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TAXONOMIC AND ECOLOGICAL STUDIES ON THREE MARINE GENERA OF DINOPHYSIALES FROM ARABIAN SEA SHELF OF PAKISTAN

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Abstract

The present paper describes the composition, occurrence and distribution of species belonging to three dinoflagellate genera *Dinophysis*, *Phalacroma* and *Histioneis* from the north Arabian Sea shelf of Pakistan and adjacent deep sea during the northeast monsoon season and the transition period. The most diverse genus was *Phalacroma* including two toxic species. It is probably for the first time that 6 species of *Histioneis* are reported from the area. The most common and widespread species was *Dinophysis caudata* Sville-Kent followed by *D .miles* Cleve and may, therefore, be regarded as characteristic species of the area. There seems to be a seasonal isolation among species on the basis of their temperature and salinity tolerances.

Introduction

The dinoflagellates are a large group of phytoplankton. Their populations are distributed depending on temperature, salinity or depth (Taylor, 1976; Hallegraeff & Lucas, 1988). Members of the order Dinophysiales Lindemann, are thecate, motile and laterally compressed with a sagittal serrate suture extended throughout the body and variable development of cingular and sulcal lists (Hernández-Becerril *et al.,* 2008). Many species of this order are non-photosynthetic, but some species are photosynthetic especially belonging to *Dinophysis* containing pigments and chloroplasts of endosymbiotic origin, related to Cryptophyta (Schnepf & Elbrachter, 1999). Many *Dinophysis* and *Phalacroma* species produce toxin which cause diarrhetic shellfish poisoning Lee *et al*., 1989; Godhe *et al*., 2002; Taylor *et al*., 2003).

The genera *Dinophysis* Ehrenberg, *Histioneis* Stein and *Phalacroma* Stein are marine planktonic dinoflagellates belonging to the order Dinophysiales Lindemann and family Dinophysiaceae Stein. G**ó**mez (2005a) described a list of 145 species of *Dinophysis* + *Phalacroma* (104 + 41) and 65 species of *Histioneis* throughout the world. They commonly occur in tropical and temperate seas throughout the world (Solum, 1962; Wood, 1968; Sournia, 1973; Hallegraeff & Lucas, 1988), but information from north Arabian Sea shelf of Pakistan is scanty and sporadic (Nooruddin, 1967; Kuzmenko, 1975; Taylor, 1976; Gul & Saifullah, 2007). The present study was carried out on the entire continental shelf of Pakistan including the deep sea vicinity of north Arabian Sea.

Materials and Methods

Samples were collected during the cruise of Norwegian research vessel “Dr. Fridtjof Nansen” which was carried out in the northwest Arabian Sea bordering Pakistan extending from 15m depth contour near shore to 150 nautical miles offshore in the open sea during the period 19.01.1977 to 20.06.1977 (Anon., 1978; Saifullah, 1979). In all 75 fixed positions were sampled repeatedly on the shelf and deep-sea vicinity occupying 230 stations on different occasions (Saifullah *et al*., 2008; Gul & Saifullah, 2009). Phytoplankton samples were colleted by horizontal net hauls of 5 minutes duration at each station, the mesh size of the net being 40µm. All samples were collected which were immediately fixed with 4% neutral formalin at the time of sampling. They were later studied and identified in the laboratory under a light research microscope. Temperature and salinity of seawater were measured using a thermometer and salinometer respectively. Water mounts using trypan blue were examined to obtain information on plate patterns to help in species identification and taking photographs by digital camera. Other samples were rinsed of salt and were mounted directly on stabs for scanning electron microscopy (SEM) for identification. The sizes of several cells of a given species were also measured. Frequency of occurrence of a given species was determined by ratio of the number of stations occupied by given species to the total number of stations sampled (230) multiplied by 100.

Observations

Dinophysiales Lindemann
Dinophysiaceae Stein

Dinophysis caudata Saville-Kent
Fig. 1

Saville- Kent, 1881, p. 455, 460; Stenidinger & Williams, 1970, p. 48, pl. 17, figs. 46, 47; Hassan & Saifullah, 1971, p. 67, fig. 4; Taylor, 1976, p. 34, pl.6, fig. 59.

Small sized body, irregularly elliptical; epitheca low; hypotheca long, widest near the middle and then gradually tapering downward to form a narrow process with bilobed end; girdle list wide, ribbed; left sulcal list extends to the base of peduncle; two daughter cells jointed together at the dorsal point by wing; theca areolate.

Dimensions: 80-100 µm L, 45-58 µm W

Dinophysis expulsa Kofoid & Michener
Fig. 2

Kofoid & Michener, 1911, p. 268; Taylor, 1976, pl. 6, figs. 62a, b.

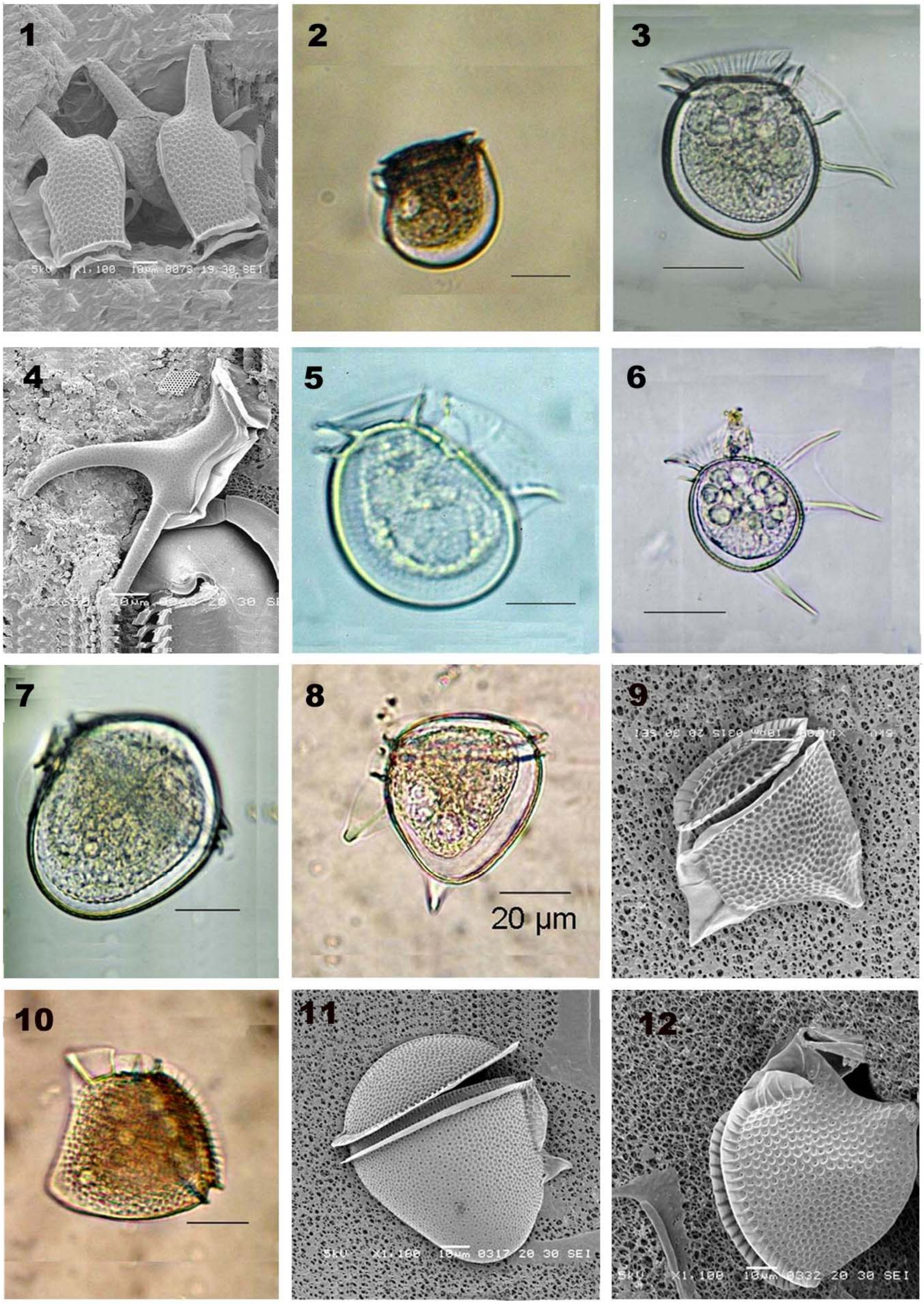
Syn: *Phalacroma expulsa* Kofoid & Skogsberg, 1928, p. 157, pl. 5, fig. 1, fig. 20/1-5.
Phalacroma stenopterygium Jörgensen, 1923, p. 11, fig. 10.

Body small, broadly rounded, sac like outline, widening posteriorly with marked lateral constrictions behind girdle; epitheca low, convex anteriorly, slightly higher ventrally; girdle moderate; anterior list wider than posterior; R3 absent, surface centrally faintly reticulate, with scattered pores centrally located in some of the meshes.

Dimensions: 60-65 µm L, 54-58 µm W

Dinophysis hastata Stein
Fig. 3

Stein, 1883, pl. 19, fig. 12; Taylor, 1976; pl.5, figs. 52-55; Stenidinger & Tangen, 1997, p. 433, pl. 12.



Figs. 1-12. Light microscopy (LM) and scanning electron microscopy (SEM). Fig. 1. *D. caudata*, SEM. Fig. 2. *D. explusa*, LM. Fig. 3. *D. hastata*, LM. Fig. 4. *D. miles*, SEM. Fig. 5. *D. ovum*, LM. Fig. 6. *D. schuettii*, LM. Fig. 7. *P. argus*, LM. Fig. 8. *P. doryphorum*, LM. 9. *P. favus*, SEM. Fig. 10. *P. mitra*, LM. Fig. 11. *P. ovum*, LM. Fig. 12. *P. rapa*, SEM. Scale bars: Figs. 2, 6, 10, 20 µm; Figs. 3, 5, 7, 15 µm.

Syn: *D. uracantha* auct. non Stein--- Silva, 1956, p. 356, pl. 3, fig. 5.

Medium sized cell, subovate, rounded posteriorly; epitheca low convex; girdle ribbed and funnel shaped; hypotheca rounded and widest near middle; left sulcal list widening to posterior main rib (R3) which curves rearward, sulcal list longer than wide, triangular hyaline posterior sail at or slightly ventral to length of posterior sail 11-14µm, theca closely areolated.

Dimensions: 70-91 µm L, 58-66 µm W

Dinophysis miles Cleve
Fig. 4

Kofoid & Skogsberg, 1928, p. 227; Hassan & Saifullah, 1971; p. 68, figs. 5a, b; Taylor, 1976, p. 38, pl.6, figs. 57- 58.

Body very variable; epitheca low and flat; hypotheca longer than wide; R1 is the rib at junction of left sulcal list and posterior cingular list, R2 is the rib of left sulcal list at place where this list is divided in binary fission, R3 is the rib of left sulcal list near posterior end of this list or; ventral margin of hypotheca to R3 almost straight or strongly wavy, with a large at R3, from which the long antapical process begins; dorsal process on dorsal side of hypotheca, running obliquely, curved from base, then straight and curved at end; anterior and posterior girdle lists similar, broad; left sulcal list reaching to the mid of posterior process; theca porlate.

Dimensions: 140-165 µm L, 56-70 µm W

Dinophysis ovum Schütt
Fig. 5

Schütt, 1895, pl. 1, fig. 6; Lebour, 1925, p. 81, pl. 12, fig. 3; Wood, 1954, p. 195, figs. 37a, b; Hassan & Saifullah, 1971, p. 66-67, fig.3.

Body irregularly oval, asymmetrical; epitheca disc shaped; hypotheca broadly rounded, dorsal contour more strongly convex than ventral; anterior girdle list wide and ribbed, left sulcal list broad, extend to half body length; theca porulate.

Dimensions: 55-60 µm L, 42-47 µm W

Dinophysis schuettii Murray & Whitting
Fig. 6

Murray & Whitting, 1899, p. 331, pl. 31, fig. 10; Kofoid & Skogsberg, 1928, p. 296, fig. 40/1-739; Taylor, 1976, pl. 6, figs. 65, 66.

Small sized species, body almost spherical to elliptical; epitheca low; hypotheca widest behind middle; posterior sail long, has a median rib joined to the marginal ribs; anterior girdle list high, left sulcal list broad, extended by R2 and R3 which are approximate to body width; theca with scattered poroids.

Dimensions: 60-72 µm L, 47-55 µm W

Phalacroma argus Stein
Fig. 7

Stein, 1883, pl. 18, figs. 15-17; Kofoid & Skogsberg, 1928, p. 104, fig. 8/1, 2, 9; Wood, 1968, p. 112, fig. 341; Steidinger & Tangen, 1997, p. 437, pl.14.

Syn: *Dinophysis argus* (Stein) Abe, 1967, p. 71, figs. 23a, b.

In ventral view body obovate; epitheca high and rounded; hypotheca rounded narrowing, areolate; girdle list may be ribbed, left sulcal list ½ body length, rounded and concave, R3 small and not well developed; theca reticulate, porulate.

Dimensions: 77-90 µm L, 72 µm W

Phalacroma doryphorum Stein
Fig. 8

Stein, 1883, p. 23, pl. 19, fig. 4; Wood, 1968, p. 114, fig. 346.

Syn: *Dinophysis doryphorum* (Stein) Abe, 1967; p. 77, fig. 26; Taylor, 1976, p. 35, pl. 4, figs. 41-42.

Body oval in lateral view; epitheca convex to flat; girdle convex, ribbed; hypotheca large, oval and narrow posteriorly; right sulcal list triangular, wide posteriorly and with acute ends; posterior sail with or without supporting rib, at or ventral to antapex; theca areolate.

Dimensions: 80-90 µm L, 62-70 µm W

Phalacroma favus Kofoid & Michener
Fig. 9

Kofoid & Michener, 1911, p. 289; Wood, 1968, p. 115, fig. 348; Steidinger & Tangen, 1997, p. 439, pl. 14.

Syn: *Dinophysis favus* (Kofoid & Michener) Balech, 1967, p. 82; Taylor, 1976, pl.5, Figs. 50, 51.

Body sub-cuneate; epitheca broadly rounded and narrow, shallow; posterior portion of hypotheca constricted to form protuberance with obtuse end, middle portion of hypotheca wide; girdle list at 40º, regularly and closely ribbed; no sagittal fin anterior and dorsal margins, ventral fin regularly and heavily ribbed with incomplete riblets.

Dimensions: 70-75 µm L, 60µm W

Phalacroma mitra Schütt
Fig. 10

Schütt, 1895, p. 149, pl. 4, fig. 18; Wood, 1968, p. 115, fig. 350; Steidinger & Tangen, 1997, p. 439, pl.14.

Syn: *Dinophysis mitra* (Schütt) Abé, 1967, p. 63, fig. 18a-q; Balech, 1988, p. 45, pl. 8, figs. 9-11.

Body laterally compressed; epitheca small cap like, slightly convex; hypotheca large with rounded base; left sulcal list widest at the base of the third rib; theca coarsely areolated.

Dimensions: 66-75 µm L, 55µm W

Phalacroma ovum Schütt
Fig. 11

Schütt, 1895, p. 90; Wood, 1954, p. 186, fig. 17;-1968, p. 116, fig. 353.

Syn: *Dinophysis amandula* Sournia, 1973, p. 18; Balech, 1988, p. 50, pl. 10, figs. 16-17.

Body ovate in lateral outline, deepest at or behind girdle; epitheca convex; hypotheca slightly inclined ventrally, may be oval wedge shaped; girdle not depressed, list without spines; sulcal list narrow anteriorly, wide posteriorly, straight or slightly concave, some times sigmoid.

Dimensions: 68-80 µm L, 60-70 µm W

Phalacroma rapa Stein
Fig. 12

Stein, 1883, p. 23, pl. 19, figs. 5, 8; Kofoid & Skogsberg, 1928, p. 139, fig. 16/1-5; Wood, 1968, p. 118, fig. 358; Steidinger & Tangen, 1997, p. 439, pl. 14.

Syn: *Dinophysis rapa* (Stein) Abe, 1967, p. 66, fig. 19; Balech, 1988, p. 44, pl. 8, figs. 6-8.

Small sized species, body subovate in lateral view; epitheca moderately convex to flat; hypotheca rounded to subacute, narrow; girdle list ribbed; right sulcal list varying in length, usually subtriangular, left sulcal list small to moderate.

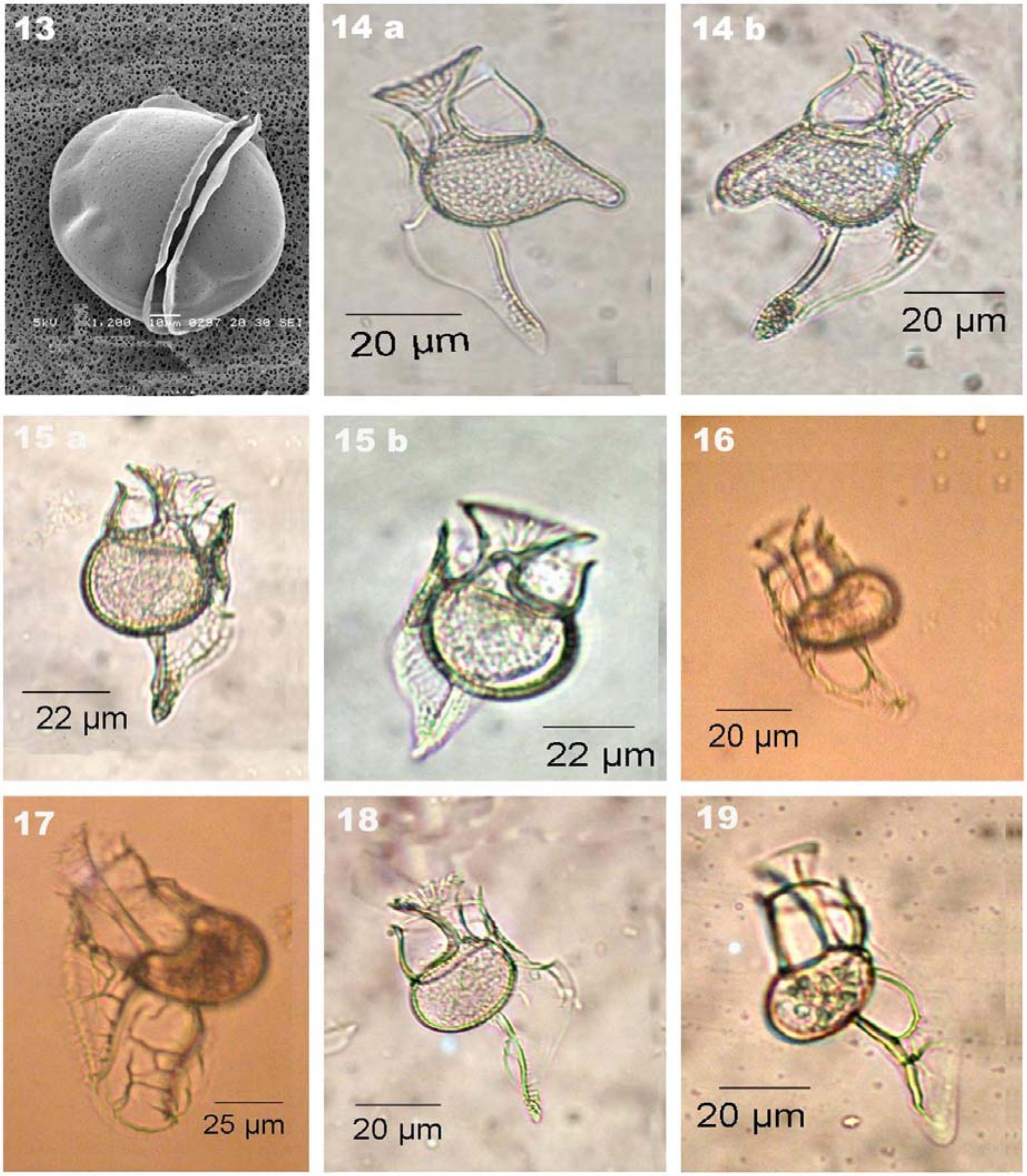
Dimensions: 80 µm L, 72 µm W

Phalacroma rotundata (Claparede & Lachmann**)** Kofoid & Michener
Fig. 13

Kofoid & Michener 1911, p. 290; Hassan & Saifullah, 1971, p. 65, fig. 2; Steidinger & Tangen, 1997, p. 439, pl. 14.

Syn: *Dinophysis rotundata* Claparede & Lachmann, 1859, p. 6, pl. 20, fig. 16.

Dinophysis whittingae Balech, 1971.



Figs. 13-19. Light microscopy (LM) and scanning electron microscopy (SEM). Fig. 13. *P. rotundata*, SEM. Fig. 14a,b. *H. biremis*, LM. Fig. 15,b. *H. crateriformis*, LM. Fig. 16. *H. depressa*, LM. Fig. 17. *H. dolon*, LM. Fig. 18. *H. elongata*, LM. Fig. 19. *H. longicollis*, LM.

Cell medium sized, broadly rounded in lateral view; epitheca small cap like; hypotheca larger & rounded shape outline; girdle not depressed; sulcal list slightly wider at R3; theca covered with poroids & scattered pores.

Dimensions: 52-57 µm L, 50-54 µm W

Histioneis biremis **Stein**
Fig. 14a, b

Stein, 1883, pl. 22, fig 13; Taylor, 1976, p. 44, pl. 9, fig 89; Hernández-Beceril *et al.*, 2008, p. 6, fig. 61.

Body boat –shaped in lateral outline, higher ventrally; anterior girdle list funnel-shaped, strongly ribbed, posterior list gibbous, narrow near apex, dorsally blazed, hyaline; body porulate, anteriorly left sulcal list narrow, posteriorly curved and wide; R2 and R3 posteriorly joined; list partly reticulate.

Dimensions: 80-100 µm L, 50-60 µm W

Histioneis crateriformis Stein
Fig. 15a, b

Stein, 1883, pl. 22, figs. 5, 6; Gómez, 2007, p. 470, fig. 80; Hernández-Beceril *et al*., 2008, p. 6, fig. 63.

Synonym: *Parahistioneis crateriformis* (Stein) Kofoid & Skogsberg.
Schiller, 1933, p. 211, figs. 200a, b.

Body rotund; epitheca conical with concave sides; hypotheca semicircular, girdle list broadly flaring, strongly ribbed, sulcal list narrow at R2, widening toward R3 which is ventral; R2 becoming posterior as margin of sulcal list and joined with R3 to form a point.

Dimensions: 80-100 µm L, 60-68 µm W

Histioneis depressa Schiller
Fig. 16

Schiller, 1928, p. 84, fig. 43; Wood, 1968, p. 77, fig. 212; Taylor, 1976, p. 44, pl. 10, fig. 94; Gómez, 2007, p. 461, figs. 4,5,7.

Body kidney shaped, epitheca low, flat, apex concave; anterior girdle list funnel shaped, flat dorsally, ribbed; lower girdle list about as high dorsally as ventrally; sulcal list extending strongly posteriorly; U-shaped space formed by R2 and R3 and the antapical wall apparently.

Dimensions: 62-80 µm L, 50 µm W

Histioneis dolon Murray & Whitting
Fig. 17

Kofoid & Skogsberg, 1928, p. 698, fig. 96/6; Wood, 1954, p. 215, fig. 72; Taylor, 1976, p.44, pl .9, 40, figs. 90, 485.

Body sausage-shaped to rounded, dorsally higher than ventrally; anterior girdle list with moderate tube and angle flare, ribbed, posterior girdle list with lateral pouches; Left sulcal list prolonged into sail much longer than body, irregular margin, reticulate; R2 almost straight, inclined posteriorly. R3 lying in the middle between R2 and antapex; R2 and R3 form reticulate branches; Theca prorate.

Dimensions: 100-110 µm L, 60-68 µm W

Histioneis elongata Kofoid & Michener
Fig. 18

Kofoid & Michener, 1911, p. 295; Wood, 1968, p. 77, fig. 213; Gómez, 2005b, figs. 25, 26.

Cell elongated; epitheca low, anterior girdle list funnel shape, ribbed, posterior list hyaline, flare, ribbed; left sulcal list long, R3 long; sail triangular, extended posteriorly from R2 to R3.

Dimensions: 90-110 μm L, 45-55 μm W

Histioneis longicollis Kofoid
Fig. 19

Kofoid, 1907, p. 204, pl. 16, fig. 54; Taylor , 1976, p. 30, pl. 2, fig. 20; Gómez, 2008, p. 30, fig. 51.

Body subrotund; epitheca depressed; anterior girdle list tubular, flared at end, posterior list high with reticulate ribs; left sulcal list long and anteriorly narrow, posteriorly wide, R2 and R3 unite and distally branched; Theca with pores.

Dimensions: 90-100 μm L, 47-60 μm W

Discussion

D. caudata was reported from Arabian Sea for the first time by Cleve (1900) who latter also reported *D. miles, D. hastata* and *D. schuettii* (1903) from the same area. Subrahmanyan (1958) and Schröeder (1906) described *D. caudata* as *D. homunculus*. *D. caudata* (Fig. 1) superficially resembles *D. tripos* and *D. diegensis* and has been called a variety of *D. caudata* (Steidinger & Tangen, 1997). *D. tripos* can be distinguished by dorso-posterior projection and from *D. digenesis* by the width and shape of the main body and the left sulcal list and also from *D. miles* Cleve (Fig. 4) which is characterized by elongated dorso-posterior region equal to or much longer than the posterior process. It was commonly observed in jointed or dividing pairs resulting from incomplete separation after fission. *D. expulsa* (Fig. 2) is a rare, distinctive species recognized most readily in ventral view where the body appears wedge-shaped with a marked depression one quarter to one third distance from the lower girdle list to the antapex. The most closely related species is *D. protuberans* (Kofoid & Skogsberg, 1928) Balech, which possesses a lateral swelling in place of the depression of *D. expulsa*, as well as other differing features (Taylor, 1976). *D. uracantha* has been distinguished from *D. hastata* (Fig. 3) principally on the basis of the dorso-antapical insertion of the antapical fin, instead of ventro-antapical in *D. hastata* (Taylor, 1976). It was represented by the variety *D. miles var. indica* which is characterized by intermediate size of the body. It has been reported to be very common in the Arabian Sea between Arabian Peninsula and east India (Taylor, 1976). The other variety *D. miles var. miles* characterized by small size is common in the Persian Gulf and Red Sea (Taylor, 1976). *D. ovum* (Fig. 5) agrees well with that described by Subrahmanyan (1958), Wood (1968) and Hernández-Bacerril *et al.*, (2008) with the exception of body size. *D. schuettii* (Fig. 6) is a distinctive species most closely related to *D. swezyae*, from which it differs in lacking the accessory lobe present on left sulcal list below R3.

P. argus (Fig. 7) is morphologically similar with *P. apicata* but differed on the bases of shape of epitheca and hypotheca and sulcal list size. Similar characteristic is that R3 is not well developed in both species. *P. circumsuta* distinguished from *P. doryphorum* (Fig. 8) by virtue of the strong, single supporting the posterior list projection, the spine being directed postero-ventrally. The posterior projection is confluent with the left sulcal list, whereas it is separate in *P. doryphorum*. *P. favus* (Fig. 9) is also morphologically similar with *P. hindmarchii* but the later species has hypothecal margin dorsally more rounded than *P. favus* and sulcal list and R3 is also shorter than *P. favus. P. mitra* (Fig. 10) and *P. rotundata* (Fig. 13) are both toxic species. They produce diarrhetic shellfish poison toxins (Lee *et al*., 1989). *P. mitra* is a photosynthetic species while *P. rotundata* is a heterotrphic species. *P. mitra* resembles with *P. rapa* (Fig. 12) but differs on the bases of hypotheca posteriorly pointed and sulcal list slightly curved. *P. rapa* also a larger species (Abe 1967; Steidinger & Tangen, 1997).*P. ovum* (Fig. 11) morphologically more resembles with Wood (1968) specimen.

Histioneis biremis (Figs. 14a, b) and *H. highleyi* are distinctive species and belong to same group *biremis*. *H. biremis* has pear shaped hypotheca while *H. highleyi* Y-shaped hypotheca. These species seem to be a transition between *Histioneis* and *Citharistes* (Gómez, 2007). *H. crateriformis* (Figs. 15a, b) belongs to *crateriformis* group and closely related to the *garrettii* group. The characterized feature of this group is that the R3 is more deflected and hypotheca is semicircular and cingulum broad (Gómez, 2007). The present specimen resembles with Balech (1988). *H. depressa* (Fig. 16) belong to the group of *cymbalaria*. *H. depressa* has been illustrated with different morphology even by the same author (Wood, 1963; 1968). According to Balech (1988) *H. cymbalaria* was similar to Taylor's (1976) figure of *H. depressa* (Gómez, 2007). *H. dolon* (Fig. 17) belongs to the group *megalocopa*. The present specimen morphologically resembles with that of Gómez (2007). *H. megalocopa* and *H. dolon* are here considered as synonyms contrary to Balech (1988). *H. elongata* (Fig. 18) resembles with *H. carinata* and *H. subcarinata* but both species have small and ornamented sulcal list. *H. longicollis* (Fig. 19) is similar to *Joergensenii* on the basis of cell shape but the shape of window is rounded in *H. longicollis* and quasi triangular in *H. Joergensenii* and also similar with *H. planeta* on the basis of window shape sulcal list but differed on the bases of reticulate phaeosome in *H. planeta*.

The north Arabian Sea shelf is famous for its upwelling phenomenon. During the southwest monsoon season (summer) there occurs a large scale upwelling due to offshore winds and a small scale upwelling in northeast monsoon season due to winter cooling on the shelf of Pakistan and India (Banse, 1968). In the present study low temperatures were recorded in shallow areas on the shelf during January and also in June indicating upwelling in both seasons (Anon., 1978; Saifullah, 1979).

Members of Dinophysiales are mostly tropical and sub-tropical in nature. *D. Caudata, D. expulsa, D. miles, D. schuettii, H. dolon, H. elongata and H. longicollis* have been reported from Indian Ocean (Taylor, 1976), Caribbean Sea (Wood, 1968) and *P. rotundata* from North Arabian Sea (Hassan & Saifullah, 1971). The remaining two species *D. hastata* and *D. ovum* occurred both in tropical and temperate waters like North Sea and Mediterranean (Lebour, 1925).

Size variation is a common feature among dinoflagellates and has been related to temperature variation. They were found to be slightly larger at lower than at higher temperatures (Dowidar, 1972). Abe (1967) and Hassan & Saifullah (1971) also observed size variation in *D. caudata* in response to change in temperature.

Table 1. Number of stations occupied by different species in different seasons, areas and frequency of occurrence.

No.	Name of species	Seasonal occurrence		Different areas		Total stations	Frequency of occurrence (%)
		N-E monsoon (Jan. to Mar)	Transition period (Apr. to June)	Sindh	Balochistan		
1.	*D. caudata*	67	75	69	74	143	62.17
2.	*D. expulsa*	5	9	10	4	14	6.08
3.	*D. hastata*	11	15	15	11	26	11.30
4.	*D. miles*	50	39	70	24	94	41
5.	*D. ovum*	35	10	34	11	45	19.5
6.	*D. schuettii*	8	12	11	9	20	8.69
7.	*P. argus*	6	15	13	8	21	9.13
8.	*P. doryphorum*	24	24	37	11	48	20.86
9.	*P. favus*	16	27	28	15	43	18.69
10.	*P. mitra*	6	8	12	2	14	6.09
11.	*P. ovum*	16	27	22	21	43	18.69
12.	*P. rapa*	8	8	14	2	16	6.96
13.	*P. rotundata*	5	10	12	3	15	6.96
14.	*H.biremis*	5	3	5	3	8	3.48
15.	*H.crateriformis*	3	2	3	2	5	2.17
16.	*H.depressa*	3	3	5	1	6	2.61
17.	*H.dolon*	3	5	8	0	8	3.48
18.	*H.elongata*	2	4	6	0	6	2.61
19.	*H. longicollis*	2	5	7	0	7	3.04

Among all the species *D. caudata* was the most common and frequent species occupying 62% stations on the shelf and adjacent deep-sea area (Table 1). It was also the most common in net samples collected from stations 59, 177, 193 and 221(Saifullah *et al*., 2008) between 8th March-8th April.1977, when it occurred very frequently (visual estimate of net sample) masking the appearance of other species in net samples. It is also known to create red tides resulting in massive fish mortality in Japan (Okaichi, 1967). *D. miles* was the next most common and frequent species occupying as many as 41% of total stations (Table 1). Red Sea (Taylor, 1976) was absent. In view of their very frequent and wide spread occurrence, *D. caudata* and *D. miles* may be regarded as characteristic of the northwestern Arabian Sea bordering Pakistan. As a matter of fact Taylor (1976) has already regarded *D. miles* as characteristic of the Indian Ocean. *D. caudata, D. hastata, D. miles, D. schuttii, P. rotundata, H. depressa, H. elongata* and *H. longicollis* were reported from north Arabian Sea by Kuzmenko (1975) while D. *ovum, H. crateriformis, H. elongata* and *H. longicollis* were not reported by Taylor (1976) from Indian Ocean. It is perhaps for the first time that six species of *Histioneis* are reported from northwest Arabian Sea.

The Indus Delta is more heterogeneous environmentally than Balochistan shelf because of intrusion of Indus river water. The intermittent flow of the river causes greater variation in temperature and salinity regimes of the area (Anon., 1978) accounting for greater diversity of species. The observations were taken only during six months, therefore, the annual ranges of temperature and salinity could not be described. However, most species occurred within a range of temperature showing a narrow difference of 5 ºC during the period of study which is also characteristic of tropical seas. The range in salinity values was even more narrow i.e., 35.78-36.89 psu. Hoshiai *et al*., (2003) used temperature salinity diagrams of dinoflagellate species as a means of their spatial isolation. The same is applied here to study the correlation in the distribution of the species (Fig. 20) *D. caudata* and *D. miles* were the most common frequent among all the species (Table 1) and, therefore, occurred in a wide range of temperature and salinity and *Phalacroma* and some *Histioneis* species were not common but were also eurythermal and euryhaline during the period of study in the area. *D. hastata* on the other hand was stenothermal and stenohaline in the higher range and *D. ovum* preferably in the lower range indicating a seasonal isolation between the two species, the former occurring in late spring and the later in winter season. Most species were either neritic or neritic-oceanic in occurrence which may be due to the fact that the area included mostly the neritic and not the oceanic province. The period of study included only two seasons i.e. the NE monsoon season (Jan-Mar) and the transition period between NE and SW monsoon season (Apr-Jun). All the species did not show any seasonal preference and occurred in both period but *H. dolon, H. elongata* and *H. longicollis* were less frequent during NE monsoon season and also did not occurr on Balochistan area (Table 1).

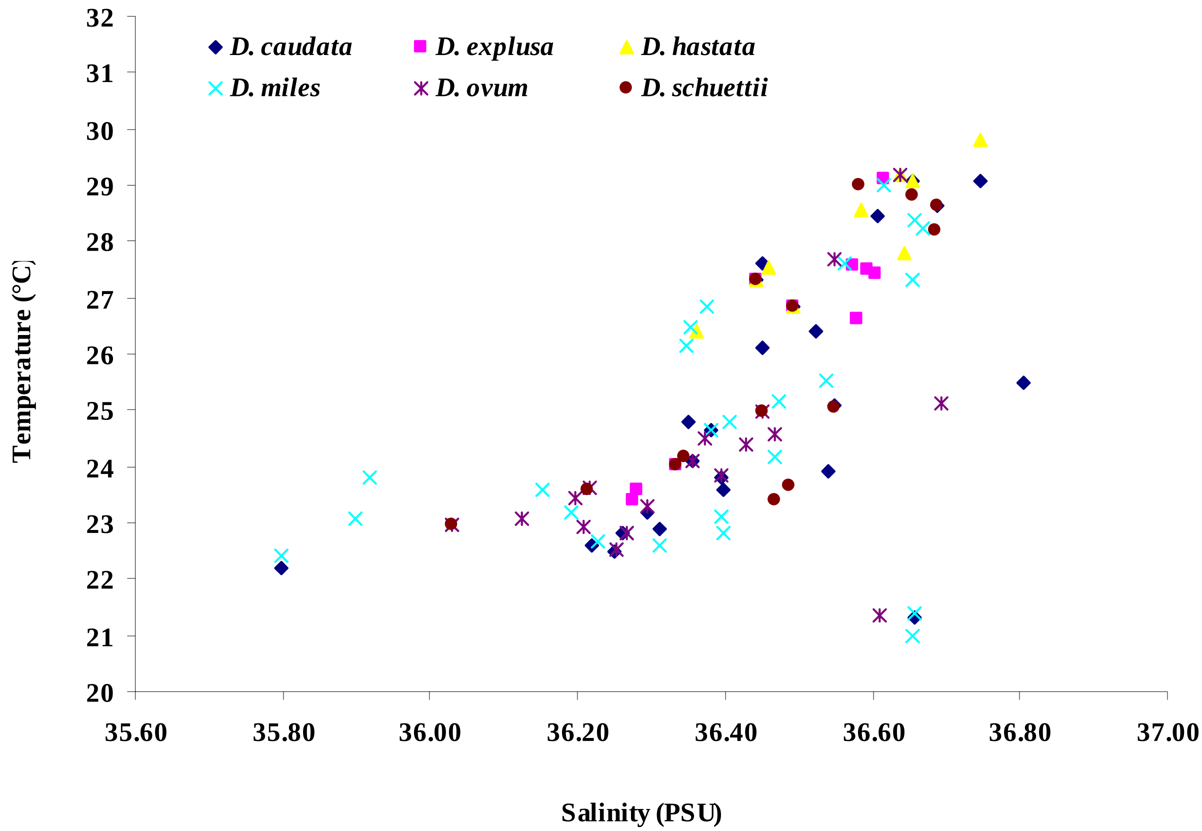


Fig. 20. Temperature and salinity diagram of the occurrence of Dinophysis species in the North Arabian sea shelf of Pakistan.

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