

## MARINE CENTRIC DIATOM *RHIZOSOLENIA* BRIGHTWELL: ITS OCCURRENCE AND DISTRIBUTION IN NERITIC WATERS OF PAKISTAN

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### Abstract

Seventeen taxa including 14 species and varieties of marine centric diatom of the genus *Rhizosolenia* Brightwell from the Northwest Arabian Sea shelf of Pakistan are described. Almost all species were recorded on both Balochistan and Indus Delta shelves. *R. imbricata* was the most common species and next were *R. bergonii* and *R. striata*. Maximum numbers of species were recorded in winter season characterized by upwelling due to surface cooling.

### Introduction

The diatom genus *Rhizosolenia* is one of the most diverse genera among centric diatoms. It has a very distinct morphological structure with respect to its cell wall and markings present on it (Round *et al.*, 1990). A great many workers throughout the world studied its morphology, ecology and physiology from different parts of the world (Cupp, 1943; Hendey, 1964; Hasle & Syvertsen, 1997; Sunesen & Sar, 2007) and specifically its unique association with blue green algae living inside the frustule as endophytes (Sundstrom, 1984). However, information of this genus from North Arabian Sea is not adequate (Subrahmanyam, 1946; Wood, 1963; Simonsen, 1974; Kuzmenko, 1975a) and that from Pakistan shelf is even more scanty (Simonsen, 1974; Kuzmenko, 1975a; Saifullah & Chaghtai, 2005). Moazzam (1973) and Saifullah & Moazzam (1978) described 20 taxa including 4 varieties in detail from Karachi Harbour only.

The present paper covers considerable information related to taxonomy, occurrence and distribution of the genus *Rhizosolenia* from the entire Pakistan shelf which could be considered as a baseline for marine studies in the area in the near future.

### Materials and Methods

Materials and methods and the area of study have already been described and discussed earlier (Tabassum & Saifullah, 2010). All the stations sampled were also the same as reported earlier.

**Observations:** Following is an account of 17 taxa including 14 species and varieties along with morphometric data regarding size measurements recorded from Northwest Arabian Sea bordering Pakistan. Their local distribution is mentioned in Table 1.

***Rhizosolenia acuminata* (H. Peragallo) Gran (Fig. 1)**

**Basionym:** *Rhizosolenia temerei* var. *acuminata* H. Peragallo

Cupp (1943), p. 94, Fig. 53; Hendey (1964), p. 151; Saunders & Glenn, (1969), p. 96, pl. 5. Fig. 23; Moazzam, (1973), p. 44, pl. 127, Fig. d; Hasle & Syvertsen, (1997), p. 153, Plate 29.

Cells cylindrical; solitary; apical part of the valve deeply conical with narrow end; spine short, pointed terminally; intercalary bands scale like.

### Morphometric data

Apical axis: 60 µm - 135 µm

Length of process: 16 µm - 18 µm

**Local distribution:** Table 1

**General distribution:** Cupp (1943), West Coast of North America; Wood (1963), Indian Ocean; Hendey (1964), British Coastal Waters; Saunders & Glenn, (1969), Memoirs of the Hourglass Cruises; Moazzam (1973), Manora Channel (Karachi).

***Rhizosolenia bergonii* H. Peragallo (Fig. 2)**

**Synonym:** *Rhizosolenia amputate* Ostensfeld

Cupp (1943), p. 81, Fig. 43. Hendey (1964), p. 151, Plate 3, Fig. 4; Moazzam (1973), p. 35, Plate 121, fig. b, c; Hasle & Syvertsen, (1997), p. 155, Plate 29; Sunesen & Sar, (2007), p. 629-631, Fig. 4-15.

Cells cylindrical, solitary; valves deeply conical with long narrow, tubular apex terminated with forked process.

### Morphometric data

Apical axis: 30 µm - 40 µm

Length of process: 9 µm - 11 µm

**Local distribution:** Table 1

**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; Sunesen & Sar, (2007), Buenos Aires coastal waters (Argentina).

***R. castracanei* var. *castracanei* H. Peragallo (Fig. 3)**

Hasle & Syvertsen, (1997), p. 51, Plate 28.

Cells cylindrical, conical with oblique apex; spine short tubular; intercalary bands scale like, rhombic.

### Morphometric data

Apical axis: 232 µm - 280 µm

Length of process: 5 µm - 6 µm

**Local distribution:** Table 1

***R. castracanei* var. *neglecta* Sundstrom (Fig. 4)**

Hasle & Syvertsen, (1997), p. 51, Plate 28.

Cells cylindrical with conical apex; intercalary bands composed in two rows, rhombic, scale like; spine triangular with pointed end with broad and hollow base.

### Morphometric data

Apical axis: 30 µm - 55 µm

Length of process: 18 µm

**Local distribution:** Table 1

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Table 1. Distribution of *Rhizosolenia* spp., on Pakistan shelf.

S. No.	Name of species	Stations
1.	<i>Rhizosolenia acuminata</i> (H. Peragallo) Gran	30, 55, 59, 75, 76, 80, 82, 88, 93, 97, 110, 111, 120, 128, 131, 135, 136, 153
2.	<i>R. bergonii</i> H. Peragallo	2, 8, 10, 12, 30, 51, 53, 58, 60, 65, 66, 67, 73, 75, 76, 77, 78, 80, 82, 84, 86, 87, 88, 90, 92, 93, 94, 95, 97, 99, 101, 102, 107, 108, 110, 113, 120, 124, 125, 127, 131, 135, 136, 141, 146, 149, 151, 153, 154, 161, 225, 295
3.	<i>R. castracanei</i> var. <i>castracanei</i> H. Peragallo	75, 107, 111, 142, 206
4.	<i>R. castracanei</i> var. <i>neglecta</i> Sundstrom	75
5.	<i>R. clevei</i> var. <i>clevei</i> Ostensfeld	8, 60, 65, 75, 94, 97, 113, 120, 128, 131
6.	<i>R. clevei</i> var. <i>communis</i> Sundstrom	73, 86, 88, 92, 93, 97
7.	<i>R. crassispina</i> Schroeder	30, 76, 77, 78, 88, 93, 99, 150
8.	<i>R. fallax</i> Sundstrom	10, 65, 84, 95, 101, 111, 121, 141, 146, 150, 295
9.	<i>R. formosa</i> H. Peragallo	65, 67, 73, 75, 77, 88, 94, 97, 101, 103, 110, 111, 113, 120, 124, 125, 128, 131, 133, 135, 136, 141, 145, 152, 153, 171, 191
10.	<i>R. hebetata</i> f. <i>semispina</i> (Hensen) Gran	8, 10, 75, 78, 79, 99, 101, 108, 131, 136, 151, 153, 161
11.	<i>R. hyalina</i> Ostensfeld in Ostensfeld & Schmidt	59, 65, 67, 73, 75, 78, 86, 88, 94, 95, 101, 110, 120, 124, 128, 139, 146, 150, 153, 191, 295
12.	<i>R. imbricata</i> Brightwell	2, 8, 10, 30, 47, 50, 51, 55, 57, 58, 59, 60, 65, 66, 67, 70, 73, 75, 76, 77, 78, 80, 84, 86, 87, 88, 92, 93, 94, 95, 97, 99, 100, 101, 102, 103, 107, 108, 110, 111, 113, 114, 120, 121, 124, 125, 127, 128, 131, 132, 133, 135, 136, 139, 134, 142, 141, 145, 149, 150, 151, 153, 154, 159, 171, 183, 196, 224, 225, 266, 274, 295
13.	<i>R. setigera</i> f. <i>pungens</i> (Cleve-Euler) Brunel	65, 76, 78, 84, 88, 93, 94, 97, 99, 101, 224
14.	<i>R. setigera</i> f. <i>setigera</i> Brightwell	30, 70, 76, 82, 86, 88, 89, 92, 93, 100, 107, 151, 153
15.	<i>R. simplex</i> Karsten	30, 84, 93, 97, 107, 141
16.	<i>R. striata</i> Greville	10, 58, 59, 65, 67, 73, 75, 78, 84, 86, 88, 94, 95, 99, 100, 101, 104, 102, 103, 107, 108, 110, 113, 114, 120, 121, 124, 125, 127, 128, 129, 131, 132, 133, 135, 136, 141, 150, 154, 160
17.	<i>R. styliiformis</i> Brightwell	2, 30, 47, 58, 60, 65, 66, 67, 70, 73, 81, 108, 110, 120, 121, 127, 128, 132, 136, 141, 151, 153

***R. clevei* var. *clevei* Ostensfeld (Fig. 5)**

Hasle &amp; Syvertsen, (1997), p. 51, Plate 28.

Cells cylindrical, deeply conical apex; intercalary bands numerous scale like.

**Morphometric data**

Apical axis: 8 µm

**Local distribution:** Table 1***R. clevei* var. *communis* Sundstrom (Fig. 6)**

Hasle &amp; Syvertsen, (1997), p. 51, Plate 28.

Cells cylindrical with conical apex; process long conical at the base; intercalary bands rhombic in two rows.

**Morphometric data**

Apical axis: 8 µm - 18 µm

Length of process: 25 µm - 28 µm

**Local distribution:** Table 1***R. crassispina* Schroeder (Fig. 7)**

Subrahmanyam (1946), p. 119, Figs. 138 &amp; 139.

Cells cylindrical; valves deeply conical furnished with long, process swollen at the base, pointed towards the end.

**Morphometric data**

Apical axis: 15 µm - 56 µm

Length of process: 45 µm - 58 µm

**Local distribution:** Table 1**General distribution:** Subrahmanyam (1946), Madras coast (India)***R. fallax* Sundstrom (Fig. 8)**

Hasle &amp; Syvertsen, (1997), p. 156, Plate 29.

Cells cylindrical, solitary or in short chains; valves obliquely conical, terminated with a process, swollen at the base, otarium present; intercalary bands zigzag in ventral view.

**Morphometric data**

Apical axis: 8 µm - 22 µm

Length of process: 13 µm - 15 µm

**Local distribution:** Table 1***R. formosa* H. Peragallo (Fig. 9)****Synonym:** *Rhizosolenia styliiformis* f. *latissima* "Brightwell" in H. Peragallo.

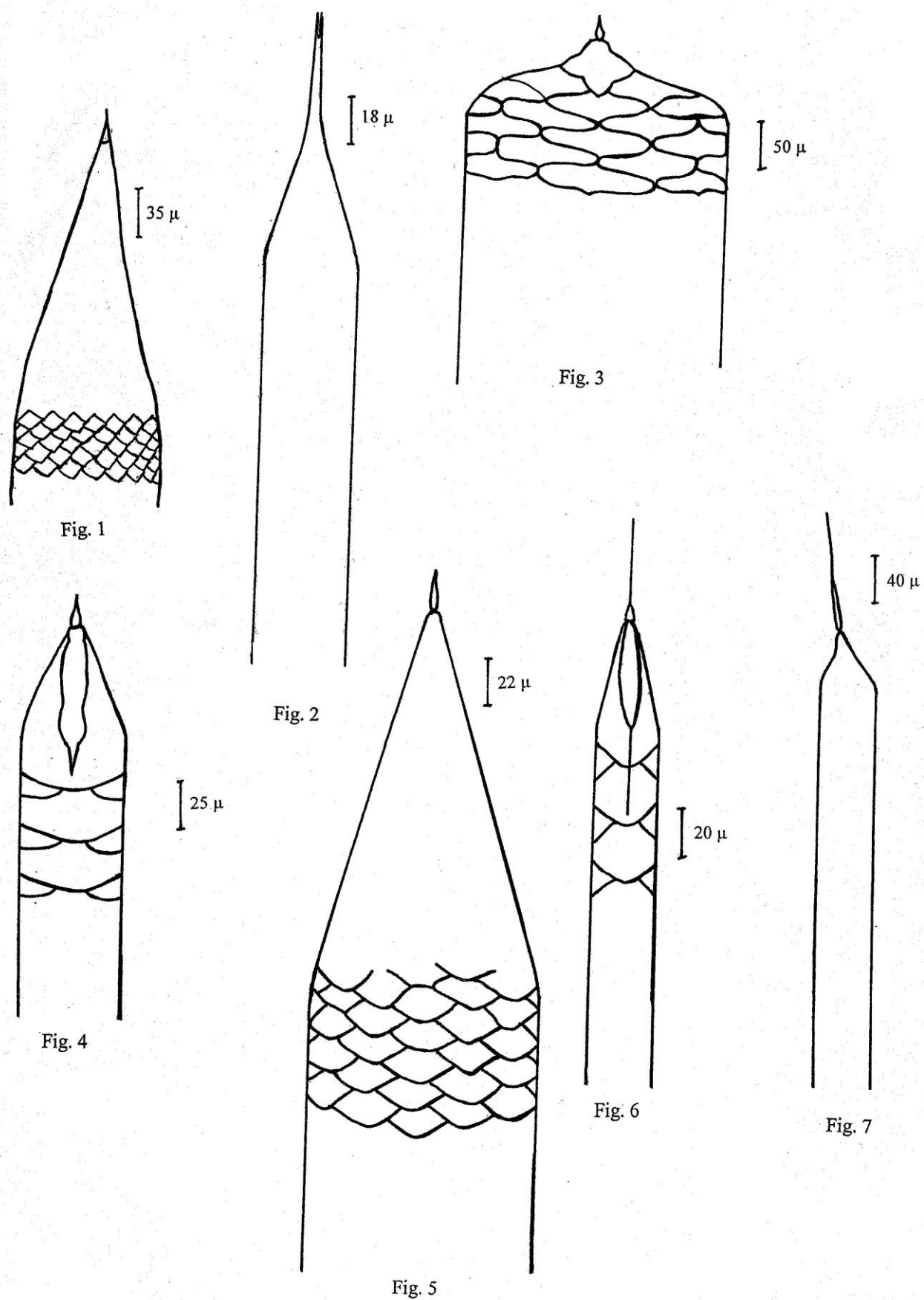
Hasle &amp; Syvertsen, (1997), p. 146, Plate 26.

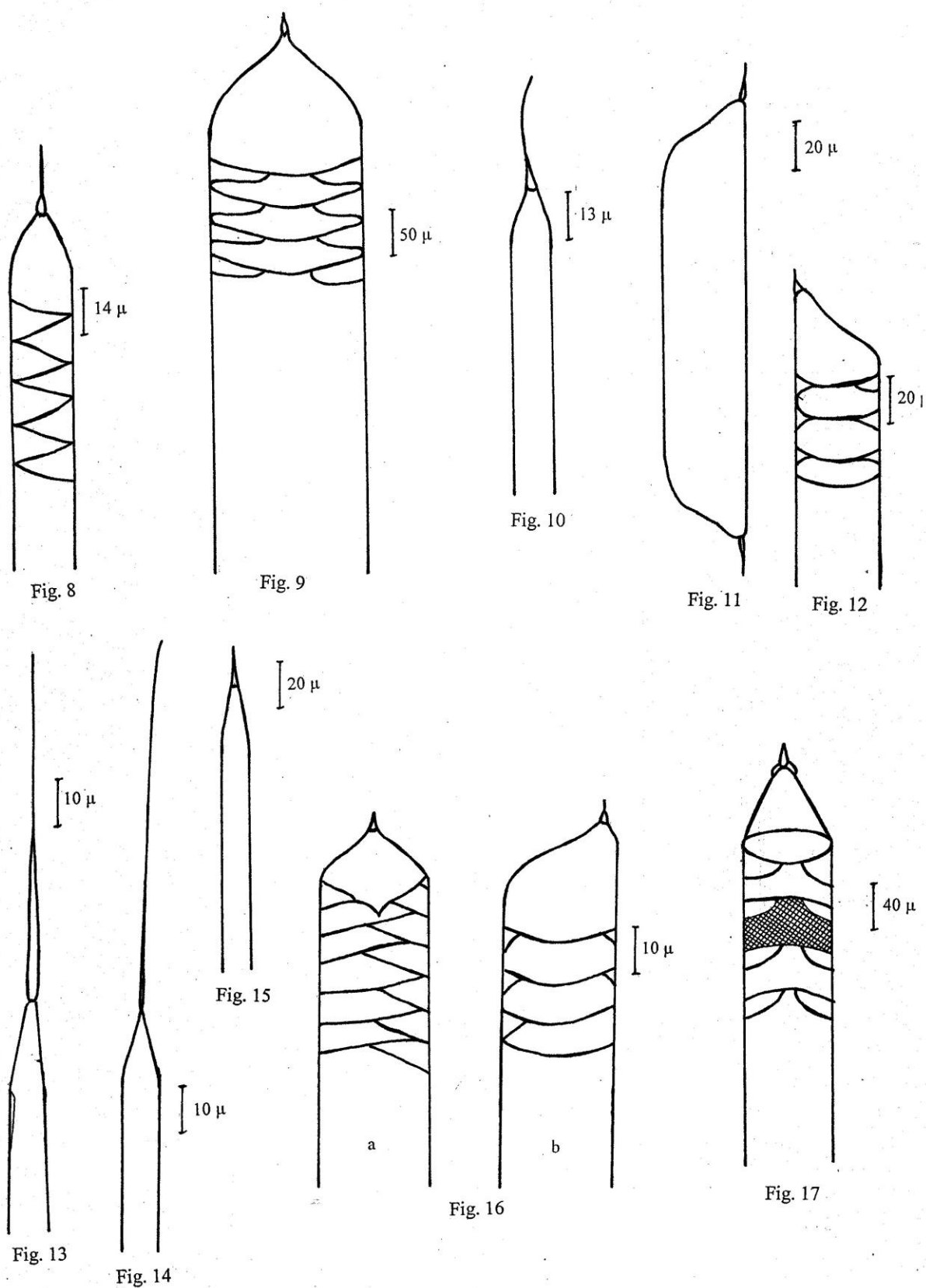
Cells cylindrical; valves conical with slightly oblique apex; process hollow, short otaria present at the base of process; intercalary bands rhombic in two rows;

**Morphometric data**

Apical axis: 118 µm - 165 µm

**Local distribution:** Table 1**General distribution:** Wood (1963), Indian Ocean.

Fig. 1. *Rhizosolenia acuminata*: girdle viewFig. 2. *Rhizosolenia bergonii*: girdle viewFig. 3. *R. castracanei* var. *castracanei*: girdle viewFig. 4. *R. castracanei* var. *neglecta*: girdle viewFig. 5. *R. clevei* var. *clevei*: girdle viewFig. 6. *R. clevei* var. *communis*: girdle viewFig. 7. *R. crassispina*: girdle view

Fig. 8. *R. fallax*: girdle viewFig. 9. *R. formosa*: girdle viewFig. 10. *R. hebetata* f. *semispina*: girdle viewFig. 11. *R. hyalina*: girdle viewFig. 12. *R. imbricata*: girdle viewFig. 13. *R. setigera* f. *pungens*: girdle viewFig. 14. *R. setigera* f. *setigera*: girdle viewFig. 15. *R. simplex*: girdle viewFig. 16. *R. striata*: (a) ventral view; (b) lateral viewFig. 17. *R. styliformis*: girdle view

***R. hebetata* f. *semispina* (Hensen) Gran (Fig. 10)****Basionym:** *Rhizosolenia semispina* Hensen

Cupp (1943), p. 88, Fig. 50-B; Hendey (1964), p. 150, Plate 2, Fig. 1; Subrahmanyam (1946), p. 119, figs. 133-136; Moazzam (1973), p. 40, pl. 125, fig. c, d; Hasle & Syvertsen, (1997), p. 149, Plate 27.

Cells cylindrical, apical part slightly conical; spines curved and straight as well and hollow at the base; intercalary bands composed of zigzag lines in lateral position of valves while rhombic in girdle view.

**Morphometric data**

Apical axis: 9 µm - 18 µm

**Local distribution:** Table 1

**General distribution:** Cupp (1943), West Coast of North America; Subrahmanyam (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.

***R. hyalina* Ostenfeld in Ostenfeld & Schmidt (Fig. 11)****Synonym:** *Rhizosolenia pellucida* Cleve

Hasle & Syvertsen, (1997), p. 151, Plate 28; Sunesen & Sar, (2007), p. 631-633, Fig. 16-24.

Cells cylindrical, valves conical, process hollow, straight and some times slightly curved, otaria present.

**Morphometric data**

Apical axis: 18 µm - 35 µm

**Local distribution:** Table 1

**General distribution:** Wood (1963), Indian Ocean; Sunesen & Sar, (2007), Buenos Aires coastal waters (Argentina).

***R. imbricata* Brightwell (Fig. 12)****Synonyms:** *Rhizosolenia shrubsolei* Cleve; *Rhizosolenia imbricata* var. *shrubsolei* (Cleve) Schroeder.

Cupp (1943), p. 84-86, Fig. 47; Subrahmanyam (1946), p. 117, figs. 116, 121-123; Hendey (1964), p. 149, Plate 3, Fig. 1; Moazzam (1973), p. 38, pl. 124, fig. a; Hasle & Syvertsen, (1997), p. 155, Plate 29; Sunesen & Sar, (2007), p. 633 & 634, Fig. 534-636.

Cells cylindrical, solitary some times in chains; process short swollen at the base; intercalary bands scale like.

**Morphometric data**

Apical axis: 25 µm - 36 µm

**Local distribution:** Table 1

**General distribution:** Cupp (1943), West Coast of North America; Subrahmanyam (1946), Madras coast (India); Wood, (1963), Indian Ocean; Hendey (1964), British Coastal Waters; Moazzam (1973), Manora Channel (Karachi); Simonsen, (1974), Indian Ocean; Sunesen & Sar, (2007), Buenos Aires coastal waters (Argentina).

***R. setigera* f. *pungens* (Cleve-Euler) Brunel (Fig. 13)****Synonym:** *Rhizosolenia pungens* Cleve Euler

Brunel (1962), Plate 4, Figs. 5, 6; Hasle & Syvertsen, (1997), p. 157, Plate 30; Sunesen & Sar, (2007), p. 633, Fig. 35-47 (635).

Cells cylindrical; valves conical, terminated with long process, narrow at the base gradually swollen almost half of its length, pointed towards ends, otaria absent.

**Morphometric data**

Apical axis: 8 µm - 48 µm

Length of process: 70 µm - 76 µm

**Local distribution:** Table 1

**General distribution:** Brunel (1962), Chaleurs Bay (Canada); Sunesen & Sar, (2007), Buenos Aires coastal waters (Argentina).

***R. setigera* f. *setigera* Brightwell (Fig. 14)**

Hasle & Syvertsen, (1997), p. 157, Plate 30; Sunesen & Sar, (2007), p. 633 & 634, Fig. 25-34 (635).

Cells cylindrical, solitary; valves conical; process long, thick at the base to some distance with tapering ends; otaria absent; intercalary bands invisible in our specimens.

**Morphometric data**

Apical axis: 8 µm - 15 µm

Length of process: 75 µm - 80 µm

**Local distribution:** Table 1

**General distribution:** Cupp (1943), West Coast of North America; Subrahmanyam (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; Sunesen & Sar, (2007), Buenos Aires coastal waters (Argentina).

***R. simplex* Karsten (Fig. 15)**

Hasle & Syvertsen, (1997), p. 155, Plate 29.

Cells cylindrical, solitary; valves conical; process short swollen at the base and pointed towards the end; otaria absent.

**Morphometric data**

Apical axis: 12 µm - 20 µm

Length of process: 12 µm - 16 µm

**Local distribution:** Table 1

**General distribution:** Wood (1963), Indian Ocean.

***R. striata* Greville (Fig. 16)**

Hasle & Syvertsen, (1997), p. 156, Plate 29.

Cells cylindrical, solitary; valves conical; process short hollow; otaria small.

**Morphometric data**

Apical axis: 18 µm - 45 µm

**Local distribution:** Table 1

***R. styliformis* Brightwell (Fig. 17)**

**Synonym:** *Rhizosolenia styliformis* var. *longispina* Hustedt in A. Schmidt

Cupp (1943), p. 87, Fig. 48-A; Subrahmanyam (1946), p. 117, figs. 114 & 125; Hendey (1964), p. 150, Plate 2, Fig. 1; Hasle & Syvertsen, (1997), p. 146, Plate 26.

Cells cylindrical; valves conical, terminated by short process provided with wings at the base; otaria present at its base; intercalary bands scale like, in two columns.

**Morphometric data**

Apical axis: 28  $\mu$ m - 87  $\mu$ m

**Local distribution:** Table 1

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

**Discussion**

In this study as many as 17 taxa belonging to 14 species of the genus *Rhizosolenia* are reported along with their spatial and temporal distribution and is the first documented description of this genus from the North Arabian Sea bordering Pakistan.

The focused area of present study includes two shelves i.e., Indus Delta shelf and Balochistan shelf. *R. imbricata* was the most frequent species found in both the shelves followed by *R. bergonii* and *R. striata* (Fig. 18). It is also evident from Fig. 19 that the species are more frequent on Balochistan shelf than on Indus Delta shelf. Three species were found exclusively on Balochistan shelf and only two on Indus Delta shelf (Fig. 19).

Comparison with earlier works (Subrahmanyam, 1946; Simonsen, 1974; Kuzmenko, 1975a; Saifullah & Moazzam, 1978) shows a significant difference not only in terms of number of species but also in the fact that some of the species of this genus have been transferred to other genera as per recent nomenclatural combinations (Round *et al.*, 1990, Hasle & Syvertsen, 1997, Sunesen & Sar, 2007). For example, several species of *Rhizosolenia* have been transferred to other genera such as *Neocalyptrella*, *Proboscia*, *Pseudosolenia*, *Guinardia* and *Dactyliosolen*. Moazzam (1973) and Saifullah & Moazzam (1978) described 20 taxa including 4 varieties from Karachi Harbour only.

Fig. 20 shows the temporal distribution of total number of species recorded in each month. It is evident that a peak in species diversity was noted during the winter period which coincides with winter upwelling season in the North Arabian Sea resulting in enrichment of the euphotic zone (Silva *et al.*, 2009).

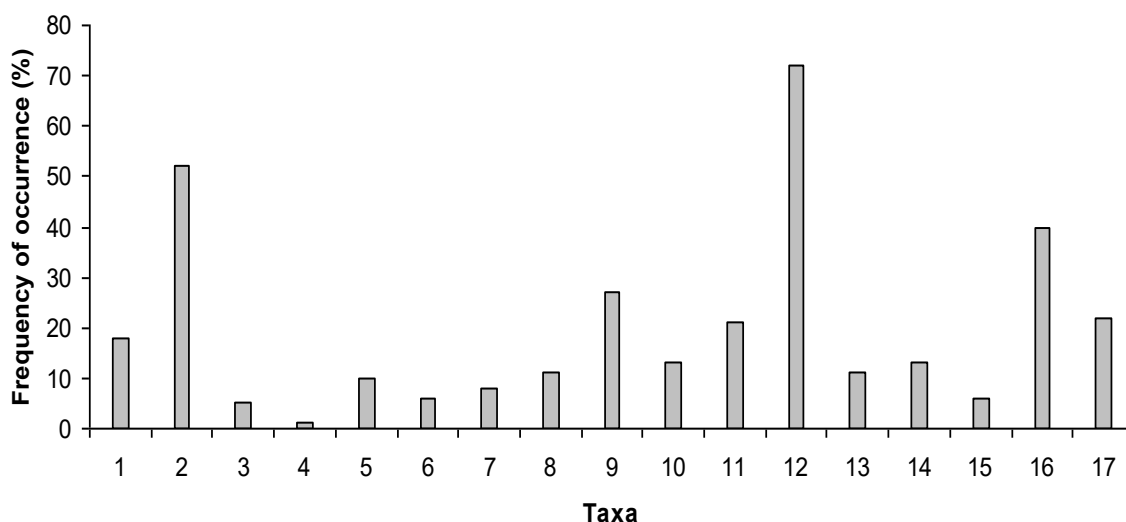


Fig. 18. Frequency of occurrence of different species of *Rhizosolenia* on the entire Pakistan shelf. (Nos. 1-17 refer to species mentioned in Table 1).

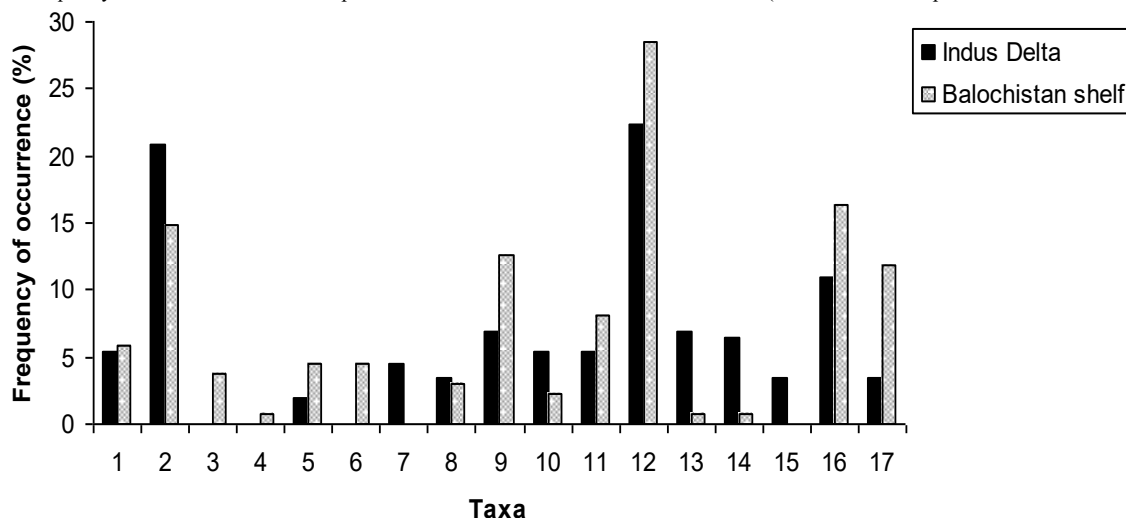


Fig. 19. Comparative frequency of occurrence of different species of *Rhizosolenia* on Indus delta and Balochistan shelves. (Nos. 1-17 refer to species mentioned in Table 1).

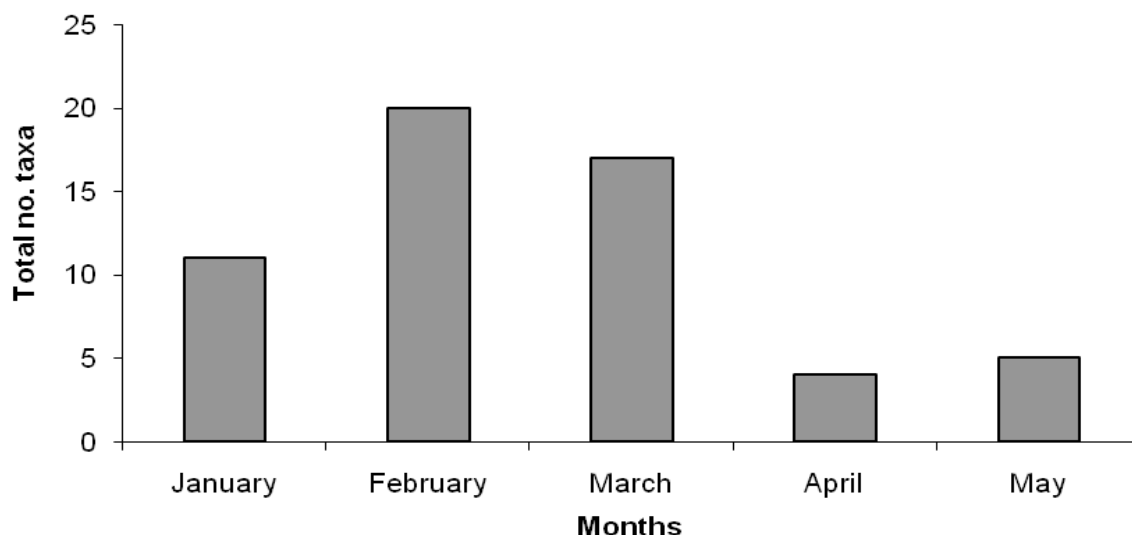


Fig. 20. Total number of taxa of *Rhizosolenia* recorded during different months in the study period.

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