Pak. J. Bot., 42(2): 1137-1151, 2010.

THE PLANKTONIC DIATOM OF THE GENUS *CHAETOCEROS* EHRENBERG FROM NORTHWESTERN ARABIAN SEA BORDERING PAKISTAN

ASMA TABASSUM[1] AND S.M. SAIFULLAH[2]

[1]*Department of Botany, University of Karachi, Karachi, Pakistan*
[2]*Institute of Marine Science, University of Karachi, Karachi, Pakistan*

Abstract

The present paper reports the occurrence of 17 species of *Chaetoceros* including two varieties from the northwestern Arabian Sea shelf of Pakistan and deep sea vicinity. *C. coarctatus* was the most common and frequent species followed by *C. messanensis* and *C. lorenzianus* while others were rare. Maximum species diversity occurred during northeast monsoon season. The Indus Delta shelf was more diverse than the Balochistan shelf. All the 17 species were present in the former area and also more frequent than the later area. Most species were neritic indicating coastal influence.

Introduction

Chaetoceros, a marine planktonic diatom, was first described by Ehrenberg in 1844 (Rines, 1999). It is the most diverse and widespread marine planktonic diatom (Cupp, 1943). As many as 400 species have been described, although a significant proportion of them are not valid (Hasle & Syvertsen, 1997). It has been studied in detail from various parts of the world oceans but information from the North Arabian Sea is scanty (Subrahmanyan, 1946; Wood, 1963; Simonsen, 1974; Kuzmenko, 1975) and that from the northwestern part bordering Pakistan including the shelf and deep sea vicinity is not available except for some sporadic observations by Simonsen (1974), Kuzmenko (1975) and Saifullah & Chaghtai (2005). Saifullah & Moazzam (1978) reported 20 species of *Chaetoceros* out of 82 species of marine centric diatoms from a strictly coastal channel of Karachi on the shelf. The present paper reports and describes species of *Chaetoceros* from the entire Pakistan shelf including the deep sea vicinity. The samples of the study were collected during the Fridtjof Nansen cruise which sampled the area both intensively and extensively during January–June, 1977.

Materials and Methods

Phytoplankton samples were collected by net hauls of mesh size 76µm during the Pak-Norwegian Cruise "Dr. Fridtjof Nansen". The cruise traversed a network 359 stations repeatedly occupied on 76 fixed locations (Fig. 1 and Table 1) all over the continental shelf of Pakistan and deep-sea vicinity during the period January 1976-June 1977. A total of 325 phytoplankton samples were examined. The samples were preserved in 4% formalin immediately. Simultaneous observations and seawater temperature and salinity were made by a reversible thermometer and a salinometer respectively.

The diatom samples were washed with distilled water for desalination, treated with strong acid like sulfuric acid and nitric acid to oxidize any organic matter attached to the diatom shells and also with hydrochloric acid to remove traces of Calcium carbonate. Samples were again washed with distilled water to remove any traces of acid. The observation and identification of diatom species were made using light microscope. The microscope was equipped with 4X, 10X and 40X objectives.

*E-mail: asmitabassum@gmail.com

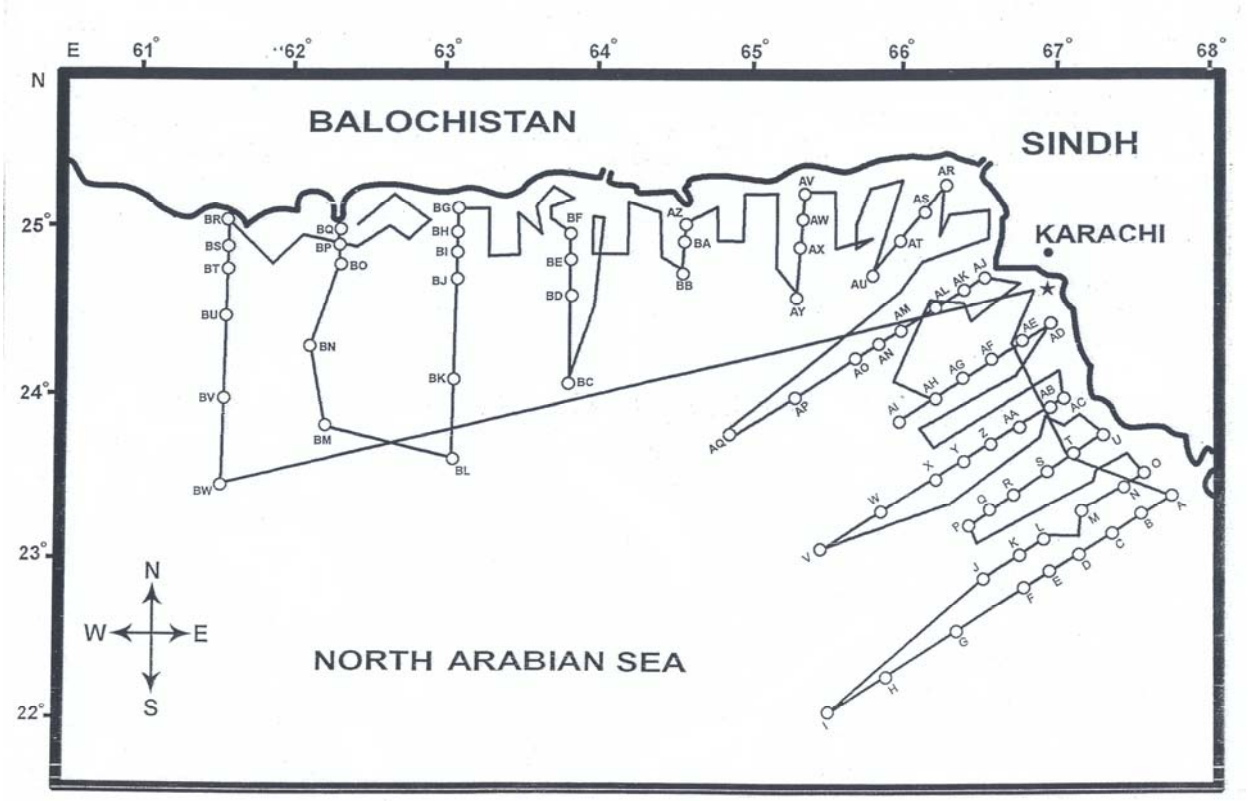

Fig. 1. Location of stations occupied by the cruise during Jan-June 1977. The alphabets indicate the number of stations occupied repeatedly on that location as per Table 1.

Observations

Following is an account of 17 species recorded from Northwest Arabian Sea bordering Pakistan. Morphometric data regarding size measurements and their local distribution are mentioned in Tables 2 and 3 respectively.

1. *Chaetoceros affinis* var. *willei* Lauder (Fig. 2)

Cupp, 1943, p. 125, Fig. 78; Hendey, 1964, p. 127, Plate 18, Fig. 3; Hasle & Syvertsen, 1997, p. 216.

Straight chains; setae different, terminal ones larger and more divergent than inner ones.

Local Distribution: Table 3.

General Distribution: Cupp, 1943; West Coast of North America; Hendey, 1964, British Coastal Waters.

2. *Chaetoceros atlanticus* var. *neapolitanus* (Schröder) Hustedt (Fig. 3)

Cupp, 1943, p. 103, Fig. 59; Hendey, 1964, p. 133, Plate 17, Fig. 6; Hasle & Syvertsen, 1997, p. 196, Plate 39; Moazzam, 1973, p. 51, pl. 129, Fig. b; Shevchenko *et al.*, 2006, p. 237 & 238, Fig. 5 (240).

Table 1. Number of stations (1-359) occupied repeatedly on 75 fixed locations (A-BW, Fig. 1) during five different cruises of "Fridtjof Nansen".

Locations	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
Cruise	Stations																									
I	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
II	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101
III	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176
IV	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251
V	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326

Locations	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU	AV	AW	AX	AY	AZ
Cruise	Stations																									
I	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
II	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127
III	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202
IV	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277
V	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352

Locations	BA	BB	BC	BD	BE	BF	BG	BH	BI	BJ	BK	BL	BM	BN	BO	BP	BQ	BR	BS	BT	BU	BV	BW
Cruise	Stations																						
I	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
II	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150
III	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225
IV	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300
V	353	354	355	356	357	358	359																

Cruises: I= 19th January – 11th February; II= 19th February – 5th March; III= 8th March – 8th April; IV= 13th April – 5th May; V= 18th May – 20th June

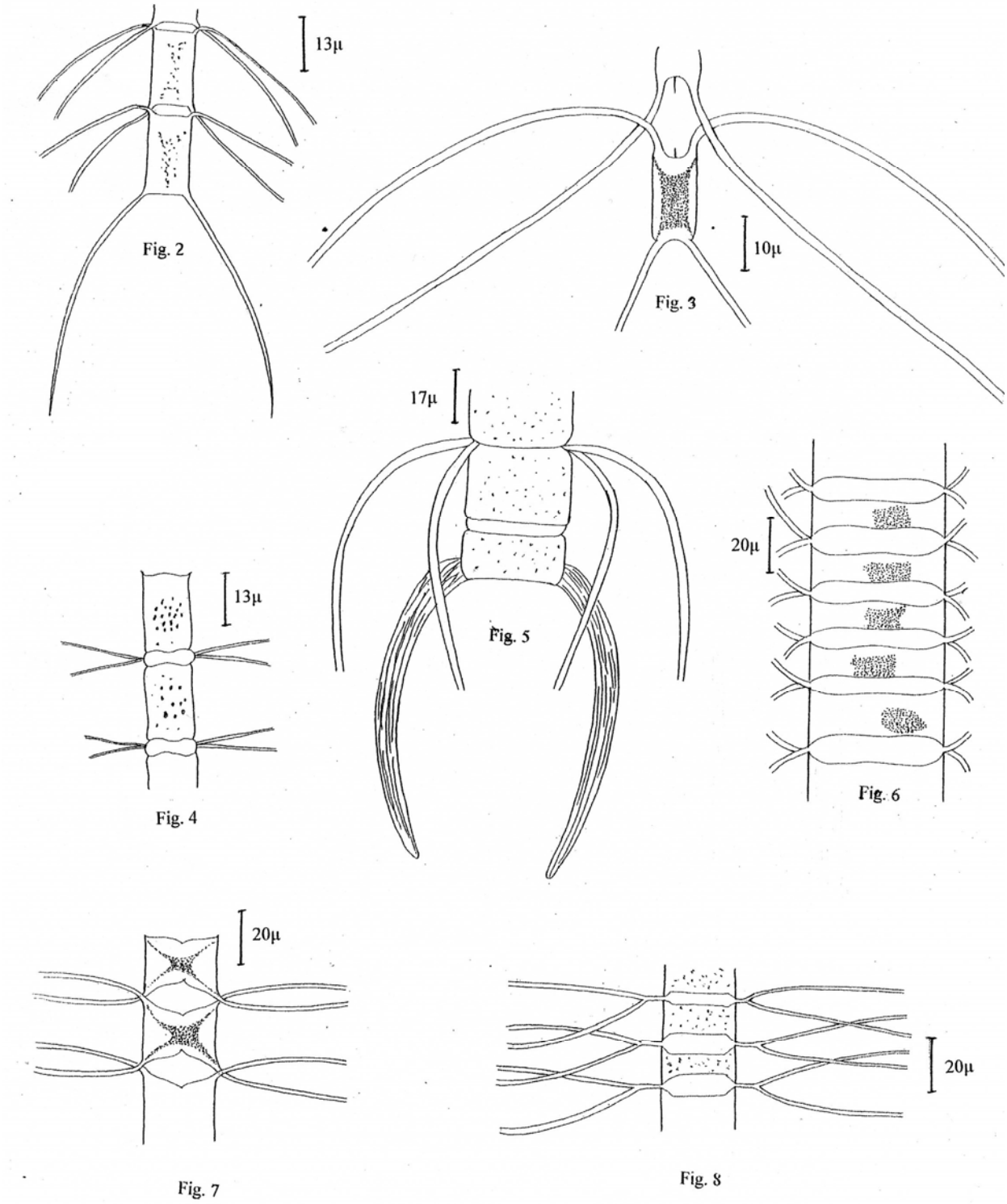

Fig. 2. *C. affinis* var. *willei* Lauder
Fig. 3. *C. atlanticus* var. *neapolitana* (Schröder) Hustedt
Fig. 4. *C. brevis* Schütt
Fig. 5. *C. coarctatus* Lauder
Fig. 6. *C. compressus* Lauder
Fig. 7. *C. curvisetus* Cleve
Fig. 8. *C. decipiens* Cleve

Table 2. Morphometric Data of *Chaetoceros* spp.

S. No.	Species	Apical axis	Pervalvar axis	Foramina
1.	*C. affinis* var *willei* Lauder	12 µ	20 µ	2 µ
2.	*C. atlanticus* var *neapolitana* (Schröder) Hustedt	7 µ - 10 µ	10 µ - 30 µ	10 µ- 17 µ
3.	*C. brevis* Schutt	12 µ	20 µ	4 µ
4.	*C. coarctatus* Lauder	12 µ - 35 µ	27 µ - 45 µ	5 µ
5.	*C. compressus* Lauder	20 µ - 40 µ	10 µ - 16 µ	5 µ - 8 µ
6.	*C. curvisetus* Cleve	25 µ - 28 µ	16 µ - 20 µ	10 µ - 12 µ
7.	*C. decipiens* Cleve	20 µ - 27 µ	10 µ - 12 µ	4 µ - 8 µ
8.	*C. diversus* Cleve	12 µ - 13 µ	8 µ - 12 µ	1.25 µ - 2 µ
9.	*C. eibenii* Grunow in Van Heurk	36 µ	32 µ	12 µ
10.	*C. laciniosus* Schütt	7 µ - 24 µ	13 µ - 40 µ	13 µ - 16 µ
11.	*C. lorenzianus* Grunow	15µ - 35µ	10 µ - 20 µ	8 µ - 12 µ
12.	*C. messanensis* Castracane	10 µ - 37 µ	6 µ - 7 µ	5 µ - 9 µ
13.	*C. pelagicus* Cleve	7 µ	21 µ	14 µ
14.	*C. peruvianus* Brightwell	13 µ	33 µ	-
15.	*C. peruvianus* var *robusta* Cleve	40 µ	24 µ	-
16.	*C. socialis* Lauder	8 µ - 12 µ	10 µ - 15 µ	2 µ - 4 µ
17.	*C. teres* Cleve	22 µ - 31 µ	49 µ	-

Straight chain; cells large, foramina long and hexagonal, rhimportula present in the centre of the mantle.

Local Distribution: Table 3.

General Distribution: Cupp, 1943, West Coast of North America; Wood, 1963, Indian Ocean; Hendey, 1964, British Coastal Waters; Moazzam, 1973, Manora Channel (Karachi); Simonsen, 1974, Indian Ocean.

3. *Chaetoceros brevis* Schütt (Fig. 4)

Cupp, 1943, p. 129, Fig. 82; Brunel, 1962, p. 120, Plate 27, Fig. 3, Plate 29, Fig. 2.

Cahins straight; valves with a protuberance in the centre so that the foramen appears dumble shaped; setae arising from margin and running obliquely.

Local Distribution: Table 3.

General Distribution: Cupp, 1943, West Coast of North America; Wood, 1963, Indian Ocean; Hendey, 1964, British Coastal Waters.

4. *Chaetoceros coarctatus* Lauder (Fig. 5)

Hendey, 1964, p. 121 & 122, pl. 12, Fig. 1; Cupp, 1943, p. 107, Fig. 62; Subrahmanyan, 1946, p. 129, Fig. 182-187(130); Hasle & Syvertsen, 1997, p. 199, Plate 40; Moazzam, 1973, p. 51, pl. 130, Fig. a.

Chains straight; cells isovalvate; valve mantle flat; 2 types of setae, posterior shorter and thicker whereas others longer and thinner; foramina almost absent.

Local Distribution: Table 3.

Table 3. Distributation of *Chaetoceros* spp. on Pakistan shelf.

S. No.	Species	Stations
1.	*C. affinis* var *willei* Lauder	50, 55, 59, 65, 88, 93, 94, 97, 99, 100, 101, 124, 141, 145, 153, 224
2.	*C. atlanticus* var *neapolitana* (Schröder) Hustedt	10, 65, 141, 153
3.	*C. brevis* Schutt	100
4.	*C. coarctatus* Lauder	8, 46, 50, 55, 59, 70, 73, 75, 77, 78, 84, 88, 95, 97, 100, 109, 110, 111, 120, 121, 125, 127, 128, 131, 132, 133, 135, 136, 137, 139, 141, 144, 145, 146, 151, 153, 154, 171, 183, 206, 231, 274, 278, 295
5.	*C. compressus* Lauder	97
6.	*C. curvisetus* Cleve	73, 84, 88, 92, 93, 94, 97, 100, 124
7.	*C. decipiens* Cleve	10, 30, 59, 65, 70, 73, 75, 76, 78, 84, 93, 97, 100, 107, 120
8.	*C. diversus* Cleve	84, 86, 97, 100
9.	*C. eibenii* Grunow in Van Heurk	10, 30, 65, 70, 73, 88, 94, 95, 97, 145
10.	*C. laciniosus* Schütt	65, 73, 77, 78, 84, 86, 88, 92, 93, 94, 97, 121, 124, 295
11.	*C. lorenzianus* Grunow	10, 53, 58, 60, 65, 67, 73, 76, 78, 82, 84, 88, 92, 93, 94, 95, 97, 99, 101, 102, 108, 120, 136, 141, 146, 149, 161, 224, 225, 274, 295
12.	*C. messanensis* Castracane	10, 30, 51, 53, 65, 73, 76, 77, 78, 84, 86, 88, 90, 92, 93, 94, 95, 97, 99, 100, 101, 102, 108, 109, 110, 120, 121, 124, 125, 135, 141, 149, 153, 295
13.	*C. pelagicus* Cleve	84, 100
14.	*C. peruvianus* Brightwell	153
15.	*C. peruvianus* var *robusta* Cleve	10, 88, 93, 100, 103, 124, 136, 141, 146,149, 153, 295
16.	*C. socialis* Lauder	59, 65, 67, 78, 84, 86, 92, 97, 101, 108, 120, 136, 141, 191, 224
17.	*C. teres* Cleve	10, 65, 70, 76, 84, 88, 94, 97

General Distribution: Cupp, 1943, West Coast of North America; Subrahmanyan, 1946, Madras coast (India); Brunel, 1962, Chaleurs Bay (Canada); Wood, 1963, Indian Ocean; Hendey 1964, British Coastal Waters; Moazzam, 1973, Manora Channel (Karachi); Simonsen, 1974, Indian Ocean.

5. *Chaetoceros compressus* Lauder (Fig. 6)

Cupp, 1943, p. 119, Fig. 74; Hendey, 1964, p. 125, Plate 16, Fig. 5; Hasle & Syvertsen, 1997, p. 206, Plate 42.

Chains straight; cells rectangular; valve slightly convex in the middle; foramina narrow slightly curved in the middle; setae thin emerging within the margin of the valve.

Local Distribution: Table 3.

General Distribution: Cupp, 1943, West Coast of North America; Subrahmanyan, 1946, Madras coast (India); Brunel, 1962, Chaleurs Bay (Canada); Wood, 1963, Indian Ocean; Hendey, 1964, British Coastal Waters; Simonsen, 1974, Indian Ocean.

6. *Chaetoceros curvisetus* Cleve (Fig. 7)

Cupp, 1943, p. 137, Fig. 93; Hendey, 1964, p. 133, Plate 17, Fig. 6; Hasle & Syvertsen, 1997, p. 211, Plate 44; Moazzam, 1973, pl. 137, Fig. b.

Chains curved valves rectangular and concave with lanceolate apertures and conneted by poles; mantle concave with a small slit in centre; setae with short or no basal part, directing outwards.

Local Distribution: Table 3.

General Distribution: Cupp, 1943, West Coast of North America; Subrahmanyan, 1946, Madras coast (India); Wood, 1963, Indian Ocean; Hendey, 1964, British Coastal Waters; Moazzam, 1973, Manora Channel (Karachi); Simonsen, 1974, Indian Ocean.

7. *Chaetoceros decipiens* Cleve (Fig. 8)

Cupp, 1943, p. 115, Fig. 70; Hendey, 1964, p. 123, Plate 12, Fig. 2; Hasle & Syvertsen, 1997, p. 204, Plate 42; Moazzam, 1973, p. 54, pl. 132, Fig. a.

Chains straight; foramina narrow rectangular or lanceolate; setae perpendicular to main axis, fusing with each other a short distance outside the margin of chain.

Local Distribution: Table 3.

General Distribution: Cupp, 1943, West Coast of North America; Brunel, 1962, Chaleurs Bay (Canada); Wood, 1963, Indian Ocean; Hendey, British Coastal Waters; Moazzam, 1973, Manora Channel (Karachi); Simonsen, 1974, Indian Ocean.

8. *Chaetoceros diversus* Cleve (Fig. 9)

Cupp, 1943, p. 132, Fig. 87; Hendey, 1964, p. 130, Plate 17, Fig. 4; Hasle & Syvertsen, 1997, p. 216, Table 53, Moazzam; 1973, p. 58, pl. 135, Fig. b.

Straight chains; intercalary setae two types; one thin other type thick, first diverging at a sharp angle from the main axis and then running parallel; terminal setae almost parallel and U-shaped.

Local Distribution: Table 3.

General Distribution: Cupp, 1943, West Coast of North America; Subrahmanyan, 1946, Madras coast (India); Brunel, 1962, Chaleurs Bay (Canada); Wood, 1963, Indian Ocean; Hendey 1964, British Coastal Waters; Moazzam, 1973, Manora Channel (Karachi); Simonsen, 1974, Indian Ocean.

9. *Chaetoceros eibenii* Grunow in Van Heurk (Fig. 10)

Cupp, 1943, p. 106, Fig. 61; Hasle & Syvertsen, 1997, p. 201, Plate 41.

Chains straight; cells isovalvate; mantle with minute spine (rhimoportula); aperture hexagonal to lanceolate.

Local Distribution: Table 3.

General Distribution: Cupp, 1943, West Coast of North America; Subrahmanyan, 1946, Madras coast (India); Brunel, 1962, Chaleurs Bay (Canada); Wood, 1963, Indian Ocean; Hendey 1964, British Coastal Waters.

10. *Chaetoceros laciniosus* Schutt (Fig. 11)

Cupp, 1943, p. 128, Fig. 80; Hendey, 1964, p. 127, Plate 13, Fig. 2; Hasle & Syvertsen, 1997, p. 209, Plate 43.

Chains straight, foramina as large as the pervalver axis; setae first running parallel and then perpendicular to the main axis after crossing each other.

Local Distribution: Table 3.

General Distribution: Cupp, 1943, West Coast of North America; Subrahmanyan, 1946, Madras coast (India); Brunel, 1962, Chaleurs Bay (Canada); Wood, 1963, Indian Ocean; Hendey 1964, British Coastal Waters.

11. *Chaetoceros lorenzianus* Grunow (Fig. 12)

Cupp, 1943, p. 118, Fig. 71; Hendey, 1964, p. 124, Plate 16, Fig. 1; Hasle & Syvertsen, 1997, p. 204, Plate 42.

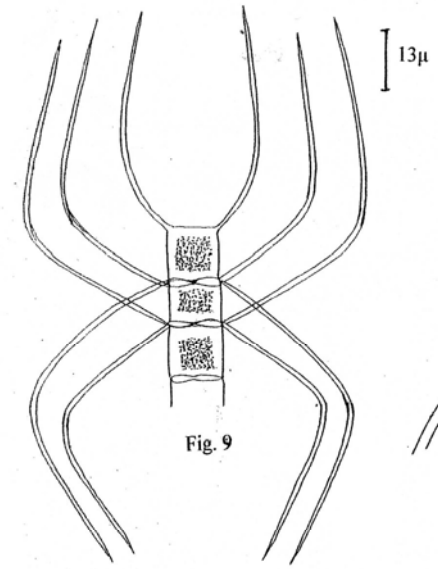

Fig. 9

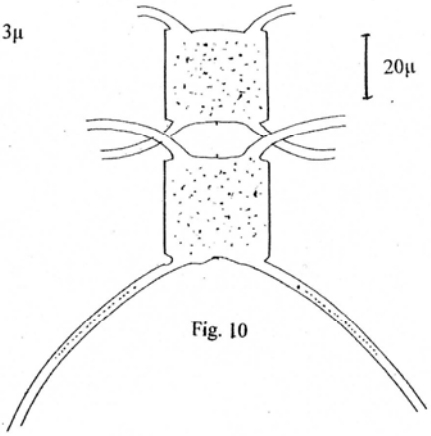

Fig. 10

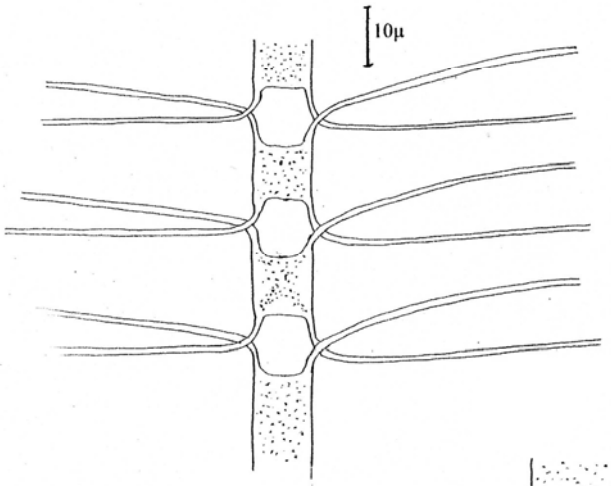

Fig. 11

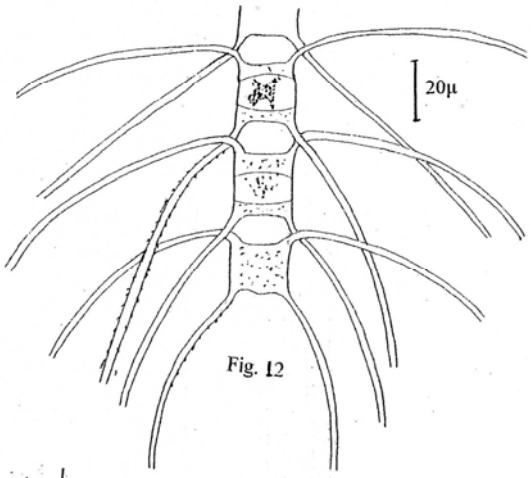

Fig. 12

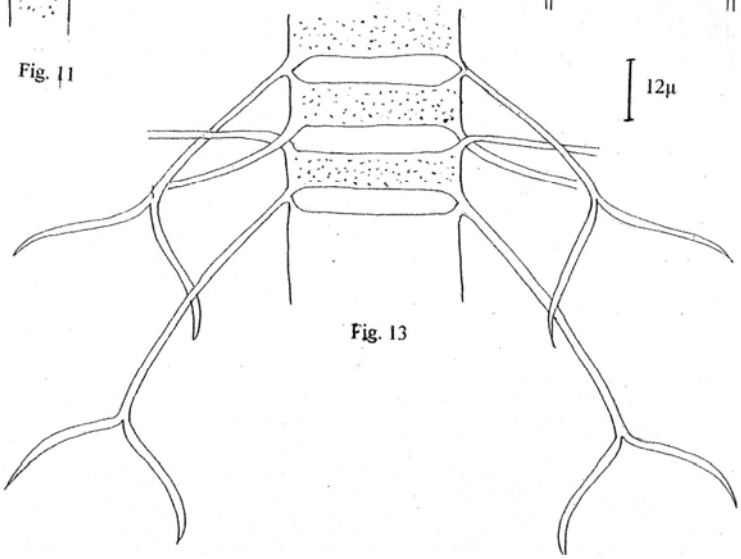

Fig. 13

Fig. 9. *C. diversus* Cleve
Fig. 10. *C. eibenii* Grunow in Van Heurk
Fig. 11. *C. laciniosus* Schütt
Fig. 12. *C. lorenzianus* Grunow
Fig. 13. *C. messanensis* Castracane

Chain straight; terminal setae almost parallel to the main axis; intercalary setae divergent with curves; foramina hexagonal.

Local Distribution: Table 3.

General Distribution: Cupp, 1943, West Coast of North America; Subrahmanyan, 1946, Madras coast (India); Brunel, 1962, Chaleurs Bay (Canada); Wood, 1963, Indian Ocean; Hendey 1964, British Coastal Waters; Moazzam, 1973, Manora Channel (Karachi); Simonsen, 1974, Indian Ocean.

12. *Chaetoceros messanensis* Castracane (Fig. 13)

Cupp, 1943, p. 133, Fig. 89; Hendey, 1964, p. 129, Plate 12, Fig. 3; Hasle & Syvertsen, 1997, p. 216, Plate 45; Moazzam, 1973, p. 59, pl. 135, Fig. a.

Straight chains; valves flat to slightly concave; semiinternal setae are forked and thicker than others.

Local Distribution: Table 3.

General Distribution: Cupp, 1943, West Coast of North America; Subrahmanyan, 1946, Madras coast (India); Brunel, 1962, Chaleurs Bay (Canada); Wood, 1963, Indian Ocean; Hendey, British Coastal Waters; Moazzam, 1973, Manora Channel (Karachi); Simonsen, 1974, Indian Ocean.

13. *Chaetoceros pelagicus* Cleve (Fig. 14)

Cupp, 1943, p. 129, Fig. 81 and 82; Brunel, 1962, p. 81.

Chain straight; cells much longer than broad; aperture large but smaller than pervalver axis; setae emerging at the margin aperture and setae similar to *Chaetoceros laciniosus*.

Local Distribution: Table 3.

General Distribution: Cupp, 1943, West Coast of North America; Subrahmanyan, 1946, Madras coast (India); Brunel, 1962, Chaleurs Bay (Canada); Wood, 1963, Indian Ocean.

14. *Chaetoceros peruvianus* Brightwell (Fig. 15)

Cupp, 1943, p.113, fig. 68; Moazzam, 1973, p. 52, pl. 131, fig. b

Frustules occurring singly with convex epitheca and concave hypotheca; apical setae arising form the centre of the mantle and then running backwards in concave curve, setae thick and stratified.

Local Distribution: Table 3.

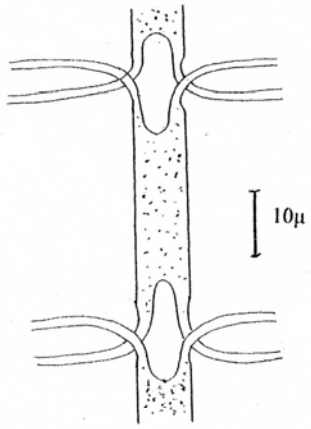

Fig. 14

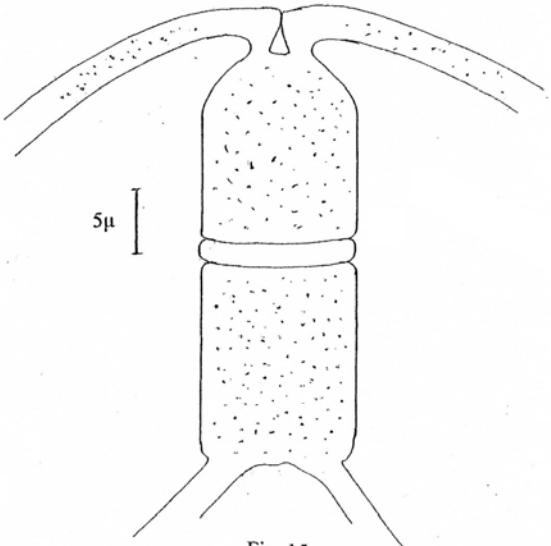

Fig. 15

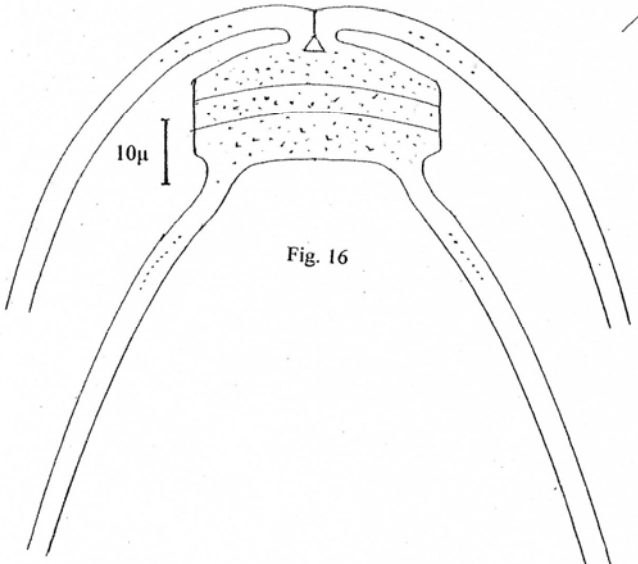

Fig. 16

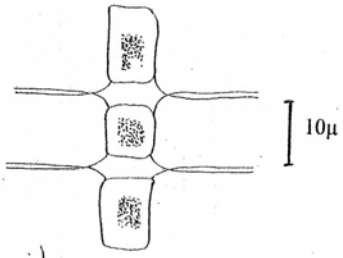

Fig. 17

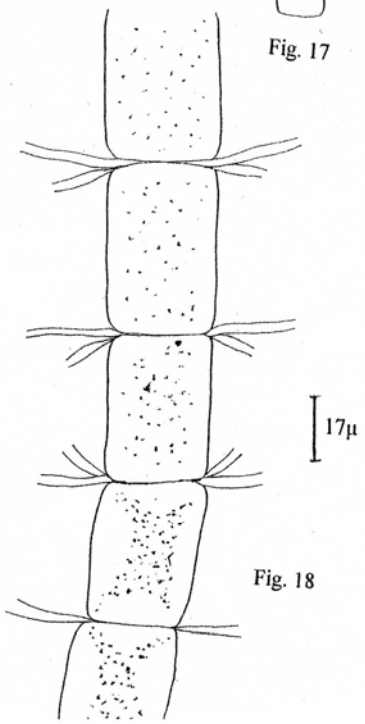

Fig. 18

Fig. 14. *C. pelagicus* Cleve
Fig. 15. *C. peruvianus* Brightwell
Fig. 16. *C. peruvianus* var. *robusta* Cleve
Fig. 17. *C. socialis* Lauder
Fig. 18. *C. teres* Cleve

General Distribution: Cupp, 1943, West Coast of North America; Subrahmanyan, 1946, Madras coast (India); Brunel, 1962, Chaleurs Bay (Canada); Wood, 1963, Indian Ocean; Hendey 1964, British Coastal Waters; Moazzam, 1973, Manora Channel (Karachi); Simonsen, 1974, Indian Ocean.

15. *Chaetoceros peruvianus* var. *robusta* Cleve (Fig. 16)

Moazzam, 1973, p. 53, pl. 131, fig. a; Subrahmanyan, 1946, p. 131, Fig. 200 & 201(132).

Cells solitary; broader than large; terminal setae arise from the centre of the mantle; chromatophores present in setae. It differs from the species in being more robust and broader than longer.

Local Distribution: Table 3.

General Distribution: Subrahmanyan, 1946, Madras coast (India); Moazzam, 1973, Manora Channel (Karachi).

16. *Chaetoceros socialis* Lauder (Fig. 17)

Cupp, 1943, p. 143, Fig. 100; Hendey, 1964, p. 136, Plate 15, Fig. 3; Hasle & Syvertsen, 1997, p. 221, Plate 47.

Short delicate and small chains forming loose colonies due to entangling of the setae, setae crossing over outside the margin of the chain; foramina hexagonal.

Local Distribution: Table 3.

General Distribution: Cupp, 1943, West Coast of North America; Subrahmanyan, 1946, Madras coast (India); Brunel, 1962, Chaleurs Bay (Canada); Wood, 1963, Indian Ocean; Hendey, 1964, British Coastal Waters.

17. *Chaetoceros teres* Cleve (Fig. 18)

Cupp, 1943, p. 118, Fig. 72; Hendey, 1964, p. 124, Plate 10, Fig. 3; Hasle & Syvertsen, 1997, p. 206, Plate 42; Moazzam, 1973, p. 56, pl. 133, Fig. a.

Cells longer than broad; apertures almost absent or as narrow lanceolate openings; setae perpendicular to main axis.

Local Distribution: Table 3.

General Distribution: Cupp, 1943, West Coast of North America; Brunel, 1962, Chaleurs Bay (Canada); Wood, 1963, Indian Ocean; Hendey 1964, British Coastal Waters; Moazzam, 1973, Manora Channel (Karachi).

Discussion

In all 17 species of *Chaetoceros* have been reported from the area of study (Table 2). This number is low when compared with other studies in the North Arabian Sea (Subrahmanyan, 1946; Simonsen, 1974; Kuzmenko, 1975; Saifullah & Moazzam, 1978) and Peter the Great Bay, in the northwestern part of the Sea of Japan (Shevchenko *et al*., 2006). The paucity of species diversity in the area may be accounted for the fact that the samples were collected thirty two years ago as a result of which some specimens were damaged to the extent that they could not be identified properly. There may be further more species but since the *Chaetoceros* specimens were not complete their identification could not be confirmed.

All species were reported by other workers in the N. Arabian Sea (Subrahmanyan, 1946; Simonsen, 1974; Kuzmenko, 1975; Saifullah & Moazzam, 1978; Saifullah & Chaghtai, 2005). Among all the species *C. coarctatus* was the most common species and next were *C. messanensis* and *C. lorenzianus*, while others were rare in the study area (Fig. 19). Kuzmenko (1975) reported *C. curvisetus* as the most abundant species in the Arabian Sea.

Maximum diversity with as many as 16 species occurred during the northeast monsoon season in the winter month of February (Fig. 21). Kuzmenko (1975) also observed maximum number of species during the same period in the Arabian Sea.

The Indus Delta shelf was more diverse and productive than the Balochistan shelf. Fig. 20 shows that all 17 species were present in the former area whereas only 13 in the latter area. Visual estimates revealed very high abundance of the species in the former area. Moreover, all the species were more frequent. Saifullah (1979) also observed high chlorophyll ‘a’ concentrations in the same area.

Ecologically, most species present were neritic (Cupp, 1943) because the area included the continental shelf of Pakistan (Table 4). The presence of some oceanic species indicates influx of oceanic water in the shelf area.

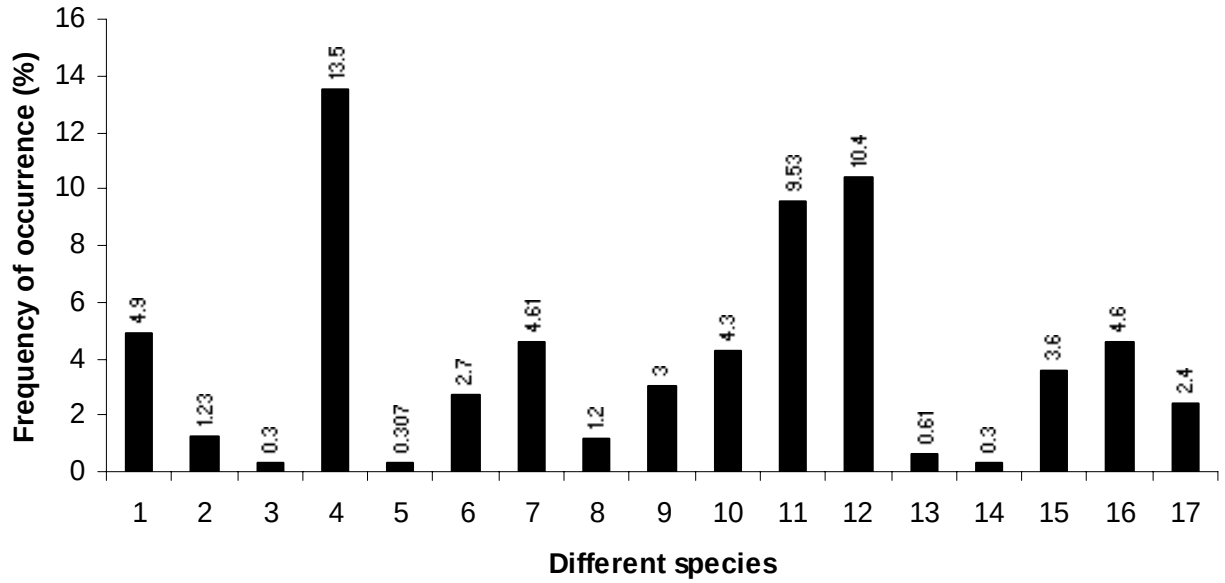

Fig. 19. Frequency of occurrence of different species of *Chaetoceros* on the entire Pakistan shelf. (Nos. 1-17 refer to species maintained in Tables 2-3).

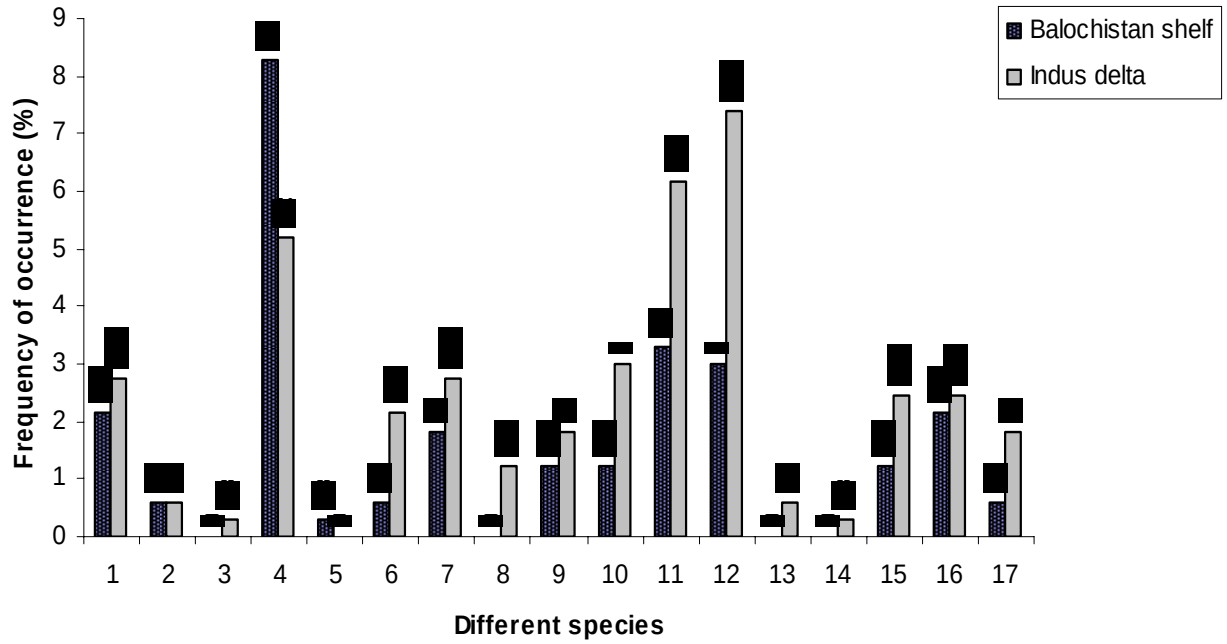

Fig. 20. Comparative frequency of occurrence of different species of *Chaetoceros* on Indus delta and Balochistan shelves. (Nos. 1-17 refer to species mentioned in Tables 2-3).

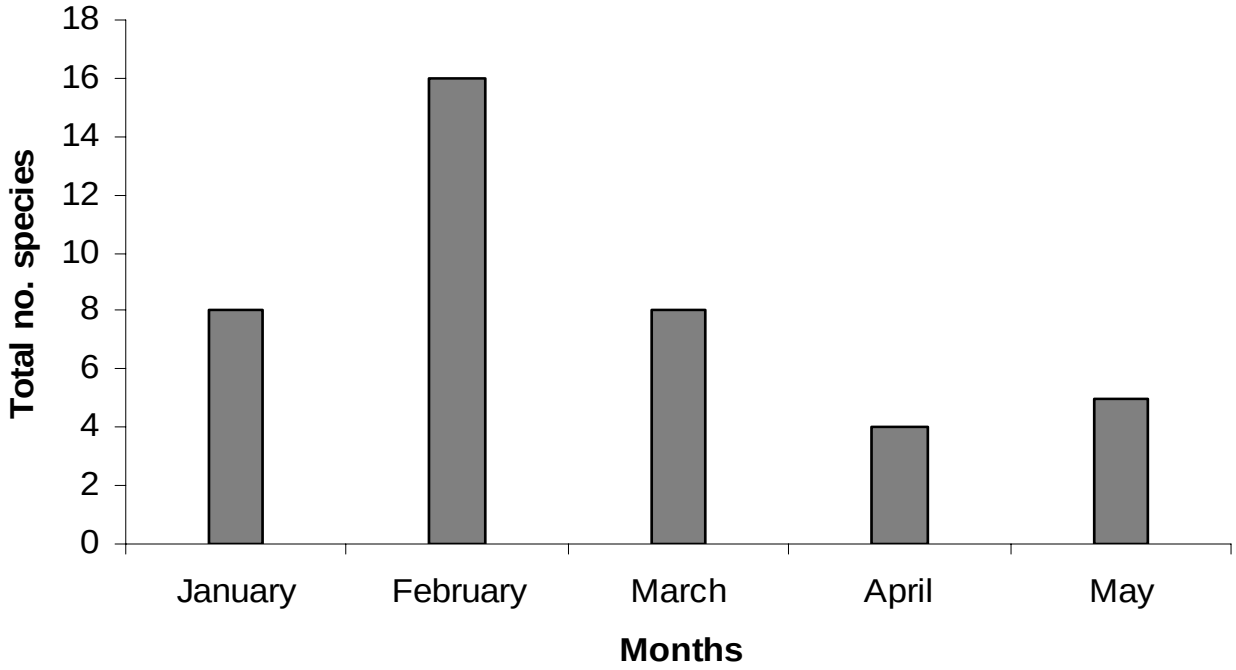

Fig. 21. Total number of species recorded in a given month of study period.

Table 4. Ecological distribution of *Chaetoceros* spp. (Cupp, 1943). No. 1-17 represent different species as in other Tables.

No. of spp.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Ecological distribution	N	O	N	O	N	N	O	N	N	N	N	O	N	O	O	N	N

N= Neritic
O= Oceanic

References

Brunel, J. 1962. *Le Phytoplankton de la Baie des Chaleurs*. Les Presses de l'Universite de Montreal. pp. 365.

Cupp. E.E. 1943. Marine planktonic diatoms of the west coast of North America. *Bull. Scripps Instn. Oceanogr. Univ. Calif*., 5(1): pp. 238.

Hasle, G.R. and E.E. Syvertsen. 1997. Marine Diatoms (5-386). In: *Identifying Marine Phytoplankton.* (Ed): C. R. Tomas. Academic Press, N.Y.

Hendey, N.I. 1964. *An introductory account of the smaller algae of British coastal waters*. Fishery Investigations Series 1V, Part V. Bacillariophyceae (Diatoms). H.M. Stationery Office, pp. 317.

Kuzmenko, V. 1975. Systematic composition of phytoplankton of Arabian Sea. *Biology of the Sea*, 34: 15-261.

Moazzam, M. 1973. *Taxonomic and seasonal studies of planktonic centric diatoms from Manora channel (Lower Harbour) Karachi*. M.Sc. Thesis, Department of Marine Biology. Karachi University, pp. 350.

Rines, J.E.B. 1999. Morphology and taxonomy of *Chaetoceros contortus* Schutt 1895, with preliminary observations on *Chaetoceros compressus* Lauder 1864 (Subgenus Hyalochaete, Section Compressa). *Bot. Mar*., 42: 539-551.

Saifullah, S.M. 1979. Occurrence of dinoflagellates and distribution of Chlorophyll 'a' on Pakistan's Shelf, 203-208. In: *Toxic dinoflagellates blooms*. (Ed.): Taylor/Seliger, Elsevier North Holland Inc.

Saifullah, S.M. and F. Chaghtai. 2005. Effect of "Tasman Spirit" oil spill on marine plants in the coastal area of Karachi. *Int. J. Biol. Biotech*., 2(2): 299-306.

Saifullah, S.M. and M. Moazzam. 1978. Species composition and seasonal occurrence of centric diatoms in a polluted marine environment. *Pak. J. Bot*., 10(1): 53-64.

Shevchenko, O.G., T.Y. Orlava and D.U. Hernandez-Becerril. 2006. The *Chaetoceros* (Bacillariophyta) from Peter the Great Bay, Sea of Japan. *Bot. Mar*., 49: 236-258

Simonsen, R. 1974. *The diatom plankton of the Indian Ocean Expedition of R/V "Meteor" 1964-1965*. "Meteor" Forschungsergebnisse. Gebruder Borntraeger, Berlin. pp. 66.

Subrahmanyan, R. 1946. A systematic account of the marine plankton diatoms of the Madras coast. *Proc. Ind. Acad. Sci*., 24B: 85-197.

Wood, E.J.F. 1963. Checklist of diatoms recorded from Indian Ocean. *Rep. Div. Fish Oceanogr*. C.S.I.R.O. 36: 1-304.

(Received for publication 30 July 2009)