (Kell & Saad, 1975; Richardson & Hussain, 2006).

Planktonic diatoms were poorly represented on the mudflats (Station 1), but material from the open sea site (Station 2) was rich in frustules of several species presumed to be deposited from the plankton. Intact and live cells of *Coscinodiscus oculus-iridis* were observed in large numbers. However, this species appears to prefer high nutrient concentrations such as those which prevail in the North West Arabian Gulf. It was previously found commonly throughout the year in this region (Al-Handal, 1988), becoming rarer towards the southern parts of the Gulf (Simonsen, 1974).

The material for this study was collected in two seasons, spring (April) and autumn (November). The species composition did not appear to vary considerably between these periods but the occurrence of few taxa did. *Ardissonea robusta* was common in April but became rare in November. Other species, such as *Achnanthes brevipes, Surirella fastuosa* and *Mastogloia* spp., were more common in spring regardless of the site. On the other hand, *Berkeleya scopulorum*, *Pleurosigma diverse-striatum* and *Gyrosigma eximium* were more common in autumn.

Most diatom taxa recorded in this study, be they of freshwater or marine origin, have a cosmopolitan geographic distribution. However, several tropical and subtropical taxa have also been found, including *Cyclotella stylorum*, *Tryblioptychus cocconeiformis*, *Trachyneis debyi*, *Trachyneis antillarum* and *Gomphotheca sinensis*.

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