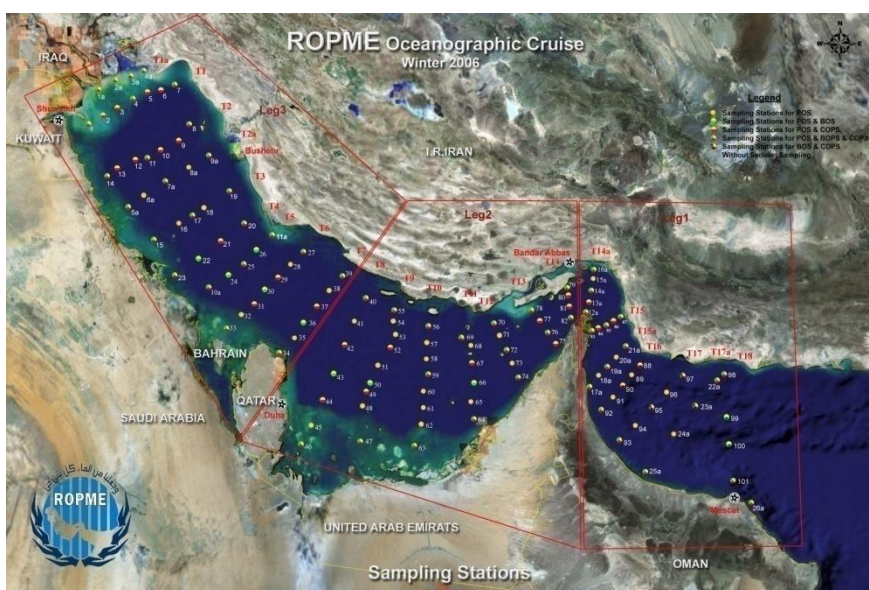




Regional Organization for the Protection of the Marine Environment

ROPME Oceanographic Cruise – Winter 2006



Monograph Series

Monograph : No. 1

Phytoplankton in the ROPME Sea Area

September 2012

ROPME Oceanographic Cruise - Winter 2006

Monograph Series:

1. Phytoplankton
2. Zooplankton
3. Meiobenthos
4. Foraminifera
5. Macrobenthos

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Preface

In recognition of the importance of the oceanographic Cruises in the ROPME Sea Area to understand the state of the marine environment, ROPME Council has assigned high priority to the ROPME scientific Cruises. In pursuance of the Council Decision CM12/7, ROPME was mandated to coordinate a comprehensive oceanographic Cruise in Winter 2006. The Cruise was planned in such a way that the results and reports of the studies can find their way into the synthesis of ROPME State of the Marine Environment Report.

As a result of sustained efforts, cooperation of Member States, guidance of the designated scientific committee for the Cruise, encouragements from the Executive Committee of ROPME and the generous provisions made by the Council, the historic Winter Cruise was carried out successfully on board of M/V Ghods of I.R. Iran during 1st February and 11th March 2006.

Totally, 115 stations covering the RSA have been surveyed and 97 experts from ROPME Member States participated in the Cruise. The survey covered most of the main oceanographic disciplines.

The samples collected during the Cruise were distributed on a competitive basis to the competent laboratories in the Region and elsewhere for detailed analyses while sub-sample sets were kept in ROPME Marine Sample Bank to enable repetitive analyses in future, when required.

To enhance benefits from the reproduced results of the Cruise among Regional scientific community towards a better understanding of the marine environment in the RSA and to enable furtherance of marine researches, ROPME Secretariat decided on the publication of the results in a series of Monographs as follows:

1. Phytoplankton
2. Zooplankton
3. Meiobenthos
4. Foraminifera
5. Macrobenthos

The present Monograph is devoted to the taxonomy of phytoplankton in the RSA. The analyses of phytoplankton and reporting have been conducted by a team of scientists led by Dr. Faiza Al-Yamani at Kuwait Institute for Scientific Research, under a contract with ROPME.

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1. Introduction

Phytoplankton species are microscopic plants that live in the sea. They are considered in general, the main primary producers, which support the pelagic and benthic food webs in the different marine ecosystems. Due to their short life cycle, planktonic microalgae respond quickly to environmental changes; and thus, are a valuable indicator of water quality. The term 'phytoplankton' encompasses all taxonomic microalgal groups in the pelagic environment and includes the diatoms (Bacillariophyceae), dinoflagellates (Dinophyceae), blue-green algae (Cyanophyceae) as well as naked flagellates, prymnesium algae and other groups.

There are serious impacts of the red tide incidences and the occurrences of the harmful algal blooms (HABs) on human health, fishery resources, and marine ecosystems throughout the world. The first recorded red tide incident in Kuwaiti waters of the inner ROPME Sea Area (RSA) was in May 1997 (Al-Yamani *et al.*, 1997; Subba Rao *et al.*, 1999). In 1999, a massive fish kill occurred due to harmful blooms of two HAB species, namely, *Karenia selliformis* and *Prorocentrum rhathymum* (Heil *et al.*, 2001; Al-Yamani *et al.*, 2004) and two incidences of red tides have been recorded in 2000 (Subba Rao *et al.*, 2003).

Microalgal blooms can cause discoloration of the water (generally known as red tides), which can have harmful effects such as mass mortalities in fish, invertebrates, birds, and mammals. When toxic species are in bloom conditions, the toxins can be quickly carried up the food chain and indirectly pass onto humans via fish and shellfish consumption, sometimes resulting in gastrointestinal disorders, permanent neurological damage, or even death. An improved understanding of the occurrence and distribution of the causative HAB species and the population dynamics of the species will improve the ability to forecast the bloom events and to reduce the harmful effects and their economic impacts (Faust and Gullledge, 2000; Larsen and Nguyen, 2004).

The ecology and taxonomy of phytoplankton in the ROPME Sea Area (RSA) have been studied during the past few decades (Enomoto, 1971; Al-Kaisi, 1976; Jacob *et al.*, 1979; Al-Yamani, 1989; Al-Yamani *et al.*, 1997; Subba Rao *et al.*, 1999) but involved in very limited detailed taxonomical studies. Information about distribution of some phytoplankton species occurring in Kuwaiti waters has been published by Enomoto (1971), Al-Yamani *et al.* (2004), and Al-Kandari *et al.* (2009). Description of the phytoplankton community from the coastal areas of Kuwait, the United Arab Emirates and from Qatar has been reported by Al-Kaisi (1976). The preliminary results of phytoplankton composition studies from the Qatari

waters have been published by Dorgham and Muftah (1986). Species composition of phytoplankton in the Shatt Al-Arab River (Iraq) has been revised by Al-Saboonchi and Al-Saad (1988). There have only been a few studies on the benthic diatom flora of the RSA (Hendey, 1970; Basson and Mohammed, 1989). A valuable review of phytoplankton diversity for the region was conducted by Subba Rao and Al-Yamani (1998), based on the limited available data on phytoplankton from the different parts of the RSA. Assessment of the phytoplankton diversity of the RSA was reported by Jacob and Al-Muzaini (1990) and the latest estimation of phytoplankton diversity in Kuwaiti waters was reported recently by Al-Yamani *et al.* (2004) and by Al-Kandari *et al.* (2009).

Available published information regarding the taxonomic studies on phytoplankton of the RSA is limited and is presented in different and isolated scientific publications. Phytoplankton in the RSA has a heterogeneous spatial distribution with variable species compositions at the different localities. Detailed investigations of phytoplankton communities for the different parts of the RSA covering all seasons is needed. This study focussed on the phytoplankton taxonomy and the spatial distribution during the Winter-2006 Cruise in the RSA.

2. Materials and Methods

Samples from the RSA for this study were collected during the ROPME Oceanographic Cruise, which was conducted during the winter season from February to March 2006. The cruise covered the inner RSA and the Sea of Oman. The cruise was divided into 3 legs and 23 transects. The general scheme of the cruise is presented in Fig. 1. The position of the stations from which the phytoplankton material was obtained for taxonomical analysis, the dates and time of collections, depth of sampling and the maximum depth for each station are included in Table 1.

The examined materials consisted of a total of 191 one-liter samples collected for quantitative analysis by the Niskin bottle from 3-depth layers (surface, middle and bottom) at each station, and a total of 42 qualitative one-liter samples, which were collected by oblique net tows (net diameter of 60 cm and mesh size of 20 μm). Samples collected by the Niskin bottle were preserved with acidified Lugol solution. Net samples were preserved with unacidified Lugol solution.

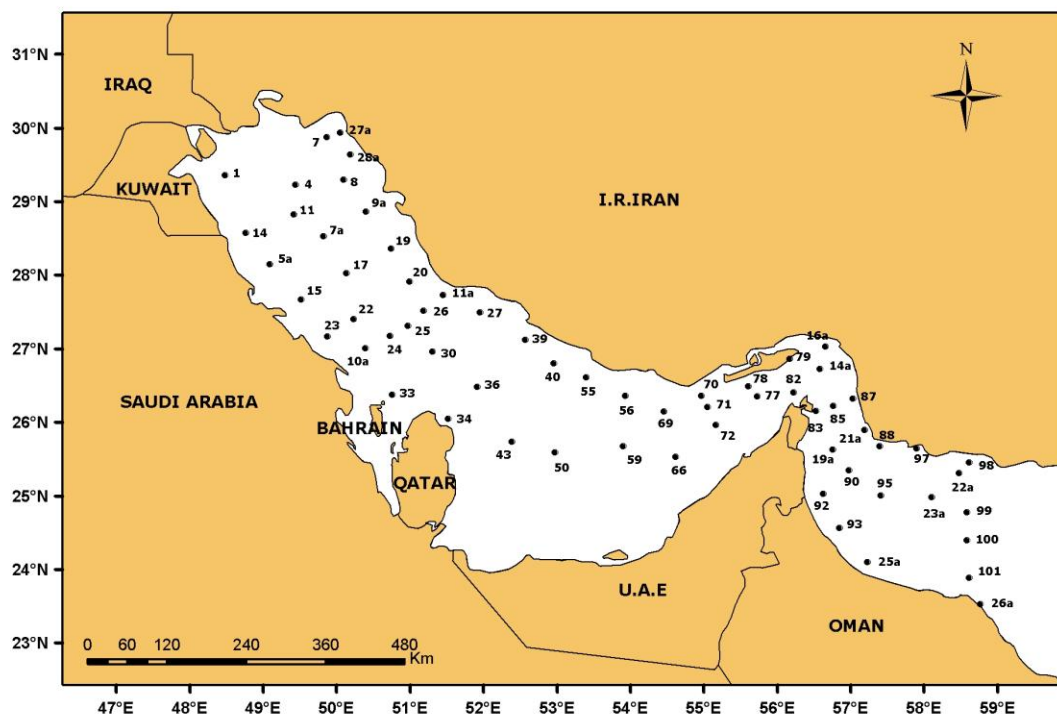


Figure 1. ROPME's map of sampling stations, for the Winter 2006 Cruise.

Table 1. Details of Sampled Stations in the RSA

Transect	Station	Coordinate		Date	Time	Depth (m)	Sampling Depth (m)			Sampling Method		
		Latitude	Longitude				Surface	Middle	Bottom	Niskin Bottle	Oblique Net	Tow
18	26a	23°31'000"	58°46'100"	3-Feb-2006	08:07	53	3	25	45	+		
	101	23°52'420"	58°36'791"	3-Feb-2006	12:32	450	3	50	100	+		
	100	24°23'404"	58°35'244"	3-Feb-2006	16:27	2700	3	50	100	+		
	99	24°46'136"	58°35'100"	3-Feb-2006	19:07	1700	3	50	100	+		
	98	25°26'801"	58°36'914"	3-Feb-2006	07:25	50	3	25	45	+		
17a	22a	25°18'070"	58°28'909"	4-Feb-2006	09:38	200	3	50	100	+		
	23a	24°58'210"	58°06'300"	4-Feb-2006	12:17	1000	3	50	100	+		
	25a	24°05'505"	57°13'813"	4-Feb-2006	19:28	55	3	25	100	+		
17	93	24°33'147"	56°50'739"	5-Feb-2006	07:17	67	3	25	45	+		
	95	24°59'595"	57°24'758"	5-Feb-2006	12:39	1039	3	50	100	+		
	97	25°38'200"	57°54'000"	5-Feb-2006	18:05	54	3	25	45	+		

Table 1. Contd.

Transect	Station	Coordinate		Date	Time	Depth (m)	Sampling Depth (m)			Sampling Method	
		Latitude	Longitude				Surface	Middle	Bottom	Niskin Bottle	Oblique Net Tow
16	88	25°40'043"	57°24'048"	5-Feb-2006	07:16	65	3	25	45	+	
	90	25°20'310"	56°58'530"	6-Feb-2006	11:13	300	3	50	100	+	
	92	25°01'340"	56°37'080"	6-Feb-2006	15:38	183	3	45	90	+	
15a	19a	25°37'386"	56°45'487"	6-Feb-2006	20:44	110	3	48	96	+	
	21a	25°53'400"	57°11'300"	6-Feb-2006	07:24	57	3	24	47	+	
15	87	26°18'900"	57°01'800"	7-Feb-2006	11:53	26	3	11	22	+	
	85	26°13'000"	56°46'000"	8-Feb-2006	07:51	104	3	32	65	+	
	83	26°08'763"	56°31'767"	8-Feb-2006	13:16	95	3	42	85	+	+
14a	14a	26°43'066"	56°34'862"	8-Feb-2006	21:58	64	3	24	47	+	+
	16a	27°01'400"	56°39'300"	9-Feb-2006	11:19	30	3	11	22	+	+
14	79	26°51'046"	56°10'378"	13-Feb-2006	08:08	45	3	16	32	+	+
	82	26°23'771"	56°13'583"	13-Feb-2006	14:21	90	4	40	80	+	+
13	77	26°20'671"	55°43'561"	13-Feb-2006	08:08	61	4	26	52	+	+
	78	26°28'769"	55°36'474"	14-Feb-2006	10:37	45	4	19	40	+	+
12	70	26°32'104"	54°57'957"	14-Feb-2006	14:17	44	4	19	40	+	
	71	26°12'000"	55°03'000"	14-Feb-2006	16:58	83	4	36	72	+	
	72	25°57'254"	55°10'080"	14-Feb-2006	18:50	72	4	29	59	+	+
11	66	25°31'090"	54°37'156"	15-Feb-2006	16:27	42	3	16	34	+	+
	69	26°08'382"	54°27'506"	15-Feb-2006	22:05	75	3	29	64	+	+
10	56	26°20'905"	53°55'864"	21-Feb-2006	07:01	93	3	41	82	+	+
	59	25°39'885"	53°53'944"	21-Feb-2006	12:49	42	3	16	36	+	+
9	50	25°35'092"	52°58'225"	22-Feb-2006	07:46	39	4	16	32	+	+
	55	26°36'057"	53°24'057"	22-Feb-2006	16:35	86	3	39	79	+	+
8	40	26°47'800"	52°57'400"	22-Feb-2006	06:41	86	3	36	74	+	+
	43	25°43'513"	52°23'170"	23-Feb-2006	14:34	33	3	11	25	+	+
7	34	26°02'500"	51°31'200"	27-Feb-2006	07:49	14	2	7	11	+	+
	36	26°28'190"	51°54'900"	28-Feb-2006	13:32	52	3	22	45	+	+
	39	27°07'000"	52°34'100"	28-Feb-2006	06:00	77	3	32	66	+	+

Table 1. Contd.

Transect	Station	Coordinate		Date	Time	Depth (m)	Sampling Depth (m)			Sampling Method		
		Latitude	Longitude				Surface	Middle	Bottom	Niskin Bottle	Oblique Net	Tow
6	27	27°29'200"	51°57'0"	1-Mar-2006	10:53	54	3	25	50	+	+	
	30	26°57'100"	51°18'500"	1-Mar-2006	17:17	71	3	31	63	+	+	
	33	26°21'800"	50°45'500"	1-Mar-2006	06:39	14	2	7	11	+	+	
5	10a	26°59'800"	50°23'700"	2-Mar-2006	16:35	26	3	11	22	+	+	
	24	27°10'100"	50°43'500"	2-Mar-2006	06:45	65	3	29	58	+	+	
	25	27°18'290"	50°58'400"	3-Mar-2006	09:08	67	3	29	58	+	+	
	26	27°30'497"	51°11'060"	3-Mar-2006	12:45	73	3	29	58	+	+	
4	11a	27°43'179"	51°27'088"	3-Mar-2006	15:10	17	2	7	11	+	+	
	20	27°54'410"	50°59'518"	4-Mar-2006	06:32	63	3	25	50	+	+	
	22	27°23'887"	50°13'952"	4-Mar-2006	12:19	57	3	25	51	+	+	
	23	27°09'561"	49°52'363"	4-Mar-2006	15:38	43	3	17	35	+	+	
3	15	27°39'842"	49°30'928"	4-Mar-2006	06:32	21	3	6	11	+	+	
	17	28°01'115"	50°07'896"	5-Mar-2006	12:39	60	3	24	49	+	+	
	19	28°21'033"	50°44'312"	5-Mar-2006	17:24	57	3	21	42	+	+	
2a	9a	28°51'200"	50°24'200"	6-Mar-2006	07:12	47	3	24	48	+	+	
	7a	28°31'145"	49°49'321"	6-Mar-2006	11:54	54	3	8	16	+	+	
	5a	28°08'501"	49°05'508"	6-Mar-2006	17:09	21	3	8	16	+	+	
2	14	28°33'885"	48°45'702"	6-Mar-2006	06:18	24	3	16	33	+	+	
	11	28°49'120"	49°25'120"	7-Mar-2006	11:58	44	3	18	36	+	+	
	8	29°17'580"	50°05'490"	7-Mar-2006	06:35	42	3	17	35	+	+	
2-1	28a	29°38'011"	50°11'008"	8-Mar-2006	09:42	26	3	11	20	+		
	27a	29°56'006"	50°03'006"	8-Mar-2006	11:54	15	3	6	11	+		
1	7	29°52'106"	49°52'049"	8-Mar-2006	14:32	13	3	5	10	+	+	
	4	29°13'245"	49°26'487"	9-Mar-2006	09:59	41	3	18	35	+	+	
	1	29°21'000"	48°29'000"	9-Mar-2006	17:57	13	2	-	10	+	+	

+ indicates that a sample was obtained

2.1 Taxonomic Analysis

Taxonomical analysis of phytoplankton for the RSA in this study was based mainly on thorough analysis and examination of about 42 one-liter samples, which were collected by the oblique net tows. This sampling strategy provides a better chance for taking more representative materials to study the taxonomic features of phytoplankton in the investigated region. Materials from these samples were used for detailed taxonomic analysis and for reporting the winter phytoplankton diversity of the RSA. Moreover, some species from the Niskin bottle samples were studied and described in addition to the aforementioned plankton net materials. Permanent slides were prepared from the net samples.

Examination by light microscopy (LM) is the standard method used in taxonomical analysis of the main phytoplankton groups. A good quality light microscope with an oil immersion objective (100×) having bright field (BF) and phase-contrast regimes should be used for observation of general cell morphology. However, some phytoplankton taxa can only be satisfactorily examined through a combined use of LM, scanning electron microscopy (SEM) and transmission electron microscopy (TEM).

2.1.1 Light Microscopy (LM)

Temporary microscope slides were prepared for the taxonomic identification of the dinoflagellates from the RSA samples, as well as for some delicate diatom species and for other phytoplankton groups. One or two drops of a sample were added to the glass slide, and then, a cover glass was placed on top. Phytoplankton cells were examined in the water mount. Slides were examined using Leica DM LM microscope and/or Axiovert 200M (Carl Zeiss) microscope with BF and phase contrast optic with 40× to 100× objectives. Slides for all the selected specimens from the collected samples were examined microscopically, and all the identified phytoplankton taxa were recorded and photographed. High quality photomicrographs were taken with Leica DFC 320 or Carl Zeiss AxioCam HRc digital cameras.

2.1.2 Epifluorescence Microscopy

In order to identify armored dinoflagellates, it is often necessary to observe the cells from a certain angle to see species-specific plate details. Observations of plate patterns were made using Calcofluor White M2R (Fritz and Triemer, 1985). A subsample (5-10 ml) from

each examined sample was centrifuged and then resuspended in 1 ml of filtered seawater and 5 μ l of a 1.0 mg/ml solution of Calcofluor White MR2 (Polysciences, Warrington, PA), which stain the cellulose thecal plates. After staining for 10 min, the material was resuspended in 2 to 10 ml of filtered seawater for analysis. Subsamples of up to 1 ml were examined on the Axiovert 200M (Carl Zeiss) microscope with a 100-W mercury lamp and a Zeiss #2 filter set (excitation 365 nm, emission 420 nm). During the microscopic examination, the dinoflagellate cells were examined from both the dorsal and the ventral sides.

2.1.3 Permanent Slide Preparation

Some diatom species were examined from permanent slides. The diatom frustules have a light refraction close to that of water, but by removing the organic material and embedding the cleaned silica parts in a medium with a different light refraction, many details, which are important for identification could be revealed under the light microscope.

Permanent slides were prepared from the ROPME winter cruise material for detailed examination of some diatom taxa. Subsamples (2 ml) from each net sample were taken for analysis. Subsamples from the same transect were consolidated. For cleaning diatoms, a mixture of sulfuric acid with potassium dichromate ($K_2Cr_2O_7$) was used. Subsamples were placed in vials where organic coatings were solubilized for 24-48 h in this mixture. After complete organic matter solubilization, the diatom frustules were washed repeatedly by centrifugation in distilled water and then dried up on a cover glass and mounted using Melmount medium.

Microscope slides of all selected samples were scanned microscopically, and all the identified phytoplankton taxa were recorded and photographed. The cleaned frustules in the permanent slides were observed by the Axiovert200 microscope (Carl Zeiss) in regimes of phase contrast under oil immersion (100 \times objective) and photographed using the AxioCam HR (a professional high-resolution digital camera with additional integrated scanner technology) in order to obtain the best results.

2.1.4 Scanning Electron Microscopy

Electron microscopic examination is essential for the detailed analysis of the microstructure in some phytoplankton species, especially for the small-sized groups. To

prepare materials from the net subsamples for the scanning electron microscopy examination, these subsamples were desalted by centrifugation with distilled water and then dehydrated through an ethanol series (15, 30, 50, 70, 90 and 100%). Dehydrated materials underwent critical point drying. About 20-nm layer of gold-palladium was coated onto the material to be examined using an SEM.

2.1.5 Estimation of Cell Sizes

Size is an important criterion for the identification of the different phytoplankton species. Cell size was measured by light microscopy using a calibrated ocular micrometer. In addition, some morphometric measurements were conducted from micrographs using AxioVision 3.0 (Carl Zeiss) software.

2.1.6 Microphotographs of Phytoplankton Taxa

A total of 1351 high quality microphotographs were obtained for the illustration of the identified species. These photos were sorted, filtered and used for the documentation of the different phytoplankton species. A collection of images for each identified phytoplankton taxon was produced based on the original photomicrographs.

2.1.7 Limitations in Identification

The sampling and preservation methods used during the cruise introduced considerable bias in the determination of the phytoplankton species composition. Thecate dinoflagellates appeared to be reasonably well preserved. However, some naked forms lost their flagella and morphological features after preservation. Some delicate diatom species appeared in rather battered condition, and most chain formers were dissociated.

Some unarmored flagellates can be properly identified only by observation of live material. Study of living samples allows for the identification of delicate flagellates, but this stage of analysis was not available due to the availability of only preserved samples from the ROPME cruise.

Naked flagellates can sometimes be identified by LM examining live samples, namely, species of raphidophytes and gymnodinioid dinoflagellates. However, a major difficulty in identifying particularly gymnodinioid dinoflagellates is the poor and imprecise

species descriptions in the scientific literature, and the general lack of identification literature. These flagellates do not possess a cell wall or other structural material, but are surrounded only by their plasma membrane. Therefore, the cells are very fragile and their morphological features (including cell shape, surface structures, and even size because of shrinkage) are usually destroyed when preserved. As a consequence, naked flagellates cannot generally be identified to the species level by LM in the RSA-preserved samples, but only to higher rank levels.

Scale-bearing naked flagellates, such as prasinophytes (e.g., *Pyramimonas*) can be identified to the species level most effectively only by examination with an electron microscope. Morphological features of species belonging to genera such as *Chaetoceros*, *Thalassiosira*, *Coscinodiscus*, *Navicula* and *Pseudo-nitzschia* need to be investigated with electron microscopy in order to be accurately identified.

For some *Chaetoceros* and *Bacteriastrum* species, only short fragments of chains with a damaged state of cells were observed in the samples, which did not allow for the accurate identification of the specimens up to the species level.

Data of sequencing of the internal transcribed spacer (ITS) of the 16S-23S rDNA region indicated that the genus *Trichodesmium* is composed of a closely related group of species. In order to investigate the genetic diversity of the closely related species of *Trichodesmium*, genetic techniques that provide high resolution are required (Orcutt *et al.*, 2002). This was not possible for the ROPME samples; and hence, identification of *Trichodesmium* species from the examined material was performed up to the genus level.

Consequently, some phytoplankton algae from the genera of *Gymnodinium*, *Gyrodinium*, *Oxytoxum*, *Pseudo-nitzschia*, *Thalassiosira*, *Trichodesmium*, and the small-sized *Protoperidinium* species were identified up to the genus level, while the naked flagellates were enumerated as a group.

3. General Identification Characteristics

3.1 Phytoplankton Diversity and General Classification

The term “marine phytoplankton” implies a diverse group of photo and heterotrophic unicellular forms from many classes of microalgae. On the basis of morphological features, phytoplankton may be grouped into diatoms (with ornamented siliceous frustule), dinoflagellates (with transverse and longitudinal flagella, large and evident nucleus),

silicoflagellates (with external silica skeleton), naked flagellates (heterogeneous group, which comprise representatives from most of the algal classes), other flagellates and coccoid forms as well as zooflagellates.

The classification of plankton microalgae may differ in accordance with the criteria on which it is based. The growing knowledge gained by advanced methods and techniques may change the ideas about phylogeny and may introduce changes in the systematics at all levels. However, at present the morphology and pigment composition provide a reasonable good basis for a practical identification system. Some characteristic features and pigments are mentioned in the listing of the plankton microalgal divisions according to the classification scheme partially modified by Tomas (1997) from that of Christensen (1962; 1966). The main divisions including flagellate species according to the system of Christensen are, namely: Chromophyta, lacking chlorophyll *b*, but with chlorophyll *a* and accessory pigments; and Chlorophyta with chlorophyll *a* and *b*. Division Cyanophyta has been added to the section Prokaryota, while class Bacillariophyceae has been included into the division Chromophyta, and the phylum (division) Zoomastigophora has been added as zooflagellates in marine plankton.

The list of plankton microalgal groups is limited here to those taxa that occur in the ROPME Sea Area during the winter season. Description of the different phytoplankton species is based on the preserved samples, which were collected during the ROPME oceanographic cruise for the winter of 2006.

Prokaryota – lacking a nucleus enveloped by a membrane

- Division **Cyanophyta**
Chlorophyll-*a*, c-phyococyanin, c-phycoerythrin
- Class **Cyanophyceae**
Bluegreen algae

Eukaryota – with a nucleus enveloped by membranes

- Division **Chromophyta**
Chlorophyll-*a* and accessory pigments, yellowish-green, golden, blue, or red chloroplasts with lamellae
- Class **Cryptophyceae**
Asymmetric cell shape with furrow or depression, furrow lined with two or more rows of ejectosomes; brown, green, red or blue color; one or two chloroplasts
- Class **Dinophyceae**
dinoflagellates; with dinokarion, with chloroplasts (chlorophyll-*a* and -*c*₂, betacarotene, peridinin, fucoxanthin with derivatives) or chloroplasts are lacking, flagella different

- Class **Psymnesiophyceae / Haptophyceae**
Yellow-brown to golden-brown or pale color; with haptonema and two most often smooth or with minute organic scales flagella
- Class **Dictyochophyceae**
Silicoflagellates; radial symmetry, external skeleton, 'flimmer'/winged flagellum
- Class **Bacillariophyceae**
Diatoms; chlorophyll-*a* and -*c*, betacarotene, fucoxanthin, diatoxanthin and diadinoxanthin, siliceous wall and organic layer
- Division **Chlorophyta**
Chlorophyll-*a* and -*b*; green chloroplasts with lamellae or grana structure
 - Class **Euglenophyceae**
Euglenids; pellicula, flagellar canal with one or two emerging flagella, containing paramylon
 - Class **Prasinophyceae**
Cell covered with organic scales; with or without flagella
- * Phylum **Zoomastigophora**
Heterotrophic flagellates
 - Class **Ebriidea**
Naked cell with two flagella and an internal siliceous skeleton

The phytoplankton community in the RSA during Winter 2006 was very diverse with 340 taxa identified, representing 9 classes.

Dinoflagellates (Dinophyceae) contained the greatest number (181) of identified taxa, followed by diatoms (Bacillariophyceae) with 149 identified taxa, Prasinophyceae (3 taxa), Dictyochophyceae (2 taxa), and Cyanophyceae, Cryptophyceae, Prymnesiophyceae, Euglenophyceae, and Ebriidae classes are with only one taxon each.

3.2 Systematic Arrangement of Taxa

A complete list of the identified phytoplankton taxa recorded from the Niskin bottle samples, as well as from of the plankton net samples and from the prepared permanent slides is here presented. The diatoms' classification is based on Simonsen (1979), with certain modifications that were introduced by Round *et al.* (1990). Dinoflagellate species (Dinophyceae) are arranged alphabetically under each order according to the classification proposed by Chrétinnot-Dinet *et al.* (1993) with the modifications in relation to the recently erected or revised taxa as follows: genera *Akashiwo*, *Balechina* and *Karenia* have been added

to the Gymnodiniaceae. The blue-green algae classification is based on the modern classification system of cyanophytes by Anagnostidis and Komarek (1986). Other microalgal groups are arranged according to the classification scheme, which is partially modified by Tomas (1997) from that of Christensen (1962; 1966).

Unknown or questionable taxa are listed as numbered taxa at the end of the appropriate sections. Most of these taxa were observed as a single specimen. Comments regarding the taxa are given in the taxonomical part.

Systematic Arrangement of the Identified Phytoplankton Taxa Encountered in the RSA during Winter 2006

PROKARYOTA

Division Cyanophyta

Class Cyanophyceae

Order Chroococcales

Family Phormidiaceae

Genus *Trichodesmium*

Trichodesmium sp.

EUKARYOTA

Division Chromophyta

Class Cryptophyceae

Order Cryptomonadales

Family Cryptomonadaceae

Genus *Teleaulax*

Teleaulax sp.

Class Prymnesiophyceae

Order Prymnesiales

Family Phaeocystaceae

Genus *Phaeocystis*

Phaeocystis globosa

Class Bacillariophyceae

Order Biddulphiales

Suborder Coscinodiscineae

Family Thalassiosiraceae

Genus *Cyclotella*

Cyclotella striata

Cyclotella stylorum

Genus *Detonula*

Detonula pumila

Genus *Lauderia*

Lauderia borealis

Genus *Planktoniella*

Planktoniella sol

Genus *Porosira*
Porosira sp.

Genus *Skeletonema*
Skeletonema costatum

Genus *Thalassiosira*
Thalassiosira eccentrica
Thalassiosira oestrupii
Thalassiosira sp.

Family Melosiraceae
Genus *Paralia*
Paralia sulcata

Genus *Stephanopyxis*
Stephanopyxis palmeriana

Family Leptocylindraceae
Genus *Leptocylindrus*
Leptocylindrus danicus
Leptocylindrus mediterraneum
Leptocylindrus minimum

Genus *Corethron*
Corethron histrix

Family Coscinodiscaceae
Genus *Coscinodiscus*
Coscinodiscus asteromphalus
Coscinodiscus granii
Coscinodiscus janischii v. *arafurensis*
Coscinodiscus jonensianus
Coscinodiscus oculus-iridis
Coscinodiscus perforatus
Coscinodiscus radiatus
Coscinodiscus wailesii
Coscinodiscus sp.

Genus *Palmeria*
Palmeria hardmaniana

Family Stellarimaceae
Genus *Stellarima*
Stellarima stellaris

Family Hemidiscaceae
Genus *Actinocyclus*
Actinocyclus curvatus
Actinocyclus octonarius
Actinocyclus octonarius v. *tenellus*

Genus *Hemidiscus*
Hemidiscus cuneiformis

Genus *Podosira*
Podosira stelliger

- Family Asterolampraceae
 - Genus *Asteromphalus*
 - Asteromphalus flabellatus*
 - Asteromphalus heptactis*
 - Asteromphalus* sp.
- Family Heliopeltaceae
 - Genus *Actinoptychus*
 - Actinoptychus senaris*
- Suborder Rhizosoleniineae
 - Family Rhizosoleniaceae
 - Genus *Dactyliosolen*
 - Dactyliosolen phuketensis*
 - Genus *Guinardia*
 - Guinardia delicatula*
 - Guinardia flaccida*
 - Guinardia striata*
 - Genus *Neocalyptrella*
 - Neocalyptrella robusta*
 - Genus *Proboscia*
 - Proboscia alata*
 - Proboscia alata* f. *gracillima*
 - Proboscia indica*
 - Genus *Pseudosolenia*
 - Pseudosolenia calcar-avis*
 - Genus *Rhizosolenia*
 - Rhizosolenia bergonii*
 - Rhizosolenia cochlea*
 - Rhizosolenia hebetata* v. *semispina*
 - Rhizosolenia hyalina*
 - Rhizosolenia imbricata*
 - Rhizosolenia setigera*
 - Rhizosolenia shrubsolei*
 - Rhizosolenia* sp.
 - Suborder Biddulphiineae
 - Family Hemiaulaceae
 - Genus *Cerataulina*
 - Cerataulina bicornis*
 - Cerataulina pelagica*
 - Genus *Climacodium*
 - Climacodium frauenfeldium*
 - Genus *Eucampia*
 - Eucampia cornuta*
 - Eucampia zodiacus*
 - Genus *Hemiaulus*
 - Hemiaulus hauckii*
 - Hemiaulus membranaceus*
 - Hemiaulus sinensis*

Family Cymatosiraceae
 Genus *Cymatosira*
 Cymatosira cf. *lorenziana*

Family Chaetocerotaceae
 Genus *Bacteriastrum*
 Bacteriastrum delicatulum
 Bacteriastrum furcatum
 Bacteriastrum hyalinum
 Bacteriastrum hyalinum v. *princeps*

Genus *Chaetoceros*
 Chaetoceros brevis
 Chaetoceros coarctatus
 Chaetoceros compressus
 Chaetoceros curvisetus
 Chaetoceros decipiens
 Chaetoceros denticulatus
 Chaetoceros diversus
 Chaetoceros eibonii
 Chaetoceros lauderi
 Chaetoceros lorenzianus
 Chaetoceros messanensis
 Chaetoceros peruvianus
 Chaetoceros peruvianus f. *gracilis*
 Chaetoceros pseudocurvisetus
 Chaetoceros socialis
 Chaetoceros tortissimus

Family Lithodesmiaceae
 Genus *Bellerochea*
 Bellerochea horologicalis

Genus *Ditylum*
 Ditylim brightwellii

Genus *Lithodesmium*
 Lithodesmium undulatum

Genus *Streptotheca*
 Streptotheca indica
 Streptotheca tamensis

Family Epodiscaceae
 Genus *Odontella*
 Odontella aurita
 Odontella mobiliensis
 Odontella sinensis

Family Triceratiaceae
 Genus *Triceratium*
 Triceratium robertsonianum

Family Biddulphiaceae
 Genus *Biddulphia*
 Biddulphia pulchella
 Biddulphia tuomeyi

Order Bacillariales
 Suborder Fragilariineae
 Family Licmophoraceae
 Genus *Licmophora*
 Licmophora abbreviata
 Family Fragilariaceae
 Genus *Synedra*
 Synedra sp.
 Family Thalassionemataceae
 Genus *Thalassionema*
 Thalassionema nitzschioides
 Genus *Thalassiothrix*
 Thalassiothrix fraunfeldi
 Thalassiothrix longissima
 Suborder Bacillariineae
 Family Naviculaceae
 Genus *Caloneis*
 Caloneis liber
 Genus *Diploneis*
 Diploneis didyma
 Diploneis weissflogii
 Genus *Ephemera*
 Ephemera planamembranacea
 Genus *Gyrosigma*
 Gyrosigma balticum
 Genus *Haslea*
 Haslea sp. aff *H. balearica*
 Genus *Lyrella*
 Lyrella abrupta
 Genus *Mastogloia*
 Mastogloia sp.
 Genus *Mastoneis*
 Mastoneis biformis
 Genus *Meuniera*
 Meuniera membranacea
 Genus *Navicula*
 Navicula directa
 Navicula palpebralis
 Genus *Petroneis*
 Petroneis granulata
 Genus *Plagiotropis*
 Plagiotropis lepidoptera
 Plagiotropis sp.

- Genus *Pleurosigma*
 - Pleurosigma diverse-striata*
 - Pleurosigma formosum*
 - Pleurosigma naviculacea*
 - Pleurosigma* cf. *planctonicum*
 - Pleurosigma strigosum*
- Genus *Trachyneis*
 - Trachyneis antillarum*
 - Trachyneis debyi*
- Family Catenulaceae
 - Genus *Amphora*
 - Amphora lineolata*
 - Amphora obtusa*
 - Amphora ostrearia* v. *ostrearia*
 - Amphora* sp.
- Family Bacillariaceae
 - Genus *Bacillaria*
 - Bacillaria paxillifera*
 - Genus *Cylindrotheca*
 - Cylindrotheca closterium*
 - Genus *Cymatolithia*
 - Cymatolithia marina*
 - Genus *Nitzschia*
 - Nitzschia distans* v. *tumescens*
 - Nitzschia fluminensis*
 - Nitzschia longissima* v. *longissima*
 - Nitzschia longissima* v. *parva*
 - Nitzschia lorenziana*
 - Nitzschia panduriformis* v. *panduriformis*
 - Nitzschia rorida*
 - Nitzschia sigma*
 - Nitzschia sigmaformis*
 - Nitzschia* sp. 1
 - Nitzschia* sp. 2
 - Nitzschia* sp. 3
 - Nitzschia* sp. 4
 - Nitzschia* sp. 5
 - Nitzschia* sp. 6
 - Genus *Pseudo-nitzschia*
 - Pseudo-nitzschia delicatissima* complex
 - Pseudo-nitzschia pungens*
 - Pseudo-nitzschia seriata/australis* complex
- Family Entomoneidaceae
 - Genus *Amphiprora*
 - Amphiprora sulcata*

Family Surellaceae
 Genus *Campilodiscus*
 Campilodiscus sp.
 Genus *Petrodyction*
 Petrodyction gemma
 Genus *Surirella*
 Surirella fastuosa

Class Dinophyceae

 Order Actiniscales

 Family Actiniscaceae

 Genus *Achradina*
 Achradina pulchra

 Genus *Actiniscus*
 Actiniscus pentasterias

 Genus *Dicroerisma*
 Dicroerisma psilonereiella

 Order Dinophysales

 Family Dinophysaceae

 Genus *Amphisolenia*
 Amphisolenia bidentata
 Amphisolenia globifera

 Genus *Dinophysis*
 Dinophysis acuminata
 Dinophysis caudata
 Dinophysis doryphorum
 Dinophysis miles
 Dinophysis mitra
 Dinophysis nasutum
 Dinophysis rapa
 Dinophysis cf. *rotundata*
 Dinophysis sp. 1
 Dinophysis sp. 2
 Dinophysis sp. 3

 Genus *Histioneis*
 Histioneis costata

 Genus *Ornithocercus*
 Ornithocercus margificus
 Ornithocercus quadratus
 Ornithocercus steinii

 Genus *Sinophysis*
 Sinophysis stenosoma

 Genus *Triposolenia*
 Triposilenia bicornis

 Order Gymnodiniales

 Family Gymnodiniaceae

 Genus *Akashiwo*
 Akashiwo sanguinea

- Genus *Balechina*
 - Balechina coerulea*
- Genus *Cochlodinium*
 - Cochlodinium brandtii*
 - Cochlodinium polykrikoides*
- Genus *Gymnodinium*
 - Gymnodinium catenatum*
 - Gymnodinium* sp. 1
 - Gymnodinium*-like group
- Genus *Gyrodinium*
 - Gyrodinium falcatum*
 - Gyrodinium fusiforme*
 - Gyrodinium spirale*
 - Gyrodinium* sp. 1
 - Gyrodinium* sp. 2
- Genus *Karenia*
 - Karenia papilionacea*
- Genus *Torodinium*
 - Torodinium robustum*
 - Torodinium teredo*
- Family Polykrikaceae
 - Genus *Polykrikos*
 - Polykrikos schwarzii*
- Family Warnowiaceae
 - Genus *Warnowia*
 - Warnowia violescens*
- Order Noctilucales
 - Family Kofoidiniaceae
 - Genus *Kofoidinium*
 - Kofoidinium velloides*
 - Family Noctilucaceae
 - Genus *Noctiluca*
 - Noctiluca scintillans*
 - Family Protodiniaceae
 - Genus *Pronoctiluca*
 - Pronoctiluca pelagica*
 - Pronoctiluca spinifera*
- Order Peridinales
 - Family Ceratiaceae
 - Genus *Ceratium*
 - Ceratium breve*
 - Ceratium candelabrum*
 - Ceratium contortum*
 - Ceratium dens*
 - Ceratium extensum*
 - Ceratium falcatum*
 - Ceratium furca*
 - Ceratium fusus*
 - Ceratium gibberum*

- Ceratium hexacanthum*
- Ceratium horridum*
- Ceratium karstenii*
- Ceratium kofoidii*
- Ceratium lineatum*
- Ceratium lunula*
- Ceratium macroceros* v. *marcoceros*
- Ceratium macroceros* v. *gallicum*
- Ceratium massiliense* v. *massiliense*
- Ceratium massiliense* v. *armatum*
- Ceratium minutum*
- Ceratium pentagonum*
- Ceratium praelongum*
- Ceratium ranipes*
- Ceratium strictum*
- Ceratium tenue* v. *buceros*
- Ceratium trichoceros*
- Ceratium tripos*
- Ceratium vultur*
- Family Ceratocorythaceae
 - Genus *Ceratocorys*
 - Ceratocorys armata*
 - Ceratocorys horrida*
- Family Goniodomataceae
 - Genus *Goniodoma*
 - Goniodoma polyedricum*
 - Genus *Pyrodinium*
 - Pyrodinium bahamense* v. *bahamense*
 - Pyrodinium bahamense* v. *compressum*
- Family Gonyaulacaceae
 - Genus *Alexandrium*
 - Alexandrium tamiyavanichii*
 - Genus *Gonyaulax*
 - Gonyaulax birostris*
 - Gonyaulax digitale*
 - Gonyaulax fragilis*
 - Gonyaulax hyalinum*
 - Gonyaulax polygramma*
 - Gonyaulax scrippsae*
 - Gonyaulax spinifera*
 - Gonyaulax turbinei*
 - Gonyaulax verior*
 - Gonyaulax* sp. 1
 - Gonyaulax* sp. 2
 - Gonyaulax* sp. 3
 - Genus *Lingulodinium*
 - Lingulodinium polyedra*
 - Genus *Protoceratium*
 - Protoceratium reticulatum*

Family Oxytoxaceae

Genus *Corythodinium*

Corythodinium constrictum

Corythodinium diploconus

Corythodinium tessellatum

Corythodinium sp.

Genus *Oxytoxum*

Oxytoxum curvatum

Oxytoxum scolopax

Oxytoxum variabile

Oxytoxum sp. 1

Oxytoxum sp. 2

Oxytoxum sp. 3

Family Peridiniaceae

Genus *Diplopelta*

Diplopelta bomba

Diplopelta steinii

Genus *Diplopsalis*

Diplopsalis lenticula

Genus *Peridinium*

Peridinium quinquecorne

Genus *Preperidinium*

Preperidinium meunieri

Genus *Protoperidinium*

Protoperidinium abei

Protoperidinium cf. *achromaticum*

Protoperidinium biconicum

Protoperidinium claudicans

Protoperidinium conicoides

Protoperidinium conicum v. *conicum*

Protoperidinium conicum v. *concavum*

Protoperidinium conicum v. *quardatianum*

Protoperidinium curtipes

Protoperidinium curvipes

Protoperidinium denticulatum

Protoperidinium depressum

Protoperidinium divergens

Protoperidinium globulus

Protoperidinium hamatum

Protoperidinium latissimum

Protoperidinium leonis

Protoperidinium mariebourae

Protoperidinium mite

Protoperidinium murrayi

Protoperidinium oblongum

Protoperidinium obtusum

Protoperidinium oceanicum

Protoperidinium ovatum

Protoperidinium ovum

Protoperidinium pellucidum
Protoperidinium pentagonum
Protoperidinium punctulatum
Protoperidinium quarnerense
Protoperidinium steinii
Protoperidinium subinermis
Protoperidinium thorianum
Protoperidinium venustum
Protoperidinium sp. 1
Protoperidinium sp. 2
Protoperidinium sp. 3
Protoperidinium sp. 4
Genus *Scrippsiella*
Scrippsiella trochoidea
Scrippsiella sp. 1
Scrippsiella sp. 2
Family Podolampadaceae
Genus *Podalampas*
Podalampas bipes
Podalampas palmipes
Genus *Pyrophacus*
Pyrophacus horologium
Pyrophacus steinii
Peridinales incertae sedis
Genus *Heterocapsa*
Heterocapsa triquetra
Heterocapsa sp.
Genus *Spiraulax*
Spiraulax jolliffei
Spiraulax sp.
Order Prorocentrales
Family Prorocentraceae
Genus *Mesoporos*
Mesoporos perforatus
Genus *Prorocentrum*
Prorocentrum balticum
Prorocentrum compressum
Prorocentrum dentatum
Prorocentrum gracile
Prorocentrum micans
Prorocentrum minimum
Prorocentrum rhathymum
Prorocentrum sigmoides
Prorocentrum sp.
Order Pyrocystales
Family Pyrocystaceae
Genus *Dissodinium*
Dissodinium pseudolunula

- Genus *Pyrocystis*
 - Pyrocystis fusiformis*
 - Pyrocystis noctiluca*
 - Pyrocystis robusta*
 - Pyrocystis obtusa*
- Class Dictyochophyceae
 - Order Dictyochales
 - Family Dictyochaceae
 - Genus *Dictyocha*
 - Dictyocha fibula*
 - Dictyocha speculum*
- Division Chlorophyta**
 - Class Euglenophyceae
 - Order Euglenales
 - Family Eutreptiaceae
 - Genus *Eutreptiella*
 - Eutreptiella* sp.
 - Class Prasinophyceae
 - Order Chlorodendrales
 - Family Halosphaeraceae
 - Genus *Prerosperma*
 - Pterosperma undulatum*
 - Pterosperma* sp.
 - Genus *Pyramimonas*
 - Pyramimonas* sp.
 - Phylum Zoomastigophora**
 - Class Eбриidea
 - Order Eбриida
 - Family Eбриidae
 - Genus *Ebria*
 - Ebria tripartita*

3.3 Diatom Taxonomy

The siliceous cell wall has been the main focus of attention for classification of diatoms. The diatom taxonomy has been almost exclusively based upon frustule characteristics: shape, size, symmetry, structure and density of striae, nature of raphe and its position, copulae and processes on the valves. However, increasingly, there is a trend towards ultrastructure and features of living cells such as chloroplastids, life cycle pattern and reproductive biology to be considered in the systematic.

The recent natural classification based on the similarity of phenetic characteristics is favoured by Round, Crawford and Mann (1990). This classification recognizes diatoms as a division **BACILLARIOPHYTA** with three major classes: **Coscinodiscophyceae** (centric

diatoms), **Fragilariophyceae** (araphid pennate diatoms), and **Bacillariophyceae** (raphid pennate diatoms) (Round *et al.*, 1990).

The centric diatoms include generally radially symmetrical forms with no raphe. The araphid pennate diatoms are generally bilaterally symmetrical without any raphe. They are largely attached to substrates. The raphid pennate diatoms may be symmetrical or asymmetrical, have raphe at least in one valve. In the order Achnanthes (monoraphid diatoms), a raphe is present in only one valve: the frustule having a raphe valve (RV) and a rapheless valve (RLV). In the rest of the members of Bacillariophyceae (biraphid diatoms), the raphe may be placed longitudinally at the centre (e.g. Naviculales) or laterally shifted to one side (e.g. Cymbellales) or eccentrically located on a keel (e.g. *Nitzschia*) or on the margins of the whole valve (e.g. *Surirella*).

Diatom taxonomy is in a state of revolutionary change involving splitting of genera, creation of new ones and revision of criteria for classification. With molecular genetics and breeding as added tools, taxonomy of diatoms has become a dynamic field of research. This has added to the value of diatoms as biomonitoring tools of aquatic systems, which has been recognized worldwide (John, 2000).

3.4 Frustule Morphology

The most obvious feature of diatoms is their siliceous cell wall (**frustule**) made of two intricately sculptured halves (**valves**). A diatom cell under the microscope may be seen in different views. The term '**valve view**' refers to the view of the 'face' of a diatom frustule. The side view (profile) is referred to as the **girdle view**.

The symmetry and structure of the frustule is extremely important in the systematic of diatoms and basically related to their axes (John, 2000). Diatoms are found in two general structural types: cells with **rotational (radial)** symmetry and those with **bilateral** symmetry. The centric diatoms exhibit symmetry about a central axis and most frequently, but not always, are circular. Pennate diatoms are generally elongated, and many exhibit bilateral symmetry, and even helical symmetry is possible (Round *et al.*, 1990). Genera with complex shapes include *Auricula*, *Entomoneis*, *Petrodictyon*, *Surirella*, *Amphora*, and *Rhopalodia*. General features of pennate diatoms are illustrated by composite diagram in Figure 2.

The upper lid of the frustule (*epivalve*) overlaps the lower lid (*hypovalve*). The epivalve and hypovalve are connected by *girdle bands* termed *copulae* made of silica. The structure and type of bands are significant in the taxonomy of diatoms. In some species of diatoms, the copulae have inwardly directed *septa*. In the genus *Mastogloia* the valvocopula has internal chambers termed *partecta*. The majority of the pennate diatoms have a longitudinal slit termed *raphe*. The pennate diatoms with raphe are referred to as '*raphids*' and without raphe as '*araphids*' (Round *et al.*, 1990; John, 2000).

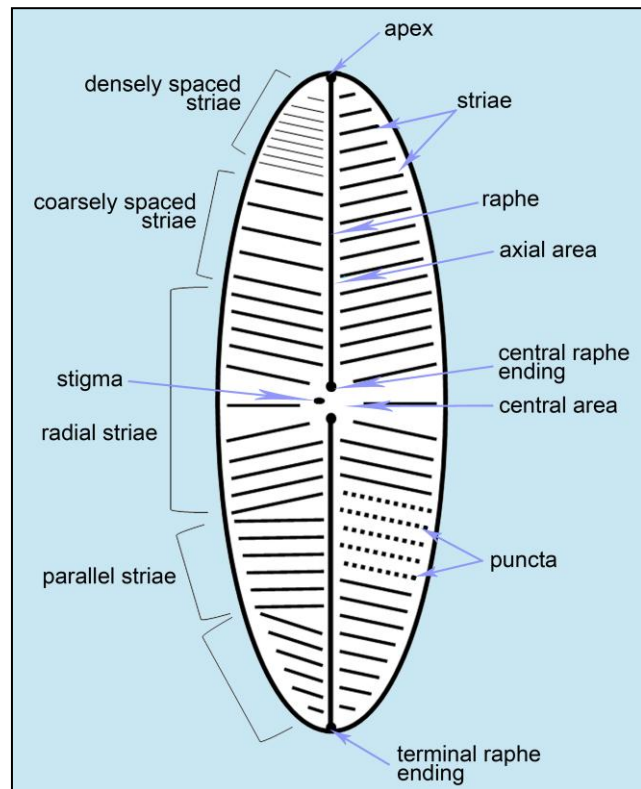


Figure 2. Structure of pennate diatom frustule.

The siliceous structure of the valve consists of transverse and short lateral ribs separated by tiny '**pores**' or '**areolae**' (**puncta**). These little holes arranged in rows are termed *striae*. Secondary deposition of silica may transform the areolae into complex '*chambers*' or *locules* as seen in centric diatoms (Round *et al.*, 1990; John, 2000).

Diatom valves may have *spines*, hair-like structures (*setae*) and *horns* which may be solid or hollow. These siliceous appendages from the frustules provide linkage between cells to form chains. In addition to these, many species have special processes termed '*portules*'. There are two types of portules: fultoportulae (*strutted processes*) and rimoportulae (*labiate processes*), the former is confined to the centric order Thalassiosirales and the latter wide spread in centric and pennate diatoms (Round *et al.*, 1990; John, 2000).

3.5 Flagellate Taxonomy

Despite the important role of flagellates in the aquatic ecosystems, their species diversity is not well known. Among protists, the flagellated forms are the most varied and difficult to identify, partly due to the lack of adequate preservatives. Beginning with the pioneering studies of benthic flagellates (e.g. Dujardin, 1841; Stein, 1878; Herdman, 1922, 1924; Hulburt, 1957; Christen, 1962; Fenchel, 1982, 1986), improved methods of light

microscopic observation and culturing, combined with the necessary use of the electron microscope and molecular diagnostics, have resulted in the identification and description of many flagellate species as well as increased our knowledge of their global distribution.

The main problem of modern taxonomy in relation to flagellates is due to the high diversity of this group including both photo- and heterotrophic species. The diversity of the flagellate group is emphasized by the fact that the marine flagellates are included in numerous botanical or/and zoological taxonomical categories (e.g. Lee *et al.*, 1985, 2000; Patterson & Hedley, 1992; Tomas, 1997). Presence or absence of photosynthetic pigments and, therefore, trophic mode is often a criterion used in classification of flagellates species. However, this approach is applied in a complicated manner to groups including both photo- and heterotrophic species. Therefore, not all dinoflagellates are photosynthetic, since some species belonging to the genera *Amphidinium*, *Gymnodinium*, *Gyrodinium* are colorless and heterotrophic. There are dinoflagellate genera, which include only heterotrophic species.

Marine flagellates historically have been studied both by workers who utilize for species descriptions the rules of nomenclature adopted by zoologists (the International Code of Zoological Nomenclature – ICZN) and by workers who apply the International Code of Botanical Nomenclature (ICBN). Two large flagellated groups presented here are included into this category: the class Dinophyceae (ICBN) = order Dinoflagellida (ICZN) and Euglenophyceae (ICBN) = Euglenida (ICZN). Some taxa were described with more than one name. Double names of such taxa are, therefore, a source of confusion and cause nomenclatural problems.

Thus, at present, there are several available modern taxonomical systems, which are applied for the classification of protists, using either botanical or zoological nomenclatures. These systems organize the protists taxonomy in accordance with the author's opinion concerning the phylogenetic relations between known taxa. In general, both of these taxonomical systems were applied in this guide in describing the species, since it was difficult to give preference, especially describing a diverse community.

In the guide, a few available modern taxonomical systems were combined for description of taxonomical positions of the collected species. Dinoflagellates presented here follow a classification scheme, which is based on Sournia (1986) with some later additions and modifications. Phototrophic flagellates are presented in accordance with classification scheme of Throndsen (1997), which is a partially modified classification of Christensen (1962, 1966).

General schemes of dinoflagellate cells (Figs. 3-6) as well as glossary with the main terms used in the species descriptions are presented below.

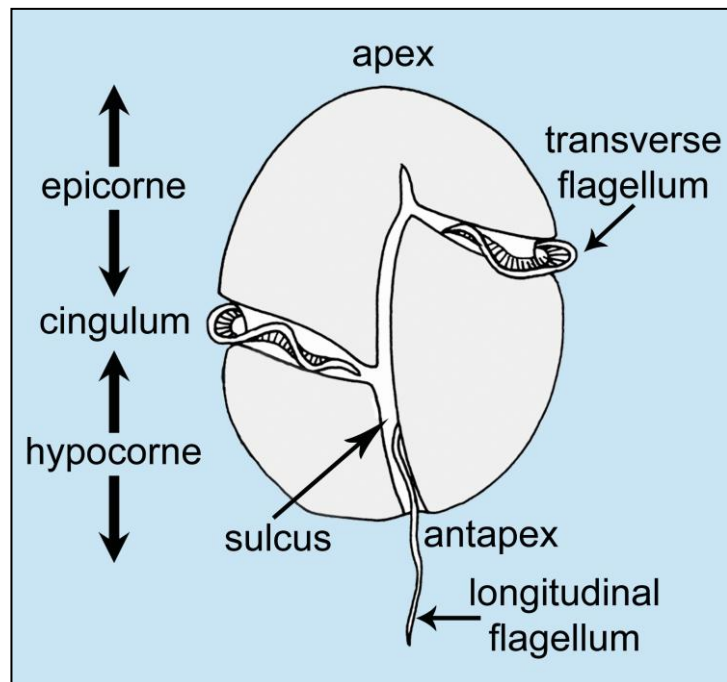


Figure 3. General descriptive terms for typical motile unarmored dinoflagellate cell, ventral view (adapted from Steidinger & Tangen, 1997).

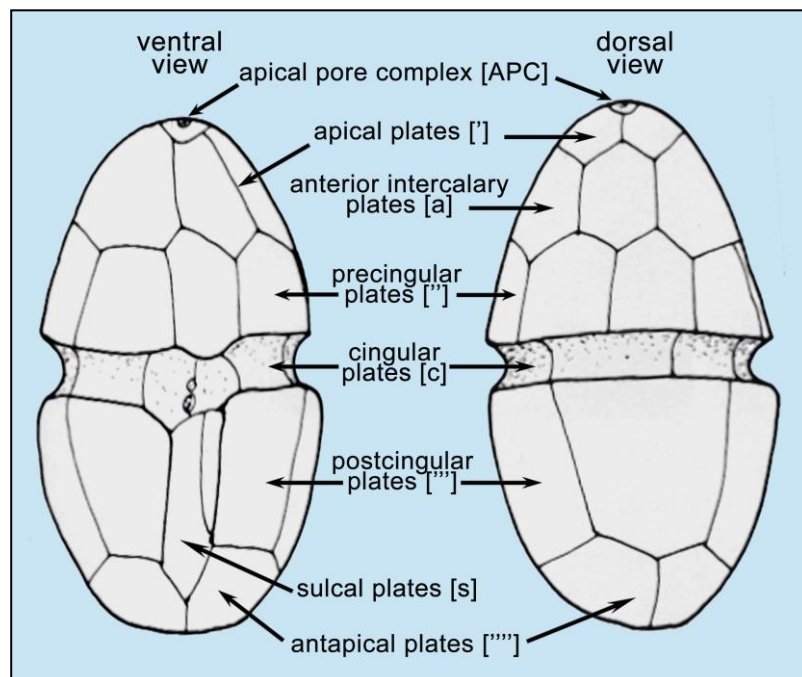


Figure 4. Peridinioid/Gonyaulacoid plate tabulation type in ventral and dorsal views, Kofoid system (adopted from Fensome *et al.*, 1993).

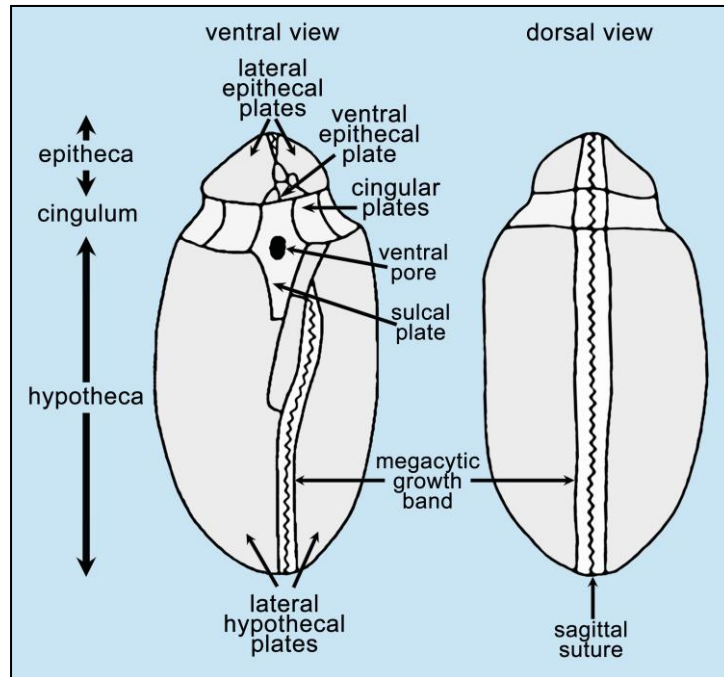


Figure 5. Dinophysoid plate tabulation type in ventral and dorsal views (adopted from Fensome *et al.*, 1993).

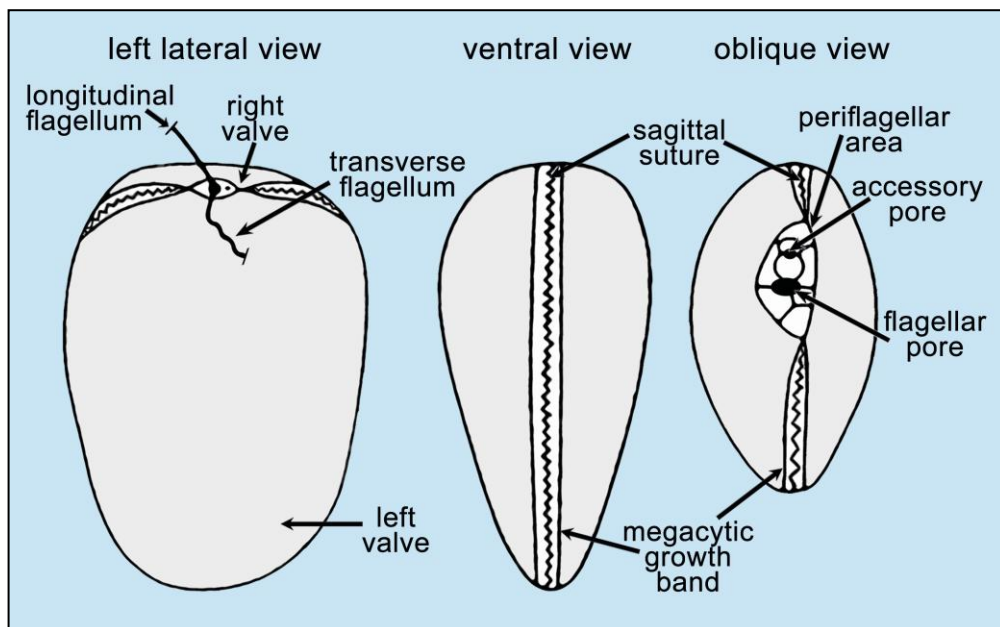


Figure 6. Prorocentroid plate tabulation type in left lateral, ventral and oblique views (adopted from Loeblich *et al.*, 1979; Fensome *et al.*, 1993).

4. Potentially Harmful Algal Bloom (HAB) Species in the RSA

A limited number of microalgae, about 60-80 species or 2% of the world flora (Sournia, 1995), may be considered harmful, as they are capable of producing toxins and some other harmful effects, which may result in human and/or marine faunal intoxication (Hansen *et al.*, 2001). Although the number of harmful species is low, their impact on the marine environment may be very significant or even catastrophic, leading to marine mortality including maricultured species during events of mass development (bloom) of the harmful algal species. Hence, it is crucial to have an efficient monitoring program, in order to minimize public health risks and damage caused to the mariculture and fishing industries. Therefore, assessment of species composition, occurrence and quantitative distribution of potentially harmful species is a very important part of the phytoplankton ecological studies. In order to determine potentially harmful species within the RSA, a detailed examination of the HAB species in the RSA phytoplankton community was performed during this study.

Harmful effects of algal blooms can be classified into at least three different categories (Hallegraeff, 1993; Andersen, 1996; GeoHAB, 2001) as follows:

- Blooms of species, which potentially produce toxins, that are accumulated in food chains (or are transported by air in aerosols from the bloom area to the coast) and cause a variety of gastrointestinal and neurological illnesses of humans and other higher animals such as the following:
 - (PSP) - Paralytic shellfish poisoning (*Alexandrium tamarense*, *Gymnodinium catenatum*, *Pyrodinium bahamense* var. *compressum*);
 - (DSP) - Diarrhetic shellfish poisoning (*Dinophysis* spp.);
 - (ASP) - Amnesic shellfish poisoning (*Pseudo-nitzschia* spp.);
 - (CFP) - Ciguatera fish poisoning (*Gambierdiscus toxicus*);
 - (NSP) - Neurotoxic shellfish poisoning (*Karenia brevis*);
 - Cyanobacterial toxin/poisoning (*Anabaena* sp.);
 - Hepatotoxicity (Cyanophyceae);
 - Respiratory problems and skin irritation, neurological effects (*Karenia brevis*, *Pfiesteria piscicida*, Cyanophyceae)
- Blooms of species, which in most cases are nontoxic to humans, but harmful to fish and invertebrates (especially in intensive aquaculture systems) e.g. by intoxication, damaging

or clogging of the gills or by other means (e.g., *Alexandrium tamarense*, *Chaetoceros convolutus*, *Gyrodinium aureolum*, *Heterosigma akashiwo*, *Nodularia spumigena*).

- Blooms of species, which produce basically harmless water discolorations, with the result that the recreational value of the bloom area decreases due to low visibility of the water and eventually, under exceptionally calm weather conditions in eutrophicated sheltered bays; the blooms can grow so dense that they cause indiscriminate fish kills and mortality of benthic invertebrates due to oxygen depletion (e.g., *Noctiluca scintillans*, *Ceratium* spp., *Prorocentrum micans*, *Heterocapsa triquetra*, *Skeletonema costatum*, *Trichodesmium erythraeum*, *Eutreptiella* spp., *Phaeocystis pouchetii*).

There is no one general algal concentration set value, which is considered a harmful concentration of cells for all species in an algal bloom. This is because the concentration in a HAB incident is species specific. Some algae cause harm at low concentrations, with no discoloration in the water, e.g., *Alexandrium tamarense* where PSP toxins are detected in shellfish at concentrations below 10^3 cells/l, whereas other algae cause harmful effects when they occur in higher concentrations, causing discoloration of the water, which is visible to the eye, and is known as red tide. For example, *Gyrodinium aureolum* kills fish and benthic animals at concentrations higher than 10^7 cells/l (Andersen, 1996).

A total of 58 identified taxa belonging to 5 different classes, can be categorized as potentially harmful species in the collected samples from the RSA during the Winter 2006 Cruise. Among them, 20 species are potentially toxic to humans. Species composition of this group with information regarding occurrence and localization of highest concentrations for each species as well as data on their related contribution (HAB Index) are included in Table 2. The highest abundances for potentially harmful phytoplankton are plotted on RSA map in Fig. 7

The occurrence of potentially toxic species within the RSA was quite high for some taxa. For example, the toxic species of *Pseudo-nitzschia* occurred frequently (*P. pungens* occurred in 29% of samples) or even have ubiquitous distribution (*P. delicatissima* complex, 79% of samples). In addition, *P. delicatissima* complex was rather abundant, especially in the Qatari coastal waters – its highest concentration was close to bloom condition and reached 10^5 cells/l, where HAB index exceeded 38%. The potentially toxic blue-green algae (Cyanophyta) *Trichodesmium* sp. occurred frequently (in 38% of samples).

Table 2. A Checklist of Potentially Harmful Species Recorded in the RSA during the Winter 2006 Cruise

Taxon	Harmful Effect	Presence in the RSA during Winter 2006					
		Occurrence		Max. (cells/l)	St.#- Depth	Area	HAB Index
		%	Category				
Potentially Toxic Species to Humans:							
<i>Trichodesmium</i> sp.	+ [NT, HT]	38	frequent	1.1×10 ³	55-S	Iran	<1
<i>Pseudo-nitzschia delicatissima</i> complex	+ [ASP,BF]	79	ubiquitous	4.6×10 ⁵	36-M	Qatar	38.1
<i>Pseudo-nitzschia pungens</i>	+ [ASP]	29	frequent	4.3×10 ⁴	36-M	Qatar	3.6
<i>Pseudo-nitzschia seriata/australis</i> complex	+ [ASP]	3	rare	2.1×10 ⁴	66-S	UAE	6.9
<i>Alexandrium tamiyavanichii</i>	+ [PSP]	15	occasional	1.9×10 ³	87-S	Iran	1.8
<i>Dinophysis acuminata</i>	+ [DSP]	3	rare	41	78-M	Iran	<1
<i>Dinophysis caudata</i>	+ [DSP]	27	frequent	389	92-S	Oman	<1
<i>Dinophysis miles</i>	+ [DSP]	14	occasional	72	28a-M	Iran	<1
<i>Dinophysis mitra</i>	+ [DSP]	3	rare	18	11-S	Saudi Arabia	<1
<i>Dinophysis rapa</i>	+ [DSP]	<1	very rare	12	78-S	Iran	<1
<i>Dinophysis</i> cf. <i>rotundata</i>	+ [DSP]	27	frequent	53	59-M	Iran	<1
<i>Gymnodinium catenatum</i>	+ [PSP]	28	frequent	1.2×10 ³	55-S	Iran	<1
<i>Karenia papilionacea</i>	+ [NSP]	9	rare	1.0×10 ³	23-M	Saudi Arabia	2.9
<i>Lingulodinium polyedrum</i>	+ [PSP]	<1	very rare	15	78-S	Iran	<1
<i>Prorocentrum balticum</i>	+?	3	rare	29	87-S	Iran	<1
<i>Prorocentrum minimum</i>	+? [NT]	21	occasional	2.9×10 ³	71-B	Iran	6.9
<i>Prorocentrum rhathymum</i>	+ [DSP?]	9	rare	280	27a-M	Iran	<1

Table 2. (Contd.)

Taxon	Harmful Effect	Presence in the RSA during Winter 2006					
		Occurrence		Max. (cells/l)	St.#- Depth	Area	HAB Index
		%	Category				
<i>Protoperidinium curtipes</i>	+? [AZP]	10	rare	48	8-S	Iran	<1
<i>Protoperidinium divergens</i>	+? [AZP]	28	frequent	133	5a-B	Iran	<1
<i>Pyrodinium bahamense</i> v. <i>compressum</i>	+ [PSP]	3	rare	105	66-S	UAE	<1
Species Potentially Causing Marine Mortality:							
<i>Proboscia alata</i> f. <i>gracillima</i>	+	26	frequent	5.0×10 ³	11a-S	Iran	3.1
<i>Akashiwo sanguinea</i>	+	<1	very rare	8	9a-M	Iran	<1
<i>Ceratium furca</i>	+	46	frequent	2.1×10 ³	7-S	Iran	1.9
<i>Ceratium fusis</i>	+	54	common	613	5a-S	Saudi Arabia	1.4
<i>Cochlodinium polykrikoides</i>	+	7	rare	1.7×10 ³	50-B	UAE	1.0
<i>Dissodinium pseudolunula</i>	+?	<1	very rare	13	26a-B	Oman	<1
<i>Gonyaulax polygramma</i>	+	13	occasional	75	90-S	Oman	<1
<i>Noctiluca scintillans</i>	+	46	frequent	688	90-S	Oman	<1
<i>Peridinium quinquecorne</i>	+	<1	very rare	45	28a-S	Iran	<1
<i>Prorocentrum micans</i>	+	47	frequent	3.3×10 ³	36-S	Qatar	<1
<i>Protoceratium reticulatum</i>	+	<1	very rare	34	50-B	UAE	<1
<i>Scrippsiella trochoidea</i>	+	51	common	7.5×10 ³	36-S	Qatar	1.4
<i>Phaeocystis</i> sp.	+	4	rare	62	88-B	Oman	<1
<i>Dictyocha fibula</i>	+	52	common	667	90-S	Oman	<1
<i>Dictyocha speculum</i>	+	4	rare	64	8-B	Iran	<1

Table 2. (Contd.)

Taxon	Harmful Effect	Presence in the RSA during Winter 2006					
		Occurrence		Max. (cells/l)	St.#- Depth	Area	HAB Index
		%	Category				
Potentially bloom-forming species:							
<i>Bacteriastrum delicatulum</i>	BF	48	frequent	1.8×10 ⁵	88-S	Oman	10.2
<i>Bacteriastrum furcatum</i>	BF	10	rare	7.8×10 ⁵	14a-M	Iran	84.9
<i>Chaetoceros compressus</i>	BF	52	common	1.5×10 ⁶	78-M	Iran	87.1
<i>Chaetoceros curvisetus</i>	BF	37	frequent	1.2×10 ⁶	88-S	Oman	66.1
<i>Chaetoceros lorenzianus</i>	BF	78	ubiquitous	2.3×10 ⁵	27-S	Iran	32.1
<i>Chaetoceros pseudocurvisetus</i>	BF	22	occasional	1.4×10 ⁵	82-B	Iran	41.9
<i>Chaetoceros socialis</i>	+ [BF]	4	rare	5.8×10 ⁵	78-S	Iran	75.6
<i>Chaetoceros tortissimus</i>	BF	34	frequent	1.6×10 ⁶	14a-S	Iran	88.3
<i>Guinardia delicatula</i>	+ [BF]	44	frequent	2.5×10 ⁵	66-M	UAE	65.6
<i>Gymnodinium</i> -like group	BF	95	ubiquitous	4.7×10 ⁵	19a-B	UAE	81.0
<i>Lauderia borealis</i>	BF	67	common	3.4×10 ⁵	97-B	Iran	61.1
<i>Skeletonema costatum</i>	+ [BF]	20	occasional	3.7×10 ⁵	36-M	Qatar	31.0
<i>Teleaulax</i> sp.	BF	87	ubiquitous	2.2×10 ⁵	25-M	Iran	83.1
<i>Leptocylindrus danicus</i>	+ [bf]	70	common	9.2×10 ⁴	9a-B	Iran	49.7
<i>Coscinodiscus wailesii</i>	+ [bf]	5	rare	16	27a-S	Iran	<1
<i>Guinardia flaccida</i>	+ [bf]	62	common	8.9×10 ³	7-B	Iran	6.6

Table 2. (Contd.)

Taxon	Harmful Effect	Presence in the RSA during Winter 2006					
		Occurrence		Max. (cells/l)	St.#- Depth	Area	HAB Index
		%	Category				
<i>Cerataulina pelagica</i>	+ [bf]	55	common	5.4×10 ⁴	93-S	Oman	14.5
<i>Chaetoceros peruvianus</i>	+ [bf]	32	frequent	1.4×10 ⁴	14-B	Kuwait	9.6
<i>Ceratium trichoceros</i>	+ [bf]	36	frequent	74	27-M	Iran	<1
<i>Prorocentrum compressum</i>	+ [bf]	30	frequent	158	14-S	Kuwait	<1
<i>Prorocentrum gracile</i>	+ [bf]	36	frequent	3.9×10 ³	36-M	Qatar	<1
<i>Prorocentrum sigmoides</i>	+ [bf]	2	rare	21	15-B	Saudi Arabia	<1
<i>Prorocentrum</i> cf. <i>gracile</i>	+ [bf]	19	occasional	427	50-M	UAE	<1

Harmful effect is indicated as follows:

“+” – known harmful effect; symptoms and effects: **PSF** – Paralytic Shellfish Poisoning; **NT** – Neurotoxic; **HT** – Hepatotoxic; **ASP** – Amnesic Shellfish Poisoning; **DSP** – Diarrhetic Shellfish Poisoning; **AZP** – Azaspiracid Shellfish Poisoning; **BF, bf** – bloom-forming species [**BF** – bloom or close to bloom abundance (10⁵-10⁶ cells/l) was detected in this study; **bf** – those species that are known to produce blooms, but with low abundance in this study]. Categories of occurrence are determined as follows: **very rare** - species was recorded in less than 1% of examined material; **rare** – 1-10% of examined material; **occasional** – 11-25%; **frequent** – 26-50%; **common** – 51-75%; **ubiquitous** – greater than 75%. **Max** = maximum abundance; St. # = station number; sampling depth/layer: **S** = surface, **M** = middle, **B** = bottom layer. **HAB Index** – percentage of abundance in a sample with respect to the total phytoplankton abundance.

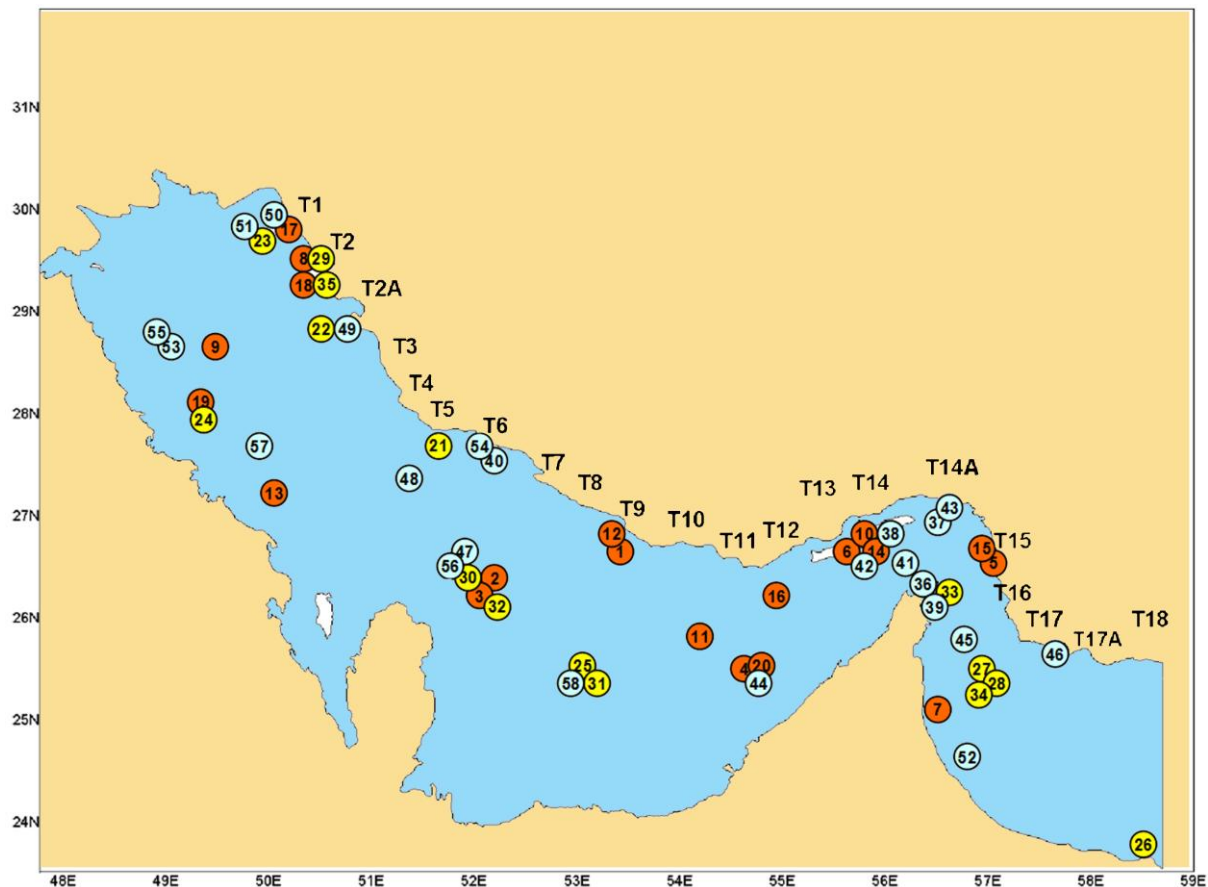


Figure 7. Distribution of the maximum abundance for the potentially harmful algal species in the RSA during Winter 2006.

Orange circles – potentially toxic species to humans; **yellow circles** – species potentially causing marine mortality; **blue circles** – potentially bloom-forming species (refer to Table 2): 1 - *Trichodesmium* sp.; 2 - *Pseudo-nitzschia delicatissima* complex; 3 - *Pseudo-nitzschia pungens*; 4 - *Pseudo-nitzschia seriata/australis* complex; 5 - *Alexandrium tamiyavanichii*; 6 - *Dinophysis acuminata*; 7 - *Dinophysis caudata*; 8 - *Dinophysis miles*; 9 - *Dinophysis mitra*; 10 - *Dinophysis rapa*; 11 - *Dinophysis* cf. *rotundata*; 12 - *Gymnodinium catenatum*; 13 - *Karenia papilionacea*; 14 - *Lingulodinium polyedrum*; 15 - *Prorocentrum balticum*; 16 - *Prorocentrum minimum*; 17 - *Prorocentrum rhathymum*; 18 - *Protoperidinium curtipes*; 19 - *Protoperidinium divergens*; 20 - *Pyrodinium bahamense* v. *compressum*; 21 - *Proboscia alata* f. *gracillima*; 22 - *Akashiwo sanguinea*; 23 - *Ceratium furca*; 24 - *Ceratium fusus*; 25 - *Cochlodinium polykrikoides*; 26 - *Dissodinium pseudolunula*; 27 - *Gonyaulax polygramma*; 28 - *Noctiluca scintillans*; 29 - *Peridinium quinquecorne*; 30 - *Prorocentrum micans*; 31 - *Protoceratium reticulatum*; 32 - *Scrippsiella trochoidea*; 33 - *Phaeocystis* sp.; 34 - *Dictyocha fibula*; 35 - *Dictyocha speculum*; 36 - *Bacteriastrum delicatulum*; 37 - *Bacteriastrum furcatum*; 38 - *Chaetoceros compressus*; 39 - *Chaetoceros curvisetus*; 40 - *Chaetoceros lorenzianus*; 41 - *Chaetoceros pseudocurvisetus*; 42 - *Chaetoceros socialis*; 43 - *Chaetoceros tortissimus*; 44 - *Guinardia delicatula*; 45 - *Gymnodinium*-like group; 46 - *Lauderia borealis*; 47 - *Skeletonema* cf. *costatum*; 48 - *Teleaulax* sp.; 49 - *Leptocylindrus danicus*; 50 - *Coscinodiscus wailesii*; 51 - *Guinardia flaccida*; 52 - *Cerataulina pelagica*; 53 - *Chaetoceros peruvianus*; 54 - *Ceratium trichoceros*; 55 - *Prorocentrum compressum*; 56 - *Prorocentrum gracile*; 57 - *Prorocentrum sigmoides*; 58 - *Prorocentrum* cf. *gracile*.

The genus *Dinophysis* was usually present in very low concentrations and with low HAB index (less than 1). Among *Dinophysis* species, only *D. caudata* and *D. cf. rotundata* were observed frequently, but in low abundances. The maximum concentration of the most abundant species (*D. caudata*) did not exceed 400 cells/l.

The potentially toxic *Alexandrium tamiyavanichii* was occasionally observed in the RSA in a rather high concentration (1.9×10^3 cells/l) in the Iranian coastal waters. It is not a bloom-forming species, but its toxic effect can be expressed at quite low cell density. Because PSP toxins produced by *Alexandrium tamarensense* can be detected in shellfish at concentrations below 10^3 cells/l, the recommended concentration limit for *Alexandrium* spp. are only 500 cells/l for Danish waters (Andersen, 1996). Evidently, this recommendation can be applied to the RSA.

Among other potentially toxic species are three species, *Gymnodinium catenatum*, *Karenia papilionacea* and *Prorocentrum minimum*, which were detected in quite high concentrations (10^3 cells/l). *G. catenatum* and *P. minimum* were associated with waters off Iran in the central part of the inner RSA, whereas *K. brevis* was found near the Saudi Arabian coastal waters. Other potentially toxic species (*Lingulodinium polyedrum*; *Prorocentrum balticum*, *P. rhathymum*; *Protoperidinium curtipes*, *P. divergens*; and *Pyrodinium bahamense* v. *compressum*) were present in the phytoplankton community of the RSA in insignificant abundances.

Potentially harmful species that are known to cause marine fish and invertebrate mortalities were observed during the winter study. A total of 15 species were detected in the RSA. Only four species out of the 15 were observed frequently or were common in rather high concentrations (10^3 cells/l) – the diatom *Proboscia alata* f. *gracillima*, and the dinoflagellates *Ceratium furca*, *Prorocentrum micans* and *Scrippsiella trochoidea*. Because these are non-toxic species, their harmful influence appear at significantly higher concentrations (exceeding 10^6 cells/l). The potentially toxic *Cochlodinium polykrikoides* was rarely observed, but when encountered, it had a density maximum of 10^3 cells/l in the coastal zone off the United Arab Emirates.

Additionally, other potentially harmful algae of non-toxic bloom-forming species was encountered in the RSA. About 13 phytoplankton taxa, mainly small-sized and chain-forming *Chaetoceros* and *Bacteriastrum* species, were observed, and displayed high concentrations. When they were the dominant species, they contributed up to 80-90% of the total

phytoplankton abundance with concentrations that were close to blooms (10^5 - 10^6 cells/l) and were frequently or commonly found in the RSA.

Analysis of available published information regarding known potentially harmful algae is summarized in the taxonomical part of the report and includes details of the harmful effects and some evidences of harmful influence on the environment for each phytoplankton taxon.

5. Taxonomic Description

The classification adopted in this study is based on the classical system, therefore, adopting the prokaryotes and eukaryotes categories. Eukaryotes are organisms whose cells have a nucleus, which holds the cell's DNA. The cells of prokaryotes, on the other hand, lack this nuclear membrane, and hence, the DNA is part of a protein-nucleic acid structure called the nucleoid. A new insight into molecular biology changed the above categorization, leading the microbiologist Carl Woese of the University of Illinois to propose reorganizing the Tree of Life into three separate Domains: Eukarya, Eubacteria (true bacteria), and Archaea.

All the microphotographs for the identified and described species from the RSA are included in Annex A.

5.1 Prokaryota

5.1.1 Division: Cyanophyta

5.1.1.1. Class: Cyanophyceae

Cyanophyceae comprises autotrophic prokaryote cells with blue-green to red color depending on the content of phycocyanin and phycoerythrin. They lack a membrane enveloped nucleus and chloroplasts (the thylakoids with chlorophyll and phycobilins lies free in the cytoplasm). The cells are also lacking flagella. The cyanophytes include unicellular as well as filamentous species (Thronsdon *et al.*, 2007). Marine and brackish water cyanobacteria can produce toxins, which result in neuromuscular and organ distress as well as external contact irritation. These toxins can affect humans as well as terrestrial animals and marine life. At least nineteen species, belonging to nine genera, have been shown to be toxin producers among the brackish water and marine cyanobacteria (Hallegraeff *et al.*, 1995).

Division: Cyanophyta

Class: Cyanophyceae

Order: Oscillatoriales Elenkin

Family: Phormidiaceae Anagnostidis *et* KomárekGenus: *Trichodesmium* Ehrenberg *ex* Gomont

Planktonic organisms mostly forming assemblages with parallel or radially arranged fascicles joined by mucilage. Trichomes are without sheath, more or less straight or curved, 6-22- μm wide with cylindrical or tapering ends. Cells isodiametric with fine homogenous content and aerotopes, blue-green or reddish in color. Apical cells straight, rounded or slightly capitate. The genus *Trichodesmium* comprises about 10 species, which have their main distribution in warm temperate and tropical waters (Cronberg and Annadotter, 2006).

Scientific name: *Trichodesmium* sp.

Plate A1: a-e (Annex A)

Description:

Straight trichomes forming assemblages with radially arranged fascicles joined by mucilage. Most cells are shorter than wide, red or brown in color. Apical cells slightly capitate.

Harmful Effect:

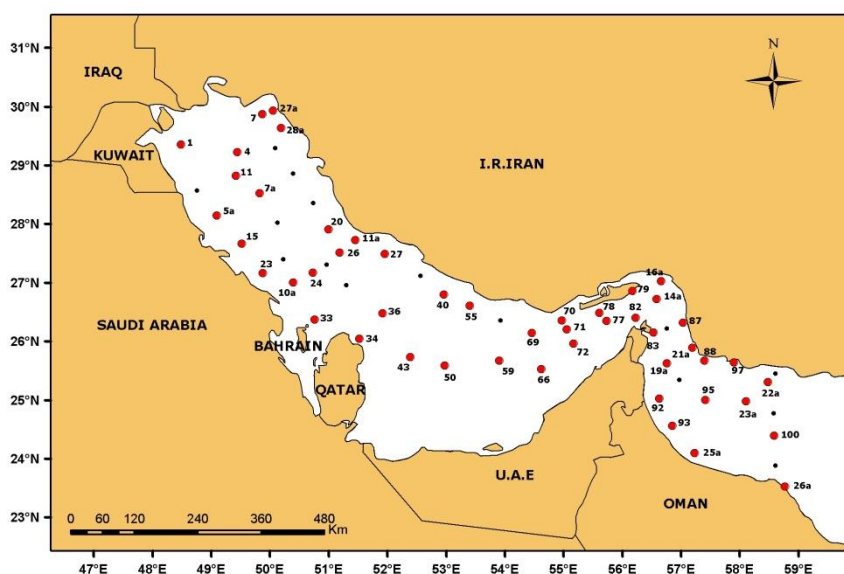
Trichodesmium is a marine cyanophyte and appears in blooms. To date, two species have been reported to be toxigenic, *T. erythraeum* and *T. thiebautii*. Strains can produce neurotoxins and hepatotoxins (Hansen *et al.*, 2001; Cronberg and Annadotter, 2006). *Trichodesmium* blooms have been reported in the past in the RSA, e.g., off Kuwait (Al-Yamani *et al.*, 2004) and the UAE

**Dimensions:**

Trichomes 7-10 μm wide; cells length 3-5 μm .

Sites of occurrence in RSA:

In Winter 2006 Cruise, *Trichodesmium* sp. was frequently found at various sites (refer sites map) the RSA samples, but never reached high abundance. The abundance was low compared to that of the other main taxonomical groups of phytoplankton, such as diatoms and dinoflagellates. Maximum contribution of *Trichodesmium* sp. to the total phytoplankton abundance did not exceed 2%; the highest concentration reached 1.1×10^3 cells/l. The maximum abundances ($> 10^3$ cells/l) were encountered in the southern part of the inner RSA. A bloom of species from the genus *Trichodesmium* (*T. erythraeum*) has been previously reported from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004).



Sites of occurrence of *Trichodesmium* sp. (filaments) in RSA

5.2 Eukaryota

5.2.1 Division: Chromophyta

5.2.1.1 Class: Cryptophyceae Fritsch

Cryptophyceans are found in the plankton all year round, often in great numbers. Most of the species are autotrophic, with cell size from 2.5 to 25 μm . Species identification is possible when the cells are studied alive. Most species are free-swimming single cells. The cells are asymmetrical in shape, with furrow and/or a gullet, which typically is lined with two or more rows of ejectosomes which can be seen as rows of refractive granules in the microscope. The

cell surface is often subdivided in a plate or punctuate pattern, which occasionally may only be observed in the light microscope. There are two heterodynamic flagella inserted on the right side of the vestibulum. Autotrophic species have one or two chloroplasts with chlorophyll *a* and *c*, but due to a varying content of carotenoids, phycocyanin and phycoerythrin, the color may be brown, green, red or blue. The pyrenoid(s) is often large and with a distinct starch shield, which will stain brown with Lugol's solution (Thronsdén *et al.*, 2007).

Division: Chromophyta

Class: Cryptophyceae Fritsch

Order: Cryptomonadales Engler

Family: Cryptomonadaceae Ehrenberg

Genus: Genus *Teleaulax* Hill

The cells are pointed apically and antapically (anterior and posterior end), with a long furrow, red-brown or orange chloroplast with a single pyrenoid (Thronsdén *et al.*, 2007).

Scientific name: *Teleaulax* sp.

Plate A1: i, j (Annex A)

Description:

Cells oval, slightly dorsoventrally flattened, with acute posterior end, rounded apically. Dorsal side strongly curved, ventral side almost straight with furrow. The flagella are equal in length.

Dimensions:

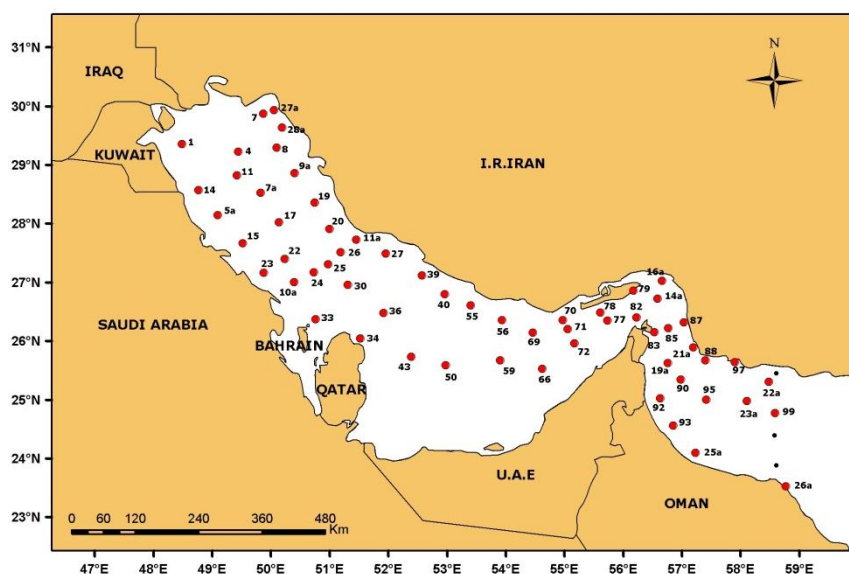
Cells 10-12 µm long, 4 µm wide.

Sites of occurrence in RSA:

In Winter 2006 Cruise, along with diatoms and dinoflagellates, the small-sized autotrophic flagellate *Teleaulax* sp. was considered a significant contributor to the total phytoplankton abundance up to 92 %. The highest concentration of *Teleaulax* sp. reached 2.2×10^5 cells/l.



Maximum abundance ($> 10^5$ cells/l) was observed in the central part of the inner RSA; localized distribution was observed in the Sea of Oman (refer sites map).



Sites of occurrence of *Teleaulax* sp. in RSA

5.2.1 Division: Chromophyta

5.2.1.2 Class: Prymnesiophyceae Hibbert

Order: Prymnesiales Papenfuss

Family: Phaeocystaceae Lagerheim

Genus: Genus *Phaeocystis* Lagerheim

Phaeocystis is a genus of foam-producing species distributed worldwide and causing problems for fishing and tourism in areas as widely scattered as New Zealand (Tasman Bay slime) and the North Sea (Davidson and Marchant, 1992). Recent evidence from Norway has shown that in addition to the problems caused by the foam, *Phaeocystis* may also form toxin(s) responsible for fish kills. *Phaeocystis* is a genus of colony-forming species, and the morphology of the individual colonies is highly variable. Several species of *Phaeocystis* were described mainly around the turn of the century but these 'old' species were all merged into one by Kornmann (1955) and Kashkin (1963), followed by Sournia (1988). This trend has now been reversed, and several authors have suggested that the genus comprises several species for which some of the old names are being applied (e.g., Baumann *et al.*, 1994).

Morphology:

At least two different stages occur in the life cycle, a colony-forming and a single-celled stage. Colonies may attain a length of up to 2 cm, and thus, become visible to the naked eye. The cells are embedded in mucilage, forming a monolayer along the periphery of the colony. Each cell contains 2 (1-4) parietal yellow-green chloroplasts, but lack flagella and haptonema. The unicellular stage is biflagellate, 3-8 μm long, with a very short haptonema which is often very difficult to see with the light microscope. The cells usually contain two chloroplasts. The cell surface is covered with submicroscopic flat scales of two kinds. In some cases, trichocyst-like structures have been found, appearing as pentagonal or nonagonal stars after discharge from the cell (Parke *et al.*, 1971). The life history of *Phaeocystis* is still unresolved, and both the colonies and the single cells may self replicate, the colonies by fragmentation. It appears likely that some colonies originate from single cells which resorb the appendages and divide into colonies. Single or few-celled stages attached to the setae of diatoms may represent flagellates that have settled. They may eventually give rise to the free-floating colonies, which can contain thousands of cells.

Taxonomy:

The taxonomy of *Phaeocystis* is still unresolved, but Medlin *et al.* (1994), based on the morphology of the colonies, geographic distribution, growth in relation to temperature and 18s small subunit ribosomal RNA sequencing recognized three species, in addition to *P. scrobiculata*, which is known only from the flagellated stage and differs markedly from the others.

Harmful Effect:

The main effects of *Phaeocystis* is clogging of fishing nets, and formation of masses of foam, which may reach several meters in thickness (Lancelot *et al.*, 1987). The foam appears when blooms are washed ashore. Like many other marine plankton algae, *Phaeocystis* blooms produce dimethylsulphide (DMS), which is believed to evaporate to the atmosphere and contribute to the acidity of rainwater (Davidson and Marchant, 1992). A direct toxic effect of *Phaeocystis pouchetii* is believed to have occurred in Norway in 1992, causing death of farmed salmon valued at NKr 1 million. The toxic compound(s) has not been identified (Hallegraeff *et al.*, 1995; IOC list, 2002).

Scientific name: *Phaeocystis globosa*

Plate A: f-h (Annex A)

Description:

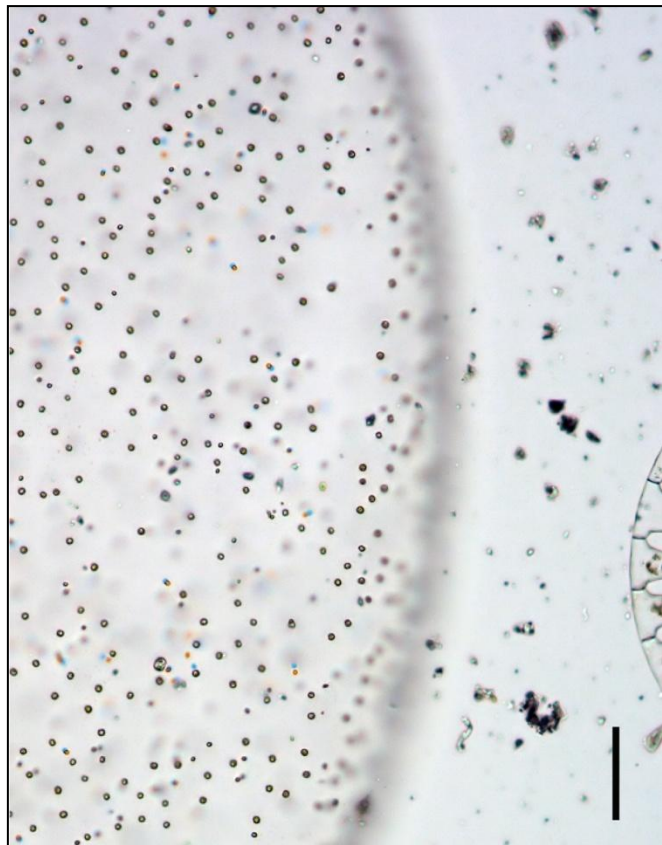
Colony-forming cells are embedded in mucilage, forming a monolayer along the periphery of the colony. Each cell contains 2 chloroplasts.

Dimensions:

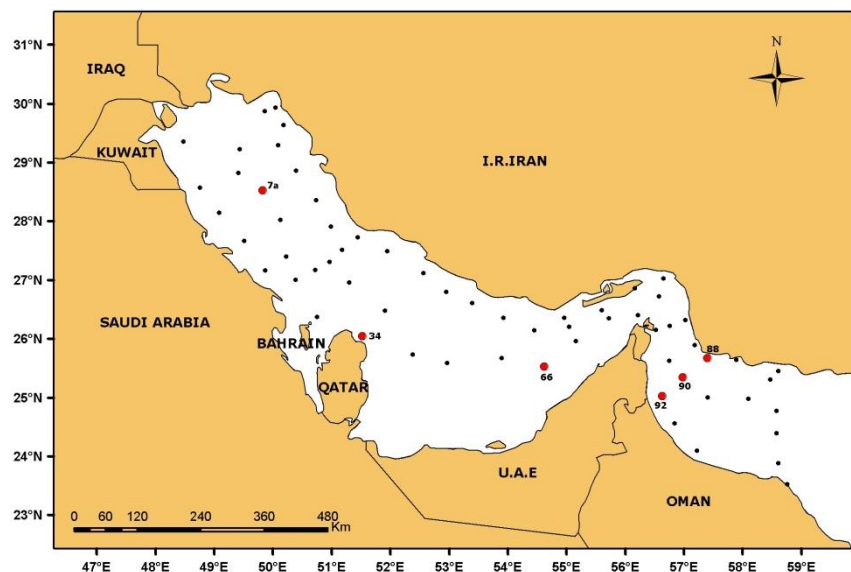
Cells 3-3.5 μm long.

Sites of occurrence in RSA:

The occurrence of the colonial stage of *Phaeocystis globosa* was found as fragments of colonies. In Winter 2006



Cruise, relatively higher occurrences were observed in the waters of the Sea of Oman (refer sites map). Earlier studies in the waters of Kuwait (Al-Yamani *et al.*, 2004) indicated blooms of the aforementioned species (with large colonies) during winter and early spring.



Sites of occurrence of *Phaeocystis globosa* in RSA

5.2.1 Division: Chromophyta

5.2.1.3 Class: Bacillariophyceae

Diatoms (Bacillariophyceae) are unicellular microalgae universally distributed in all types of aquatic environment. The most obvious feature of diatoms is their siliceous cell wall (frustule) made of two intricately sculptured halves (valves). Diatoms form the majority of floating algae (planktonic) in marine and freshwaters. It is estimated that these microalgae may account for 40 to 45 % of oceanic production making them more productive than all the world's rainforests (Mann, 1999). These microalgae play an important role in global cycling of silica and carbon and at the same time sustain fisheries (Mann, 1999). Diatoms multiply rapidly, maintaining a dynamic population of varying size.

In Winter 2006 Cruise, diatoms dominated the phytoplankton community at most of the sampled stations. As the dominant group, diatoms contributed 70-90 % (and up to 99.75 %) of the total phytoplankton abundance; the highest concentration reached 1.83×10^6 cells/l. The higher abundances of diatoms ($> 10^6$ cells/l) were associated with the central part of the inner RSA off the Iranian coast, extending to the Strait of Hormuz area and the coastal zone of the Sea of Oman. Localized peaks at the bottom layer were detected in Kuwaiti waters.

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Coscinodiscineae

Family: Thalassiosiraceae Lebour

Genus: Genus *Cyclotella* (Kützinger) Brébisson

Cells usually solitary, but sometimes united in short chains. Frustules short, cylindrical, discoid, rectangular in girdle view, the valve appearing to be undulated; valves circular, valve surface undulate, undulation more evident in the middle area. Middle area punctate, marginal

area striate. Chromatophores, numerous rounded bodies are scattered throughout the cell and often lying against the valves (Hendey, 1964).

Scientific name: *Cyclotella striata* (Kützinger) Grunow *ex* Cleve *et* Grunow

Plate A2: g-l (Annex A)

Synonyms:

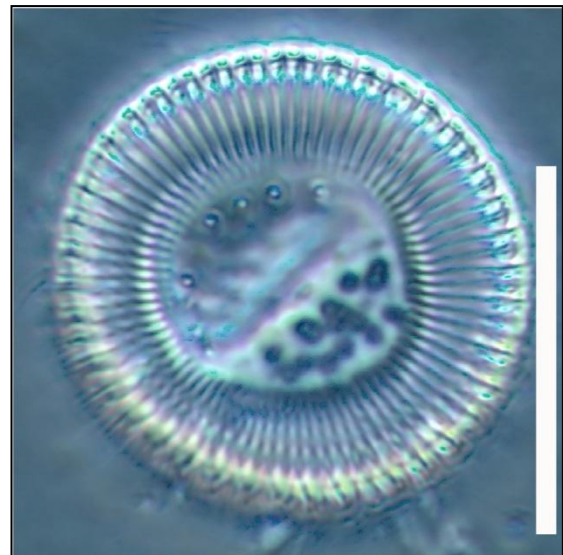
Coscinodiscus striatus Kützinger; *Cyclotella dallasiana* Smith

References:

Hustedt, 1930: p. 344, Fig. 176; Hendey, 1964: p. 74; Simonsen, 1974: p. 13; Ricard, 1987: p. 159, Fig. 108-111.

Description:

Cells discoid, somewhat rectangular in girdle view. Valve circular, strongly undulate, valve surface marked by a diametrical fold, very evident in the central area. Valve surface is divided sharply into two areas, the center being somewhat coarsely punctate, puncta irregularly scattered, and the marginal area, from about half of radius, being radially striate, radial striae 8 in 10 μm ; diameter of valve 20-60 μm (Hendey, 1964).



Dimensions:

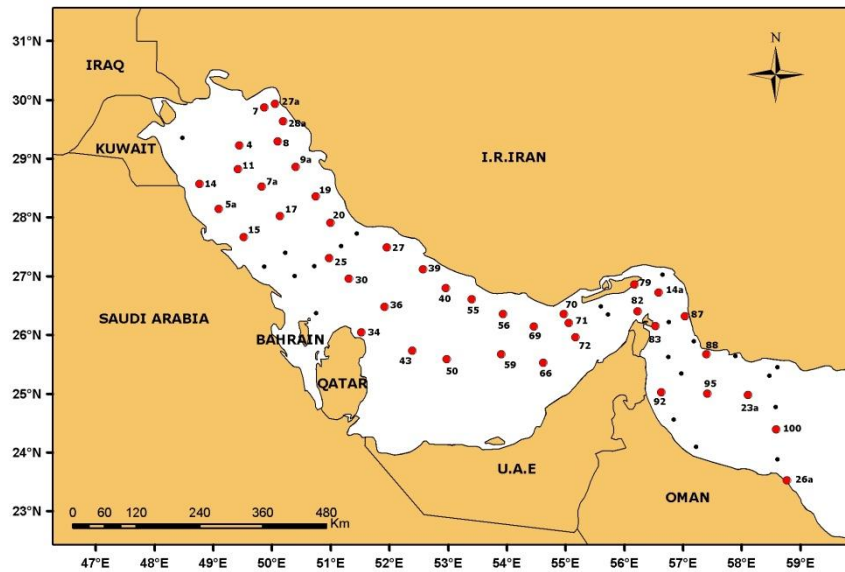
Valve diameter 25-30 μm .

Distribution:

Common marine and brackish-water species, often abundant in estuaries.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was frequently found mainly in the northwestern part of the inner RSA (refer sites map). Species has been previously reported from the northern part of the inner RSA (Simonsen, 1974) and from Kuwaiti waters (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Cyclotella striata* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Coscinodiscineae

Family: Thalassiosiraceae Lebour

Genus: Genus *Cyclotella* (Küzing) Brébisson

Species: *stylorum*

Scientific name: *Cyclotella stylorum* Brightwell

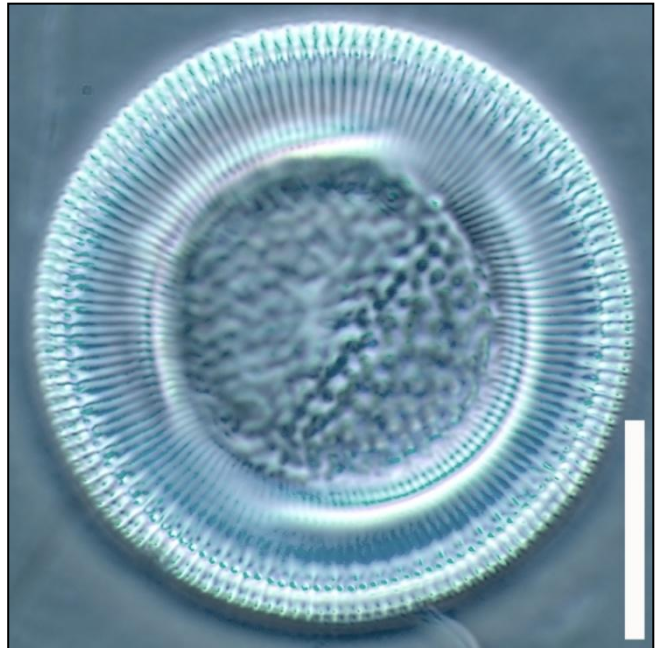
Plate A2: a-f (Annex A)

References:

Hustedt, 1930: p. 349, Fig. 179; Hendey, 1970: p. 112, Pl. 6: 68; Simonsen, 1974: p. 13.

Description:

The surface structure of the valve is very complex. The outer striated zone is slightly elevated at the margin, and is depressed as it meets the central portion. This central portion is raised to the same level as the outer zone, and its surface has an irregularly corrugated appearance



(not distinctly punctate) and is crossed by an undulation which does not extend into the striate outer zone. Diameter 24-32 μm , but cells may be larger (Hendey, 1970).

Dimensions:

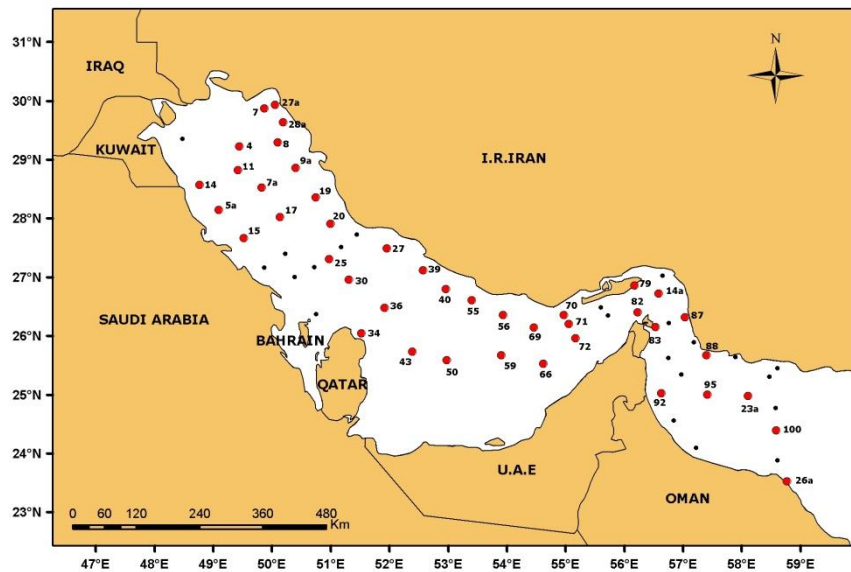
Valve diameter 35-44 μm .

Distribution:

It is littoral benthic species, mainly distributed in warm waters; allochthonous in the plankton.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed in the north-western part of the inner RSA (refer sites map). It has been previously reported from the inner RSA (Simonsen, 1974) and from Kuwaiti shore (Hendey, 1970) and coastal waters (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Cyclotella stylorum* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Coscinodiscineae

Family: Thalassiosiraceae Lebour

Genus: *Detonula* Schütt *ex* De Toni

Cells cylindrical, close together in chains by a central thread form a strutted process and by outer tubes from strutted processes in a margin ring. One marginal labiate process is present (Thronksen *et al.*, 2007).

Scientific name: *Detonula pumila* (Castracane) Schütt

Plate A3: a-d (Annex A)

Synonyms:

Schroederella delicatula Pavillard; *Thalassiosira condensata* Cleve; *Lauderia delicatula* Péragallo; *Detonula delicatula* Gran; *Detonula schroderi* Gran; *Lauderia schroderi* Bergon; *Schroederella schroderi* (Bergon) Pavillard

References:

Pavillard, 1925: p. 22, Fig. 33 (as *Schroederella delicatula*); Hustedt, 1930: p. 552, Fig. 314 (as *Schroederella delicatula*); Allen and Cupp, 1935: p. 123, Fig. 26 (as *Schroederella delicatula*); Cupp, 1943: p. 76, Fig. 36 (as *Schroederella delicatula*); Crosby and Wood, 1958: p. 494, Pl. 35: 15 (as *Schroederella delicatula*); Hendey, 1964: p. 142, Pl. V: 4; VII: 6; Simonsen, 1974: p. 13, Pl. 6: 3; Ricard, 1987: p. 161, Fig. 133; Throndsen *et al.*, 2007: p. 128.

**Description:**

Cells are cylindrical. Valves are more or less convex, sometimes almost flat, always with a depression in the middle; diameter 16-42 µm. Cells are bound in straight, more or less stiff or loose chains; intercalary bands collarlike, varying greatly in number. Mantle surface of the cell is delicately areolated, 18-20 areolae in 10 µm, sometimes very difficult to see, arranged in a two-line system with the lines crossing each other. Marginal spines or threads are 7-8 in 10 µm. Resting spores and auxospores, unknown (Cupp, 1943).

Dimensions:

Cells length 19-22 µm; diameter 22-26 µm.

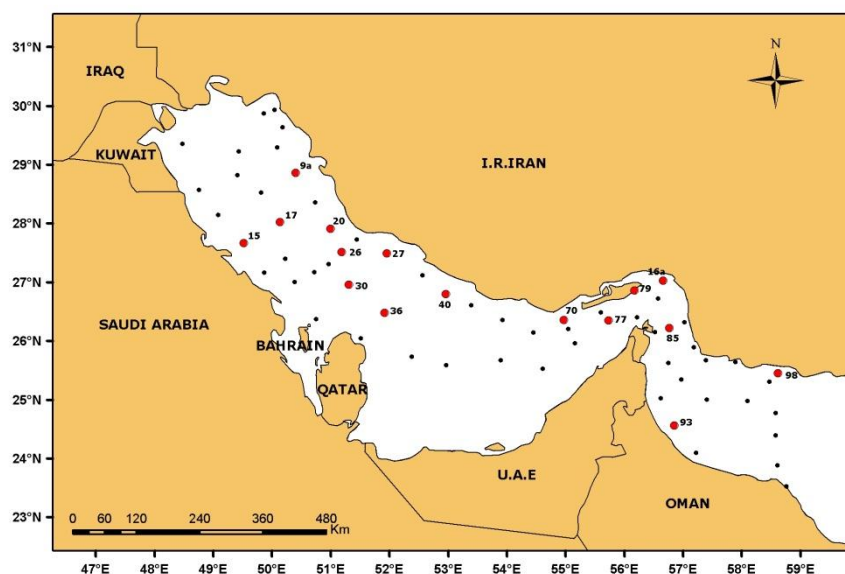
Distribution:

Cosmopolitan species, but most frequently encountered in warmer seas.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred usually in small numbers at certain sites (refer sites map); maximum abundance (5.4×10^4 cells/l) was associated with the Strait of Hormuz

area (St. 79, 85). It has been previously reported from the inner RSA (Simonsen, 1974) and from Kuwaiti waters (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Detonula pumila* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Coscinodiscineae

Family: Thalassiosiraceae Lebour

Genus: *Lauderia* Cleve

Cells cylindrical. Valves rounded. Cells united in straight chains by very fine gelatinous threads, cells either touching or separated. An unpaired, oblique, outwardly directed apiculus on each valve, and numerous very small spinulae or slime canals at the margin and over most of the surface. Center of valve is slightly concave. Intercalary bands numerous; collarlike; more or less conspicuous. Chromatophores are numerous small plates. Nucleus more or less central, in a cytoplasmic cord which binds the central parts of the valves together. Although the cell wall is thin, it has a distinct structure. The valve surface is radially striated, the mantle surface of the intercalary bands delicately areolated (Cupp, 1943).

Scientific name: *Lauderia borealis* Gran

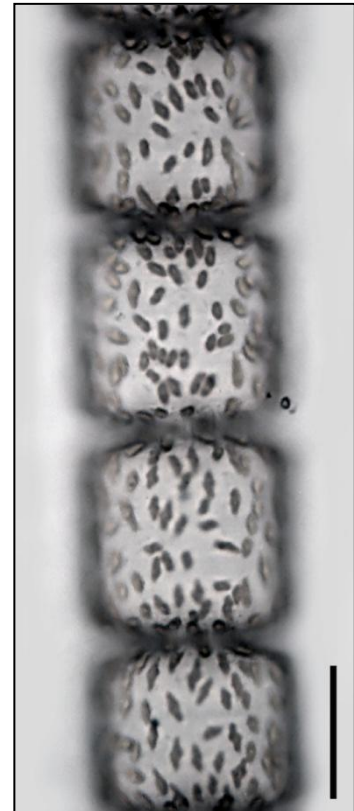
Plate A4: a-h (Annex A)

References:

Pavillard, 1925: p. 21, Fig. 32; Hustedt, 1930: p. 550, Fig. 313; Cupp, 1943: p. 74, Fig. 35; Hendey, 1964: p. 143; Ricard, 1987: p. 163, Fig. 147.

Description:

Cells in thick, straight chains, touching their valve surfaces. Valves slightly concave in the center, rounded at the margins. Marginal spinulae straight with gelatinous straight, radiating, longer or shorter threads, the longer reaching the adjacent cell. A single unpaired spine, thicker and more robust than the others, occurs near the margin of the valve. Diameter of cells 28-47 μm . Intercalary bands, as in general, the entire cell wall, are comparatively delicate, indistinct in water except in older cells or on older valve. Mantle surface delicately areolated-punctated, puncta in irregular rows. Intercalary bands with about 16 puncta in 10 μm , irregularly arranged. No resting spores known. Chromatophores are small, lobed, grouped at ends of cell in strong light (Cupp, 1943).



Dimensions:

Cells diameter 38-55 μm .

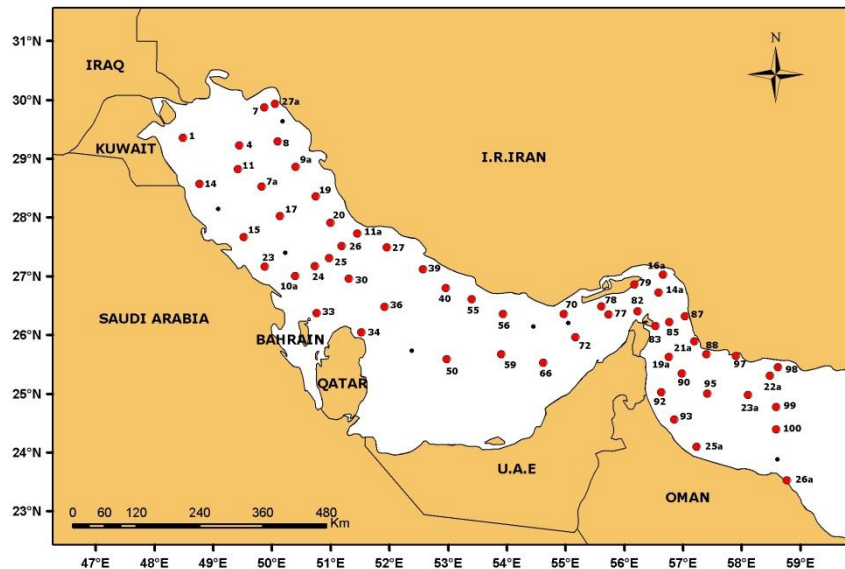
Distribution:

Neritic, temperate species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, *Lauderia borealis* was commonly found in the RSA phytoplankton (refer sites map), often in significant abundance. It contributed up to 61 % of the total phytoplankton abundance; the highest concentration reached 3.4×10^5 cells/l. High abundance

of *Lauderia borealis* ($> 10^5$ cells/l) was observed in the Sea of Oman (Stations 97 and 25a). Species has been previously reported from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004).



Sites of occurrence of *Lauderia borealis* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Coscinodiscineae

Family: Thalassiosiraceae Lebour

Genus: *Planktoniella* Schütt

Cells single; disk-shaped, with a hyaline winglike expansion all around consisting of extracellular chambers strengthened by radial rays. The winglike expansion is weakly siliceous, an organ of flotation. Areolae hexagonal, arranged in slightly curved, nearly parallel rows, based on arrangement of seven divisions. Central areola with seven areolae grouped around it. Chromatophores are numerous small plates which lie along the valve surface (Cupp, 1943).

Scientific name: *Planktoniella sol* (Wallich) Schütt

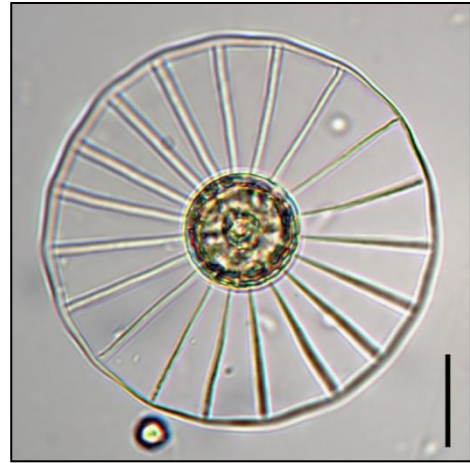
Plate A5: a-f; 6: a-d (Annex A)

Synonym:

Coscinodiscus sol Wallich

References:

Pavillard, 1925: p. 15, Fig. 21; Hustedt, 1930: p. 465, Fig. 259; Allen and Cupp, 1935: p. 120, Fig. 19; Cupp, 1943: p. 64, Fig. 27; Crosby and Wood, 1958: p. 498, Pl. 32: 18; Hendey, 1964: p. 82; Simonsen, 1974: p. 12; Ricard, 1987: p. 161, Figs. 124-128; Throndsen *et al.*, 2007: p. 130.



Description:

Valves nearly flat; cells disk-shaped. Areolae hexagonal, arranged in slightly curved, nearly parallel rows, based on arrangement of seven divisions. Central areola with seven areolae grouped around it. Areolae 5-7 in 10 μm in center of valve; 7-8 midway to margin; and 8-9 near margin. Central disk varies in diameter from 21 to 81 μm ; entire cell from 50 to 165 μm . Only one valve of the cell is provided with the wings, so upon division one daughter cell has none. Few wingless cells have been observed, however, perhaps because they sink rapidly, because they are not distinguishable from *Coscinodiscus excentricus*, or because new wings are produced rapidly (Cupp, 1943).

Dimensions:

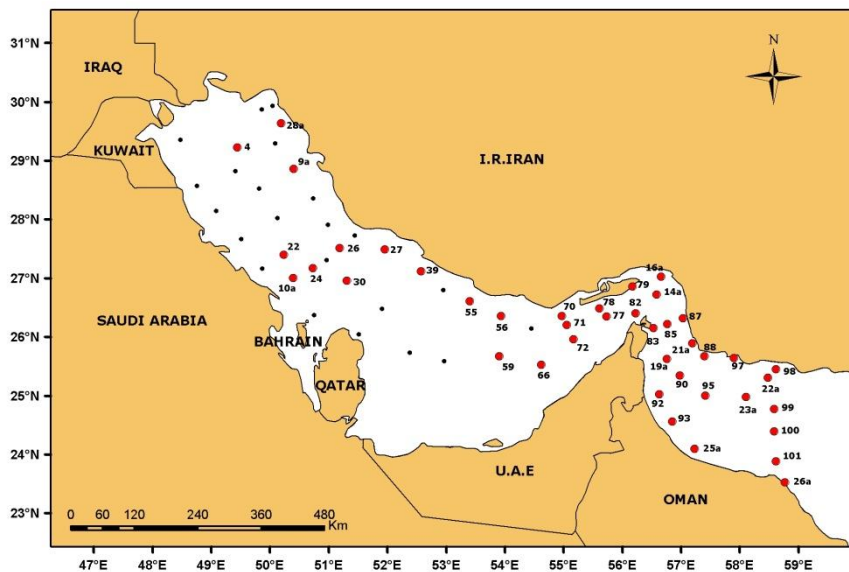
Diameter of central disk 45-70 μm ; entire cell 100-110 μm .

Distribution:

Oceanic species; probably living near the bottom. Widely distributed but most common in subtropical or tropical seas (Cupp, 1943).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at various sites (refer sites map), usually in small numbers; however, it was quite abundant at some localities; maximum abundance (10^3 cells/l) was associated with the Sea of Oman (St. 25a, 26a). It has been previously reported from the inner RSA (Simonsen, 1974) and Kuwaiti waters (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Planktoniella sol* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Coscinodiscineae

Family: Thalassiosiraceae Lebour

Genus: *Porosira* Jørgensen

Cells usually united by means of a thick mucous rope or pad to form chains. Cells rectangular, with rounded corners, and furnished with spines. Valve surface very finely areolata. Girdle composed of several bands. Chromatophores numerous, rounded or irregular plates (Hendey, 1964).

Scientific name: *Porosira* sp.

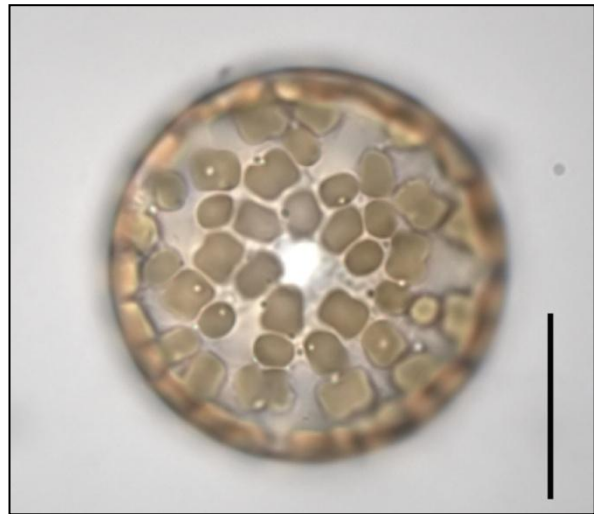
Plate A35: f, g (Annex A)

Description:

Valve circular; slightly convex. Valve surface furnished with irregularly scattered pores. Numerous chloroplasts as irregular plates. Only solitary cells were observed in preserved material.

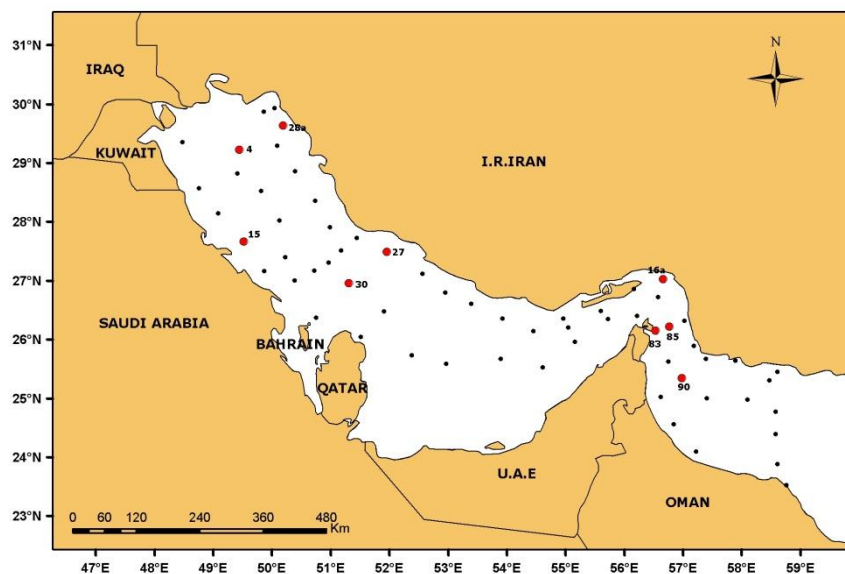
Dimensions:

Valve diameter 39-43 μm .



Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at few sites (refer sites map) in low abundance and occurred in the northwestern part of the inner RSA and within the Strait of Hormuz area.



Sites of occurrence of *Porosira* sp. RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Coscinodiscineae

Family: Thalassiosiraceae Lebour

Genus: *Skeletonema* Greville

Cells circular, lens-shaped, oblong, or cylindrical. Valves circular, somewhat arched, without distinct structure, with a row of fine spines at the edge of the valve parallel to longitudinal perivalvar axis. Spines interlock midway between adjacent cells and unite cells into chains. Cytoplasm of neighboring cells in contact through hollow spines. Chromatophores one or two in a cell. Nucleus central. Auxospores formed (Cupp, 1943).

Scientific name: *Skeletonema* cf. *costatum* (Greville) Cleve

Plate A7: f-k (Annex A)

Synonym:*Melosira costata* Greville**References:**

Pavillard, 1925: p. 8, Fig. 8; Hustedt, 1930: p. 312, Fig. 149; Allen and Cupp, 1935: p. 113, Fig. 3; Cupp, 1943: p. 44, Fig. 6; Crosby and Wood, 1958: p. 492, Pl. 35: 4; Hendey, 1964: p. 91, Pl. VII: 3; Simonsen, 1974: p. 13; Ricard, 1987: p. 161, Fig. 134-139; Throndsen *et al.*, 2007: p. 130-131.

Description:

Cells lens-shaped, elliptical, or cylindrical with rounded ends. Chains are long, thin, usually straight. Cells are held in chains only by means of spines. Spaces between cells are usually or often longer than cells themselves. Chromatophores two. Nucleus central. Diameter of cells 3-20 μm . Auxospores not uncommon. In chains, 6 μm in diameter, auxospores are 17-20 μm in diameter (Cupp, 1943).



Harmful Effect:

Non-toxic bloom-forming species. It is not considered harmful, but dense blooms may lead to loss of appetite and change in behavior among farmed fish. Blooms of this species produce basically harmless water discolorations, with the result that the recreational value of the bloom area decreases due to low visibility of the water and eventually, under exceptionally weather conditions in sheltered bays, the blooms can grow so dense that they cause escape reactions and indiscriminate fish kills and kills of benthic invertebrates due to oxygen depletion (Andersen, 1996).

Dimensions:

Cells length 10-12 μm ; diameter 7-8 μm .

Taxonomic Remarks:

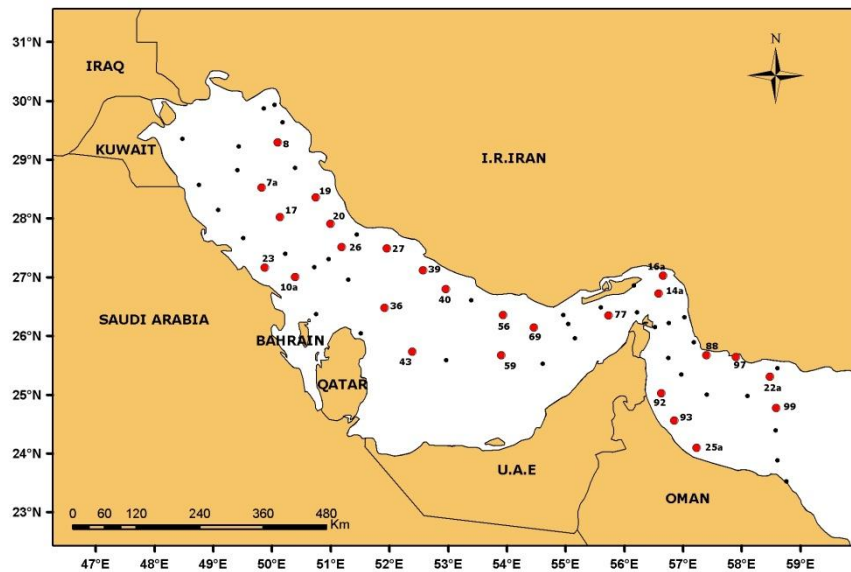
Prior to the year 2005, seven *Skeletonema* had been described, of which *Skeletonema costatum* was regarded as cosmopolitan and was one of, or perhaps the most frequently recorded planktonic diatom globally. Examination of type material of *Skeletonema costatum* from Hong Kong Bay by EM, and further genetic and fine structural studies of a huge material from all oceans showed, however, that what had been recorded as *Skeletonema costatum*, could well be any of the six new *Skeletonema* species described after the turn of the century (Thronsen *et al.*, 2007).

Distribution:

Neritic, widely distributed in all sea species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, *Skeletonema* cf. *costatum* was observed occasionally in the samples of scattered stations (refer sites map), often in high concentrations. Its maximum contribution to the total phytoplankton abundance reached 57 %; the highest concentration was 7.9×10^5 cells/l. Distribution of this species was localized. High abundance of *Skeletonema* cf. *costatum* ($> 10^5$ cells/l) was recorded in the waters off the Iranian coast in the central part of the inner RSA. It has been previously reported from the Indian Ocean (Simonsen, 1974) and from Kuwaiti waters (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Skeletonema cf. costatum* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Coscinodiscineae

Family: Thalassiosiraceae Lebour

Genus: *Thalassiosira* Cleve

Cells usually drum- or disk-shaped, united in flexible chains by a cytoplasmic or gelatinous thread, or living in formless gelatinous masses, or seldom solitary. One or more intercalary bands to each valve. Valves with areolae or delicate radial rows of punctations. Structure is often difficult to see. Marginal spinulae or little spines are present, usually distinct, sometimes with mucilage threads extruding which may be much longer than the cell itself. Valves rounded or flat, in a few species depressed in the center. Chromatophores are numerous, small, and platelike. Auxospores are formed as large bladders by separation of the valves and formation of larger cells in these. Resting spores known in several species, resembling biconvex lenses, formed in regular cells. A true planktonic genus. Mucilaginous threads help adapt it for floating (Cupp, 1943).

Scientific name: *Thalassiosira eccentrica* (Ehrenberg) Cleve

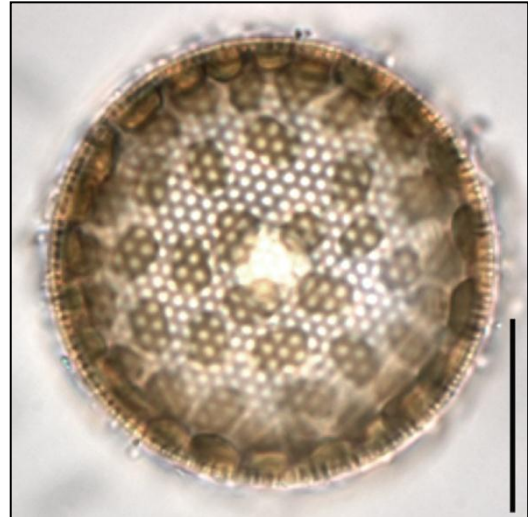
Plate A8: a-f (Annex A)

Synonym:

Coscinodiscus eccentricus Ehrenberg

References:

Pavillard, 1925: p. 10, Fig. 12 (as *Coscinodiscus excentricus*); Hustedt, 1930: p. 388, Fig. 201 (as *Coscinodiscus excentricus*); Allen and Cupp, 1935: p. 113, Fig. 5 (as *Coscinodiscus excentricus*); Crosby and Wood, 1958: p. 496, Pl. 31: 10 (as *Coscinodiscus excentricus*); Hendeey, 1964: p. 80, Pl. XXIV: 7 (as *Coscinodiscus eccentricus*); Simonsen, 1974: p. 9, Pl. 2: 1-3; Throndsen *et al.*, 2007: p. 136.



Description:

Girdle view: valve face flat, mantle low and rounded. Connecting thread between cells in chains relatively long, up to about twice the length of cell diameter. Valve view: areolae in curved tangential rows (eccentricus structure) with tendency to fasciation in larger cells. Central strutted process is close to a larger areola surrounded by seven areolae. Strutted processes are scattered over the valve face and in two marginal rings. One ring of coarse spines at some distance from the margin (Throndsen *et al.*, 2007).

Dimensions:

Valve diameter 39-52 μm .

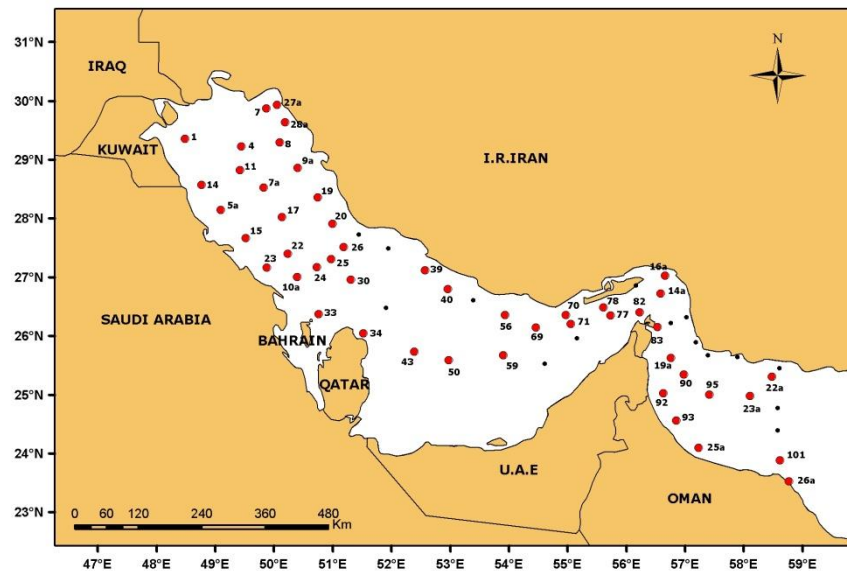
Distribution:

Neritic cosmopolitan species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at various sites (refer sites map), usually in small numbers; however, it was quite abundant at some localities; maximum abundance

(5×10^3 cells/l) was associated with the northwestern part of the inner RSA off Saudi Arabia (St. 23). It has been previously reported from the inner RSA (Simonsen, 1974) and Kuwaiti waters (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Thalassiosira eccentrica* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Coscinodiscineae

Family: Thalassiosiraceae Lebour

Genus: *Thalassiosira* Cleve

Species: *oestrupii*

Scientific name: *Thalassiosira oestrupii* (Ostenfeld) Hasle

Plate A9: a-h (Annex A)

Synonyms:

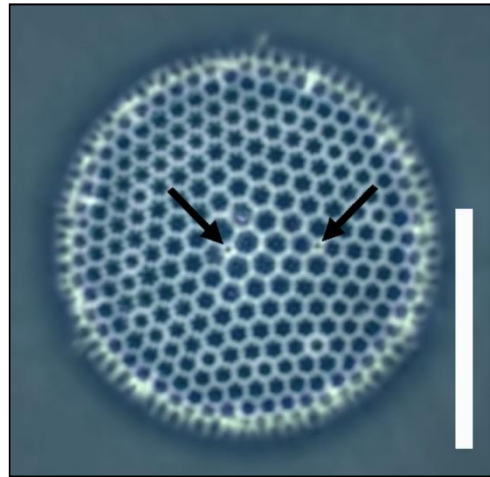
Coscinosira oestrupii Ostenfeld; *Thalassiosira antiqua* var. *septata* Proschkina-Lavrenko

References:

Allen and Cupp, 1935: p. 113, Fig. 4 (as *Coscinosira oestrupii*); Hustedt, 1930: p. 318, Fig. 155 (as *Coscinosira oestrupii*); Hendey, 1964: p. 89 (as *Coscinosira oestrupii*); Simonsen, 1974: p. 10, Pl. 1: 3-5; Scott and Marchant, 2005: p. 108, Fig. 2.56: a-d.

Description:

Cells chain-forming, united by chitinous threads from the off-central strutted process, discoid to rectangular in girdle view; perivalvar axis 0.5-2 times valve diameter. Valves circular, 7-60 μm diameter, flat to slightly convex. Areolation eccentric, coarse; areolae 5-10 in 10 μm in the center, 6-12 in 10 μm nearer the margin. Strutted processes trifurcate and operculate, with internal extensions; 1 process in an off-center position and 1 marginal ring of processes 6-8 in 10 μm (not visible by LM). Labiate process solitary, not marginal, internally flattened and parallel to margin (Scott and Marchant, 2005).

**Dimensions:**

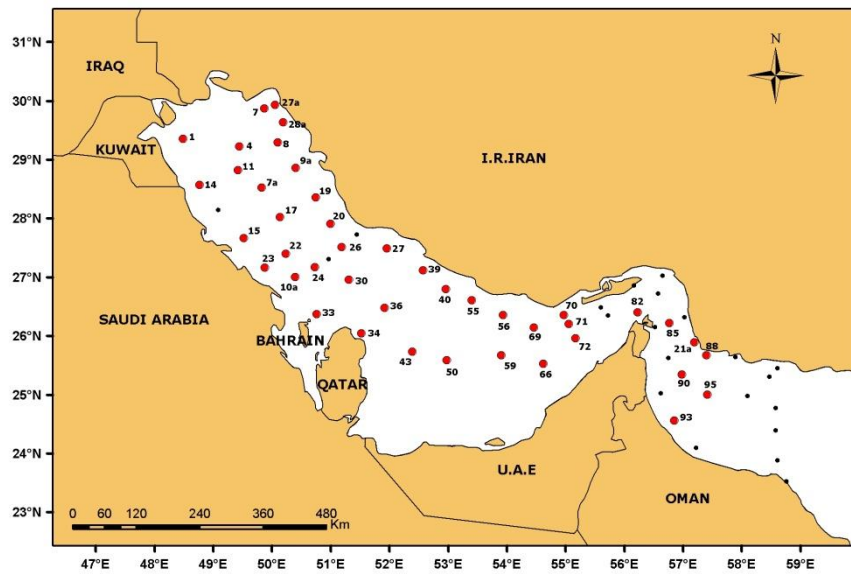
Valve diameter 18-30 μm .

Distribution:

Cosmopolitan species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at various sites (refer sites map), usually in small numbers; however, it was rather abundant at some localities; maximum abundance (1.9×10^4 cells/l) was associated with the northwestern part of the inner RSA off Saudi Arabia (St. 23). It has been previously reported from the inner RSA (Simonsen, 1974) and Kuwaiti waters (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Thalassiosira oestrupii* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Coscinodiscineae

Family: Thalassiosiraceae Lebour

Genus: *Thalassiosira* Cleve

Scientific name: *Thalassiosira* sp.

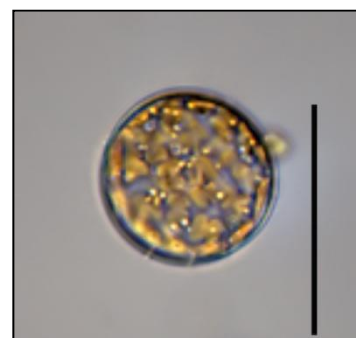
Plate A9: i, j (Annex A)

Description:

Valve circular, valve surface flat, convex in center. Cells very small, valve structure is not distinct by LM.

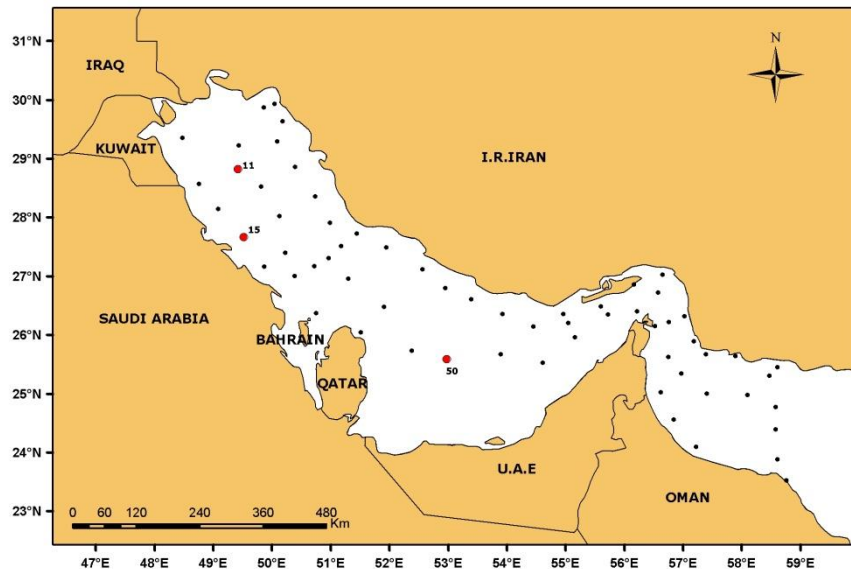
Dimensions:

Valve diameter 6-7 μm .



Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was found at three sites (refer sites map) in low density.



Sites of occurrence of *Thalassiosira* spp. in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Coscinodiscineae

Family: Melosiraceae Kützing

Genus: *Paralia* Heiberg

Cells shortly cylindrical; united to form chains. Valves circular. Valve surface with faint radial lines merging into a wide, downwards sloping valve margin, and valve mantle that is strongly loculate and ornamented with a coarse network of sub-hexagonal cellulation. Chromatophores usually numerous small rounded bodies (Hendey, 1964).

Scientific name: *Paralia sulcata* (Ehrenberg) Cleve

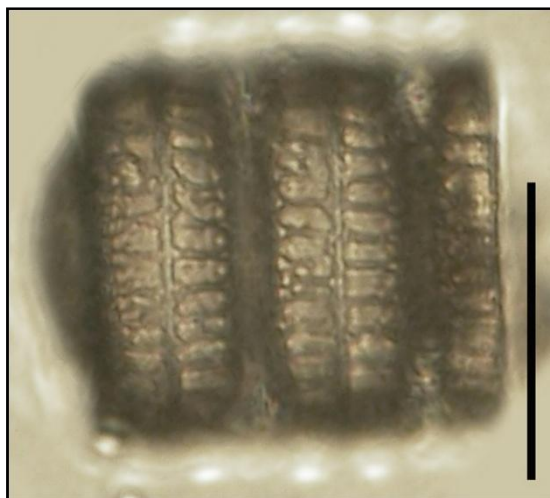
Plate A6: e-h (Annex A)

Synonyms:

Melosira sulcata (Ehrenberg) Kützing;
Gaillonella sulcata Ehrenberg

References:

Pavillard, 1925: p. 4, Fig. 1; Hustedt, 1930: p. 276, Fig. 118; Allen and Cupp, 1935: p. 112, Fig. 1; Cupp, 1943: p. 40, Fig. 2 (as *Melosira sulcata*); Crosby and Wood, 1958: p. 489, Pl. 31: 2 (as *Melosira sulcata*); Hendeby, 1964: p. 73, Pl. XXIII: 5; Hendeby, 1970: p. 109; Simonsen, 1974: p. 8; Ricard, 1987: p. 167, Fig. 174-182; Witkowski *et al.*, 2000: p. 37, Pl. 8: 10, 11; Throndsen *et al.*, 2007: p. 145.

**Description:**

Girdle view: dense chains. Cell wall, coarsely silicified. Cells wider than high. Valve face flat; several small disc-shaped chloroplasts. Valve view: end valve of chains without spines and elevations. Pervalvar axis 3-45 μm ; diameter 8-130 μm (Throndsen *et al.*, 2007).

Dimensions:

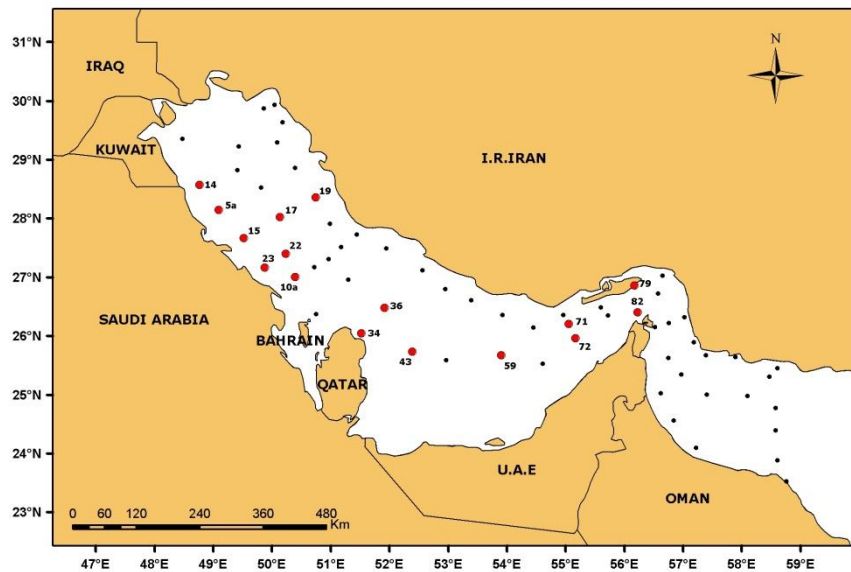
Cells length 8-12 μm ; diameter 15-22 μm .

Distribution:

Species is common in coastal plankton.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at different sites (refer sites map) in small numbers; maximum abundance (5.2×10^2 cells/l) was associated with the central part of the inner RSA (St. 43). It has been previously reported from the northern part of the inner RSA (Simonsen, 1974) and from Kuwaiti shore (Hendeby, 1970) and coastal waters (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Paralia sulcata* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Coscinodiscineae

Family: Melosiraceae Kützinger

Genus: *Stephanopyxis* Ehrenberg

Cells oblong, oval, or nearly circular, with hexagonal areolations. Usually in short chains. Margins rounded, with a crown of stout spines or hollow needles, nearly parallel with the perivalvar axis. Cytoplasm of adjacent cells in contact through hollow spines. No intercalary bands. Chromatophores are small, numerous and rounded. Resting spores known (Cupp, 1943).

Scientific name: *Stephanopyxis palmeriana* (Greville) Grunow

Plate A10: a-f (Annex A)

Synonym:

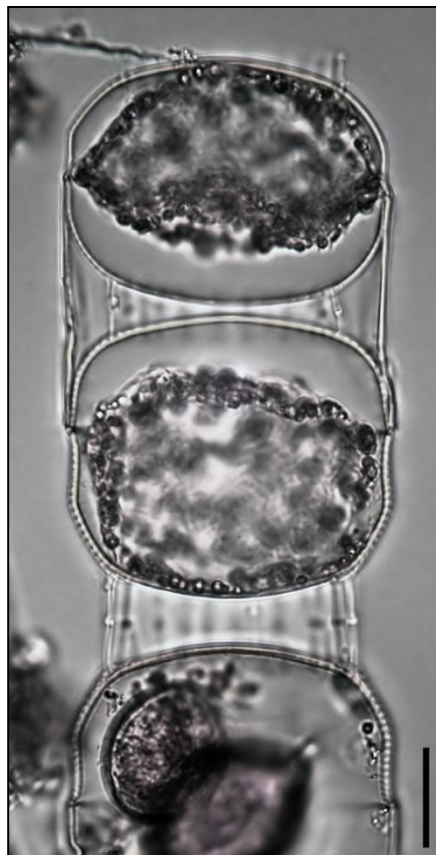
Creswellia palmeriana Greville

References:

Pavillard, 1925: p. 5, Fig. 3; Hustedt, 1930: p. 308, Fig. 147; Allen and Cupp, 1935: p. 112, Fig. 2; Cupp, 1943: p. 40-41, Fig. 4; Crosby and Wood, 1958: p. 491, Pl. 35: 2; Simonsen, 1974: p. 7.

Description:

Cells oblong, with the slight narrowing of the cylindrical part of the valve against the margin, and by the hexagonal areolations which are slightly smaller near the girdle line than on the rest of the valve. Areolae $1\frac{1}{2}$ - $2\frac{1}{2}$ in 10 μ m at center of valve; $3\frac{1}{2}$ -4 on upper part of mantle; and 5 - $5\frac{1}{2}$ near girdle line. On the newly formed valves, 2 - $2\frac{1}{2}$ areolae in 10 μ m on mantle. Diameter of cells 27-71 μ m. Cells united in chains by 10-22 hollow spines arranged in a circle at each end of cell. Chromatophores numerous, platelike.



Nucleus central. Twin resting spores large, like vegetative cells but thicker-walled; primary valve with uniting spines more radiating than in vegetative cells; secondary valves with acute, diverging spines without connection with another valve (Cupp, 1943).

Dimensions:

Cells diameter 45-62 μ m.

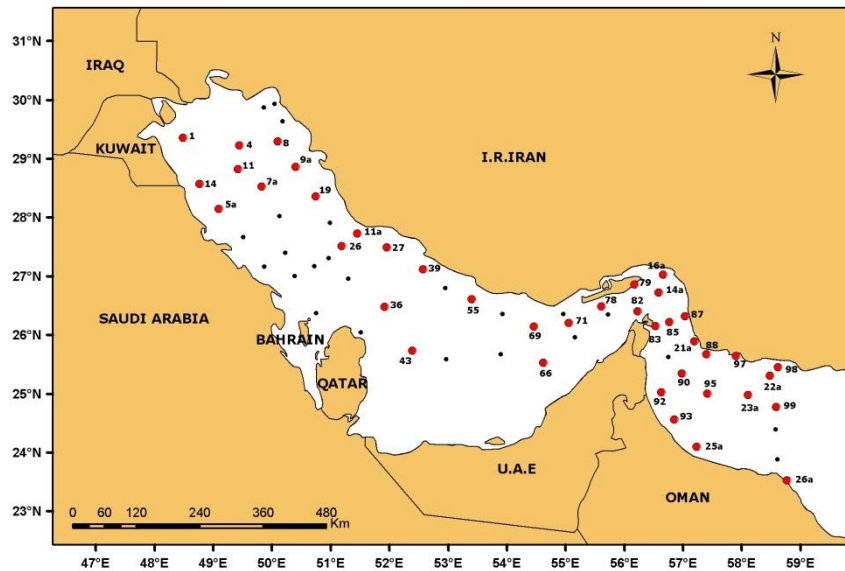
Distribution:

Neritic, warm-water species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was frequently observed at various sites (refer sites map), usually in small numbers; however, it was quite abundant at some localities; maximum abundance (1.1×10^3 cells/l) was associated with the Sea of Oman (St. 88). It has been

previously reported from the inner RSA (Simonsen, 1974) and from Kuwaiti waters (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Stephanopyxis palmeriana* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Coscinodiscineae

Family: Leptocyliindraceae Lebour

Genus: *Leptocyliindrus* Cleve

Cells long, cylindrical, united into chains by whole valve surface. Valves flat, without spines or processes. Intercalary bands present, but very difficult to see. Cells thin-walled, hyaline, without visible sculpturing. Chromatophores one or many roundish plates or granules. Resting spores known (Cupp, 1943).

In Winter 2006 Cruise, the genus *Leptocyliindrus* included three species, of which *Leptocyliindrus danicus* was the most abundant. The genus contains small-sized chain-forming diatom algae. When abundant, it contributed up to 50 % of the total phytoplankton

abundance; the highest concentration reached up to 9.2×10^4 cells/l. High abundance of *Leptocylindrus* spp. ($> 10^4$ cells/l) was recorded in the northwestern part of the inner RSA, in the southern part of the inner RSA near the Strait of Hormuz (off the Iranian coast) and in the Sea of Oman.

Scientific name: *Leptocylindrus danicus* Cleve

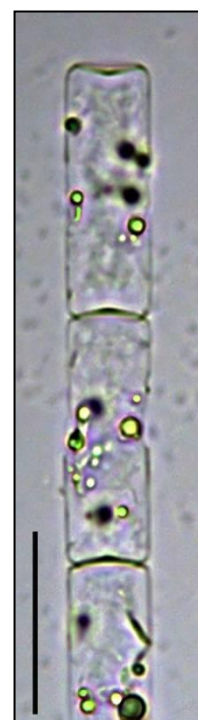
Plate A7: a-c (Annex A)

References:

Pavillard, 1925: p. 24, Fig. 35; Hustedt, 1930: p. 559, Fig. 318, 319; Allen and Cupp, 1935: p. 124, Fig. 27; Cupp, 1943: p. 77, Fig. 39; Crosby and Wood, 1958: p. 524, Pl. 39: 80; Hendey, 1964: p. 140, Pl. V: 2; Ricard, 1987: p. 175, Fig. 250; Throndsen *et al.*, 2007: p. 146.

Description:

Cells cylindrical, 7-10 μm in diameter, two to ten times as long. United in closed, long, stiff chains. Valves flat or convex, occasionally concave, without visible sculpturing. Adjacent cells often with only one cell wall between two valves. Intercalary bands present, but very difficult to see. Chromatophores, few to numerous, not very small, oval plates, distributed throughout the cell. Resting spores and auxospores known. Resting spores covered with spicules (Cupp, 1943).



Dimensions:

Cells length 32-37 μm ; diameter 9-10 μm .

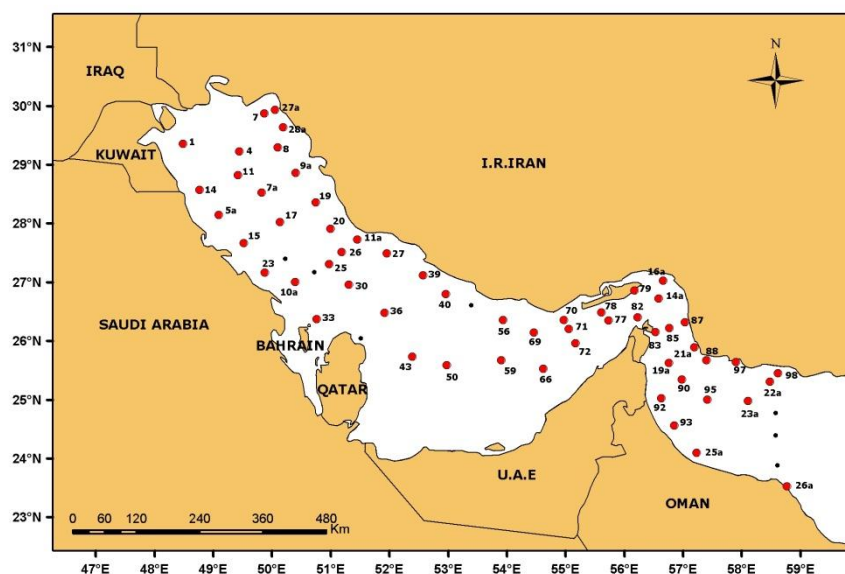
Distribution:

Neritic species, widespread distribution.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was commonly observed at various sites (refer sites map), often in large numbers; maximum abundance (9.2×10^4 cells/l) was associated with the north-

western part of the inner RSA (St. 9a). Species has been previously reported from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Leptocylindrus danicus* in RSA

Harmful Effect:

Nontoxic bloom-forming species. Blooms of this species may produce fish kill in mariculture cages (Yan *et al.*, 2008 – www.pices.int/publications/scientific_reports/Report23/HAB_China.pdf).

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Coscinodiscineae

Family: Leptocylindraceae Lebour

Genus: *Leptocylindrus* Cleve

Species: *mediterraneus*

Scientific name: *Leptocylindrus mediterraneus* (H. Péragallo) Hasle

Plate A7: d, e (Annex A)

Synonym:

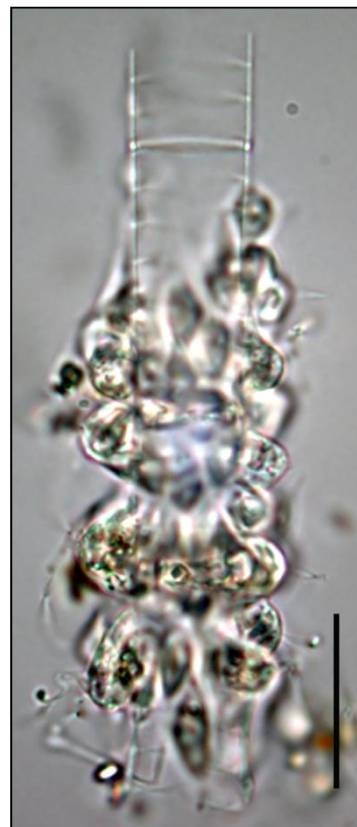
Dactyliosolen mediterraneus H. Pérageallo

References:

Pavillard, 1925: p. 23, Fig. 34 (as *Dactyliosolen mediterraneus*); Hustedt, 1930: p. 559, Fig. 317 (as *Dactyliosolen mediterraneus*); Cupp, 1943: p. 77, Fig. 38 (as *Dactyliosolen mediterraneus*); Crosby and Wood, 1958: p. 524, Pl. 39: 81 (as *Dactyliosolen mediterraneus*); Priddle and Fryxell, 1985: p. 62-63; Throndsen *et al.*, 2007: p. 146.

Description:

Cells cylindrical, with numerous intercalary bands and consequently, usually a very long perivalvar axis. Bound in thick, close-set, even stiff chains. Valves 7-11 μm in diameter, with delicate, irregular areolae, without spines or processes. Intercalary bands 1-5 in 10 μm , with ends lying in a straight perivalvar line. Intercalary bands with large or small areolae, in two-line system, 6-11 in 10 μm . Chromatophores several, not very small, roundish plates. Living cells are nearly always found with yellow epiphytic flagellate, *Rhizomonas setigera* (Pavillard) Patterson *et al.* = *Solenicola setigera* Pavillard, attached on the chains in the girdle-band zone (Cupp, 1943).

**Dimensions:**

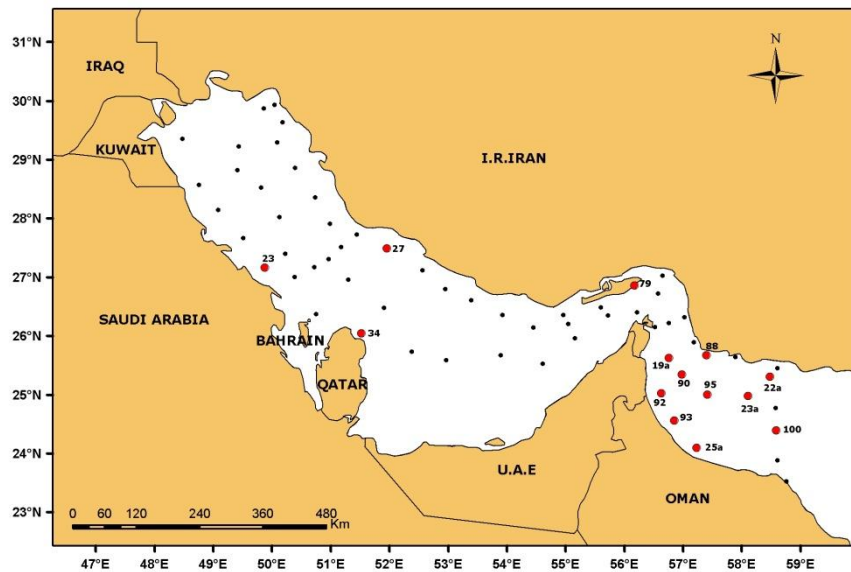
Cells length 30-32 μm ; diameter 15-17 μm .

Distribution:

Neritic, sporadically oceanic widespread species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at scattered stations (refer sites map), usually in small numbers; maximum abundance (1.7×10^3 cells/l) was associated with the Sea of Oman (St. 93).



Sites of occurrence of *Leptocylindrus mediterraneus* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Coscinodiscineae

Family: Leptocylindraceae Lebour

Genus: *Leptocylindrus* Cleve

Species: *minimus*

Scientific name: *Leptocylindrus minimus* Gran

Plate A7: a (Annex A)

References:

Hustedt, 1930: p. 560, Fig. 321; Hendeby, 1964: p. 140, Pl. V: 3; Throndsen *et al.*, 2007: p. 146.

Description:

1-2 elongate chloroplasts; diameter, 1.5-4.5 μm . Chains sometimes undulated, produces resting spores (Throndsen *et al.*, 2007).



Dimensions:

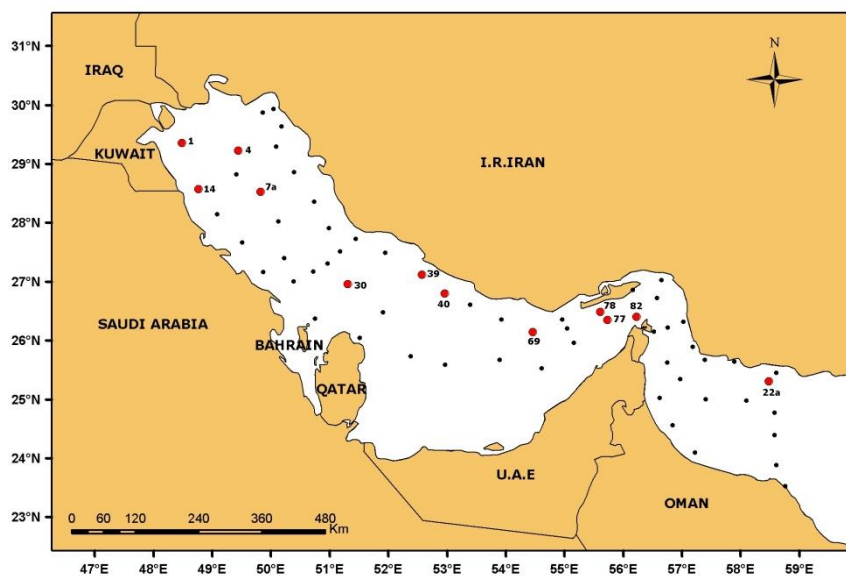
Cells length 7-9 μm ; diameter 3-4 μm .

Distribution:

Neritic species, widespread distribution.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at scattered stations (refer sites map), usually in small numbers; maximum abundance (2.3×10^3 cells/l) was associated with the Sea of Oman (St. 22a). It has been previously reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Leptocylindrus minimus* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Coscinodiscineae

Family: Leptocylindraceae Lebour

Genus: *Corethron* Castracane

Cells living singly. Cylindrical with rounded valves having a crown of long thin spines or setae at the margin directed outward at an angle. Numerous intercalary bands, scalelike, often very indistinct. Cell wall delicate, weakly siliceous. Chromatophores numerous, small (Cupp, 1943).

Scientific name: *Corethron histrix* Hensen

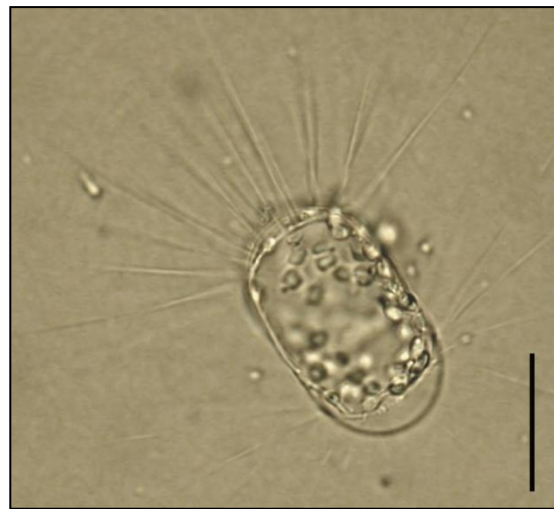
Plate A11: a-c (Annex A)

References:

Hustedt, 1930: p. 543, Fig. 311; Cupp, 1943: p. 70-74, Fig. 34 A-C; Throndsen *et al.*, 2007: p. 146.

Description:

Cells with cylindrical mantle and arched hemispherical valves. Diameter 12–38 μm . In individuals with auxospores, old cells varied from 13 to 24 μm in diameter, auxospores, from 33 to 38 μm . Circle of long slender setae at edge of valve. After cell division, while setae are enclosed within the girdle zone, they are parallel to the perivalvar axis. When free, on one valve, all radiate out in same direction from center of cell; on other valve, two types of setae are formed, longer ones of uniform width and approximately parallel to those of the first valve, and shorter ones ending in an irregularly twisted knob. These shorter ones radiate forward. Intercalary bands, not usually visible in water, collarlike. Chromatophores numerous round or slightly elongated plates (Cupp, 1943).



Dimensions:

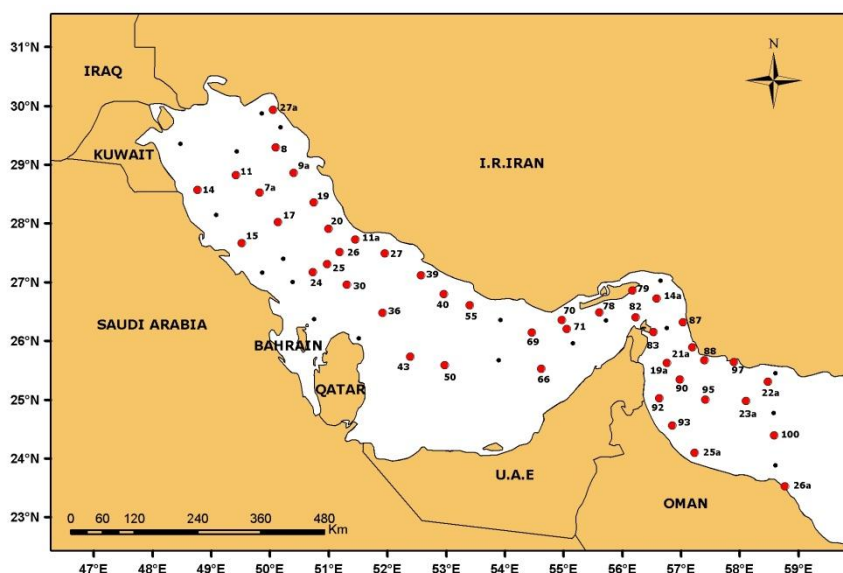
Cells length 28-33 μm ; diameter 19-21 μm .

Distribution:

Oceanic, temperate species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at various sites (refer sites map), often in large numbers; maximum abundance (6.1×10^3 cells/l) was associated with the northwestern part of the inner RSA (St. 19).



Sites of occurrence of *Corethron hystrix* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Coscinodiscineae

Family: Coscinodiscaceae Kützing

Genus: *Coscinodiscus* Ehrenberg

Cells disk- or box-shaped, single or in twos immediately after cell division. Valves circular, without large knobs or processes, with hexagonal areolae arranged in various ways or fine round puncta. In the coarser areolated forms, two membrane layers are usually clearly distinguishable. These are bound together by pervalvar-directed areolae walls. The outer layer is either smooth, at least apparently so, or more or less poroid. In this case the areolae,

especially their partitions, appear to be punctated. The inner layer has usually under each areola a larger or smaller opening toward the cell center (inside). Upon examination of the valve from the outside, these openings appear to be round central spots in the areolae. The areolae are usually in a closed mesh system but in a number of species, they are more or less rounded and do not touch one another. The center of the disk is either smooth or sculptured, often with larger areolae forming a rosette. In some species, the rosette may be present or the central area may be clear. In many species, distinct but small meshes, interstitial meshes, are present at the beginning of short radial rows of areolae. These may be of systematic importance. Marginal spinulae, present or absent, are usually small and difficult to see. Apiculi one (apiculus) or two, present or absent. If two are present, apiculi are located asymmetrically at an angle of more than 90° and less than 180° on the margin. Intercalary bands often present. Girdle zone formed of a single girdle band to each valve or of one or more collar-like intercalary bands. Chromatophores numerous small plates. Nucleus usually at center of one valve, or suspended in center of cell by protoplasmic strands. Auxospores formed by separation of the valves. A large bladderlike mass of protoplasm comes from one end. The valves may be perfectly flat, slightly or much rounded, flat or depressed in the center with rounded edges. The cell may be low (almost coin-shaped) to nearly as high as broad, or may be higher on one side than on the other. Positive identification of species in water mounts is frequently difficult, because of the inability to see fine details, spinulae, and apiculi without special preparation. A knowledge of the general contour of the valves and cell as a whole is consequently of great help in deciding upon at least a preliminary identification. Many species are marine pelagic and form an important part of the plankton. Many are bottom forms only occasionally found in the plankton, and many are heavy, true bottom forms (Cupp, 1943).

In Winter 2006 Cruise, the *Coscinodiscus* genus includes 9 species. Some of them were frequently observed in the phytoplankton community of the RSA, but never reached high concentration (not more than 5.1×10^3 cells/l; 28 % of total phytoplankton abundance). Relatively high abundance of *Coscinodiscus* group ($> 10^3$ cells/l) was occasionally observed mainly in the inner RSA along the southern coast.

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Coscinodiscineae

Family: Coscinodiscaceae Kützing

Genus: *Coscinodiscus* Ehrenberg

Species: *asteromphalus*

Scientific name: *Coscinodiscus asteromphalus* Ehrenberg

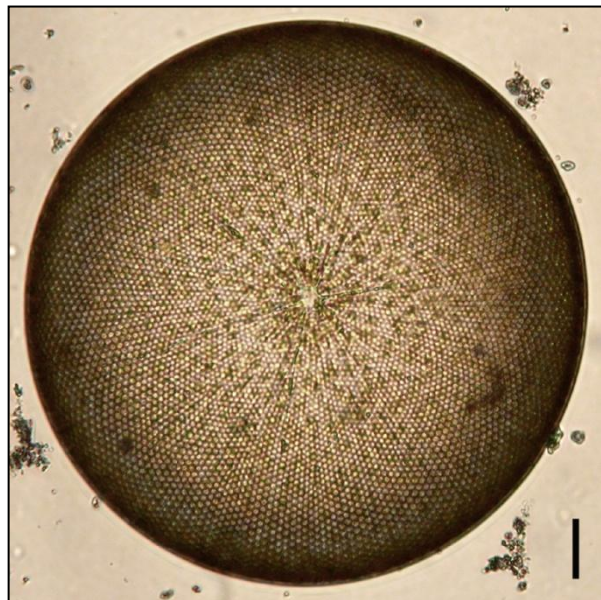
Plate A12: a-f (Annex A)

Synonym:

Coscinodiscus asteromphalus var.
conspicua Grunow ex van Heurck

References:

Hustedt, 1930: p. 452, Fig. 250; Allen and Cupp, 1935: p. 118, Fig. 14; Hendey, 1964: p. 78, Pl. XXIV: 2; Hendey, 1970: p. 111; Simonsen, 1974: p. 14; Priddle and Fryxell, 1985: p. 128-129.



Description:

Cells discoid, large, solitary. Valves slightly convex. Valve surface covered with a strong areolation, having a large central rosette enclosing a small structureless area. Areolae polygonal; outside the central rosette for a short distance along the radius, the areolae are somewhat small, gradually becoming larger, until at distance equal to half the radius, they attain their maximum size, after which they again decrease. Areolae furnished with characteristic secondary and tertiary structure. Chromatophores: numerous large rounded plates. Diameter of valve 230-360 (mostly 330) μm (Hendey, 1964).

Dimensions:

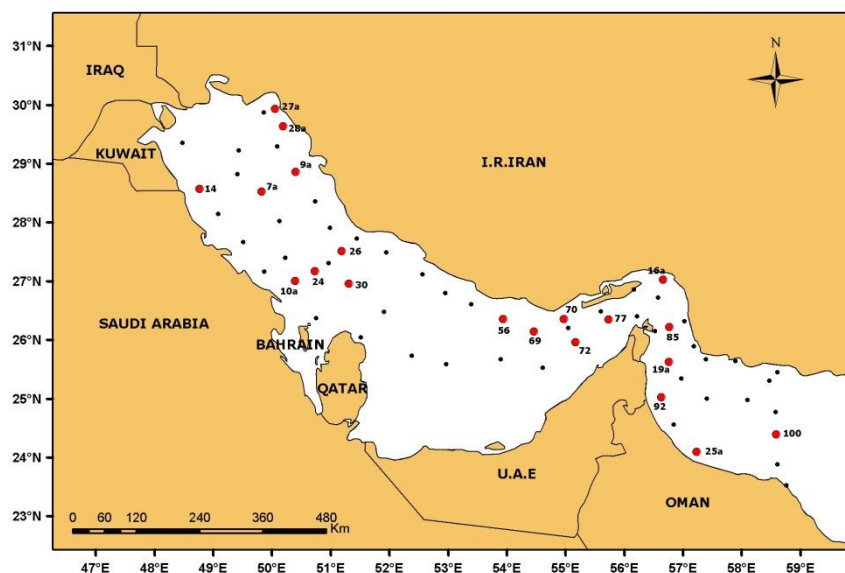
Valve diameter 280-320 μm .

Distribution:

Pelagic plankton species with a worldwide distribution.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at different sites (refer sites map) in very small numbers; maximum abundance (35 cells/l) was associated with the Iranian coast in the central part of the inner RSA (St. 56). It has been previously reported from the inner RSA (Simonsen, 1974) and from Kuwaiti shore (Hendey, 1970) and coastal waters (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Coscinodiscus asteromphalus* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Coscinodiscineae

Family: Coscinodiscaceae Kützing

Genus: *Coscinodiscus* Ehrenberg

Species: *granii*

Scientific name: *Coscinodiscus granii* Gough

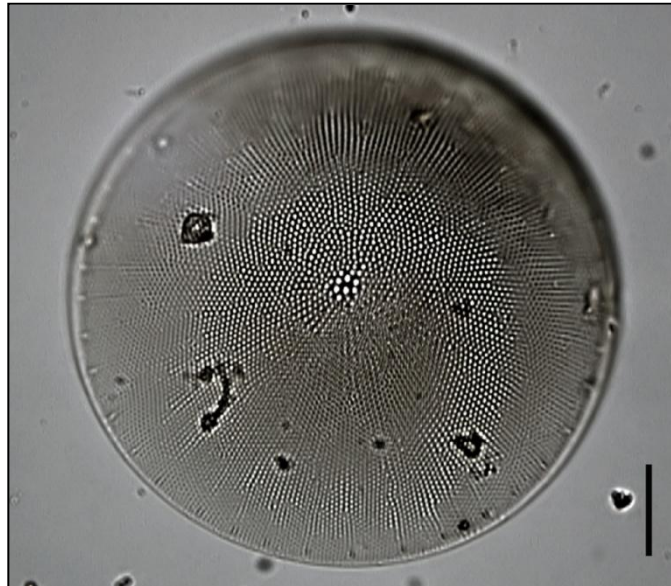
Plate A13: a-d (Annex A)

References:

Hustedt, 1930: p. 436, Fig. 237;
Cupp, 1943: p. 57, Fig. 21; Crosby
and Wood, 1958: p. 496, Pl. 36: 17;
Hendey, 1964: p. 79; Simonsen,
1974: p. 16; Throndsen *et al.*, 2007:
p. 150.

Description:

Cells with eccentric arched valves;
one side of cell almost twice as high
as the other. Diameter 95-190 μm .



Central areolae in a definite rosette. About 8 areolae in 10 μm near center, 10 midway to margin, and 11 near margin; on edge of valve mantle 13 in 10 μm . Chamber openings small, dotlike. Outer closing membrane of areolae very delicately poroid. Radial rows and secondary spiral rows distinct. Marginal spinulae and the hyaline lines radiating from the spinulae toward the center distinct, 5-7 μm apart. Two small processes or apiculi on margin at distance of about 120° from each other. Girdle formed from the two similar girdle bands. No intercalary bands (Cupp, 1943).

Dimensions:

Valve diameter 85-120 μm .

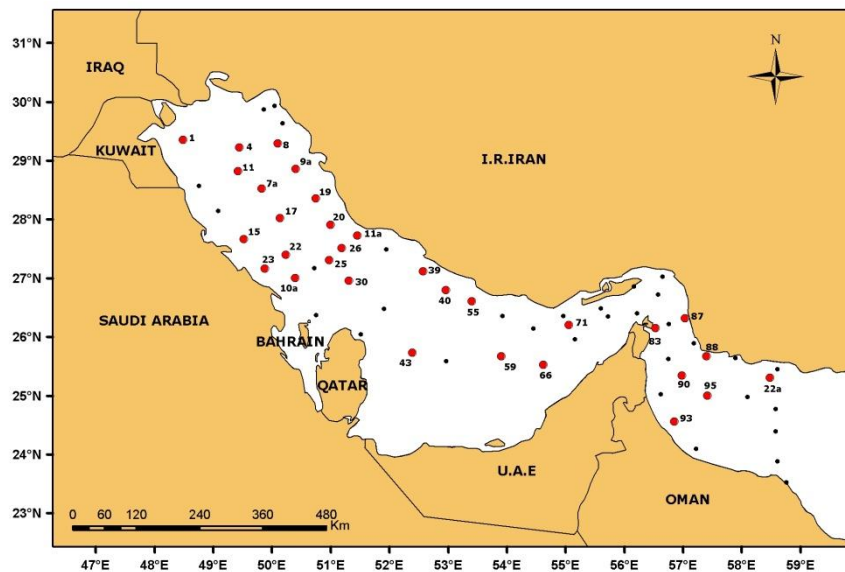
Distribution:

Neritic, widely distributed; north temperate or boreal species. It has been previously reported from the Indian Ocean (Simonsen, 1974).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at various sites (refer sites map) in small numbers; maximum abundance (1.2×10^2 cells/l) was associated with the northwestern part of

the inner RSA off Saudi Arabia (St. 23). It has been previously reported from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Coscinodiscus granii* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Coscinodiscineae

Family: Coscinodiscaceae Kützing

Genus: *Coscinodiscus* Ehrenberg

Species: *janischii*

Variety: *arafurensis*

Scientific name: *Coscinodiscus janischii* Schmidt var. *arafurensis* Grunow

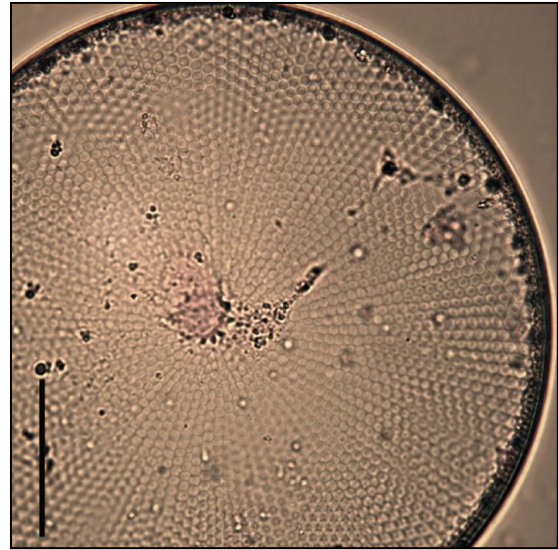
Plate A14: a-d (Annex A)

References:

Hustedt, 1930: p. 461, Fig. 257; Allen and Cupp, 1935: p. 120, Fig. 17 a-d.

Description:

Cell disc-shaped, with almost flat valves, slightly depressed in the center. Central area small, but distinct. A row of small areoles near the margin, about 4 in 10 μm ; around the central area $2\frac{1}{2}$ to 3 in 10 μm ; on rest of surface valve of nearly equal size, about 2 in 10 μm . Valve hyaline in appearance. Radial and secondary spiral rows, distinct. Valve margin small, with radial striae, about 5-6 in 10 μm . Diameter 170-261 μm (Allen and Cupp, 1935).

**Dimensions:**

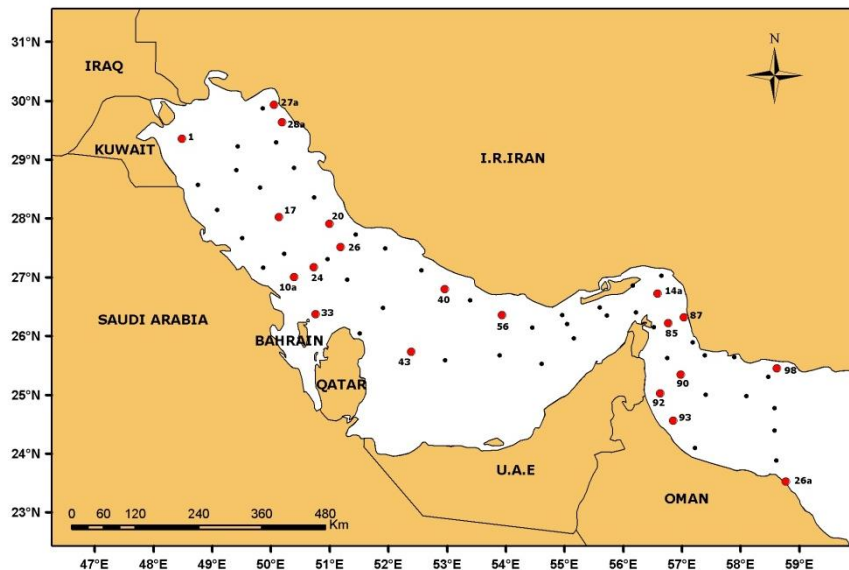
Valve diameter 220-245 μm .

Distribution:

Subtropical and tropical waters.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at different sites (refer sites map) in small numbers; maximum abundance (1.5×10^2 cells/l) was associated with the Iranian coast in the central part of the inner RSA (St. 40).



Sites of occurrence of *Coscinodiscus janischii* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Coscinodiscineae

Family: Coscinodiscaceae Kützing

Genus: *Coscinodiscus* Ehrenberg

Species: *jonesianus*

Scientific name: *Coscinodiscus jonesianus* (Greville) Ostenfeld

Plate A15: a-g (Annex A)

Synonym:

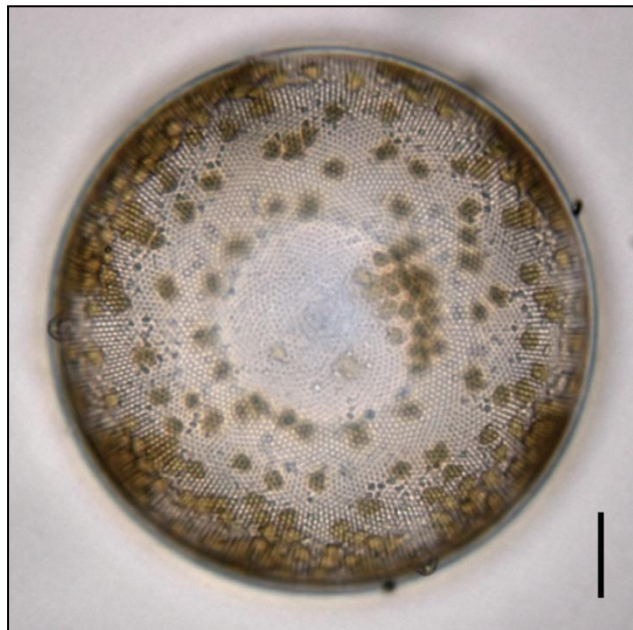
Eupodiscus jonesianus Greville

References:

Crosby and Wood, 1958: p. 495 (as *Coscinodiscus concinnus* var. *jonesianus*); Hendey, 1964: p. 79; Ricard, 1987: p. 145, Fig. 4.

Description:

Cells double convex, solitary, free. Valves circular, flat or slightly concave in the middle, sometimes a little higher on one side than on the other. Valve surface covered with a fine subhexagonal areolation, radiating from a more or less distinct rosette of large areolae in the center. Central areolae often elongated or sub-elliptical. Areolae 5-6 in 10 µm near the center, 8-9 in 10 µm about half of radius and 13-15 in 10 µm near the margin. Areolae loculate with a cover pore in the inner membrane and a finely poroid sieve membrane. Near the margin the areolae are arranged in obliquely decussating rows of curved lines. At about half of radius, there is often an irregular ring of interstitial spinulae. Inside the margin is a distinct row of spinulae, about 8-10 µm apart, from which narrow hyaline darts run towards the center. The darts are made prominent by a row of slightly larger areolae bordering them upon either side. Two large conical apiculi are situated near the margin, separated by an angle of approximately 110-120°. Diameter of valve 140-250 µm (Hendey, 1964).



Dimensions:

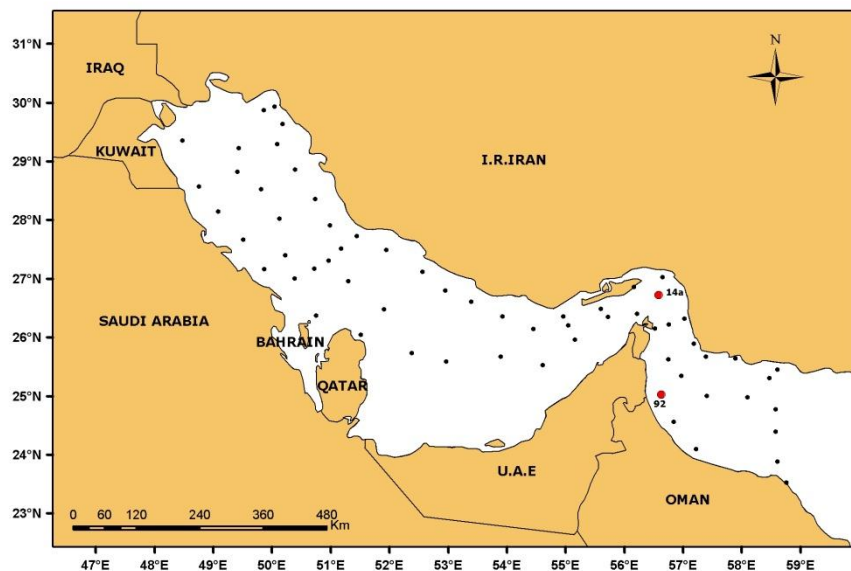
Valve diameter 120-160 μm .

Distribution:

Common in sub-tropical waters.

Sites of occurrence in RSA:

In Winter 2006 Cruise, a single specimen was found in each of the samples from the Strait of Hormuz and the Sea of Oman (refer sites map). Species has been previously reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Coscinodiscus jonesianus* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Coscinodiscineae

Family: Coscinodiscaceae Kützinger

Genus: *Coscinodiscus* Ehrenberg

Species: *oculus-iridis*

Scientific name: *Coscinodiscus oculus-iridis* Ehrenberg

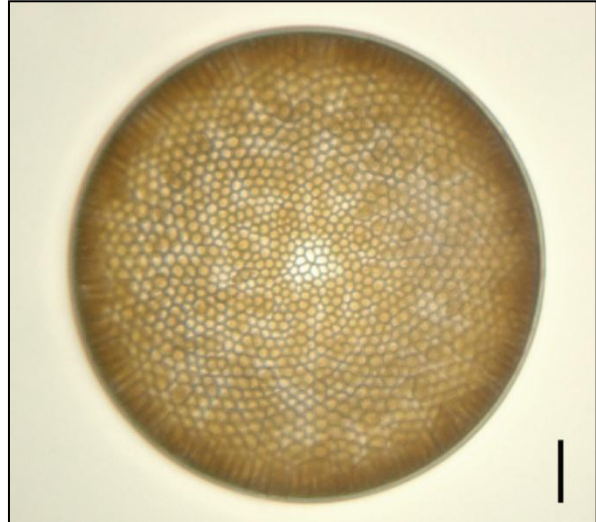
Plate A16: a-d (Annex A)

References:

Hustedt, 1930: p. 454, Figs. 252, 253; Allen and Cupp, 1935: p. 118, Fig. 15; Cupp, 1943: p. 63, Fig. 26, Pl. 3: 2; Hendey, 1964: p. 78, Pl. XXIV: 1; Hendey, 1970: p. 111; Simonsen, 1974: p. 17; Priddle and Fryxell, 1985: p. 138-139.

Description:

Cells disk-shaped. Central part of valves slightly concave. Diameter 120-150 μm . Areolae large. Rosette usually large, sometimes with a small central hyaline area. Areolae $3\frac{1}{2}$ - $4\frac{1}{2}$ in 10 μm near center, near marginal region $2\frac{1}{2}$ - $3\frac{1}{2}$ in 10 μm . Margin small, with radial striae corresponding to the outer areolae, about 7 in 10 μm . Chamber openings distinct. Outer closing membrane with delicate and scarcely visible poroids. Radial and secondary spiral rows well marked. Marginal spinulae not visible in valve view, the two asymmetrical processes small but usually distinct (Cupp, 1943).



Dimensions:

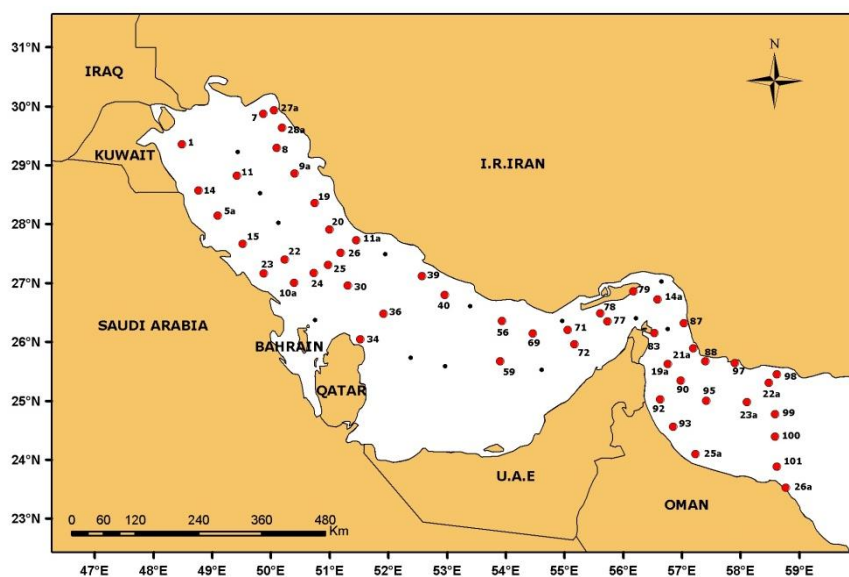
Valve diameter 110-140 μm .

Distribution:

Widely distributed oceanic species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at various sites (refer sites map), usually in small numbers; however, it was quite abundant at some localities; maximum abundance (1.5×10^3 cells/l) was associated with the Strait of Hormuz area (St. 83). It has been previously reported from the inner RSA (Simonsen, 1974) and from Kuwaiti shore (Hendey, 1970) and coastal waters (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Coscinodiscus oculus-irdis* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Coscinodiscineae

Family: Coscinodiscaceae Kützing

Genus: *Coscinodiscus* Ehrenberg

Species: *perforatus*

Scientific name: *Coscinodiscus perforatus* Ehrenberg

Plate A14: e, f (Annex A)

References:

Cupp, 1943: p. 61; Fig. 25 A, Pl. 3: 1; Hendey, 1964, p. 77.

Description:

Valves flat or slightly convex in the center or sometimes slightly concave. Diameter 90-110 μm . Valves with large areolae forming a closed network, unlike the type in which the areolae are free. Rosette present in center of valve in all individuals observed in the material. Areolae become larger from center toward middle of radius, then smaller again; $4\frac{1}{2}$ in 10 μm in center, 4 midway, and $4\frac{1}{2}$ -5 near margin. Inner chamber openings, distinct; outer closing

membrane poroid especially on the margins of the areolae. Radial rows of areolae are somewhat more marked than secondary spiral rows. Regular and distinct interstitial mesh placed before the inserted radial rows. Valve margin small, radially striated, striae 8 in 10 μm . Marginal spinulae indistinct, the two asymmetrical processes or apiculi small (Cupp, 1943).

Dimensions:

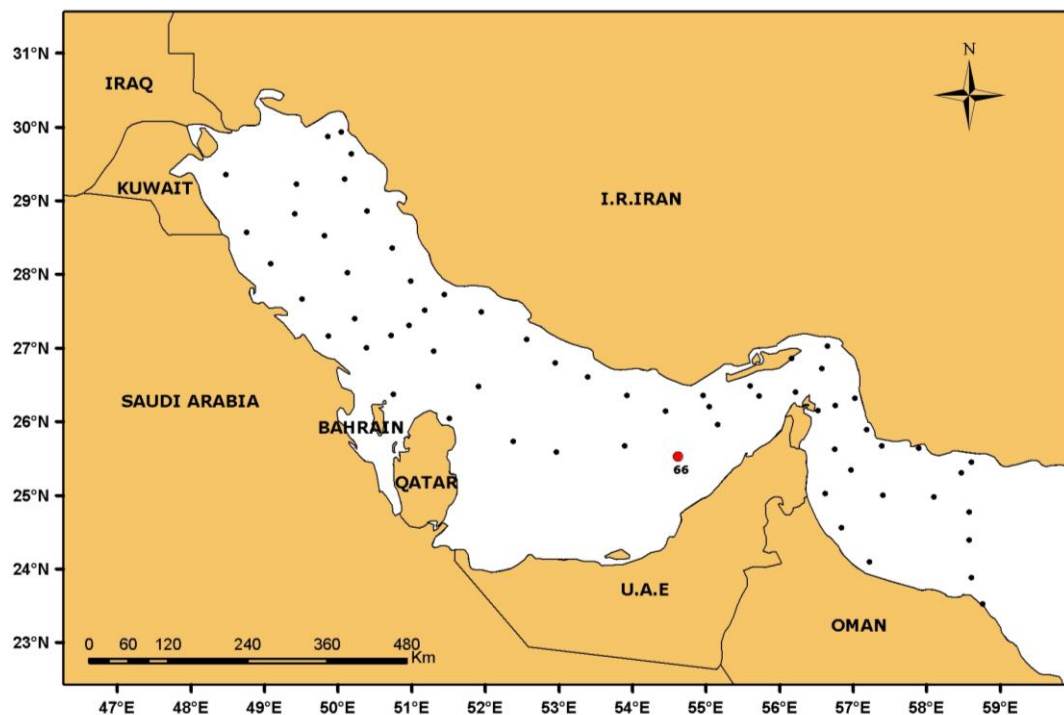
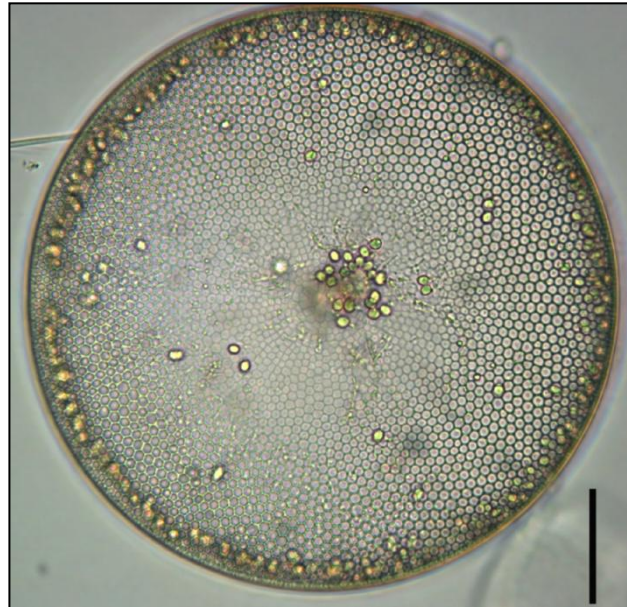
Valve diameter 100-150 μm .

Distribution:

Pelagic plankton species.

Sites of occurrence in RSA:

This species was occurred at Station 66 (refer site map) and in small numbers at Transects 2a and 6 of northern inner RSA during Leg 3 of the Winter 2006 Cruise.



Site of occurrence of *Coscinodiscus perforatus* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Coscinodiscineae

Family: Coscinodiscaceae Kützing

Genus: *Coscinodiscus* Ehrenberg

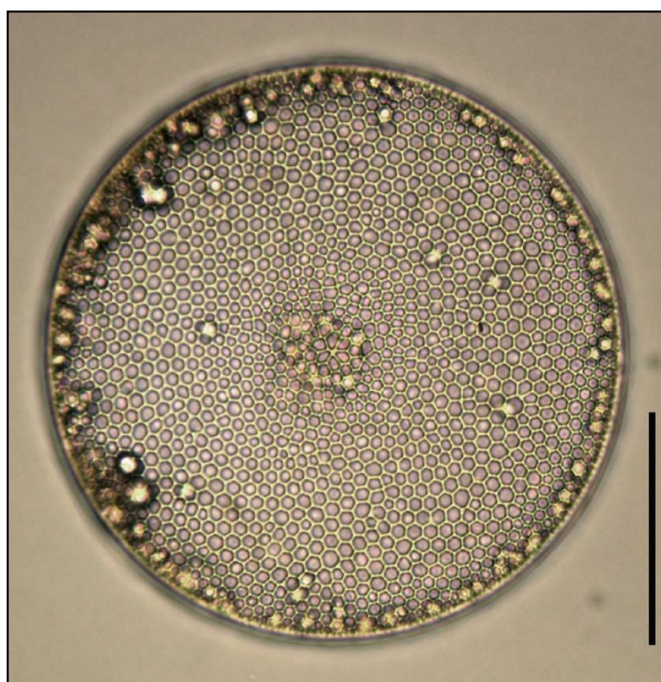
Species: *radiatus*

Scientific name: *Coscinodiscus radiatus* Ehrenberg

Plate A17: a-f (Annex A)

References:

Pavillard, 1925: p. 11, Fig. 12;
Hustedt, 1930: p. 420, Fig. 225; Allen
and Cupp, 1935: p. 115, Fig. 8; Cupp,
1943: p. 56, Fig. 20; Pl. 1: 4; Crosby
and Wood, 1958: p. 496, Pl. 31: 12;
Hendey, 1964: p. 76, Pl. XXII: 7;
Simonsen, 1974: p. 17; Ricard, 1987:
p. 145, Figs. 1-3; Throndsen *et al.*,
2007: p. 151.



Description:

Cells flat, coin-shaped disks. Valves flat or very slightly arched. Diameter 35-60 μm . Valve surface with coarse areolae, without rosette or central area. Areolae are nearly same size on whole valve, 3-4 in 10 μm , except at margin where they are smaller, 6-7 in 10 μm . Inner chamber openings, rather indistinct; outer membrane of the areolae apparently homogeneous. Radial rows usually distinct, secondary rows in spirals, not always apparent. The structure in this species tends to be irregular. Valve margin small, radially striated, 9-11 striae in 10 μm . No spinulae or apiculi. Girdle zone low. No intercalary bands (Cupp, 1943).

Dimensions:

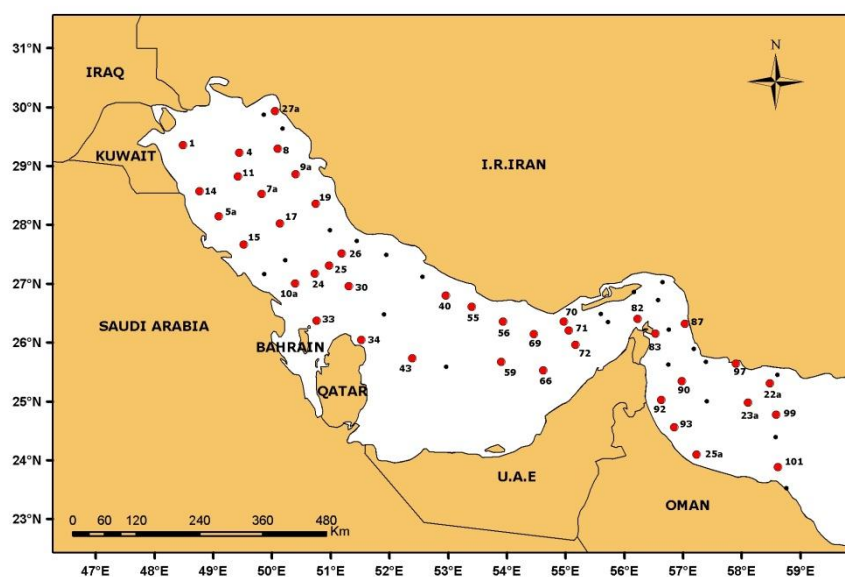
Valve diameter 55-84 μm .

Distribution:

Oceanic and neritic cosmopolitan species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred both in inner RSA and Sea of Oman (refer sites map), although never in large numbers; maximum abundance (98 cells/l) was associated with the northwestern part of the inner RSA (St. 19). It has been previously reported from the inner RSA (Simonsen, 1974) and from Kuwaiti waters (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Coscinodiscus radiatus* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Coscinodiscineae

Family: Coscinodiscaceae Kützing

Genus: *Coscinodiscus* Ehrenberg

Species: *wailesii*

Scientific name: *Coscinodiscus wailesii* Gran *et* Angst

Plate A16: e, f (Annex A)

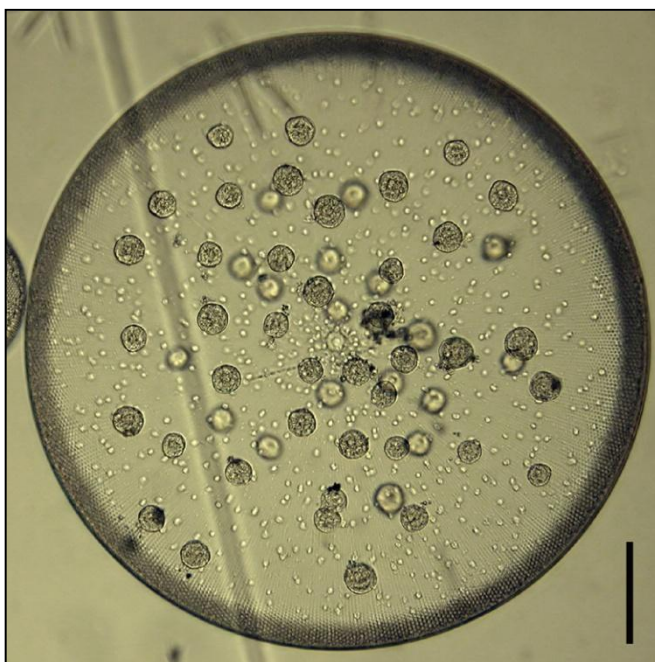
References:

Cupp, 1943: p. 59, Fig. 23;

Thronsen *et al.*, 2007: p. 151.

Description:

Cells cylindrical with concave ends, large, 230-350 μm in diameter. Mantle cylindrical, 44-70 μm high. Center of valve hyaline with irregular outline and free areolae. Areolae about 6 in 10 μm , slightly increasing in size from central area outward, farther out decreasing. Outer



membrane delicately poroid. Marginal spines not visible in valve view, 3-5 μm from edge of mantle, 10-12 μm apart. Distinct hyaline lines radiate inward. Areolae of same size at both sides of spinulae, 6 in 10 μm . Intercalary bands two at each valve, first one broader than the second (Cupp, 1943).

Harmful Effect:

Non-toxic bloom-forming species. In the late 1970 the fishermen in the Plymouth area complained that their nets became clogged with a heavy jelly-like material. Mucilage produced in cultures of *Coscinodiscus wailesii*, is an important constituent of the phytoplankton in these waters from 1977, and mucilage from the nets were shown to have basically the same chemical structure (Boalch, 1984).

Dimensions:

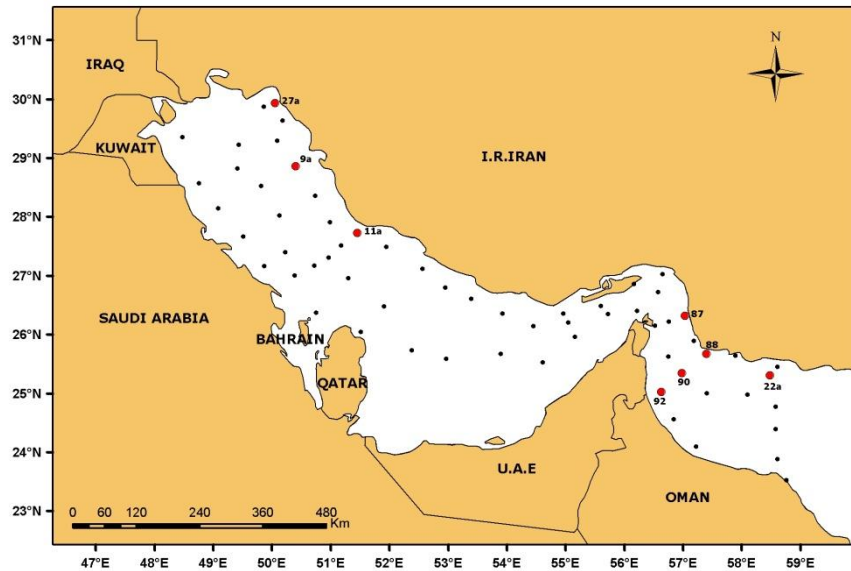
Valve diameter 250-320 μm .

Distribution:

Oceanic and neritic cosmopolitan species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at various stations in very small numbers (refer sites map). It has been previously reported from the inner RSA (Kuwaiti waters) (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Coscinodiscus wailesii* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Coscinodiscineae

Family: Coscinodiscaceae Kützing

Genus: *Coscinodiscus* Ehrenberg

Scientific name: *Coscinodiscus* sp.

Plate A18: a-g (Annex A)

Description:

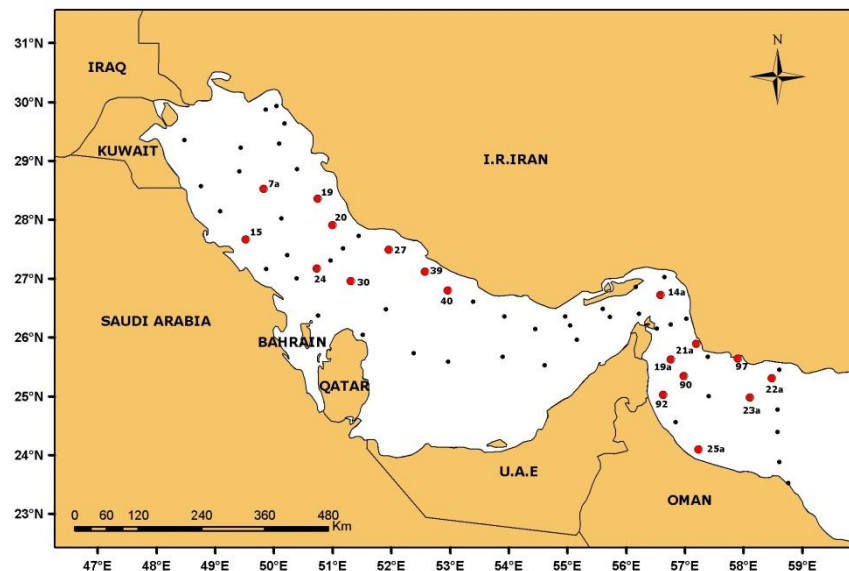
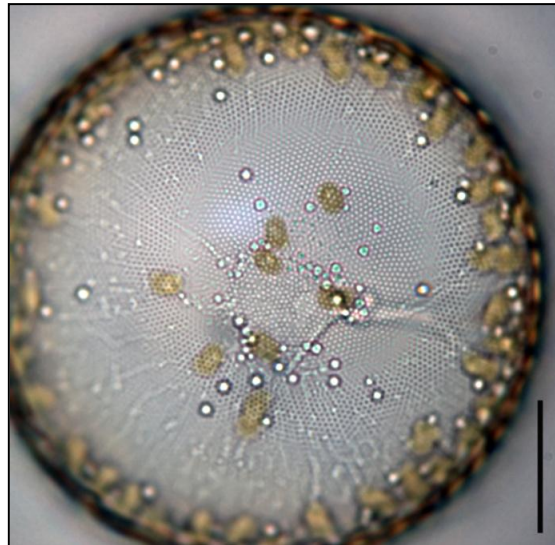
Valves flat, valve surface with small areolae, without rosette or central area. Areolae are nearly same size on whole valve.

Dimensions:

Valve 75-85 μm in diameter.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred occasionally in small numbers at different sites (refer sites map); maximum abundance (200 cells/l) was associated with the central part of the inner RSA (St. 30).



Sites of occurrence of *Coscinodiscus* sp.1 in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Coscinodiscineae

Family: Coscinodiscaceae Kützing

Genus: *Palmeria* Greville

Species: *hardmaniana*

Scientific name: *Palmeria hardmaniana* Greville

Plate A11: d-f (Annex A)

Synonym:

Hemidiscus hardmanianus (Greville)

Mann

References:

Allen and Cupp, 1935: p. 151, Fig. 91 (as *Hemidiscus hardmanianus*); Simonsen, 1974: p. 19; Hasle and Syvertsen, 1997: p. 112, Pl. 18.

Description:

Valves semicircular; valve face approximately plane. Central area of valve is hyaline. Radial areolation with incomplete striae, inserted from the margin. Distinct hyaline lines, associated with marginal processes, two processes larger than the others. The ventral line of small labiate processes (those along the straight valve margin) is ca 10 areolae away from the margin. Length 303-534 μm , width 162-270 μm , 12-14 areolae in 10 μm (Hasle and Syvertsen, 1997).



Dimensions:

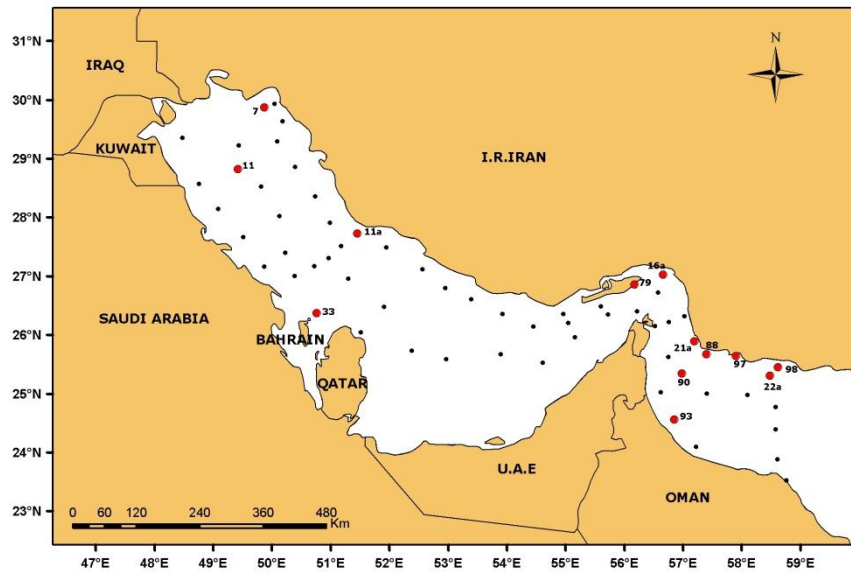
Cells length 420-450 μm ; width 190-230 μm .

Distribution:

Warm-water species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at few sites (refer sites map) in very small numbers. It has been previously reported from the inner RSA (Simonsen, 1974) and from Kuwaiti waters (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Palmeria hardmaniana* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Coscinodiscineae

Family: Hemidiscaceae Hendey

Genus: *Actinocyclus* Ehrenberg

Genus is characterized by more or less distinct fasciculated areolation (areola rows in sectors); more or less distinct marginal zone different from the rest of the valve; distinct central annulus and pseudonodulus at or near the valve margin. Many small chloroplasts are present (Thronsen *et al.*, 2007).

Scientific name: *Actinocyclus curvatulus* Janisch

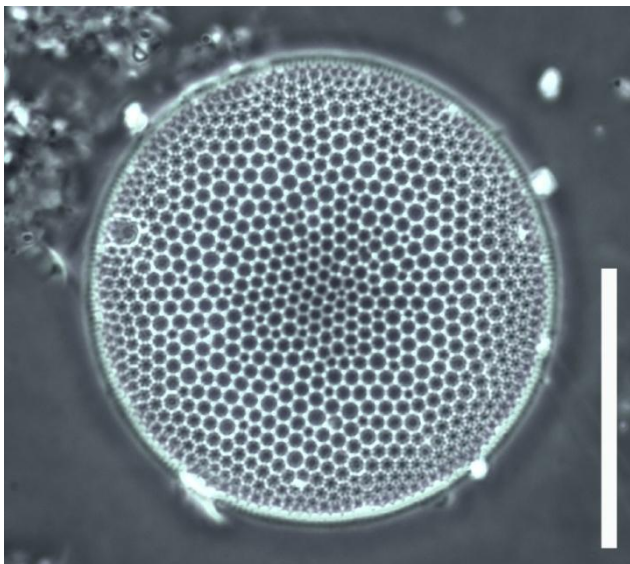
Plate A19: a-c (Annex A)

Synonym:

Coscinodiscus curvatulus var. *subocellata* Grunow

References:

Pavillard, 1925: p. 14, Fig. 19 (as *Coscinodiscus curvatulus*); Hustedt, 1930: p. 538, Fig. 307; Cupp, 1943: p. 55, Fig. 17, Pl. 1: 2 (as *Coscinodiscus curvatulus*); Hendey, 1964: p. 81 (as *Coscinodiscus curvatulus*); Simonsen, 1974: p. 20; Priddle and Fryxell, 1985: p. 106-107; Witkowski *et al.*, 2000: p. 20, Pl. 6: 2; Throndsen *et al.*, 2007: p. 147.

**Description:**

Central annulus irregular in outline. Areola rows are slightly curved and parallel to the side row of the sectors. Labiate processes at the end of side rows. Pseudonodulus small and close to the mantle. Diameter 13-160 μm ; 8-18 areolae in 10 μm ; 7-9 μm between the marginal processes (Throndsen *et al.*, 2007).

Dimensions:

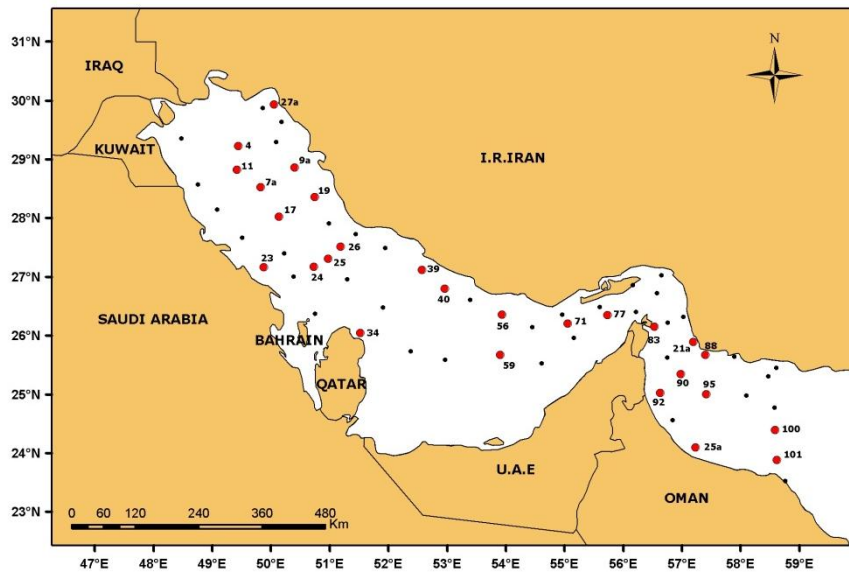
Valve diameter 35-42 μm .

Distribution:

Cosmopolitan species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at various sites (refer sites map), usually in small numbers; maximum abundance (1.2×10^2 cells/l) was observed in the waters of the Sea of Oman (St. 95). It has been previously reported from the inner RSA (Simonsen, 1974).



Sites of occurrence of *Actinocyclus curvatulus* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Coscinodiscineae

Family: Hemidiscaceae Hendey

Genus: *Actinocyclus* Ehrenberg

Species: *octonarius*

Scientific name: *Actinocyclus octonarius* Ehrenberg

Plate A20: a-e (Annex A)

Synonym:

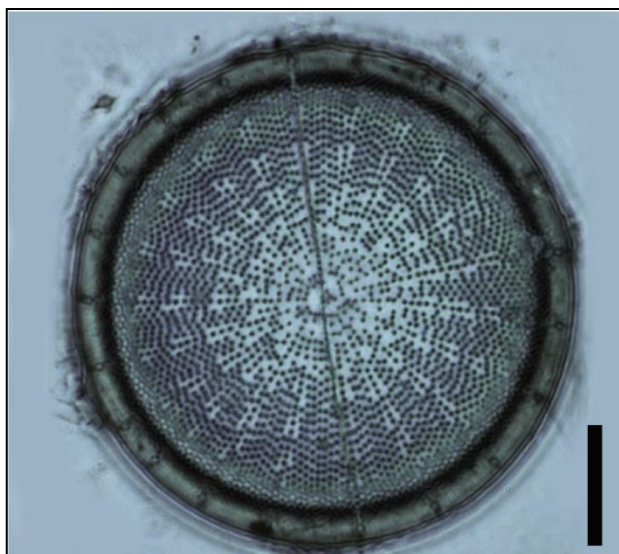
Actinocyclus ehrenbergii Ralfs

References:

Pavillard, 1925: p. 20, Fig. 30 (as *Actinocyclus ehrenbergii*); Hustedt, 1930: p. 525, Figs. 298, 299, 301 (as *Actinocyclus ehrenbergii*); Hendey, 1964: p. 83-84, Pl. XXIV: 3, 4; Hendey, 1970: p. 113; Simonsen, 1974: p. 21; Priddle and Fryxell, 1985: p. 108-109; Ricard, 1987: p. 149, Figs. 35-39; Witkowski *et al.*, 2000: p. 21, Pl. 4: 2, 3; Throndsen *et al.*, 2007: p. 147.

Description:

Each areola row parallel to the central row of the sectors. Labiate processes at the end of side rows. Broad marginal zone with areolae, smaller than elsewhere on the valve face. Processes and pseudonodulus are readily seen with LM. Diameter 50-300 μm ; 6-8 areolae in 10 μm ; 8-11 μm between marginal processes (Thronsdon *et al.*, 2007).

**Dimensions:**

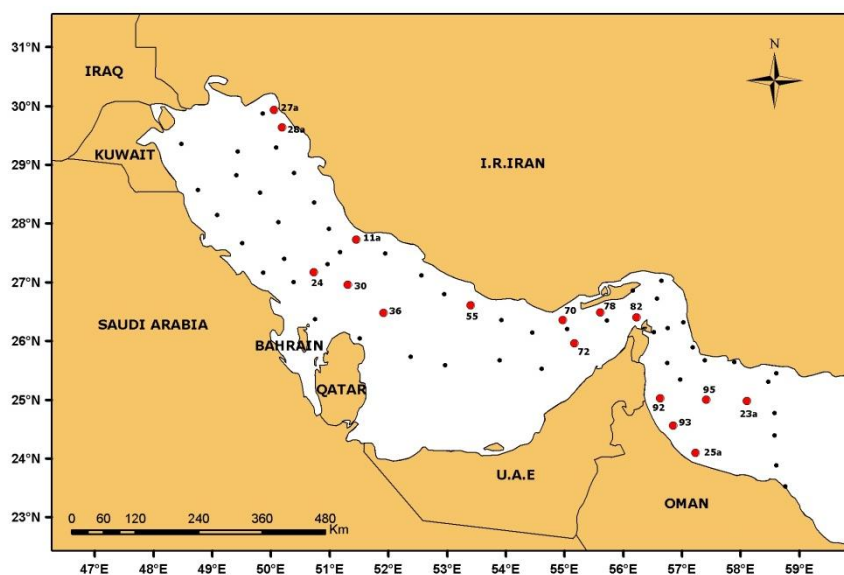
Valve diameter 60-75 μm .

Distribution:

Common species in neritic plankton, cosmopolitan.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred in small numbers at scattered sites (refer sites map). It has been previously reported from the inner RSA (Simonsen, 1974) and from Kuwaiti shore (Hendey, 1970) and coastal waters (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Actinocyclus octonarius* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Coscinodiscineae

Family: Hemidiscaceae Hendey

Genus: *Actinocyclus* Ehrenberg

Species: *octonarius*

Variety: *tenellus*

Scientific name: *Actinocyclus octonarius* var. *tenellus* (Brébisson) Hendey

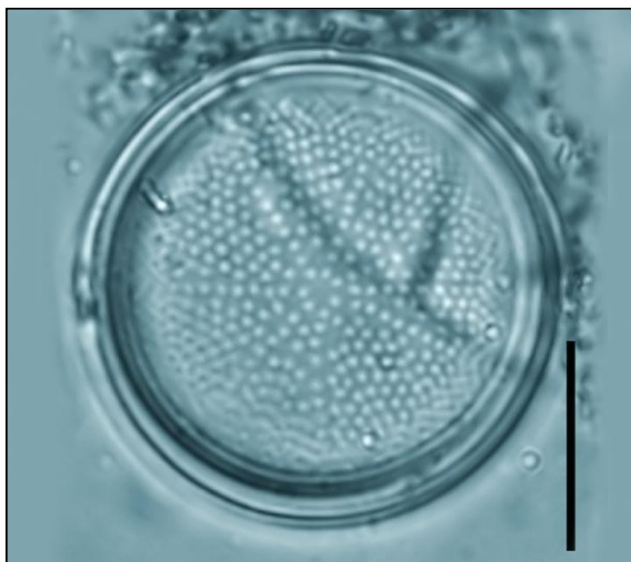
Plate A20: f (Annex A)

Synonyms:

Actinocyclus ehrenbergii var. *tenella*
(Brébisson) Hustedt; *Actinocyclus*
tenellus (Brébisson) Grunow;
Eupodiscus tenellus Brébisson

References:

Hustedt, 1930: p. 533, Fig. 302;
Hendey, 1964: p. 84; Hendey, 1970: p.
113.



Description:

Cells solitary; valves circular. Valve surface flat; divided into usually six sectors of loosely fasciolate striae. Puncta smaller as they approach the valve margin. Valve margin narrow, striate, apiculate; usually an apiculus is situated where the sectorial striae terminates on the valve margin. Diameter of valve 25-60 μm (Hendey, 1964).

Dimensions:

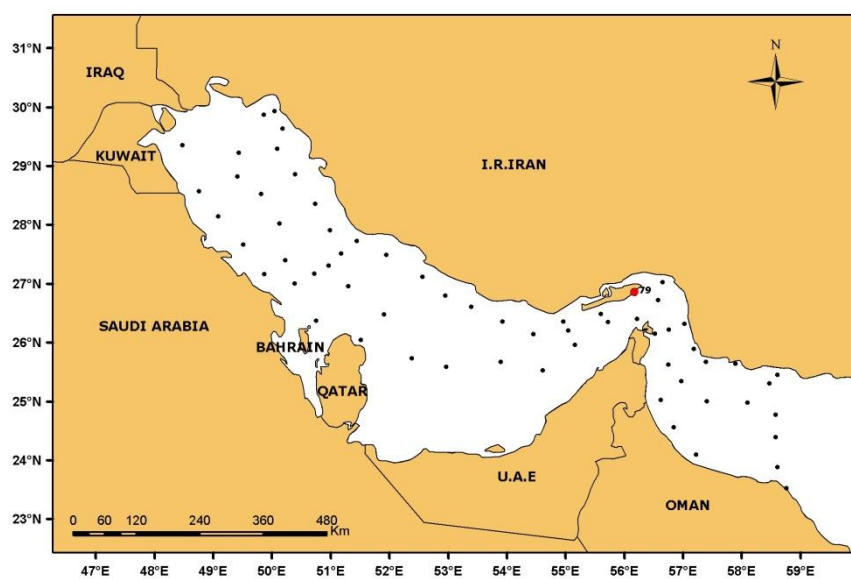
Valve diameter 38 μm .

Distribution:

Neritic species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, a single specimen was recorded at one locality (St. 79) in the Strait of Hormuz area (refer site map). It has been previously reported in the inner RSA from Kuwaiti shore (Hendey, 1970) and coastal waters (Al-Kandari *et al.*, 2009).



Site of occurrence of *Actinocyclus octonarius* var. *tenellus* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Coscinodiscineae

Family: Hemidiscaceae Hendey

Genus: *Hemidiscus* Wallich

Semicircular with radial areolation, partly in bundles/groups, and with a central annulus. Marginal ring of labiate processes and a pseudonodulus, midway along the straight side (Throndsen *et al.*, 2007).

Scientific name: *Hemidiscus cuneiformis* Wallich

Plate A13: f (Annex A)

Synonyms:

Euodia cuneiformis (Wallich) Schütt;
Euodia radiata Castracane; *Euodia*
inornata Castracane; *Euodia gibba*
(Bailey) Ralfs in Pritchard

References:

Pavillard, 1925: p. 9, Fig. 10 (as *Euodia cuneiformis*); Hustedt, 1930: p. 903, Fig. 542; Cupp, 1943: p. 170, Fig. 121; Crosby and Wood, 1958: p. 525, Pl. 34: 53; Hendey, 1964: p. 94, Pl. XXII: 9; Simonsen, 1974: p. 21; Ricard, 1987: p. 149, Figs. 30-34; Throndsen *et al.*, 2007: p. 148.



Description:

Trapezoid in girdle view, with curved valve with a central depression. Valve distinctly fasciculated; annulus less distinct. Length (apical axis) 58-288 μm ; width (transapical axis) 32.5-158 μm ; areolae in 10 μm in the center 6-9; at valve margin 10-13 (Throndsen *et al.*, 2007).

Dimensions:

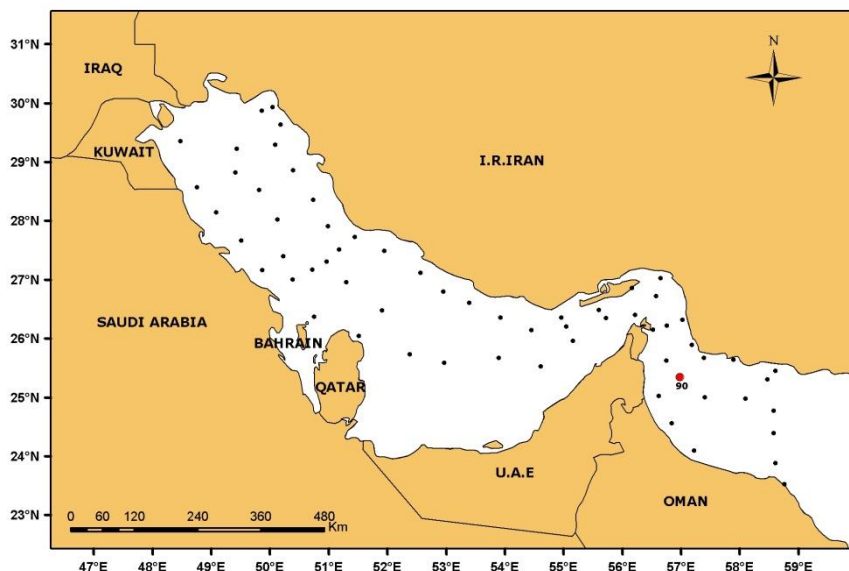
Cells length 110 μm ; width 65 μm .

Distribution:

Warm water species. It has been previously reported from Indian Ocean (Simonsen, 1974).

Sites of occurrence in RSA:

In Winter 2006 Cruise, a single specimen was observed at one locality (St. 90) in the Sea of Oman (refer site map). It has been previously reported from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Site of occurrence of *Hemidiscus cuneiformis* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Coscinodiscineae

Family: Hemidiscaceae Hendey

Genus: *Podosira* Ehrenberg

Cells solitary or united in short chains. Valves circular; convex. Frustule almost elliptical in girdle view. Valve surface punctuate; umbilicus absent; girdle composed of numerous narrow intercalary bands. Chromatophores are small, granular. Cells usually fixed by means of a mucous pad to the substratum, but frequently found in plankton (Hendey, 1964).

Scientific name: *Podosira stelliger* (Bailey) Mann

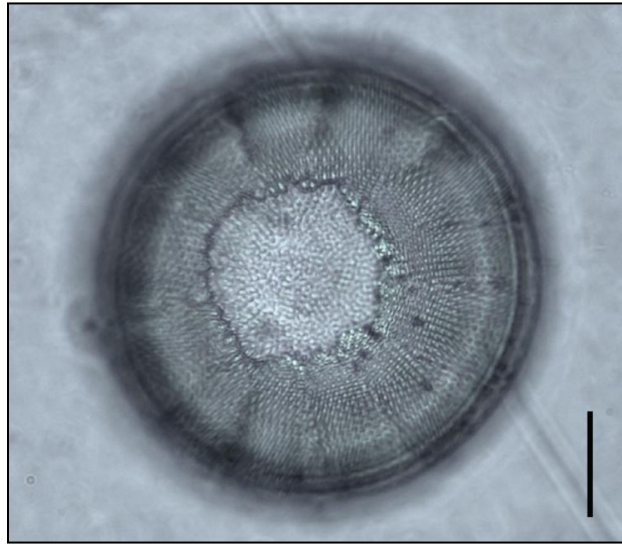
Plate A19: d-f (Annex A)

Synonym:

Hyalodiscus stelliger Bailey

References:

Hustedt, 1930: p. 286, Fig. 128; Crosby and Wood, 1958: p. 491, Pl. 31: 5; 35: 1 (as *Hyalodiscus stelliger*); Hendey, 1964: p. 90, Pl. XXII: 6; Simonsen, 1974: p. 8; Ricard, 1987: p. 169, Figs. 191, 192.



Description:

Cells discoid; valves strongly convex, finely striate; striae moniliform. Central area of valve strongly differentiated; peripheral zone striate; striae often parallel or nearly so, fasciculate, giving the appearance of dividing the valve into sectors. Marginal zone strong, finely striate. In the central area, the puncta are few and irregularly arranged. Girdle is composed of numerous narrow intercalary bands. Chromatophores, numerous small plates. Diameter of valve 40-78 μm , perivalvar axis 15-30 μm (Hendey, 1964).

Dimensions:

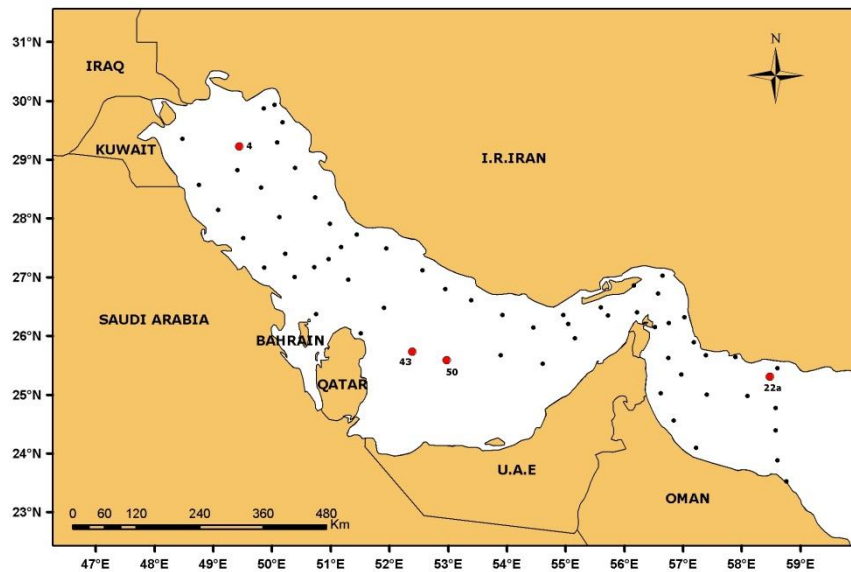
Valve diameter 55-68 μm .

Distribution:

This is a bottom form that favors a high salinity medium. The cells live either singly or in short chains, attached to the substratum by a small pad of mucilage. A tychopelagic form, common in the plankton.

Sites of occurrence in RSA:

In Winter 2006 Cruise, a single specimen was observed at each site (refer sites map) in the inner RSA and the Sea of Oman. Species has been previously reported from the inner RSA (Simonsen, 1974).



Sites of occurrence of *Podosira stelliger* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Coscinodiscineae

Family: Asterolampraceae Smith

Genus: *Asteromphalus* Ehrenberg

Cells single, disk-shaped, with circular or slightly ovoid outline. Valves flat, with radial undulations. Areolated with a central smooth region and smooth radial rays running from the central smooth area to the margin. Rays are raised above plane of the valve more as they progress outward. One ray narrower than others. Girdle zone undulating, following the rays and depressions between them. Chromatophores numerous, often arranged in rays (Cupp, 1943).

Scientific name: *Asteromphalus flabellatus* (Brébisson) Greville

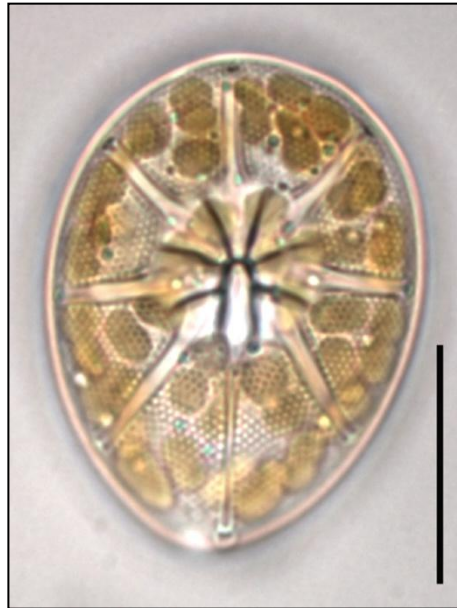
Plate A22: a-c (Annex A)

References:

Pavillard, 1925: p. 19, Fig. 27; Hustedt, 1930: p. 498, Fig. 279; Allen and Cupp, 1935: p. 122, Fig. 22; Hendey, 1970: p. 115; Simonsen, 1974: p. 25; Ricard, 1987: p. 151, Fig. 58; Hasle and Syvertsen, 1997: p. 135, Pl. 24.

Description:

Central area slightly eccentric. Separating lines straight. Extension of the narrow ray inside the central area rectangular to club shaped. The remaining hyaline rays straight or slightly curved and narrow. Areolated sectors narrow and curved toward valve center. Longer diameter 40-60 μm , shorter diameter 24-50 μm ; 16 areolae in 10 μm ; 7-11 hyaline rays, central area 0.4-0.6 \times diameter (Hasle and Syvertsen, 1997).

**Dimensions:**

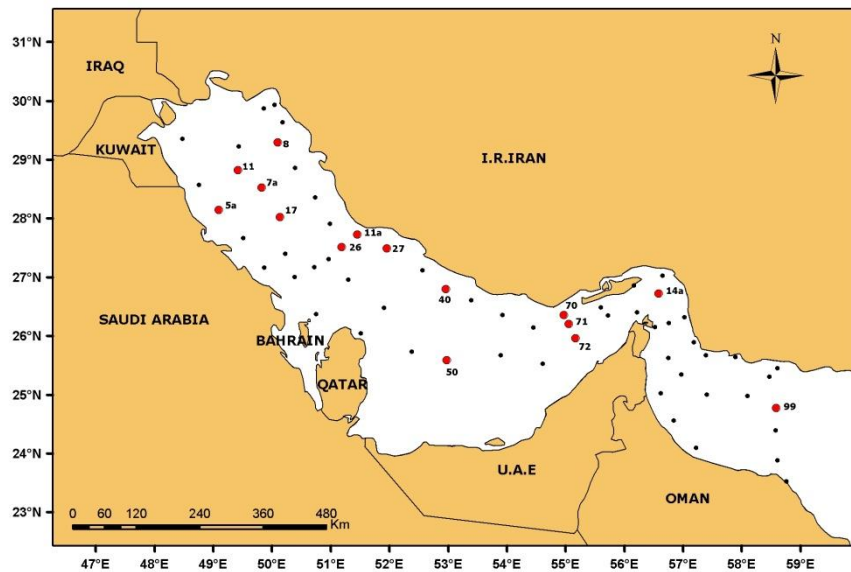
Longer diameter 42-48 μm ; shorter diameter 28-31 μm .

Distribution:

Warm-water species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred in small numbers at scattered sites (refer sites map); maximum abundance (65 cells/l) was associated with the central part of the inner RSA (St. 50). It has been previously reported from the inner RSA (Simonsen, 1974) and from Kuwaiti shore (Hendey, 1970) and coastal waters (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Asteromphalus flabellatus* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Coscinodiscineae

Family: Asterolampraceae Smith

Genus: *Asteromphalus* Ehrenberg

Species: *heptactis*

Scientific name: *Asteromphalus heptactis* (Brébisson) Ralfs

Plate A21: e-g (Annex A)

Synonym:

Spantangidium heptactis Brébisson

References:

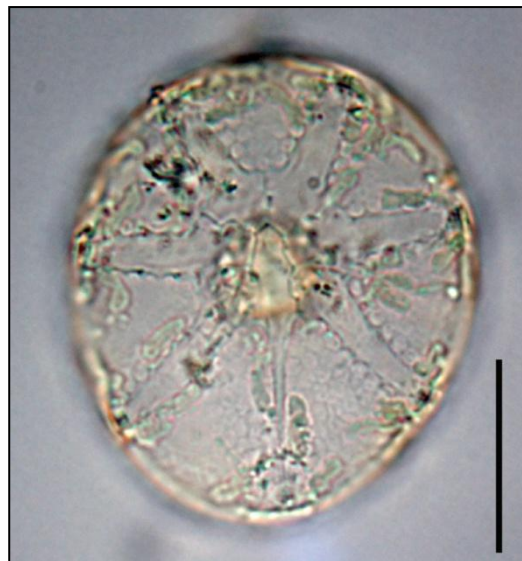
Hustedt, 1930: p. 494, Fig. 277; Cupp, 1943: p. 69, Fig. 32; Hendeby, 1964: p. 96, Pl. XXIV: 5; Hendeby, 1970: p. 115; Simonsen, 1974: p. 25; Priddle and Fryxell, 1985: p. 116-117 (A, E); Ricard, 1987: p. 151, Figs. 54-57.

Description:

Usually seven rays of unequal length, the narrow ray somewhat longer than the others. Central field slightly eccentric, one-fourth to one-third, the diameter of cell. Diameter of cells 38-100 μm . Areolae rather large, 6 or $6\frac{1}{2}$ in 10 μm (Cupp, 1943).

Dimensions:

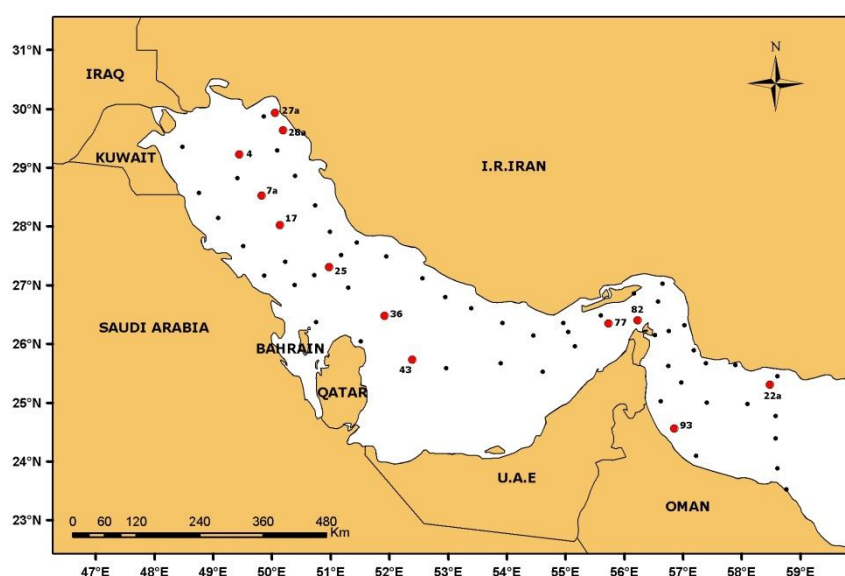
Longer diameter 40-43 μm ; shorter diameter 35-38 μm .

**Distribution:**

Oceanic, temperate species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred in very small numbers at scattered sites (refer sites map); maximum abundance (32 cells/l) was associated with the southern part of the inner RSA (St. 77). Species has been previously reported from the inner RSA (Simonsen, 1974) and from Kuwaiti shore (Hendey, 1970) and coastal waters (Al-Yamani *et al.*, 2004).



Sites of occurrence of *Asteromphalus heptactis* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Coscinodiscineae

Family: Asterolampraceae Smith

Genus: *Asteromphalus* Ehrenberg

Scientific name: *Asteromphalus* sp.

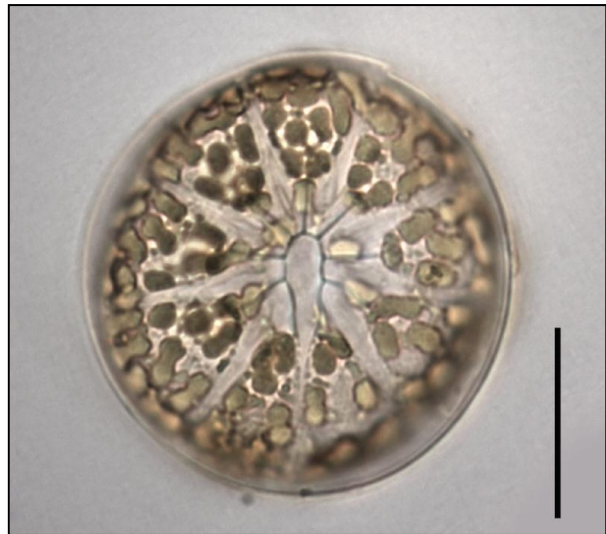
Plate A21: a-d (Annex A)

Description:

Cells disk-shaped, single. Central area slightly eccentric. Separating lines straight. Extension of the narrow ray inside the central area club shaped. The remaining hyaline rays straight and narrow, 9-10 hyaline rays.

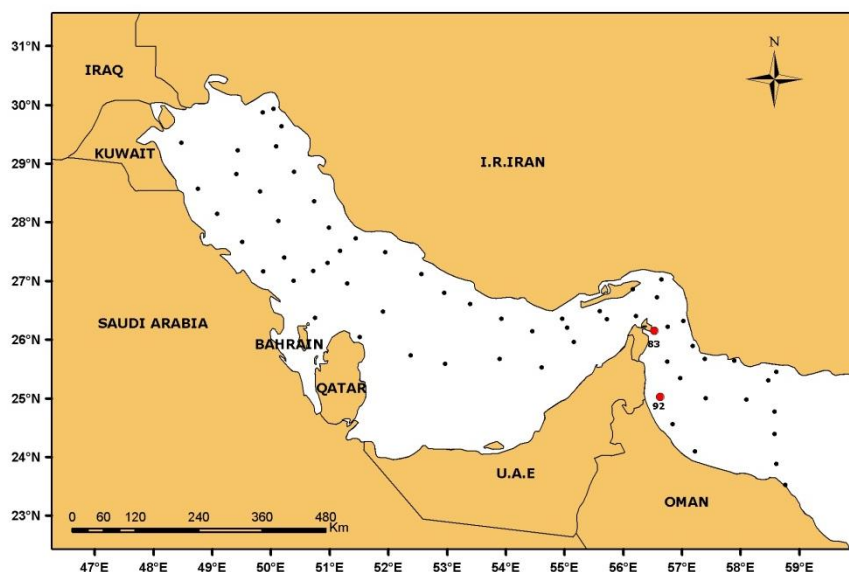
Dimensions:

Cells diameter 53-65 μm .



Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred in small numbers at two sites in the Sea of Oman (refer sites map).



Sites of occurrence of *Asteromphalus* sp. in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Coscinodiscineae

Family: Heliopeltaceae Smith

Genus: *Actinoptychus* Ehrenberg

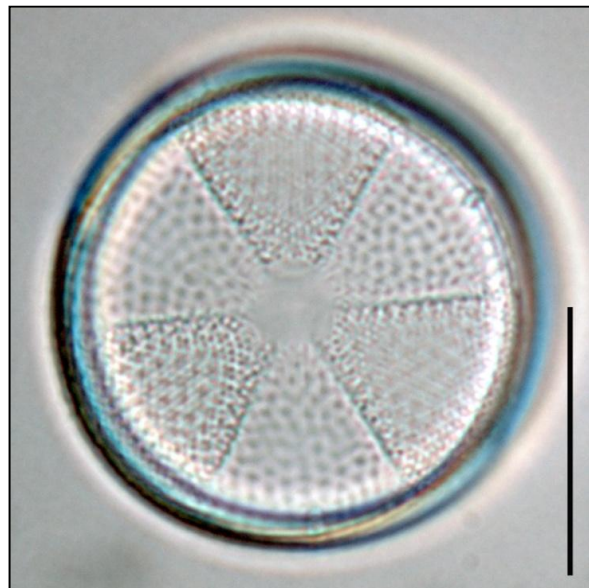
Cells disk-shaped, single. Valves divided into sectors which are alternately raised and depressed. Smooth central area. No intercalary bands. Cell wall usually of several layers, the individual membranes punctated (the puncta in crossing lines) and more or less strongly areolated. The areolation is strongest on the outer layer, on the inner membrane, often entirely lacking. On outer margin of the sectors, often only on the raised ones, seldom displaced toward the cell center, one or more claw-like processes that communicate with the inner cell by a pore canal. Valve margin more or less wide and often with numerous marginal spinulae (Cupp, 1943).

Scientific name: *Actinoptychus senarius* (Ehrenberg) Ehrenberg

Plate A3: e, f (Annex A)

Synonym:*Actinocyclus senarius* Ehrenberg**References:**

Crosby and Wood, 1958: p. 498, Pl. 32: 19;
Hendey, 1964: p. 95, Pl. XXIII: 1, 2;
Hendey, 1970: p. 114; Simonsen, 1974: p. 23;
Priddle and Fryxell, 1985: p. 110-111;
Witkowski *et al.*, 2000: p. 22, Pl. 3: 4, 5;
Throndsen *et al.*, 2007: p. 152.

**Description:**

Valve divided into sectors, usually six, that are alternating elevated and depressed. Hexagonal non-areolated area in valve center. One labiate process with outer tube at each of the elevated

sectors. Strong and irregular areolation. Diameter 20-150 μm ; 4-7 areolae in 10 μm (Thronsdon *et al.*, 2007).

Dimensions:

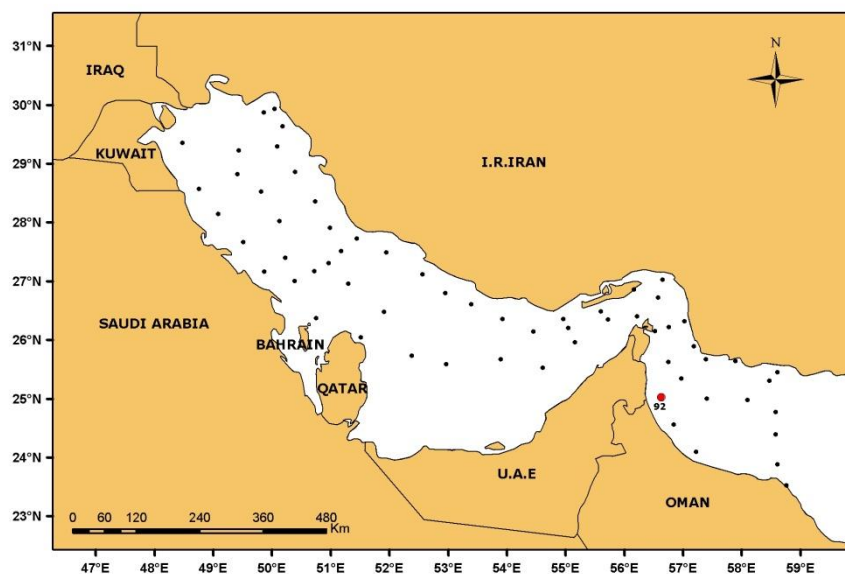
Diameter 35-44 μm .

Distribution:

Cosmopolitan species, common in neritic plankton.

Sites of occurrence in RSA:

In Winter 2006 Cruise, a single specimen was observed at one locality in the Sea of Oman (St. 92) (refer site map). It has been previously reported from the inner RSA (Simonsen, 1974) and from Kuwaiti shore (Hendey, 1970).



Site of occurrence of *Actinoptychus senarius* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Rhizosoleniineae

Family: Rhizosoleniaceae De Toni

Genus: *Dactyliosolen* Castracane

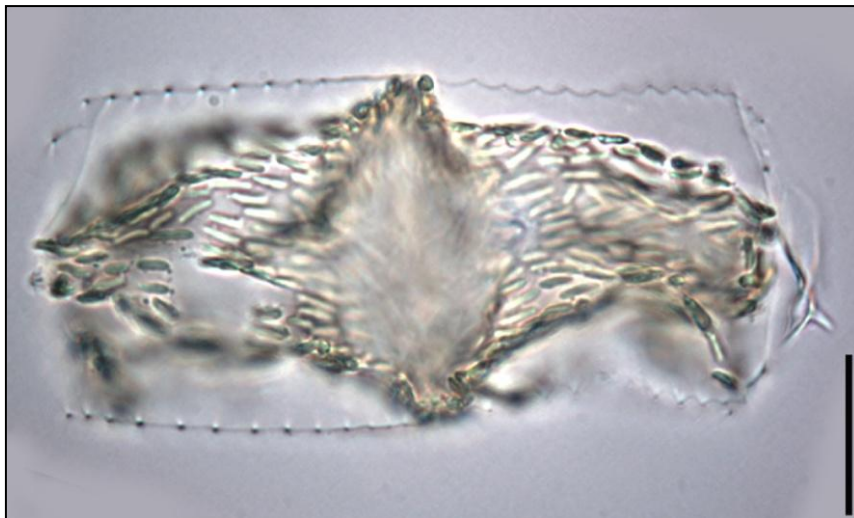
Cells cylindrical, living singly or united in long, stiff, closed chains by the flat valve surfaces. Valves circular, without noticeable spines or processes; on the margin, sometimes with indistinct little nodules. Intercalary bands numerous, half-collar-shaped, somewhat spirally twisted and with their wedge-shaped thin ends fitting together in a toothlike manner. Mantle surface with fine or coarse areolae. The ends of the intercalary bands do not always lie in an even line in the perivalvar direction, but sometimes form a spiral line. The girdle band is frequently unilaterally displaced and considerably closer to the younger valve (Cupp, 1943).

Scientific name: *Dactyliosolen phuketensis* (Sundström) Hasle

Plate A22: d-f (Annex A)

Synonym:

Rhizosolenia phuketensis Sundström



Reference:

Throndsen *et al.*, 2007: p. 155.

Description:

Cells curved. Chains close set, curved or spiraling. Bands visible with LM (Throndsen *et al.*, 2007).

Dimensions:

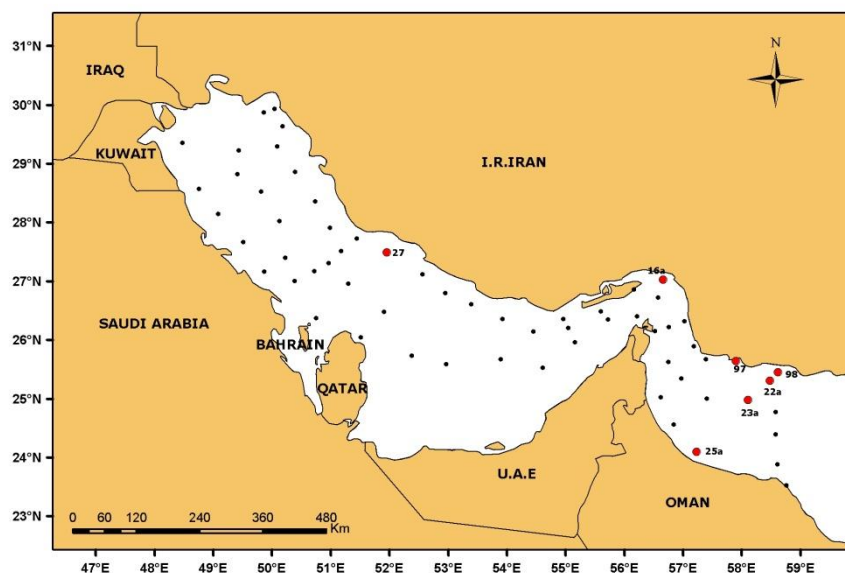
Cells length 85-94 μm ; diameter 38-42 μm .

Distribution:

Warm water species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at few scattered sites (refer sites map), usually in small numbers; maximum abundance did not exceed 10^3 cells/l and was associated with the Sea of Oman.



Sites of occurrence of *Dactyliosolen phuketensis* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Rhizosoleniineae

Family: Rhizosoleniaceae De Toni

Genus: *Guinardia* H. Pérégallo

Cells cylindrical; longer than broad, with a straight or slightly curved perivalvar axis, living singly or united in straight to twisted close-set chains. Intercalary bands numerous, collarlike or with wedge-shaped ends. Valves circular, surface flat, with an asymmetrical lateral rudimentary tooth at the valve margin. Chromatophores numerous, roundish, more or less lobed. Nucleus is usually lying in a central plasma mass, suspended by cytoplasmic strands extending to the cell walls (Cupp, 1943).

The *Guinardia* genus included 3 species. In Winter 2006 Cruise, small *Guinardia delicatula* was recorded as the most abundant species. This group contributed occasionally up to 74% of the total phytoplankton abundance; the highest concentration reached 2.5×10^5 cells/l. High abundance of *Guinardia* spp. ($> 10^5$ cells/l) was associated mainly with the waters of the Sea of Oman, and some local peaks occurred off the coast of the UAE and Qatar.

Scientific name: *Guinardia delicatula* (Cleve) Hasle

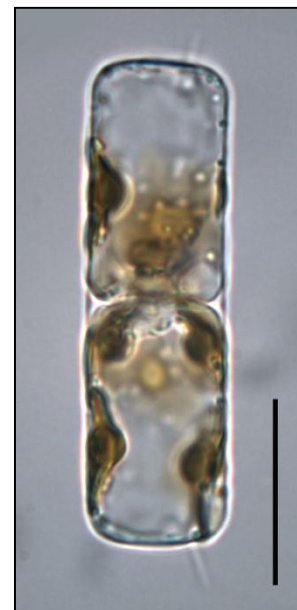
Plate A23: a-e (Annex A)

Synonym:

Rhizosolenia delicatula Cleve

References:

Pavillard, 1925: p. 28, Fig. 40 (as *Rhizosolenia delicatula*); Hustedt, 1930: p. 579, Fig. 328 (as *Rhizosolenia delicatula*); Cupp, 1943: p. 83, Fig. 44 (as *Rhizosolenia delicatula*); Crosby and Wood, 1958: p. 522, Pl. 39: 71 (as *Rhizosolenia delicatula*); Hendey, 1964: p. 147, Pl. IV: 2 (as *Rhizosolenia delicatula*); Throndsen *et al.*, 2007: p. 156.



Description:

Cells cylindrical, with almost completely flat valves, rounded only slightly on margins. United in closely set, straight chains. Cells 9-16 μm in diameter, usually about three times as long. Intercalary bands usually difficult to see, ring-shaped. Valve with marginal, short spine

which fits into a corresponding furrow or depression on the adjacent cell. Chromatophores two or several large plates, near the girdle wall, more or less crenated or lobed (Cupp, 1943).

Harmful Effect:

Non-toxic bloom-forming species. No harmful incident has been reported, but species may be regarded as potentially harmful during its blooms (Fryxell and Hasle, 2004).

Dimensions:

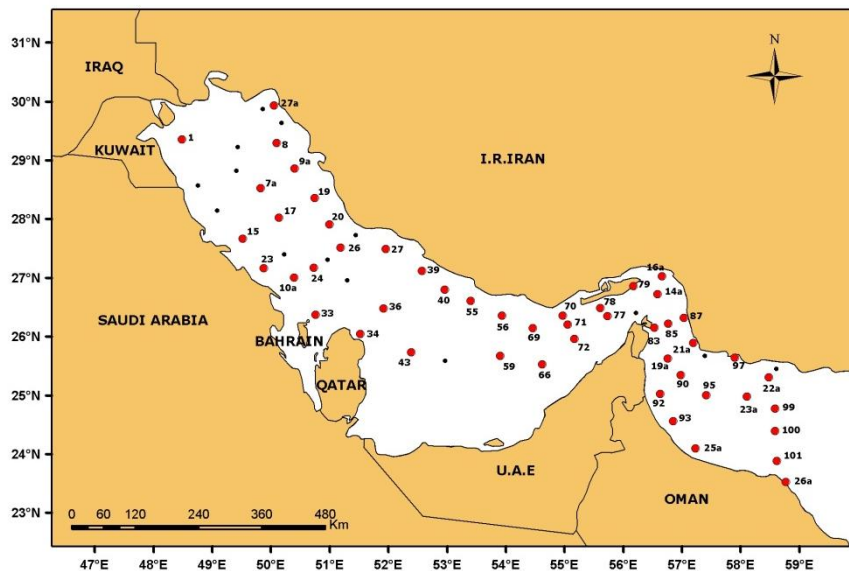
Cells length 22-27 μm ; diameter 11-17 μm .

Distribution:

Neritic, temperate species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was frequently observed, often in large numbers at various sites (refer sites map); maximum abundance (2.5×10^5 cells/l) was associated with the southern part of the inner RSA (St. 66). It has been previously reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Guinardia delicatula* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Rhizosoleniineae

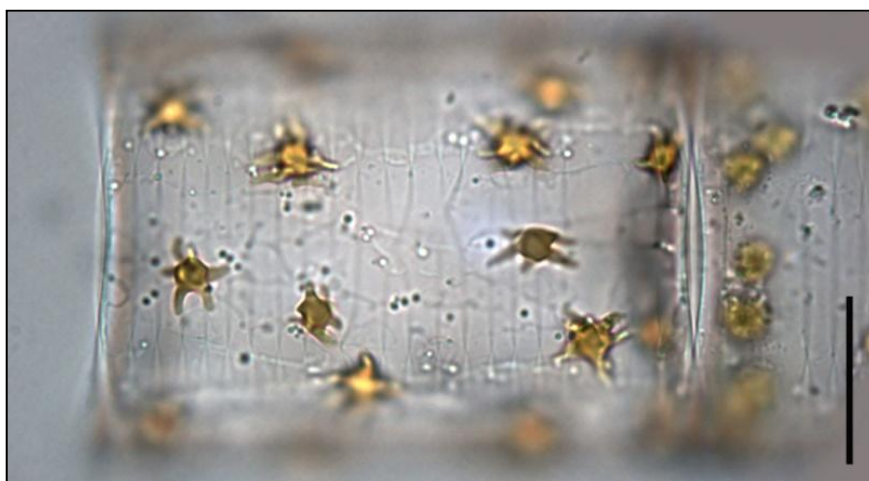
Family: Rhizosoleniaceae De Toni

Genus: *Guinardia* H. Péragallo

Species: *flaccida*

Scientific name: *Guinardia flaccida* (Castracane) H. Péragallo

Plate A24: a-d (Annex A)



Synonyms:

Rhizosolenia flaccida Castracane; *Rhizosolenia castracanei* Cleve

References:

Pavillard, 1925: p. 24, Fig. 36; Hustedt, 1930: p. 563, Fig. 322; Allen and Cupp, 1935: p. 124, Fig. 28; Cupp, 1943: p. 78, Fig. 40; Crosby and Wood, 1958: p. 524, Pl. 39: 79; Hendey, 1964: p. 141, Pl. V: 5; Simonsen, 1974: p. 30; Ricard, 1987: p. 175, Figs. 241-249; Throndsen *et al.*, 2007: p. 156.

Description:

Cells typically cylindrical, one and a half to several times longer than broad, single or united in chains by whole valve surface. Valve nearly flat, very slightly concave, with an irregular tooth at the margin. Diameter 30-53 μm . Cell wall weakly siliceous, collapsing when dried,

without visible sculpturing. Chromatophores lying near the wall, round to biscuit-shaped, more or less lobed or cleft plates in large numbers, with one pyrenoid. Nucleus more or less central (Cupp, 1943).

Harmful Effect:

Non-toxic, but harmful bloom forming species. Harmful effects have been recorded in 1980 within South China Sea: death of fish and invertebrates was observed, resulting in the reduction of fish mariculture output and tourism was affected in this area (Yan *et al.*, source: web-site).

Dimensions:

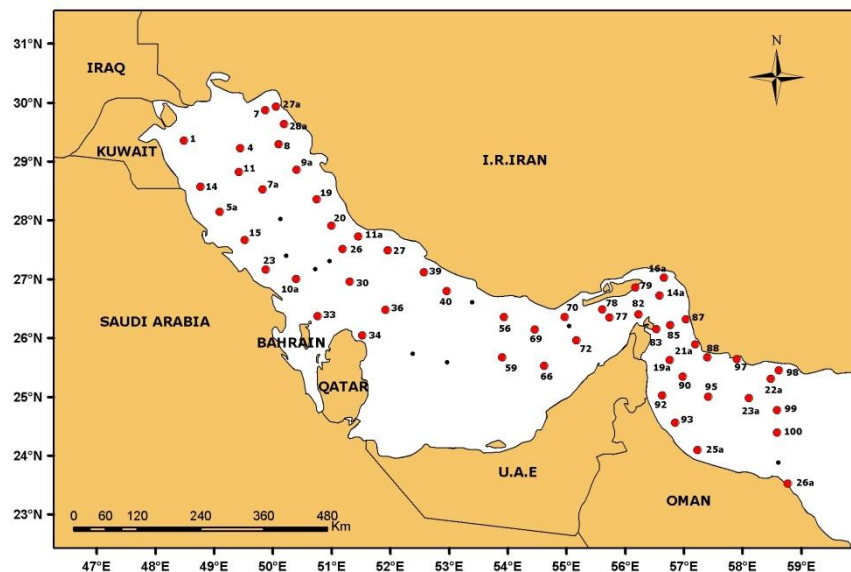
Cells length 60-75 μm ; diameter 33-44 μm .

Distribution:

Neritic, south temperate species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was commonly observed in many sites (refer sites map), often in large numbers; maximum abundance (8.9×10^3 cells/l) was associated with the northwestern part of the inner RSA (St. 7). It has been previously reported from the inner RSA (Simonsen, 1974) and from Kuwaiti waters (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Guinardia flaccida* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Rhizosoleniineae

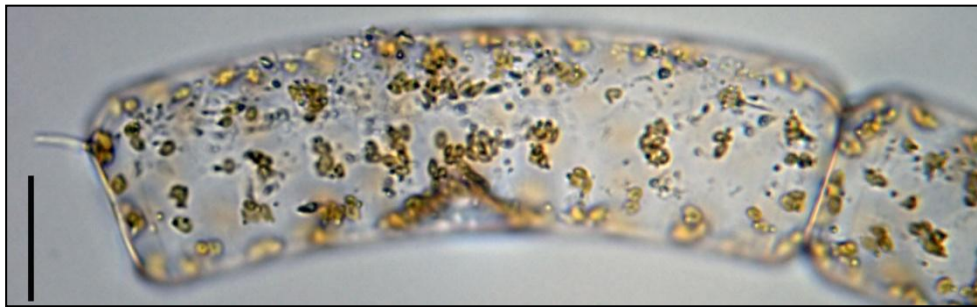
Family: Rhizosoleniaceae De Toni

Genus: *Guinardia* H. Péragallo

Species: *striata*

Scientific name: *Guinardia striata* (H. Péragallo) Hasle

Plate A23: f-i (Annex A)



Synonyms:

Rhizosolenia stolterfothii H. Péragallo; *Eucampia striata* Stolterfoth

References:

Pavillard, 1925: p. 28, Fig. 42 (as *Rhizosolenia stolterfothii*); Hustedt, 1930: p. 579, Fig. 329 (as *Rhizosolenia stolterfothii*); Allen and Cupp, 1935: p. 125, Fig. 29 (as *Rhizosolenia stolterfothii*); Cupp, 1943: p. 84, Fig. 45 (as *Rhizosolenia stolterfothii*); Crosby and Wood, 1958: p. 523, Pl. 39: 77 (as *Rhizosolenis stolterfothii*); Hendey, 1964: p. 148, Pl. IV: 5 (as *Rhizosolenia stolterfothii*); Ricard, 1987: p. 171, Figs. 209-211 (as *Rhizosolenis stolterfothii*); Throndsen *et al.*, 2007: p. 156.

Description:

Cells cylindrical; 6-30 μm in diameter. Uniformly curved along perivalvar axis. United in curved chains, often spiral. Valves flat, rounded at the edges. Strong spine on valve margin, fits into depression on adjacent cell. Intercalary bands collarlike, numerous. Imbrication lines

not always distinct, but very clear sometimes. Cell wall weakly siliceous, without detectable structure. Chromatophores numerous, small, oval. Nucleus near wall (Cupp, 1943).

Dimensions:

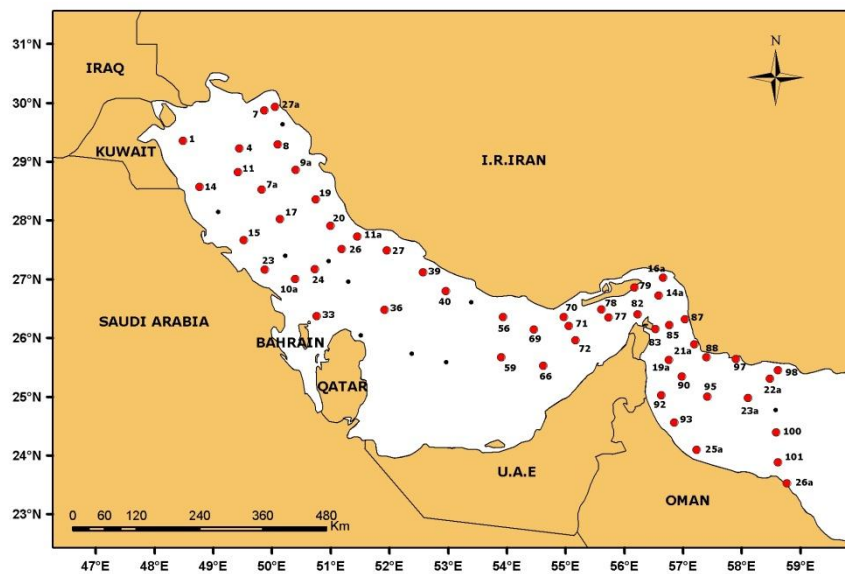
Cells length 65-78 μm ; diameter, 28-33 μm .

Distribution:

Neritic, sometimes regarded as oceanic; very widespread species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, it was one of the commonest species occurred at most of the sites in the RSA (refer sites map), encountered in 64.9% of the samples. Species were observed often in large numbers; maximum abundance (4.7×10^4 cells/l) was associated with the Sea of Oman (St. 25a). Species have been previously reported (as *Rhizosolenia stolterforthii*) from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Guinardia striata* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Rhizosoleniineae

Family: Rhizosoleniaceae De Toni

Genus: *Neocalyptrella* Hernández-Becerril *et* Meave

This genus has one species. Genus description as for the species.

Scientific name: *Neocalyptrella robusta* (Norman) Hernández-Becerril *et* Meave

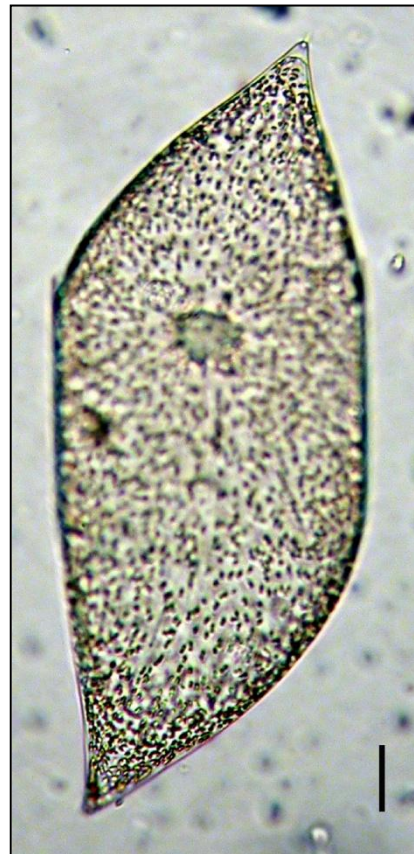
Plate A25: a, b (Annex A)

Synonym:

Rhizosolenia robusta Norman

References:

Pavillard, 1925: p. 29, Fig. 43 (as *Rhizosolenia robusta*); Hustedt, 1930: p. 581, Fig. 330 (as *Rhizosolenia robusta*); Allen and Cupp, 1935: p. 126, Fig. 31 (as *Rhizosolenia robusta*); Cupp, 1943: p. 85, Fig. 46 (as *Rhizosolenia robusta*); Crosby and Wood, 1958: p. 523, Pl. 39: 75 (as *Rhizosolenia robusta*); Hendey, 1964: p. 148, Pl. II: 5 (as *Rhizosolenia robusta*); Simonsen, 1974: p. 29 (as *Rhizosolenia robusta*); Ricard, 1987: p. 171, Figs. 212-214 (as *Rhizosolenia robusta*); Throndsen *et al.*, 2007: p. 157.



Description:

Cells cylindrical with deeply convex or conical curved valves; 48-130 μm in diameter, up to 0.5 mm or even 1 mm long. Valvar plane elliptical. Cells either crescent-shaped or S-shaped. Usually living singly or in short chains. Intercalary bands robust, numerous, typically collar-shaped. Calyptrae with distinct longitudinal lines (growth sectors) and eccentric process with a fine, bristlelike point and suddenly dilated, hollow base. Cell wall thin, but more strongly siliceous than in most of the other species of this genus. Membrane delicately punctated, puncta in three-line, self-crossing system (quincunx). Puncta on valve 19-20 in 10 μm ; on intercalary bands 24-26 in 10 μm . Chromatophores numerous, lying along the wall. Nucleus near the wall (Cupp, 1943).

Dimensions:

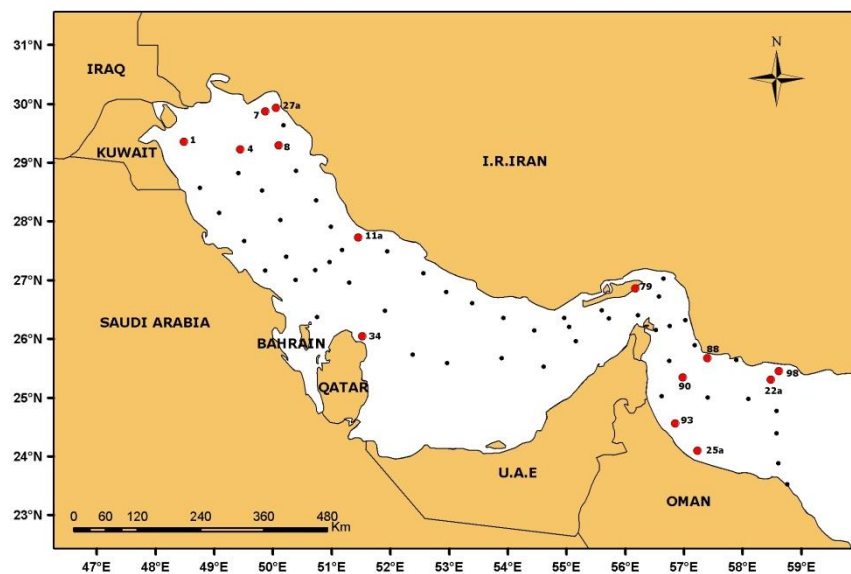
Cells length 420-580 μm ; diameter 100-110 μm .

Distribution:

Oceanic species; widely distributed, especially in warm water.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred occasionally in very small numbers at different sites (refer sites map). It has been previously reported (as *Rhizosolenia robusta*) from the inner RSA (Simonsen, 1974) and from Kuwaiti waters (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009 – as *Rhizosolenia robusta*).



Sites of occurrence of *Neocalyptrella robusta* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Rhizosoleniineae

Family: Rhizosoleniaceae De Toni

Genus: *Proboscia* Sundström

The generic type, *Proboscia alata*, was first described as *Rhizosolenia alata* with a series of forms, all with valve extended into a shorter or longer tube with truncate tip (proboscis), and no internal processes. Chain formation by the proboscis of neighboring cells fitting into the claspers on the adjacent valve. Auxospores, formed terminally. The different forms are now regarded as separate species (Thronsdon *et al.*, 2007).

Scientific name: *Proboscia alata* (Brightwell) Sundström

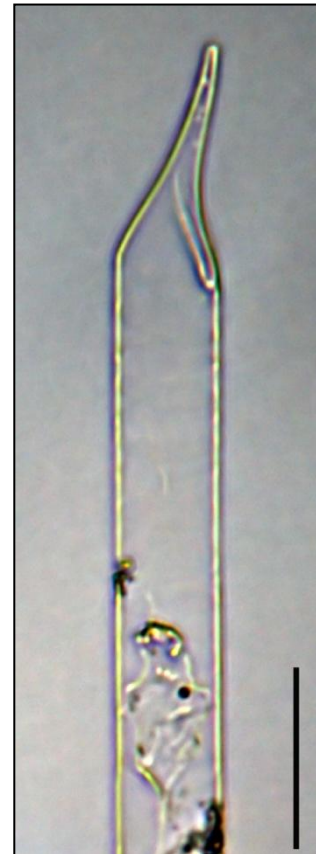
Plate A26: a, b (Annex A)

Synonym:

Rhizosolenia alata Brightwell

References:

Pavillard, 1925: p. 26, Fig. 38 (as *Rhizosolenia alata*); Hustedt, 1930: p. 599, Fig. 344 (as *Rhizosolenia alata*); Allen and Cupp, 1935: p. 130, Fig. 43 (as *Rhizosolenia alata*); Cupp, 1943: p. 91, Fig. 52 A (as *Rhizosolenia alata*); Crosby and Wood, 1958: p. 520, Pl. 38: 62 a (as *Rhizosolenia alata*); Hendey, 1964: p. 146, Pl. II: 2 (as *Rhizosolenia alata* f. *alata*); Simonsen, 1974: p. 28 (as *Rhizosolenia alata*); Priddle and Fryxell, 1985: p. 76-77; Ricard, 1987: p. 171, Figs. 202-205 (as *Rhizosolenia alata* f. *alata*); Thronsdon *et al.*, 2007: p. 157.



Description:

Cells rod-shaped, cylindrical, straight; 7-18 μm in diameter, up to 1 mm in length. Valve shortly conical ending in tubelike, more or less curved oblique process. Depression at base of tube into which apex of adjoining cell fits. Intercalary bands scalelike, rhombic, in two dorsoventrally rows. Cell wall thin, weakly siliceous; finely striated. On valve 21-23 puncta in 10 μm . None observed on intercalary bands. Chromatophores are numerous, small. Auxospores and resting spores, known. Auxospores growing out in the same plane as the main cell (Cupp, 1943).

Dimensions:

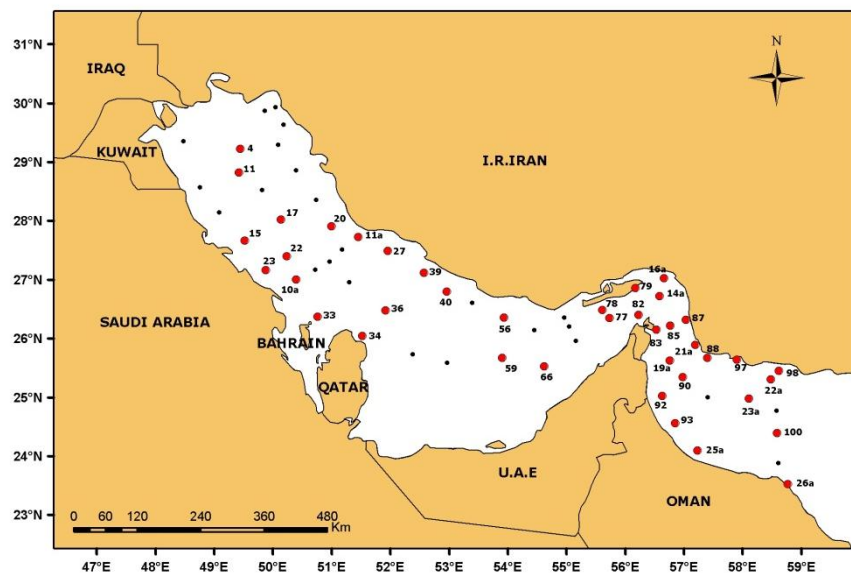
Cells length 380-550 μm ; diameter 17-20 μm .

Distribution:

Oceanic, but often near the coast, temperate species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was frequently observed, often in large numbers at various sites (refer sites map); maximum abundance (5.6×10^3 cells/l) was associated with the Sea of Oman (St. 25a). It has been previously reported (as *Rhizosolenia alata*) from the inner RSA (Simonsen, 1974) and from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Proboscia alata* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Rhizosoleniineae

Family: Rhizosoleniaceae De Toni

Genus: *Proboscia* Sundström

Species: *alata*

Forma: *gracillima*

Scientific name: *Proboscia alata* f. *gracillima* (Cleve) Licea et Moreno

Plate A25: c-g (Annex A)

Synonyms:

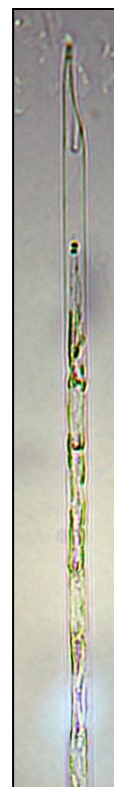
Rhizosolenia alata var. *gracillima* Cleve; *Rhizosolenia alata* form *gracillima* (Cleve) Grunow; *Rhizosolenia gracillima* Cleve

References:

Hustedt, 1930: p. 601, Fig. 345 (as *Rhizosolenia alata* f. *gracillima*); Allen and Cupp, 1935: p. 130, Fig. 44 (as *Rhizosolenia alata* f. *gracillima*); Cupp, 1943: p. 92, Fig. 52 B (as *Rhizosolenia alata* f. *gracillima*); Crosby and Wood, 1958: p. 520, Pl. 38: 62 b (as *Rhizosolenia alata* f. *gracillima*); Hendey, 1964: p. 146, Pl. II: 3 (as *Rhizosolenia alata* f. *gracillima*).

Description:

Like the type, but narrower. Diameter 4-7 µm. Production of auxospores bring it to same size as the type (Cupp, 1943).



Harmful Effect:

Non-toxic, but harmful bloom-forming species. Harmful effects have been recorded in 1983 within South China Sea: a large loss of fish, shrimp, and shellfish was reported, resulting in reduction of fish mariculture outputs (in one country alone, Gaoyang, 75 tons of fish-kill) (Yan *et al.*, source: web-site).

Dimensions:

Cells length 320-480 µm; diameter 6-9 µm.

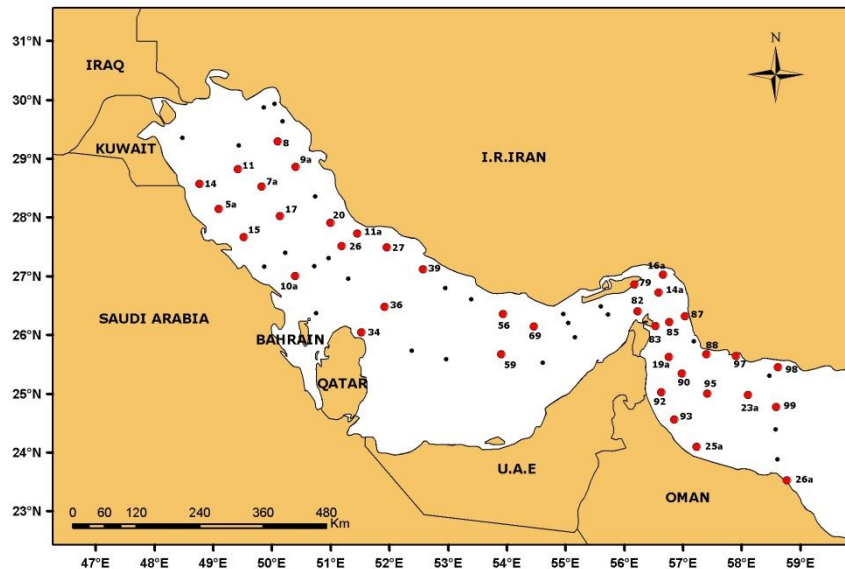
Distribution:

Coastal form, perhaps truly neritic.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was frequently observed at various sites (refer sites map), often in large numbers; maximum abundance (4.9×10^3 cells/l) was associated with the Iranian

coast in the northwestern part of the inner RSA (St. 11a). It has been previously reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Proboscia alata* f. *gracillima* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Rhizosoleniineae

Family: Rhizosoleniaceae De Toni

Genus: *Proboscia* Sundström

Species: *indica*

Scientific name: *Proboscia indica* (H. Péragallo) Hernandez-Becerril

Plate A26: c-f (Annex A)

Synonyms:

Rhizosolenia indica H. Péragallo; *Rhizosolenia alata* form *indica* (H. Péragallo) Ostensfeld

References:

Pavillard, 1925: p. 27, Fig. 39 (as *Rhizosolenia indica*); Hustedt, 1930: p. 601, Fig. 346 (as *Rhizosolenia alata* f. *indica*); Allen and Cupp, 1935: p. 130, Fig. 45 (as *Rhizosolenia alata* f. *indica*); Cupp, 1943: p. 92, Fig. 52 C (as *Rhizosolenia alata* f. *indica*); Crosby and Wood, 1958: p. 520, Pl. 38: 62 c (as *Rhizosolenia alata* f. *indica*); Hendey, 1964: p. 147, Pl. II: 4 (as *Rhizosolenia alata* f. *indica*); Simonsen, 1974: p. 28 (as *Rhizosolenia alata* f. *indica*); Ricard, 1987: p. 171, Figs. 200, 201 (as *Rhizosolenia alata* f. *indica*)

Description:

Cells much larger and broader than the type; 16-54 µm in diameter; calyptrae, because of this greater diameter, more strongly and suddenly attenuated, the process more striking. Structure very delicate; in many individuals, however, coarser than in the type. Cell wall finely punctated, puncta in quincunx rows, short and consequently, appear to be irregular (Cupp, 1943).

Dimensions:

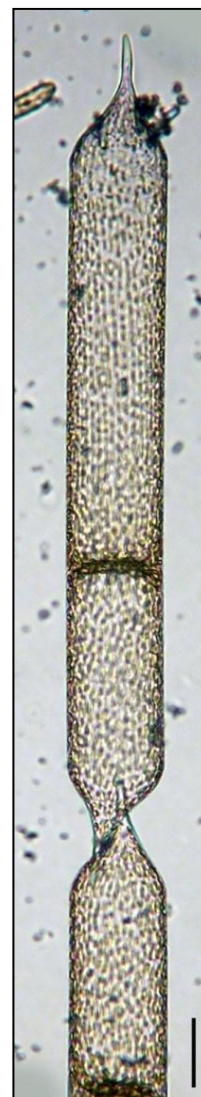
Cells length 390-710 µm; diameter 45-50 µm.

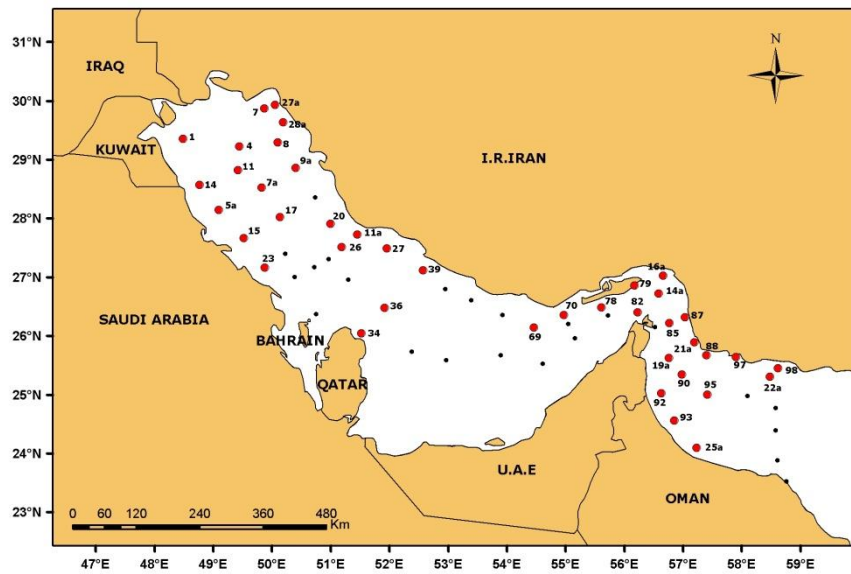
Distribution:

Warm water species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was frequently observed at various sites (refer sites map), often in large numbers; maximum abundance (5.3×10^3 cells/l) was associated with the northwestern part of the inner RSA (St. 7). It has been previously reported from the inner RSA (Simonsen, 1974) and from Kuwaiti waters (Al-Kandari *et al.*, 2009 as *Proboscia alata* f. *indica*).





Sites of occurrence of *Proboscia indica* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Rhizosoleniineae

Family: Rhizosoleniaceae De Toni

Genus: *Pseudosolenia* Sundström

This genus has one species. Genus description as for the species.

Scientific name: *Pseudosolenia calcar-avis* (M. Schultze) Sundström

Plate A27: a (Annex A)

Synonym:

Rhizosolenia calcar avis M. Schultze

References:

Pavillard, 1925: p. 34, Fig. 52 (as *Rhizosolenia calcar avis*); Hustedt, 1930: p. 593, Fig. 339 (as *Rhizosolenia calcar avis*); Allen and Cupp, 1935: p. 129, Fig. 41 (as *Rhizosolenia calcar-avis*); Cupp, 1943: p. 90, Fig. 51 (as *Rhizosolenia calcar avis*); Crosby and Wood, 1958: p. 521, Pl. 38: 65 (as *Rhizosolenia calcar avis*); Hendey, 1964: p. 151, Pl. IV: 3 (as *Rhizosolenia calcar-avis*); Hendey, 1970: p. 121 (as *Rhizosolenia calcar-avis*); Simonsen, 1974: p. 28 (as *Rhizosolenia calcar-avis*); Throndsen *et al.*, 2007: p. 158.

Description:

Cells rod-shaped cylindrical; the valves, not oblique, more regularly conical, curved at the apex. Cells 6-53 μm in diameter, up to nearly 1 mm in length. Intercalary bands scalelike, rhombic, in small individuals in two dorsiventral rows, in the widest forms, sometimes up to eight or more rows. Imbrication lines difficult to see. Process strong, gradually diminishing in size from the base to the point, curved like a claw. No wings on process. Cell wall thin and weakly siliceous; very delicately punctated. Puncta on valve 22-24 in 10 μm ; on intercalary bands 20-23 in 10 μm . Chromatophores small, numerous (Cupp, 1943).

**Dimensions:**

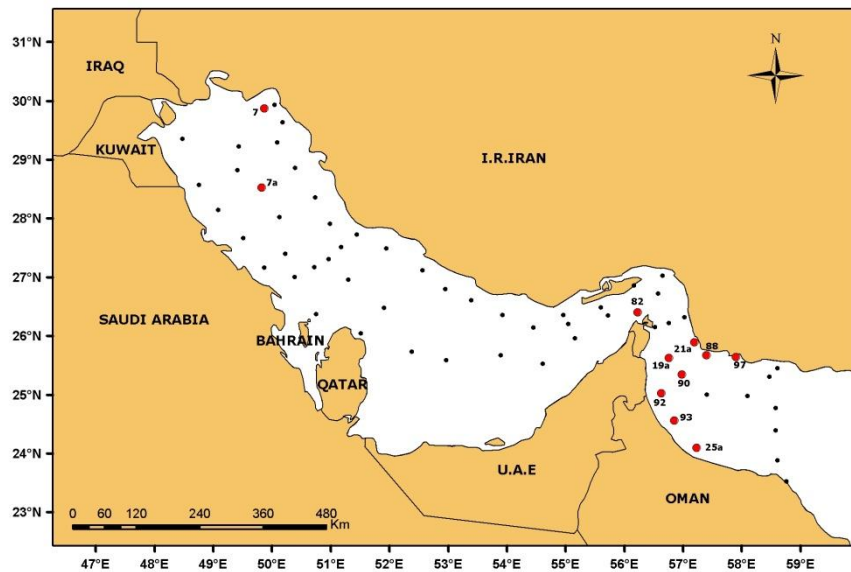
Cells length 450-640 μm ; diameter 35-48 μm .

Distribution:

Oceanic, warm-water species, subtropical to tropical.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at few sites (refer sites map) and in very small numbers. Species have been previously reported (as *Rhizosolenia calcar-avis*) from the inner RSA (Simonsen, 1974) and from Kuwaiti shore (Hendey, 1970) and coastal waters (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Pseudosolenia calcar-avis* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Rhizosoleniineae

Family: Rhizosoleniaceae De Toni

Genus: *Rhizosolenia* (Ehrenberg) Brightwell

Cells cylindrical with greatly elongated pervalvar axis, living singly or in compact or loose chains. Cells usually straight or more rarely curved, forming spirally twisted chains. Cross section elliptical or circular. Intercalary bands usually very numerous, but in some species, difficult to see. Only a few species with ring-shaped intercalary bands; in most species, they are rhombic, trapezium-like, or scale-shaped. Their separation lines are called imbrication lines. The valves called calyptrae in the genus *Rhizosolenia*, are in some species almost flat or symmetrically cone-shaped, usually, however, eccentric sharp cone-shaped or hood-shaped. Likewise, the valves have a usually eccentric process, short or bristle-like elongated, blunt or sharp, solid or hollow. In a few species, the process is completely absent, and only the valve is more strongly drawn out and thinner to resemble a process. The cells are thin-

walled throughout and usually collapse when dried. The membrane structure frequently difficult to see, consists of puncta or little dots arranged in quincunx or definitely arranged lines. The chromatophores are usually small, numerous, distributed on the entire cell wall, but especially massed in the girdle zone about the nucleus. In some species, larger plate-like chromatophores are present. Dimorphic forms occur. These are often classed as separate species. Auxospores, resting spores, and microspores are known. Auxospores are either at right angles to the mother cell or longitudinal. The resting spores occur singly or in pairs within the mother cell. They are thick-walled and cylindrical, with one valve rounded; the other sharply conical (Cupp, 1943).

Scientific name: *Rhizosolenia bergonii* H. Péragallo

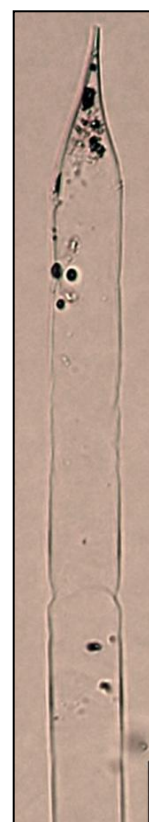
Plate A28: a-c (Annex A)

References:

Pavillard, 1925: p. 30, Fig. 45; Hustedt, 1930: p. 576, Fig. 327; Cupp, 1943: p. 82, Fig. 43; Crosby and Wood, 1958: p. 521, Pl. 38: 64; Hendey, 1964: p. 151, Pl. III: 4; Simonsen, 1974: p. 28.

Description:

Cells with cylindrical central region, elongated cone-shaped valves. Diameter 22-70 μm ; length up to 530 μm . Intercalary bands scalelike, usually in four or five rows, with regular bow-shaped margins. Imbrication lines distinct. Apical process short, straight, centrally located, traversed by a canal in center, cut off abruptly at end. Canal enlarged at base, bell-shaped at apex. Walls of valve moderately robust, with rows of punctuations beginning somewhat below the process and diverging toward the base of the calyptra, 17-18 puncta in 10 μm near apex, 20-22 near base of valve. The membrane of the intercalary bands more delicate, with puncta in three crossing systems, 22-24 puncta in 10 μm . Chromatophores numerous, small. Auxospores formed at right angles to long (perivalvar) axis of cell. Diameter of cell with auxospore 22 μm , of auxospore 46 μm (Cupp, 1943).



Dimensions:

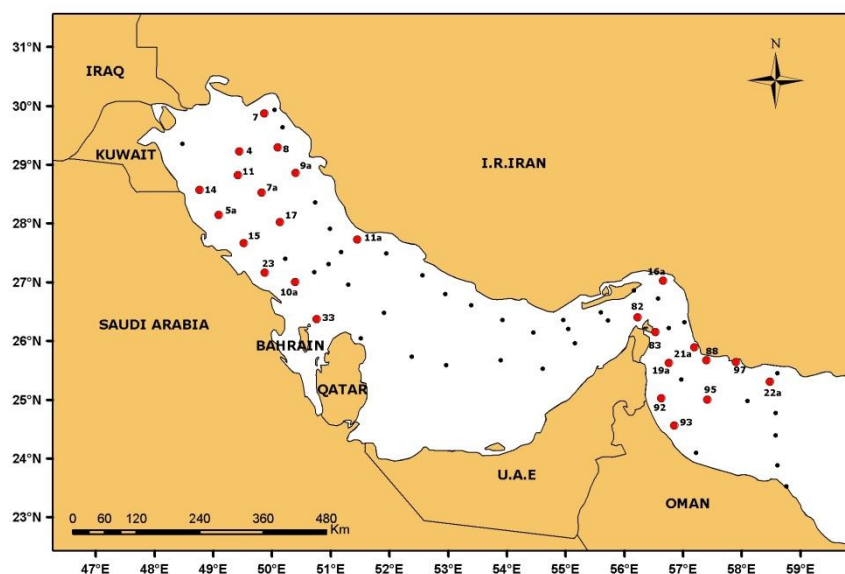
Cells length 320-450 µm; diameter 45-55 µm.

Distribution:

Oceanic, warmer-water species, south temperate or subtropical.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred occasionally at various sites (refer sites map), usually in small numbers; maximum abundance (1.1×10^2 cells/l) was associated with the northwestern part of the inner RSA (St. 11). species have been previously reported from the inner RSA (Simonsen, 1974) and from Kuwaiti waters (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Rhizosolenia bergonii* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Rhizosoleniineae

Family: Rhizosoleniaceae De Toni

Genus: *Rhizosolenia* (Ehrenberg) Brightwell

Species: *cochlea*

Scientific name: *Rhizosolenia cochlea* Brun

Plate A27: b-e (Annex A)

Synonym:

Rhizosolenia calcar-avis var. *cochlea* Ostensfeld

Reference:

Simonsen, 1974.

Description:

Cells cylindrical, mainly solitary or in short chains. Valves regularly conical, distinctly curved at apex. Process strong, gradually tapering from the base to the point, curved, without wings. Chromatophores small, numerous.

Dimensions:

Cells 60-65 µm in diameter; 350-400 µm in length.

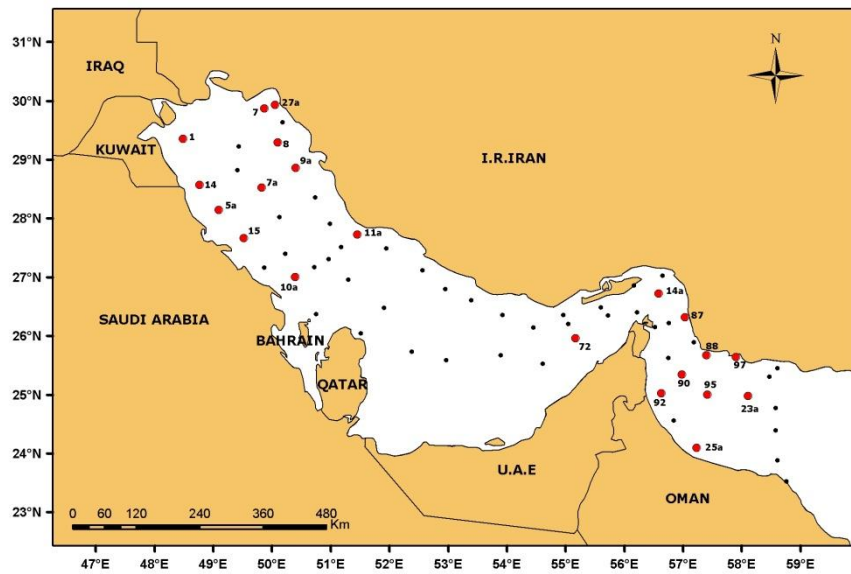
Distribution:

Warm water species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred occasionally in small numbers at various sites (refer sites map); maximum abundance (2.3×10^2 cells/l) was associated with Kuwaiti waters in the northwestern part of the inner RSA (Stations 1 and 14). Species have been previously reported from the inner RSA (Simonsen, 1974) and from Kuwaiti waters (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).





Sites of occurrence of *Rhizosolenia cochlea* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Rhizosoleniineae

Family: Rhizosoleniaceae De Toni

Genus: *Rhizosolenia* (Ehrenberg) Brightwell

Species: *hebetata*

Forma: *semispina*

Scientific name: *Rhizosolenia hebetata* f. *semispina* (Hensen) Cleve

Plate A29: a-c (Annex A)

Synonym:

Rhizosolenia semispina Hensen

References:

Pavillard, 1925: p. 32, Figs. 48, 49 (as *Rhizosolenia semispina*); Hustedt, 1930: p. 591, Fig. 338; Allen and Cupp, 1935: p. 129, Fig. 42; Crosby and Wood, 1958: p. 522, Pl. 39: 73 b; Hendey, 1964: p. 150, Pl. III: 5; Simonsen, 1974: p. 29; Priddle and Fryxell, 1985: p. 86-87; Ricard, 1987: p. 173, Fig. 230; Throndsen *et al.*, 2007: p. 161.

Description:

Cells cylindrical; valves, conical, very finely striate and produced to terminate in a long slender spine. Spine usually straight or only slightly curved, and processing an internal basal cavity. Cirdle composed of two dorsiventral lines of intercalary scale-like plates, scales almost rhombic, but presenting the appearance of a zigzag line when the cell offers a lateral aspect. The scales at the base of the valve are often clearly marked with an elongated depression which corresponds to the spine of the neighboring cell. Diameter of valve 5-12 µm (Hendey, 1964).

Dimensions:

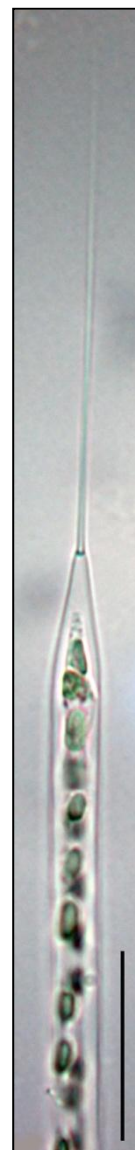
Cells length 250-330 µm; diameter 7-8 µm.

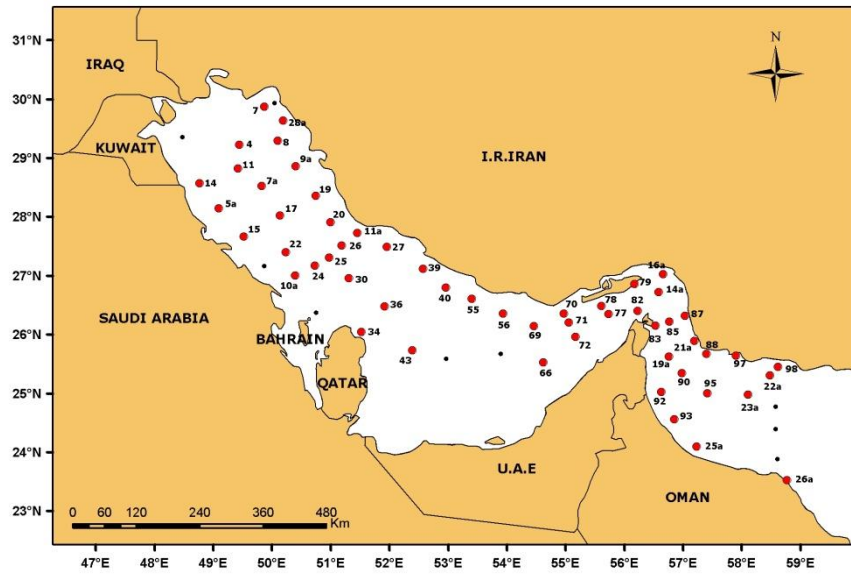
Distribution:

Oceanic form; common in all sub-tropical and temperate waters.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was commonly observed at various sites (refer sites map), often in large numbers; maximum abundance (3.3×10^4 cells/l) was associated with the central part of the inner RSA (St. 36). It has been previously reported from the inner RSA (Simonsen, 1974) and from Kuwaiti waters (Al-Yamani *et al.*, 2004).





Sites of occurrence of *Rhizosolenia hebetata* f. *semispina* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Rhizosoleniineae

Family: Rhizosoleniaceae De Toni

Genus: *Rhizosolenia* (Ehrenberg) Brightwell

Species: *hyalina*

Scientific name: *Rhizosolenia hyalina* Ostenfeld

Plate A28: d-f (Annex A)

Synonym:

Rhizosolenia pellucida Cleve

Reference:

Hasle and Syvertsen, 1997.

Description:

Process slightly bent near the end of the otaria. Otaria narrow, extending along process for ca 4-6 μm . Diameter 9-60 μm , length of process up to 40 μm , band areolae 31-36 in 10 μm (Hasle and Syvertsen, 1997).

Dimensions:

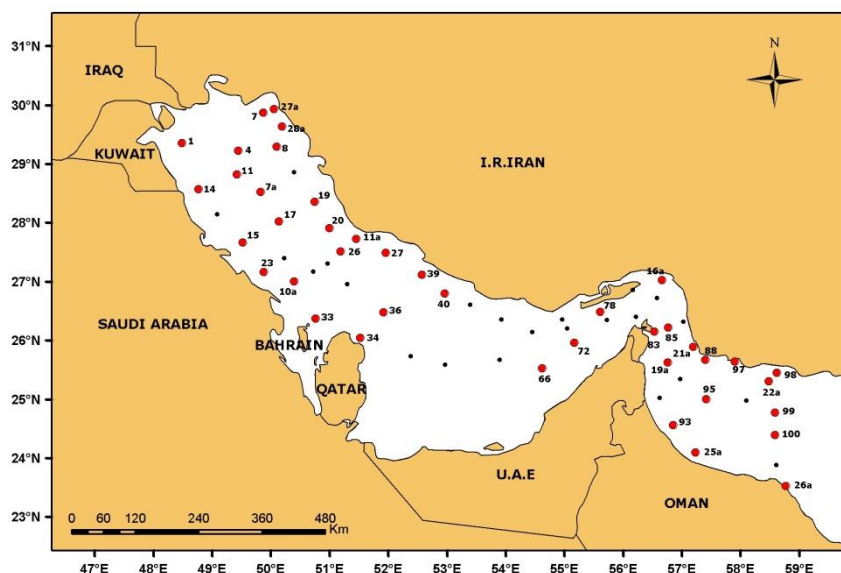
Cells length 180-220 μm ; diameter 40-45 μm .

Distribution:

Warm-water species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was frequently observed at various sites (refer sites map), although never in large numbers; maximum abundance (4.4×10^2 cells/l) was associated with the northwestern part of the inner RSA (St. 11).



Sites of occurrence of *Rhizosolenia hyalina* in RSA



Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Rhizosoleniineae

Family: Rhizosoleniaceae De Toni

Genus: *Rhizosolenia* (Ehrenberg) Brightwell

Species: *imbricata*

Scientific name: *Rhizosolenia imbricata* Brightwell

Plate A30: a-f (Annex A)

Synonym:

Rhizosolenia striata Greville

References:

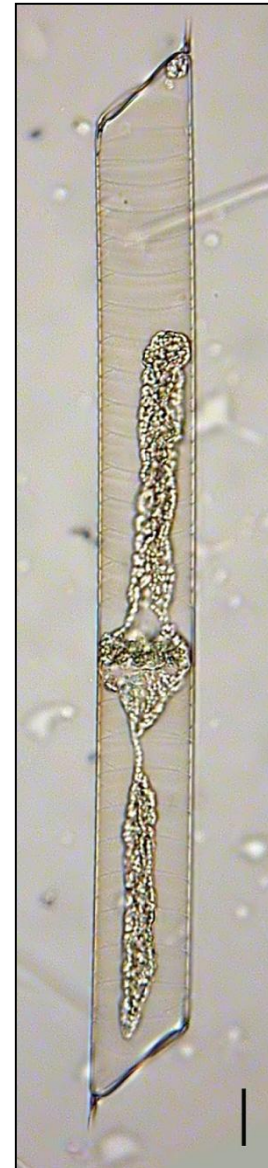
Hustedt, 1930: p. 582, Fig. 331; Allen and Cupp, 1935: p. 127, Fig. 35; Crosby and Wood, 1958: p. 522, Pl. 39: 74 a; Hendeby, 1964: p. 149, Pl. III: 1; Hendeby, 1970: p. 121; Simonsen, 1974: p. 29; Ricard, 1987: p. 173, Figs. 216-218; Throndsen *et al.*, 2007: p. 162.

Description:

Cells large, cylindrical, slightly flattened and furnished with depressed or flattened conical valves having a strongly oblique ventral margin. Valves furnished with a strong marginal spine which appears as a continuation of the dorsal side of the valve. Girdle composed of two lateral rows of intercalary scale-like markings. The segments have oblique ends, and their edges form regular rings around the cell. Intercalary scales coarsely striate, striae oblique, converging upon a line or hyaline break which runs up the middle of the girdle. Markings finely areolate. Diameter of valve up to 80 μm , length of cell up to 400 μm (Hendeby, 1964).

Dimensions:

Cells length 350-420 μm ; diameter 45-58 μm .

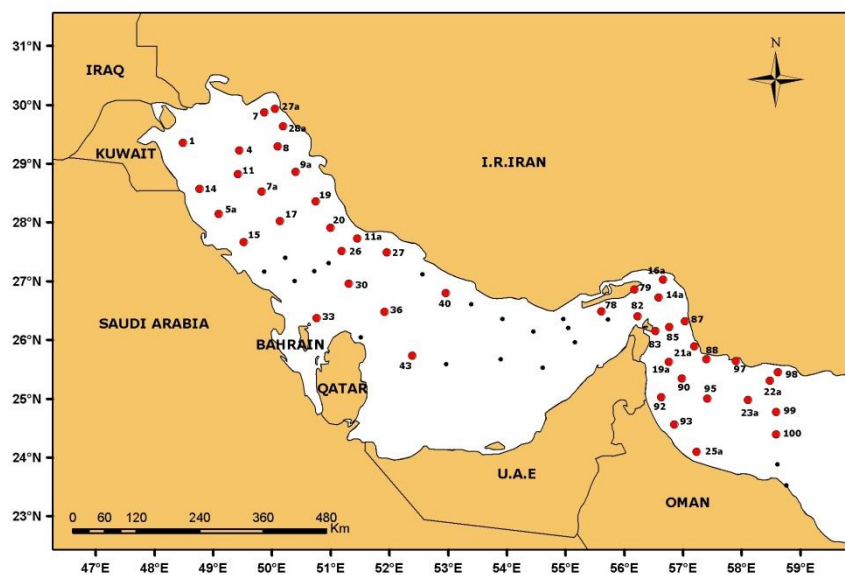


Distribution:

Marine cosmopolitan species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was frequently observed at various sites (refer sites map), although never in large numbers; maximum abundance (9.9×10^2 cells/l) was associated with the Iranian coast in the Sea of Oman (St. 88). It has been previously reported from the inner RSA (Simonsen, 1974) and from Kuwaiti shore (Hendey, 1970) and coastal waters (Al-Yamani et al., 2004; Al-Kandari et al., 2009).



Sites of occurrence of *Rhizosolenia imbricata* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Rhizosoleniineae

Family: Rhizosoleniaceae De Toni

Genus: *Rhizosolenia* (Ehrenberg) Brightwell

Species: *setigera*

Scientific name: *Rhizosolenia setigera* Brightwell

Plate A31: a-d (Annex A)

Synonyms:

Rhizosolenia japonica Castracane; *Rhizosolenia henssenii* Schütt

References:

Pavillard, 1925: p. 32, Fig. 48; Hustedt, 1930: p. 589, Fig. 336; Allen and Cupp, 1935: p. 128, Fig. 37; Cupp, 1943: p. 88, Fig. 49; Crosby and Wood, 1958: p. 523, Pl. 39: 76; Hendey, 1964: p. 149, Pl. IV: 1; Simonsen, 1974: p. 29; Ricard, 1987: p. 173, Fig. 226; Throndsen *et al.*, 2007: p. 161.

Description:

Cells rodlike, cylindrical. Diameter 4-20 µm. Valves conical, only slightly oblique. Apical process cylindrical, thickened for some distance from base, solid at base or with a very fine canal in the center, with a very long, fine, straight spine. Intercalary bands scale-like, two long bands pointing toward apex. Cell wall thin, weakly siliceous, without distinct or visible structure. Chromatophores numerous, small, elliptical (Cupp, 1943).

Dimensions:

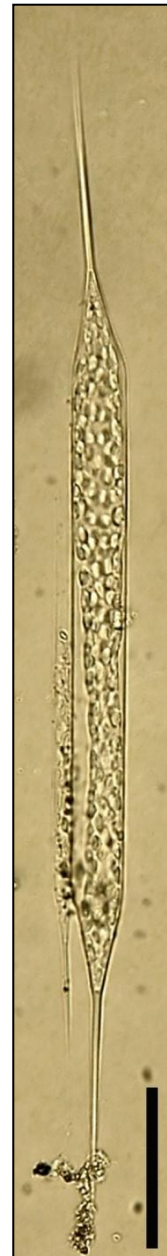
Cells length 300-350 µm; diameter 16-19 µm.

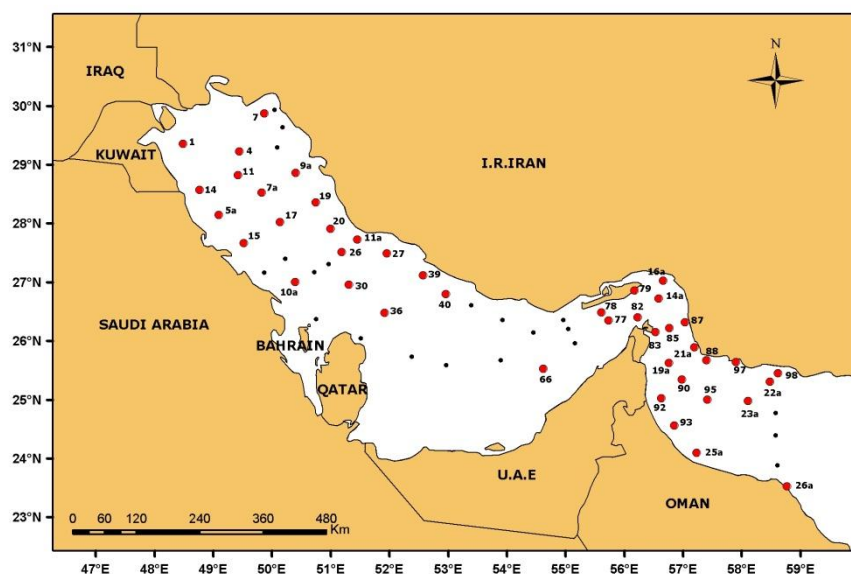
Distribution:

Neritic, north temperate species (Cupp, 1943).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was frequently observed at various sites (refer sites map), although never in large numbers; maximum abundance (8×10^2 cells/l) was associated with the Iranian coast in the Sea of Oman (St. 88). It has been previously reported from the inner RSA (Simonsen, 1974) and from Kuwaiti waters (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).





Sites of occurrence of *Rhizosolenia setigera* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Rhizosoleniineae

Family: Rhizosoleniaceae De Toni

Genus: *Rhizosolenia* (Ehrenberg) Brightwell

Species: *shrubsolei*

Scientific name: *Rhizosolenia shrubsolei* Cleve

Plate A29: d, e (Annex A)

Synonym:

Rhizosolenia imbricata Brightwell v. *shrubsolei* (Cleve) Schröder

References:

Pavillard, 1925: p. 31, Fig. 46; Hustedt, 1930: p. 583, Fig. 332 (as *Rhizosolenia imbricata* v. *shrubsolei*); Allen and Cupp, 1935: p. 128, Fig. 36 (as *Rhizosolenia imbricata* v. *shrubsolei*); Cupp, 1943: p. 86, Fig. 47 (as *Rhizosolenia imbricata* v. *shrubsolei*); Crosby

and Wood, 1958: p. 522, Pl. 39: 74 b (as *Rhizosolenia imbricata* v. *shrubsolei*); Hendey, 1964: p. 149, Pl. III: 2; Priddle and Fryxell, 1985: p. 90-91; Ricard, 1987: p. 173, Figs. 219-221.

Description:

Cells cylindrical, 12-18 µm in diameter, up to 575 µm in length. Cells single or united in chains. Valves oblique, pointed, the apical process, hollow most of the way up, with small wings at the base, regularly decreasing in size until the point is reached. Small wings run up about a third of the spine; do not extend to valve itself. Intercalary bands numerous, scale-like in two long rows, each band, a triangular scale with the corner pointing so that they form an imbricating row on each side of the apex. Intercalary bands with ribs running from the middle line fan-like toward the sides, on an average, 17-18 in 10 µm, between the ribs coarsely lined with 24 cross lines in 10 µm. Girdle bands and valves much more delicate. Girdle bands with 19-22 perivalvar rows of lines and 25-28 puncta in 10 µm, lines on the valves from the base toward the excentric point 20-22 in 10 µm, with 26-30 puncta in 10 µm. Chromatophores numerous, small, lying near the cell wall. Nucleus near wall (Cupp, 1943).

Dimensions:

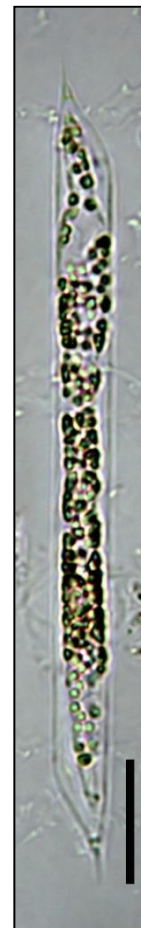
Cells length 350-430 µm; diameter 9-11 µm.

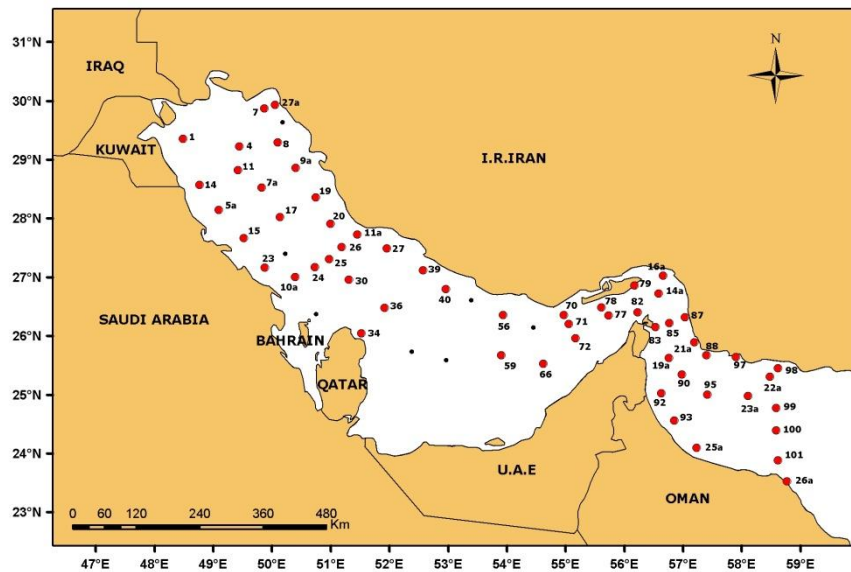
Distribution:

Neritic, temperate species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, it was one of the commonest species in the RSA samples, encountered in 68.1% of the samples. This species was observed often in large numbers at various sites (refer sites map); maximum abundance (6.4×10^4 cells/l) was associated with the northwestern part of the inner RSA (St. 7). It has been previously reported from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).





Sites of occurrence of *Rhizosolenia shrubsolei* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Rhizosoleniineae

Family: Rhizosoleniaceae De Toni

Genus: *Rhizosolenia* (Ehrenberg) Brightwell

Scientific name: *Rhizosolenia* sp.

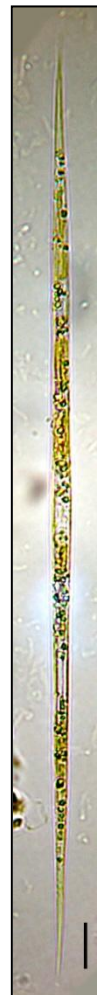
Plate A31: e (Annex A)

Description:

Cells thin, cylindrical. Valves conical, only slightly oblique. Apical process long, fine, straight spine. Cell wall thin, weakly siliceous, without distinct or visible structure. Chromatophores numerous, small.

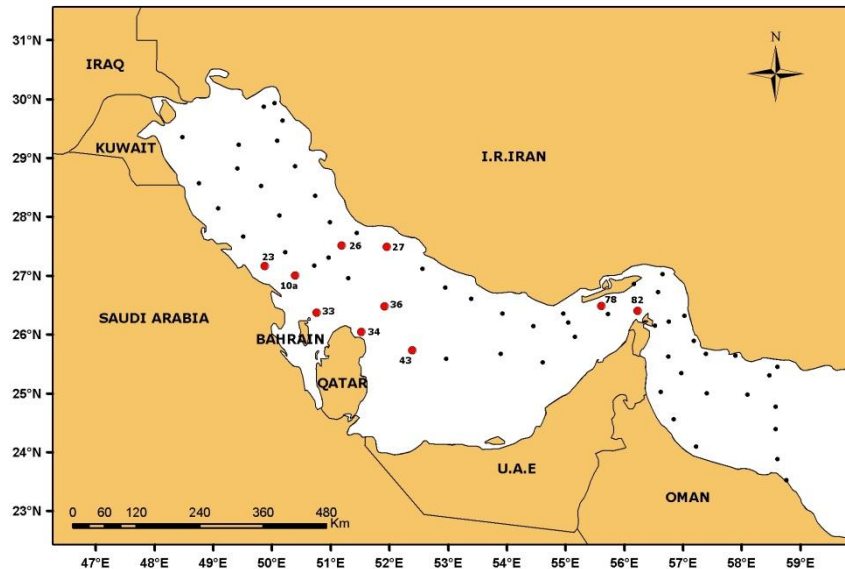
Dimensions:

Cells 7-9 μm in diameter, 220-260 μm in length.



Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was present in small numbers at scattered stations (refer sites map).



Sites of occurrence of *Rhizosolenia* sp.1 RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Biddulphiineae

Family: Hemiaulaceae Heiberg

Genus: *Cerataulina* H. Pérégallo

Cells cylindrical, usually in chains. Valves slightly arched, with two blunt projections or processes near their margin; attached to adjacent cell by means of a fine, small, curved, hair-like process which fits into the valve of the adjacent cell. Intercalary bands numerous, annular. Chromatophores numerous, small. Nucleus against the cell wall. Cell wall soft and weakly siliceous, collapsing when dried. Sculpturing very delicate (Cupp, 1943).

Scientific name: *Cerataulina bicornis* (Ehrenberg) Hasle *ex* Hasle *et* Sims

Plate A32: a-c (Annex A)

Synonyms:

Syringidium bicornis Ehrenberg; *Cerataulina compacta* Ostenfeld;
Cerataulina daemon (Greville) Hasle

Reference:

Hasle and Syvertsen, 1997: p. 171, Pl. 32.

Description:

Species are characterized by broad wing-like extensions of the elevations fitting into V-shaped deep furrows on mantle of adjacent valve. Labiate process marginal; areola array irregular. Diameter 5-75 µm, perivalvar axis 87-200 µ; 18-30 valve striae in 10 µm (Hasle and Syvertsen, 1997).



Dimensions:

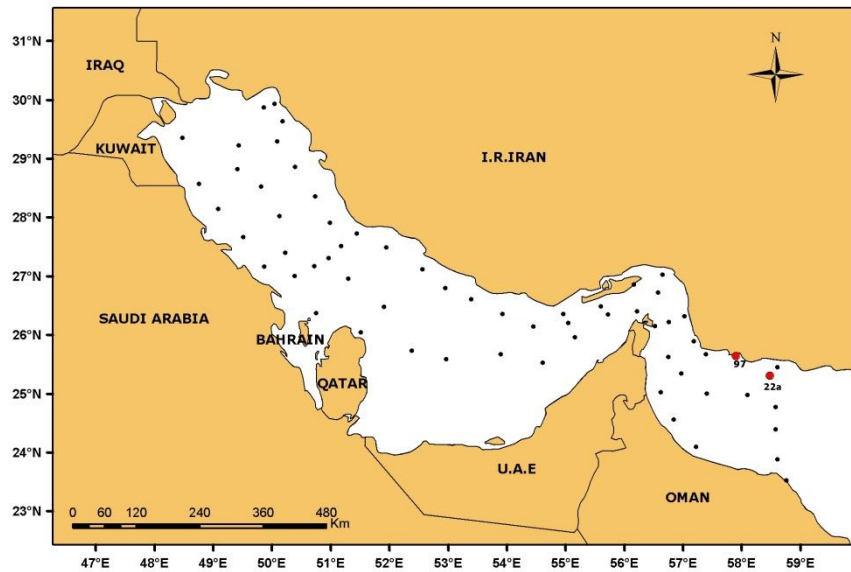
Cells length 65-95 µm; diameter 22-37 µm.

Distribution:

Coastal warm-water species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at two sites (refer sites map), usually in small numbers; maximum abundance (1.7×10^3 cells/l) was associated with the Sea of Oman (St. 22a). It has been previously reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Cerataulina bicornis* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Biddulphiineae

Family: Hemiaulaceae Heiberg

Genus: *Cerataulina* H. Pérezgallo

Species: *pelagica*

Scientific name: *Cerataulina pelagica* (Cleve) Hendey

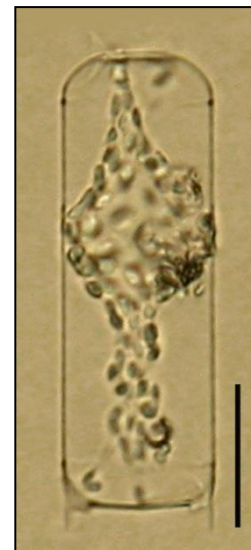
Plate A32: d-f (Annex A)

Synonym:

Cerataulina bergonii (H. Pérezgallo) Schütt

References:

Pavillard, 1925: p. 56, Fig. 99 (as *Cerataulina bergonii*); Hustedt, 1930: p. 870, Fig. 517 (as *Cerataulina bergonii*); Allen and Cupp, 1935: p. 148, Fig. 86 (as *Cerataulina bergonii*); Cupp, 1943: p. 167, Fig. 117 (as *Cerataulina bergonii*); Crosby and Wood, 1958: p. 502, Pl. 36: 18. Hendey, 1964: p. 113, Pl. IV: 4; Simonsen, 1974: p. 33 (as *Cerataulina bergonii*); Ricard, 1987: p. 187, Figs. 331-338; Throndsen *et al.*, 2007: p. 177.

**Description:**

Cells twisted about the central axis of the chain; apertures between cells, often very small. Processes short. Diameter of cells 11-36 μm .

Intercalary bands numerous; collarlike, very indistinct. Cell wall weakly siliceous and very delicately sculptured. Valves with radial rows of puncta, 21-23 puncta in 10 μm . Chromatophores small and numerous (Cupp, 1943).

Harmful Effect:

Non-toxic bloom-forming species. Death of benthic shellfish and bony fish was attributed to anoxia, and clogging of the gills during a bloom of *Cerataulina pelagica* off the coast of northeastern New Zealand in 1983 (Taylor *et al.*, 1985).

Dimensions:

Cells length 38-62 μm ; diameter 18-26 μm .

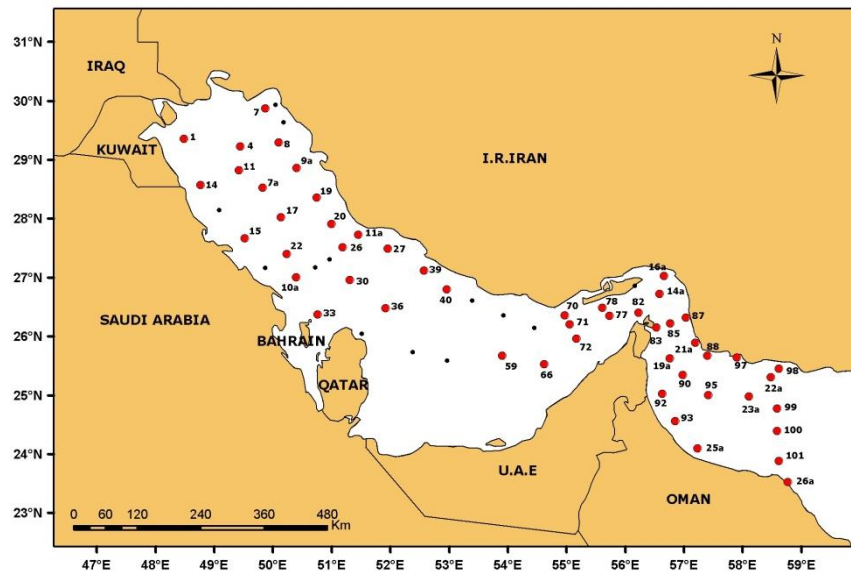
Distribution:

Neritic, south temperate species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, *Cerataulina pelagica* was commonly observed at various sites in the RSA (refer sites map) phytoplankton community, sometimes in high abundance. When this species was abundant, its contribution to the total phytoplankton abundance reached up to 52%; the highest concentration recorded was 5.3×10^4 cells/l. High abundance of *Cerataulina*

pelagica ($> 10^4$ cells/l) was encountered mainly in the Sea of Oman and a localized peak was recorded in Kuwaiti waters. It has been previously reported from the inner RSA (Simonsen, 1974, as *Cerataulina bergonii*) and from Kuwaiti waters (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Cerataulina pelagica* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Biddulphiineae

Family: Hemiaulaceae Heiberg

Genus: *Climacodium* Grunow

Cells straight, but usually forming somewhat twisted chains. Apertures oval or squarish-oblong as a result of the hammerlike ends of the cells. Cell wall very weakly siliceous, without visible sculpturing. Intercalary bands absent. Pervalvar axis of the cell usually short. Chromatophores are numerous and small. All species marine pelagic (Cupp, 1943).

Scientific name: *Climacodium frauenfeldianum* Grunow

Plate A32: g, h (Annex A)



References:

Hustedt, 1930: p. 777, Fig. 453; Allen and Cupp, 1935: p. 143, Fig. 76; Cupp, 1943: p. 147, Fig. 105; Crosby and Wood, 1958: p. 511, Pl. 36: 30; Simonsen, 1974: p. 33; Ricard, 1987: p. 189, Fig. 341.

Description:

Cells straight, flat, often united into long ribbonlike chains. In girdle view with small, linear middle part with more or less long, thin processes on the poles of the apical axis. Length of apical axis 70-95 μm , pervalvar axis 12-15 μm . Intercalary bands absent; pervalvar axis, therefore, always very short. Cells in valve view small linear-elliptical, valve surface between the processes, flat; the apertures, therefore, almost right-angled or very large oblongs, in pervalvar direction, usually wider than the cell. Structure of the membrane extremely difficult to see (Cupp, 1943).

Dimensions:

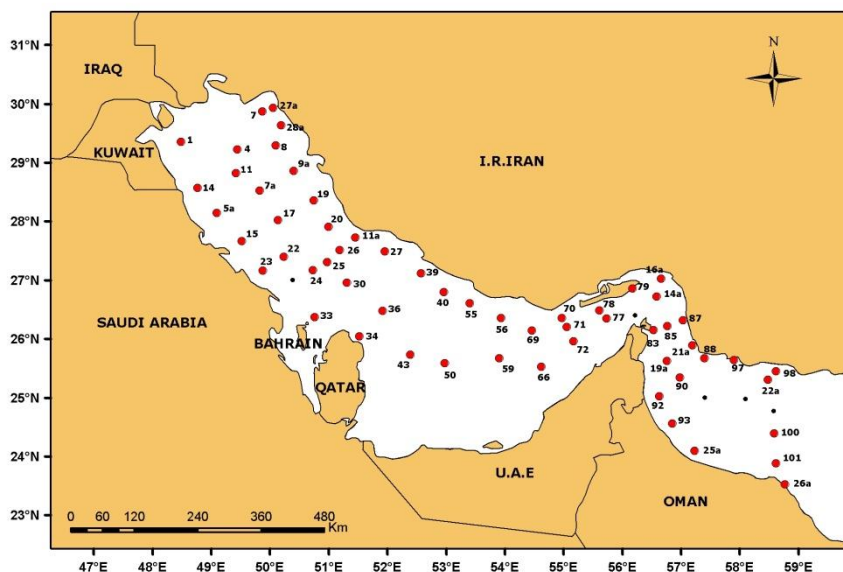
Cells length 80-90 μm ; width 14-16 μm .

Distribution:

Oceanic species with distribution from the tropical to temperate latitudes of all oceans.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was commonly observed at many sites (refer sites map), often in large numbers; maximum abundance (6.7×10^3 cells/l) was associated with the central part of the inner RSA (St. 36). It has been previously reported from the inner RSA (Simonsen, 1974) and from Kuwaiti waters (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Climacodium frauenfeldianum* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Biddulphiineae

Family: Hemiaulaceae Heiberg

Genus: *Eucampia* Ehrenberg

Valves elliptical in surface view with two blunt processes, without spines or setae. Numerous intercalary bands are difficult to see in water mounts. Chains spirally curved; large apertures between the cells. Chromatophores are numerous and small. Pelagic species (Cupp, 1943).

Scientific name: *Eucampia cornuta* (Cleve) Grunow

Plate A33: g, h (Annex A)

Synonym:

Moelleria cornuta Cleve

References:

Hustedt, 1930: p. 775, Fig. 452; Allen and Cupp, 1935: p. 142, Fig. 75; Cupp, 1943: p. 146, Fig. 104; Crosby and Wood, 1958: p. 511, Pl. 36: 29; Simonsen, 1974: p. 34; Ricard, 1987: p. 189, Figs. 344-347.

Description:

Similar to *E. zodiacus* in character of chain and general appearance. Differentiated by much more prominent intercalary bands, and longer, thinner processes, so that the apertures are wider. Sculpturing on valves, similar but not identical, in more definite rows from center to ends of processes, 18-20 puncta in 10 μm . Surface of intercalary bands, similarly punctated, very fine puncta in rows, running in direction of perivalvar axis. Length of apical axis 29-36 μm (Cupp, 1943).



Dimensions:

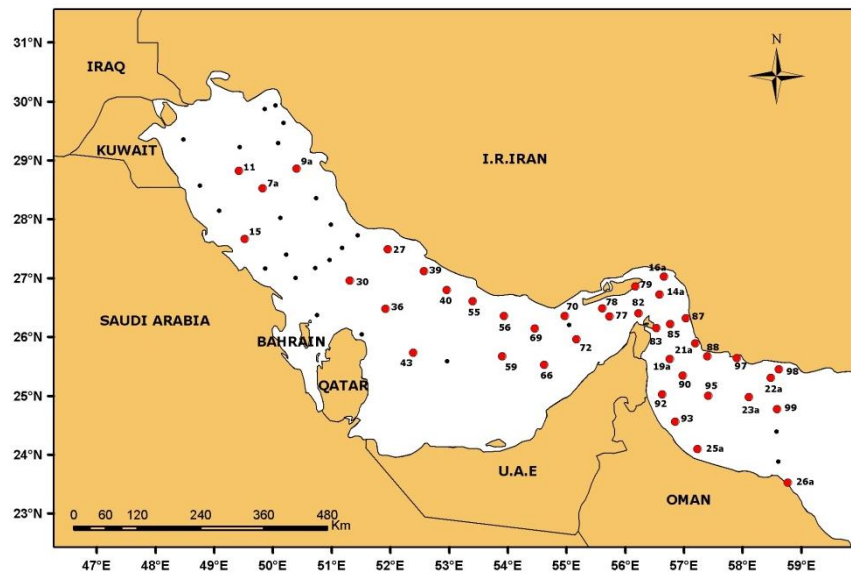
Cells length 30-45 μm .

Distribution:

Neritic, warm-water species, from subtropical to tropical areas.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was frequently observed at various sites (refer sites map), often in large numbers; maximum abundance (8.1×10^3 cells/l) was associated with the Iranian coast in the Sea of Oman (St. 88). It has been previously reported from the inner RSA (Simonsen, 1974).



Sites of occurrence of *Eucampia cornuta* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Biddulphiineae

Family: Hemiaulaceae Heiberg

Genus: *Eucampia* Ehrenberg

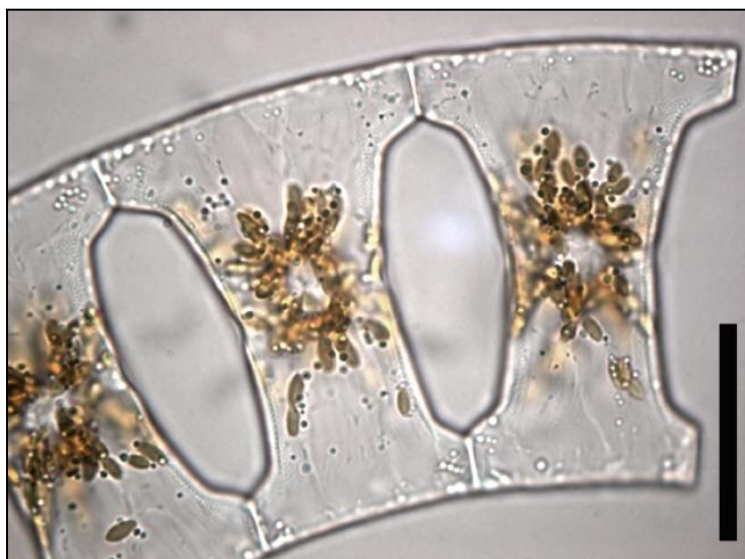
Species: *zodiacus*

Scientific name: *Eucampia zodiacus* Ehrenberg

Plate A33: a-e (Annex A)

References:

Pavillard, 1925: p. 53, Fig. 89; Hustedt, 1930: p. 773, Fig. 451; Allen and Cupp, 1935: p. 142, Fig. 74; Cupp, 1943: p. 145, Fig. 103; Crosby and Wood, 1958: p. 511, Pl. 36: 28; Hendey, 1964: p. 107, Pl. VII: 1; Simonsen, 1974: p. 34; Ricard, 1987: p. 189, Figs. 342, 343; Throndsen *et al.*, 2007: p. 178.



Description:

Cells flattened, elliptical-linear in valve view, united in chains by two blunt processes. Chains spirally curved, with relatively narrow lanceolate or elliptical apertures. Apertures variable in size and shape. Length of cell along apical axis 10-61 μm . Valves distinctly sculptured, with puncta in more or less regular radial rows running outward from center toward processes, 16-20 puncta in 10 μm . Sculpturing on intercalary bands visible only under high magnification, 28-33 rows of puncta in 10 μm . Chromatophores small and numerous. Minute, highly refractive, colorless granules present in ends of processes (Cupp, 1943).

Dimensions:

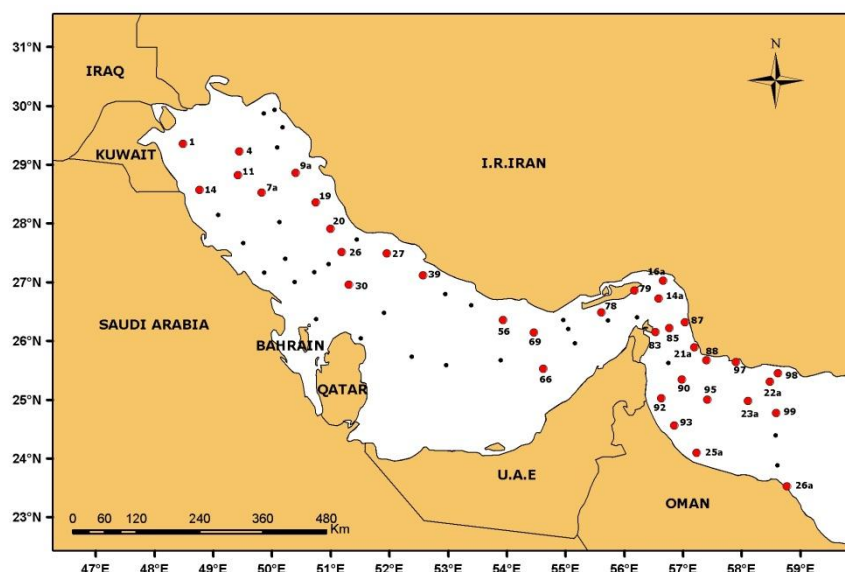
Cells length 40-65 μm .

Distribution:

Neritic, south temperate species; very widely distributed.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was frequently observed at various sites (refer sites map), often in large numbers; maximum abundance (3.5×10^4 cells/l) was associated with the Sea of Oman (St. 93). It has been previously reported from the inner RSA (Simonsen, 1974) and from Kuwaiti waters (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Eucampia zodiacus* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Biddulphiineae

Family: Hemiaulaceae Heiberg

Genus: *Hemiaulus* Ehrenberg

Cells single or united in chains. Valves elliptical in section, with two narrow, pointed, more or less long processes at the ends of the apical axis, parallel to perivalvar axis. One or more hyaline claws on the end of the processes. Intercalary bands indistinct or absent, without septa. Membrane strongly or weakly siliceous, finer or coarser areolated or punctated. Cells more or less bent; chromatophores numerous (Cupp, 1943).

In Winter 2006 Cruise, the genus *Hemiaulus* included three species (*H. membranaceus*, *H. sinensis* and *H. hauckii*). The genus contains medium-sized chain-forming diatom algae. Species of this genus were occasionally observed in the RSA phytoplankton community, however, never reached high concentration (not more 8.4×10^3 cells/l; 5.7% of total

phytoplankton abundance). Relatively high abundance of *Hemiaulus* spp. ($> 10^3$ cells/l) was associated with the northwestern part of the inner RSA; the second maximum was recorded in the Sea of Oman.

Scientific name: *Hemiaulus hauckii* Grunow

Plate A34: h (Annex A)

References:

Pavillard, 1925: p. 56, Fig. 100; Hustedt, 1930: p. 875, Fig. 518; Cupp, 1943: p. 168, Fig. 118; Crosby and Wood, 1958: p. 509, Pl. 36: 23; Hendey, 1964: p. 106; Simonsen, 1974: p. 33.

Description:

Cells long, straight or twisted, often forming chains more or less turned about the long axis. In broad girdle view oblong, with long thin processes which are strongly pointed. Apical axis 12-35 μm long. Valve surface flat or slightly concave, grooves absent. Valve mantle high, no groove at junction with girdle band. Apertures between cells large because of long processes. Cell wall weakly siliceous, often without visible sculpturing; puncta when visible, 16-17 in 10 μm on valves (Cupp, 1943).



Dimensions:

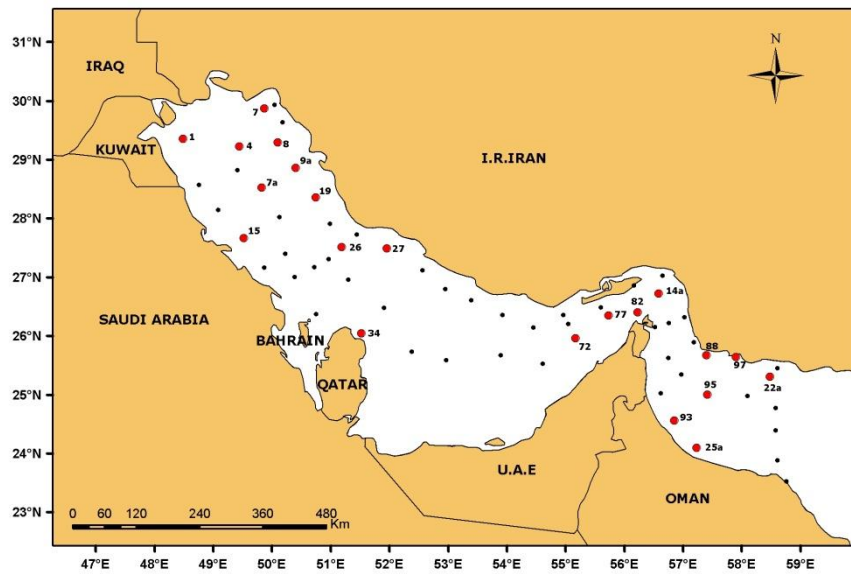
Cells length 30-42 μm ; width 15-19 μm .

Distribution:

Oceanic or neritic; temperate and tropical species. It has been previously reported from the Indian Ocean (Simonsen, 1974).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred occasionally at various sites (refer sites map), usually in small numbers; maximum abundance (2.8×10^3 cells/l) was associated with Kuwaiti waters in the northwestern part of the inner RSA (St. 1).



Sites of occurrence of *Hemiaulus hauckii* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Biddulphiineae

Family: Hemiaulaceae Heiberg

Genus: *Hemiaulus* Ehrenberg

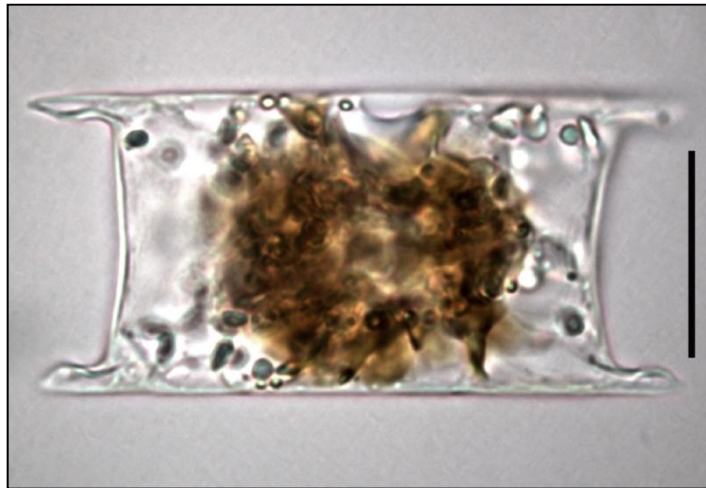
Species: *membranaceus*

Scientific name: *Hemiaulus membranaceus* Cleve

Plate A34: f, g (Annex A)

References:

Allen and Cupp, 1935: p. 150, Fig. 90; Cupp, 1943: p. 170, Fig. 120; Crosby and Wood, 1958: p. 510, Pl. 36: 25; Simonsen, 1974: p. 33; Ricard, 1987: p. 187, Fig. 330.



Description:

Cells in girdle view from almost square to five or six times wider (length along apical axis) than long (length along pervalvar axis). Valves concave or nearly flat between processes. Processes short, with a more or less sharp point; united in chains by processes. Apertures narrow, linear to elliptical, or even broadly elliptical. Cell wall weakly siliceous. Punctuation on valves very fine, difficult to see. Length of apical axis 30-97 μm (Cupp, 1943).

Dimensions:

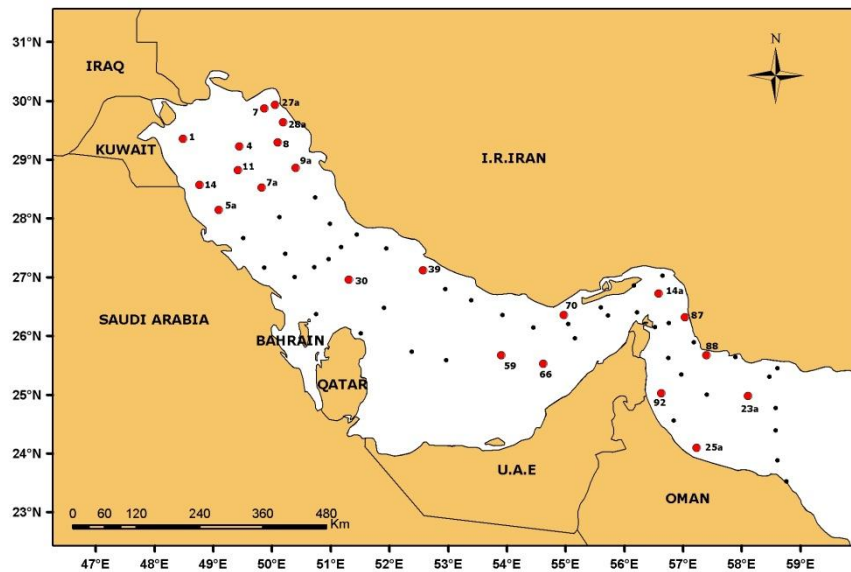
Cells length 45-60 μm ; width 25-32 μm .

Distribution:

Tropical oceanic species; reported in eastern Pacific only from near equator (lat. 3°150 S.) (Cupp, 1943).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred occasionally at various sites (refer sites map), usually in small numbers; however, it was quite abundant at some localities; maximum abundance (3.9×10^3 cells/l) was associated with the Sea of Oman (St. 88). species have been previously reported from the inner RSA (Simonsen, 1974) and from Kuwaiti waters (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Hemiaulus membranaceus* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Biddulphiineae

Family: Hemiaulaceae Heiberg

Genus: *Hemiaulus* Ehrenberg

Species: *sinensis*

Scientific name: *Hemiaulus sinensis* Greville

Plate A34: a-e (Annex A)

References:

Pavillard, 1925: p. 57, Fig. 101; Hustedt, 1930: p. 876, Fig. 519; Allen and Cupp, 1935: p. 149, Fig. 88; Cupp, 1943: p. 169, Fig. 119; Crosby and Wood, 1958: p. 509, Pl. 36: 24; Hendey, 1970: p. 119; Simonsen, 1974: p. 33; Ricard, 1987: p. 187, Figs. 326-329.

Description:

Cells broadly elliptical in valve view. Chains straight or curved, more or less long. Pervalvar axis more or less elongated. Apical axis 15-36 μm long. Valves with slightly convex surface of elliptical outline. Valve mantle high, no groove at base. Processes on valves thin, but strong, with a strong claw on the ends. Cell wall more strongly siliceous than in *H. hauckii*, areolated-punctated. Areolae in radial, on the mantle surface pervalvar, rows of characteristic excentric arrangement, in that the center of the areolation does not coincide with the center of the valve, but lies on one of the mantle surfaces. Areolae in the center of the valve 7-9 in 10 μm , on the base of the mantle 11-13 in 10 μm . Intercalary bands visible with special preparation. Very fine punctation present on bands in rows, 28-29 rows in 10 μm (Cupp, 1943).

**Dimensions:**

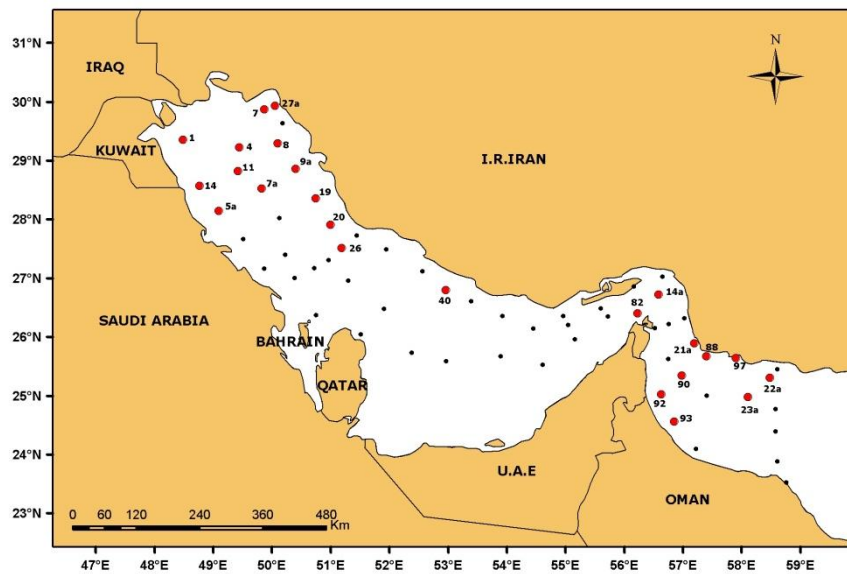
Cells length 38-55 μm ; width 17-21 μm .

Distribution:

Neritic, south temperate or subtropical species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred occasionally at various sites (refer sites map), usually in small numbers, however, it was quite abundant at some localities; maximum abundance (8.2×10^3 cells/l) was associated with Kuwaiti waters in the northwestern part of the inner RSA (St. 1, 14). It has been previously reported from the inner RSA (Simonsen, 1974) and from Kuwaiti shore (Hendey, 1970) and coastal waters (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Hemiaulus sinensis* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Biddulphiineae

Family: Cymatosiraceae Hasle

Genus: *Cymatosira* Grunow

Cells small, usually united in small packets valve to valve, by means of a system of spines. Frustules linear in girdle view, inflated in the middle and at the ends. Valves linear, inflated in the middle. Valve surface punctate. Raphe absent, pseudoraphe absent or much obscured (Hendey, 1964).

Scientific name: *Cymatosira* cf. *lorenziana* Grunow

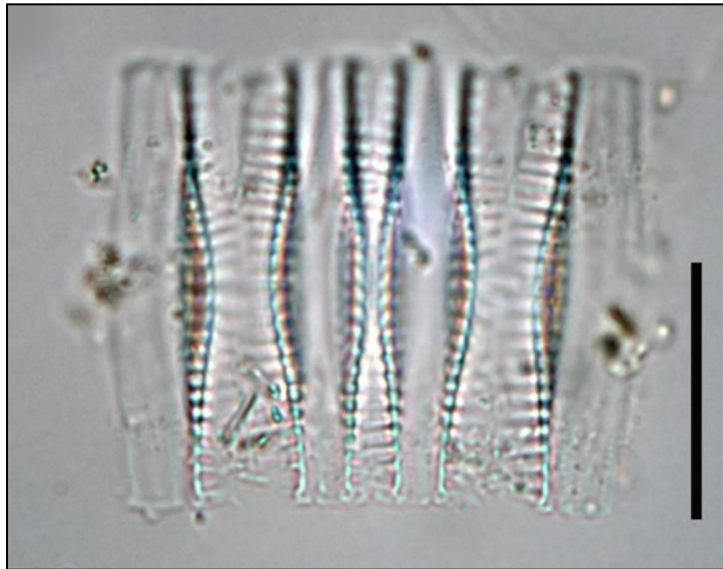
Plate A34: i, j (Annex A)

References:

Hendey, 1970: p. 125, Pl. 6: 69; Ricard, 1987: p. 195, Figs. 379-381; Throndsen *et al.*, 2007: p. 180; Witkowski *et al.*, 2000: p. 27, Pl. 11: 12-15.

Description:

Frustules in girdle view rectangular with acutely rounded corners slightly incised beneath apices. Valves rhombic-lanceolate with protracted, acutely rounded apices, 15-27 μm long, 7-10 μm broad; transapical striae composed of puncta, 8-12 in 10 μm , sternum (pseudoraphe), absent (Witkowski *et al.*, 2000).

**Dimensions:**

Cells length 26-32.

Taxonomic Remarks:

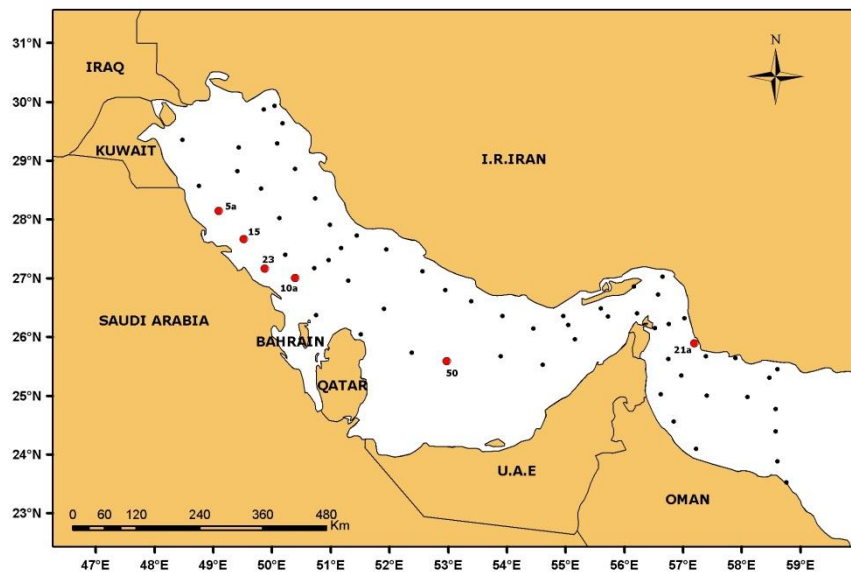
This species was rare and has been examined only in girdle view; valve structure was not determined. Cells were similar in morphology and size to *C. lorenziana* in girdle view.

Distribution:

Marine littoral species, occasionally found in plankton.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at few sites (refer sites map), usually in small numbers; maximum abundance (3.5×10^3 cells/l) was associated with the northwestern part of the inner RSA off Saudi Arabia (St. 15). It has been previously reported from Kuwaiti shore (Hendey, 1970).



Sites of occurrence of *Cymatosira cf. lorenziana* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Biddulphiineae

Family: Chaetocerotaceae Ralfs in Pritchard

Genus: *Bacteriastrum* Shadbolt

Cells cylindrical in cross section, circular. Bound into loose chains by the fusion of more or less numerous setae that are regularly arranged around the margin of the cells. Setae of two adjacent cells are fused for a certain distance beyond the base, farther out divided again. Terminal setae different from others, often curved are not fused, and therefore, not bifurcating. Intercalary bands, absent as a rule. Apertures, between cells of varying widths. Cell wall delicate and hyaline, without clearly visible structure. Chromatophores are numerous, small, roundish, more or less lobed. Resting spores near middle of cell with small spines on one valve. All species are marine, pelagic (Cupp, 1943).

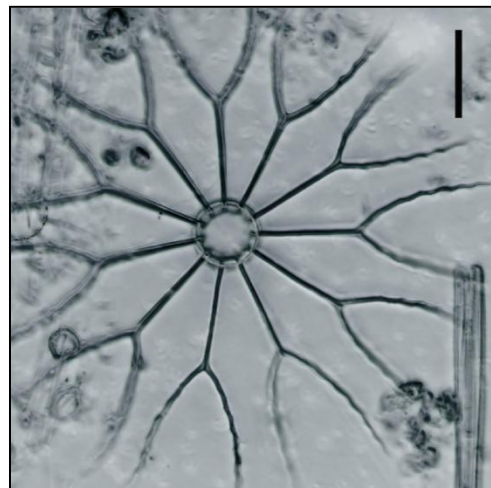
In Winter 2006 Cruise, the genus *Bacteriastrum* is morphologically close to *Chaetoceros*, which is the small-sized chain-forming diatoms. Three species of this genus (*B. delicatulum*, *B. furcatum* and *B. hyalinum*) were encountered and were important contributors to the total abundance of centric diatoms and phytoplankton as a whole at several stations, comprising up to 86% of the total phytoplankton abundance; the highest concentration reached 7.9×10^5 cells/l. High abundance of *Bacteriastrum* spp. ($> 10^5$ cells/l) was recorded off the Iranian coast in the Sea of Oman and in the Strait of Hormuz.

Scientific name: *Bacteriastrum delicatulum* Cleve

Plate A35: a-e (Annex A)

References:

Pavillard, 1925: p. 37, Fig. 57; Hustedt, 1930: p. 613, Fig. 353; Allen and Cupp, 1935: p. 131, Fig. 46; Cupp, 1943: p. 97, Fig. 55; Crosby and Wood, 1958: p. 519, Pl. 38: 61; Hendey, 1964: p. 139, Pl. VI: 2; Ricard, 1987: p. 217, Figs. 535, 536.



Description:

Cells cylindrical, 6-15 μm in diameter. Chains long, straight. Setae 6-12, with strong, long basal part. Apertures usually relatively large. The bifurcation plane of inner setae lies in the valvar plane, transverse to chain axis. Forked parts are slightly curved, smooth or somewhat wavy. Terminal setae of both ends are directed toward the inside of the chain, and in front view of the valve, similarly curved. Stronger than inner setae and with fine spines, arranged spirally. Chromatophores are small, numerous and distributed along cell wall (Cupp, 1943).

Dimensions:

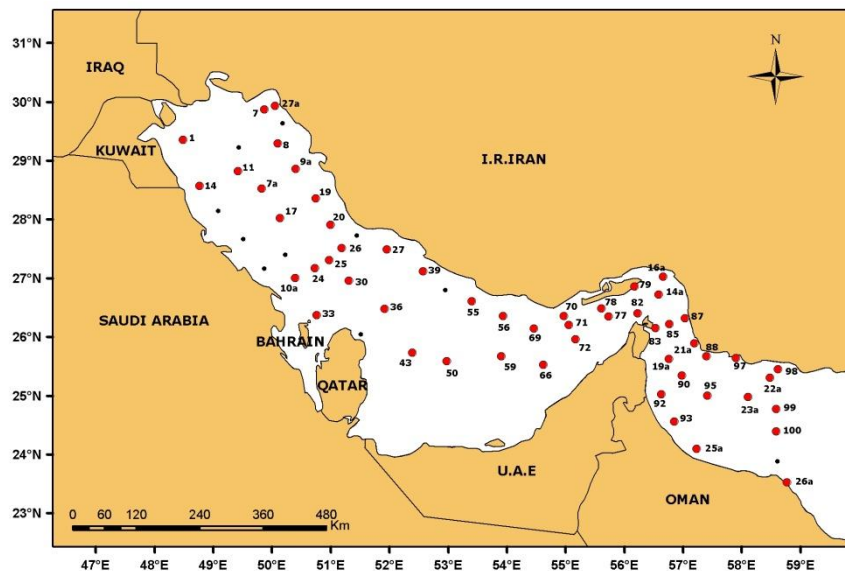
Cells diameter 12-15 μm .

Distribution:

Oceanic, temperate species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was frequently observed at various sites (refer sites map), sometimes in very large numbers; maximum abundance (1.8×10^5 cells/l) was associated with the Iranian coast in the Sea of Oman (St. 88). It has been previously reported from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Bacteriastrium delicatulum* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Biddulphiineae

Family: Chaetocerotaceae Ralfs in Pritchard

Genus: *Bacteriastrium* Shadbolt

Species: *hyalinum*

Scientific name: *Bacteriastrium hyalinum* Lauder

Plate A36: c-e (Annex A)

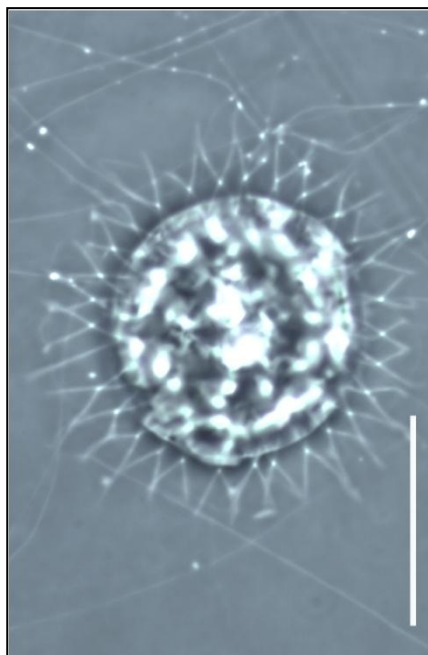
References:

Pavillard, 1925: p. 37, Fig. 58; Hustedt, 1930: p. 614, Fig. 354; Allen and Cupp, 1935: p. 131, Fig. 47; Cupp, 1943: p. 97, Fig. 56 A; Hendey, 1964: p. 139, Pl. VI: 1; Ricard, 1987: p. 217, Fig. 537; Throndsen *et al.*, 2007: p. 163.

Description:

Cells cylindrical, 14-28 µm in diameter. Pervalvar axis often shorter than diameter. Chains long, straight or slightly curved. Apertures narrow, but distinct. Inner setae 12-25 on each valve, with short basal part. Bifurcations in peralvar axis (parallel to chain axis)

giving cells a hairy appearance. Forked parts are slightly curved and usually weakly twisted. Terminal setae differ little from those of *B. delicatulum*, umbrella-shaped, stronger than inner setae, and with spirally arranged tiny spines as in previous species. Chromatophores small and numerous. Resting spores in pairs in adjacent cells, one in each cell. With high arched valves, the primary valve is slightly contracted above the base, with fine spines when fully formed, smooth in process of formation. Secondary valve is similarly rounded and smooth (Cupp, 1943).

**Dimensions:**

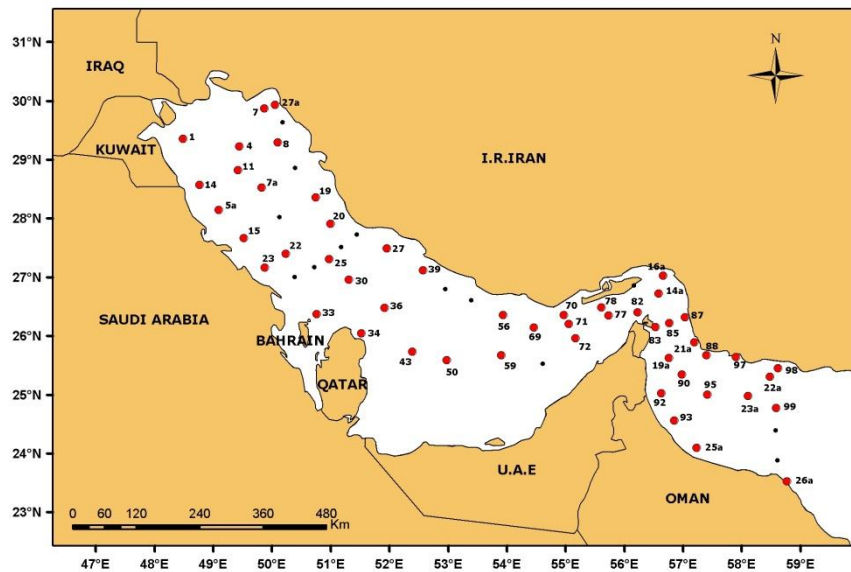
Cells diameter 22-26 µm.

Distribution:

Neritic species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was frequently observed at various sites (refer sites map), often in large numbers; maximum abundance (4.7×10^4 cells/l) was associated with the Strait of Hormuz (St. 16a). It has been previously reported from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Bacteriastrum hyalinum* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Biddulphiineae

Family: Chaetocerotaceae Ralfs in Pritchard

Genus: *Bacteriastrum* Shadbolt

Species: *hyalinum*

Variety: *princeps*

Scientific name: *Bacteriastrum hyalinum* Lauder var. *princeps* (Castracane) Ikari

Plate A36: a, b (Annex A)

References:

Cupp, 1943: p. 98, Fig. 56 B.

Description:

Differs from the type in the spirally twisted bifurcations on the inner setae (Cupp, 1943).

Dimensions:

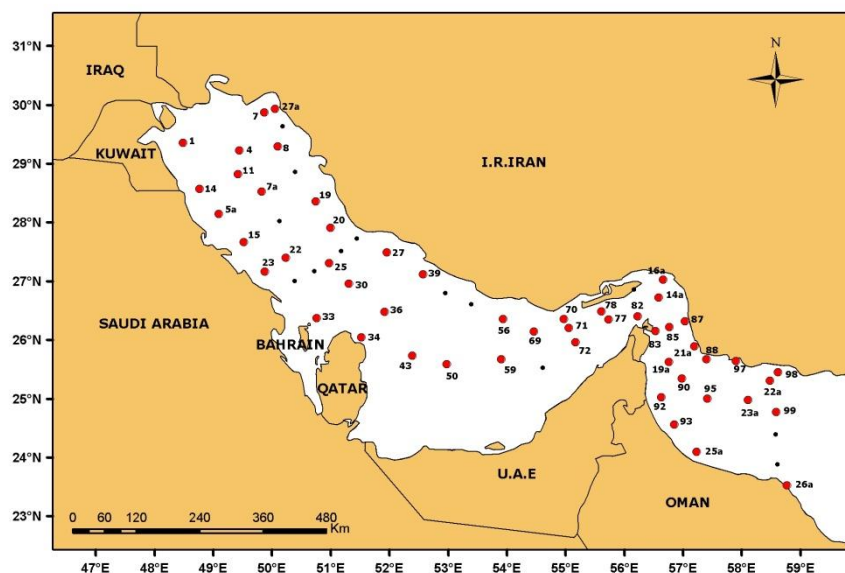
Cells diameter 25-30 μm .

Distribution:

Neritic warm water species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at various sites in small numbers (refer sites map).



Sites of occurrence of : *Bacteriastrium hyalinum* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Biddulphiineae

Family: Chaetocerotaceae Ralfs in Pritchard

Genus: *Bacteriastrium* Shadbolt

Species: *furcatum*

Scientific name: *Bacteriastrium furcatum* Shadbolt

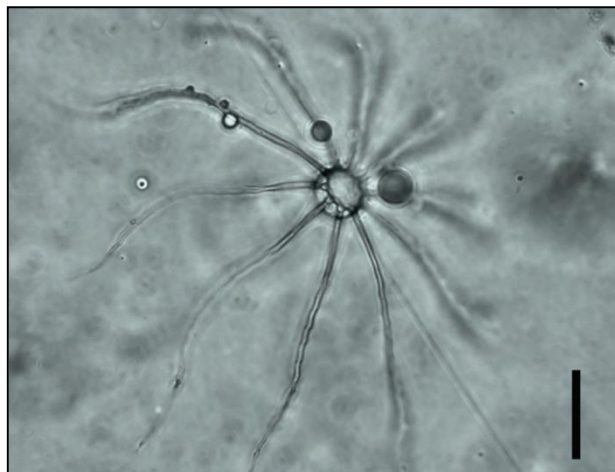
Plate A36: f-j (Annex A)

Synonym:

Bacteriastrium varians Lauder

References:

Allen and Cupp, 1935: p. 132, Fig. 48 (as *Bacteriastrium varians*); Crosby and Wood, 1958: p. 519, Pl. 38: 60 (as *Bacteriastrium varians*); Hendey, 1970: p. 121 (as *Bacteriastrium varians*); Ricard, 1987: p. 217, Figs. 538, 539 (as *Bacteriastrium varians*); Hasle and Syvertsen, 1997: p. 186, Pl. 37.



Description:

Cells of nearly equal width and length. Setae 10 to 25, at right angles to chain axis; basal part usually shorter than in *B. delicatulum*. Apertures small; terminal setae with fine spines arranged in spiral rows. Diameter 30-36 μm (Allen and Cupp, 1935). Terminal setae first transverse to chain axis, then abruptly obliquely curved toward the chain in their outer part (Hasle and Syvertsen, 1997).

Dimensions:

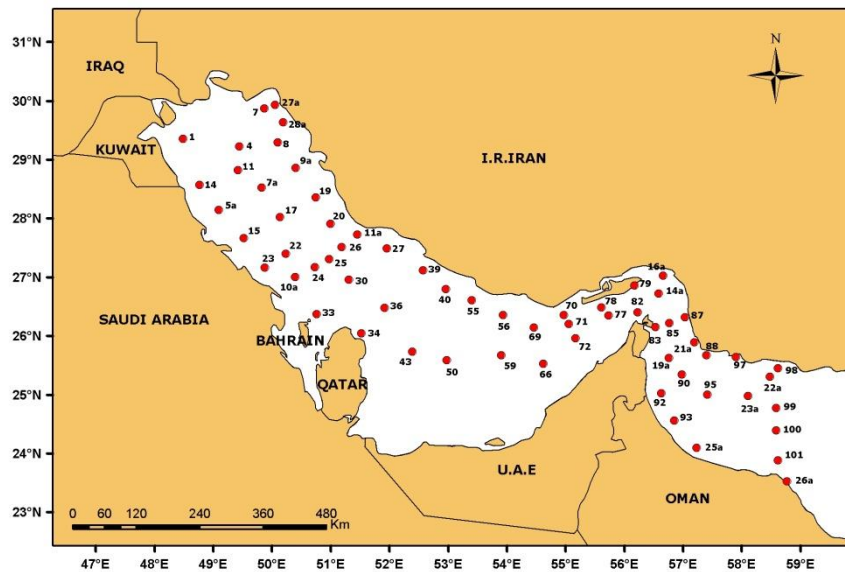
Cells diameter 12-14 μm .

Distribution:

Neritic species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at various sites (refer sites map), it was quite abundant at some localities; maximum abundance (7.8×10^5 cells/l) was associated with the Strait of Hormuz (St. 14a). It has been previously reported from Kuwaiti shore (Hendey, 1970).



Sites of occurrence of *Bacteriastrium furcatum* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Biddulphiineae

Family: Chaetocerotaceae Ralfs in Pritchard

Genus: *Chaetoceros* Ehrenberg

Cells with oval section to almost or rarely completely circular in valve view; in broad girdle view, quadrangular with straight sides and concave, flat, or slightly convex ends. Valve with a more or less flat end surface or valve surface and a cylindrical part or valve mantle which are bound together without a seam. A long thick or thin seta, bristle or awn, at each end of the long or apical axis of the valve on the corners. The opposite setae of neighboring cells touch one another near their origin, usually directly or sometimes by a bridge, and fuse firmly at a point near their base holding the cells in chains, usually with large or small apertures or foramina between the cells. Basal portion of the setae is parallel to the perivalvar axis or directed diagonally outward with the outer portion, frequently perpendicular to the axis of the chain. In most species, the length of the chain is limited with the formation of special end cells; terminal setae, usually shorter and thicker and more nearly parallel to the chain axis

than the others. In relatively few species are cells solitary. Cell wall is formed of two valves and one or two girdle bands. Two frequently unequally developed girdle bands are always present in most species. Intercalary bands, present in some species, usually difficult to see without special preparations. Cytoplasm (protoplast) either forms a thin layer along the cell wall or fills the greater part of the cell. Nucleus against the cell wall or central. Chromatophores vary greatly in number, size, form, and position in different species; may be one to several, small or large, but are constant for a given species, and consequently, indispensable for species demarcation. In many species, pyrenoids are distinctly visible. Resting spores are formed in most neritic species. Only one spore is formed in a vegetative cell, usually in cylindrical part near the girdle band of the mother cell, in some species near the cell end. Free ends of spores are often armed with spines or spicules. Each spore is with two valves, but only primary valve is provided with a valve mantle. Younger resting spores, often smooth. If spore lies near end of cell, one valve may be in common with that of mother cell, with valve mantle rudimentary and setae, shorter and thicker than in vegetative cells. Such spores are always in pairs; formed in adjacent cells, simultaneously. Auxospores, known in only a few species. Contents of cell are empty laterally, and form a large globule or bladder within which the new daughter cell is formed. Microspores known in several species; formed by repeated divisions of nucleus and cytoplasm. Contain organized chromatophores. Locomotion observed in some species. Great variations may be observed in chains of the same species from different localities and at different times of the year. The genus *Chaetoceros* includes the greatest number of species of the truly planktonic diatoms, and is by far the most important one in abundance of species and number of cells in the temperate and subtropical waters. A small number of species are oceanic, but the greater number is neritic (Cupp, 1943).

Harmful Effect:

Large concentrations of *Chaetoceros* spp. may clog the gills of farmed fish, and also cause bleeding (Tangen, 1987; Hallegraeff, 1993). This effect had been observed on lingcod by *C. convolutus* already in 1961, and the hypothesis was that, the spiny *Chaetoceros* setae actually penetrated the gill tissue (Bell, 1961). Laboratory bioassays with Atlantic salmon and environmentally common (as well as greater) concentrations of *C. concavicornis* documented a physical action of the diatom on the fish gills. The gills started to produce mucus that induced hypoxia (or deficiency of oxygen to the tissues of the body) and hypercapnia (or excessive amount of carbon dioxide to the blood) (Rensel, 1993).

In Winter 2006 Cruise, among the centric diatoms, the *Chaetoceros* genus was the most abundant and diverse; it included small-sized chain-forming species. Species of the genus *Chaetoceros* were the main contributors to the total abundance of centric diatoms and phytoplankton as a whole, contributing up to 94 % of total phytoplankton abundance; the highest concentration reached 1.7×10^6 cells/l. Blooms of *Chaetoceros* ($> 10^6$ cells/l) were associated with the Sea of Oman, the Strait of Hormuz waters and the adjacent zones.

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Biddulphiineae

Family: Chaetocerotaceae Ralfs in Pritchard

Genus: *Chaetoceros* Ehrenberg

Species: *brevis*

Scientific name: *Chaetoceros brevis* Schütt

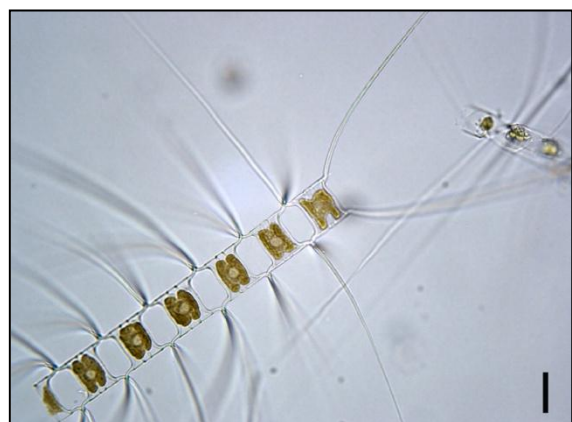
Plate A37: a-d (Annex A)

Synonyms:

Chaetoceros hiemale Cleve; *Chaetoceros pseudobreve* Pavillard

References:

Hustedt, 1930: p. 706, Fig. 403 a, b; Allen and Cupp, 1935: p. 140, Fig. 70; Cupp, 1943: p. 129, Fig. 82; Hendey, 1964: p. 127, Pl. IX: 5; Ricard, 1987: p. 205, 213, Figs. 465, 516; Throndsen *et al.*, 2007: p. 171.



Description:

Closely related to *C. laciniosus*, but, as in *C. pelagicus*, only one chromatophore per cell, pressed against one valve. Setae almost straight, not so far from apical plane. Terminal setae diverging in broad girdle view at angle of about 90° or more. Cells 8-17 µm broad. Resting spores similar to those of *C. laciniosus*, with dissimilarly arched valves, smooth or with fine spicules. Positive identification difficult (Cupp, 1943).

Dimensions:

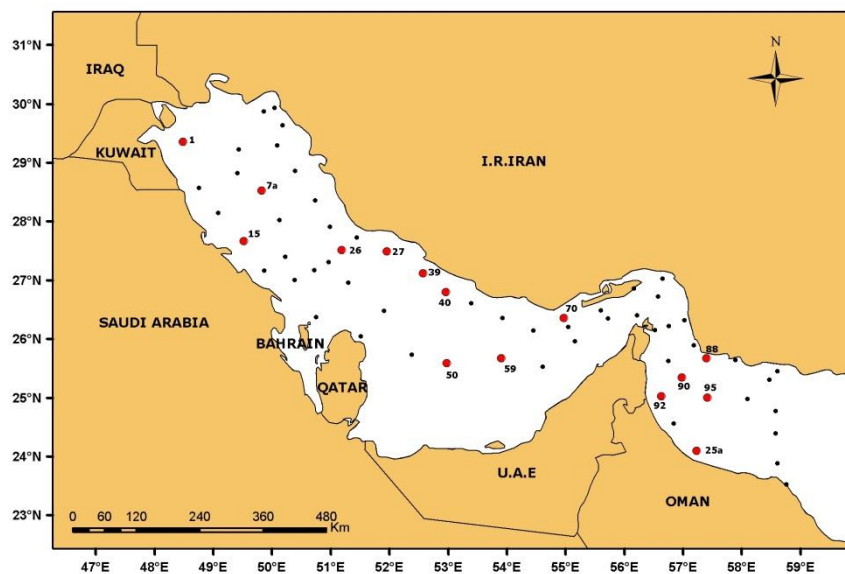
Apical axis 20-22 µm; perivalvar axis 12-16 µm.

Distribution:

Neritic, warm-water species; south temperate to subtropical waters.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at various sites (refer sites map), usually in small numbers; however, it was quite abundant at some localities; maximum abundance (5.1×10^4 cells/l) was associated with the Iranian coast in the central part of the inner RSA (St. 27).



Sites of occurrence of *Chaetoceros brevis* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Biddulphiineae

Family: Chaetocerotaceae Ralfs in Pritchard

Genus: *Chaetoceros* Ehrenberg

Species: *coarctatus*

Scientific name: *Chaetoceros coarctatus* Lauder

Plate A38: a-c (Annex A)

Synonym:

Chaetoceros rudis Cleve

References:

Hustedt, 1930: p. 656, Fig. 370; Allen and Cupp, 1935: p. 134, Fig. 52; Cupp, 1943: p. 107, Fig. 62; Crosby and Wood, 1958: p. 514, Pl. 37: 38; Hendey, 1964: p. 121, Pl. XII: 1; Simonsen, 1974: p. 30.

Description:

Cells cylindrical, elliptical in valve view. Chains long, robust in appearance, with two ends markedly different, 30-44 μm wide; apertures very small. Valve surface flat, with rather high mantle, one-third to two-thirds of the apical axis. More or less deep, but always distinct constriction at suture between mantle and girdle band; posterior terminal setae large, strongly curved, heavily spined, shorter than others; anterior terminal setae less robust, curved toward posterior end, spined less heavily; setae in center of chain curved like anterior terminal setae, spined; setae with rows of fine puncta running lengthwise visible usually only on posterior terminal setae where they occur in double rows. Usually found with a species of *Vorticella* (probably *Vorticella oceanica*) attached, sometimes in large numbers (Cupp, 1943).



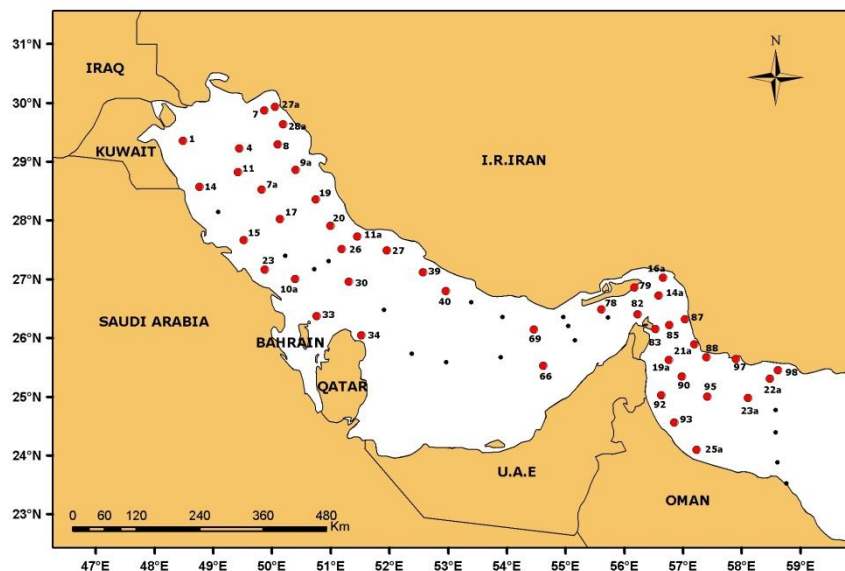
Dimensions:

Apical axis 28-33 μm ; perivalvar axis 32-35 μm .

Distribution: Oceanic, tropical or subtropical species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was frequently observed at various sites (refer sites map), often in large numbers; maximum abundance (2.7×10^3 cells/l) was associated with the Strait of Hormuz (St. 16a). It has been previously reported from the inner RSA (Simonsen, 1974) and from Kuwaiti waters (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Chaetoceros coarctatus* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Biddulphiineae

Family: Chaetocerotaceae Ralfs in Pritchard

Genus: *Chaetoceros* Ehrenberg

Species: *compressus*

Scientific name: *Chaetoceros compressus* Lauder

Plate A39: a-g (Annex A)

References:

Pavillard, 1925: p. 45, Fig. 72; Hustedt, 1930: p. 685, 686, Fig. 388, 389; Allen and Cupp, 1935: p. 137, Fig. 60; Cupp, 1943: p. 119, Fig. 74; Crosby and Wood, 1958: p. 514, Pl. 37: 39; Hendey, 1964: p. 73, Pl. XVI: 5; Simonsen, 1974: p. 30; Ricard, 1987: p. 203, 211, Figs. 456, 506-509.

Description:

Cells 7-24 μm wide, four-cornered in broad girdle view, with rounded corners not touching those of adjacent cells; valves slightly convex, or flat. Chains straight, with cells more or less twisted about the axis of the chain. Apertures



four- or six-sided, slightly curved in the middle, more or less wide, sometimes only a slit. Setae arising within the margin of the valve, basal part always distinct, outer part perpendicular to chain axis, and then bent. Setae delicate except for some pairs often differentiated, usually near center of chain; these setae are shorter than the others, thickened, twisted and directed toward one end of chain, almost parallel to chain axis. Chromatophores are small, 4-20 in each cell; resting spores in the middle of mother cell or at one end, with a thick girdle band fused to it, smooth, without row of small spines on upper margin in primary valve as recorded by Gran (Cupp, 1943).

Dimensions:

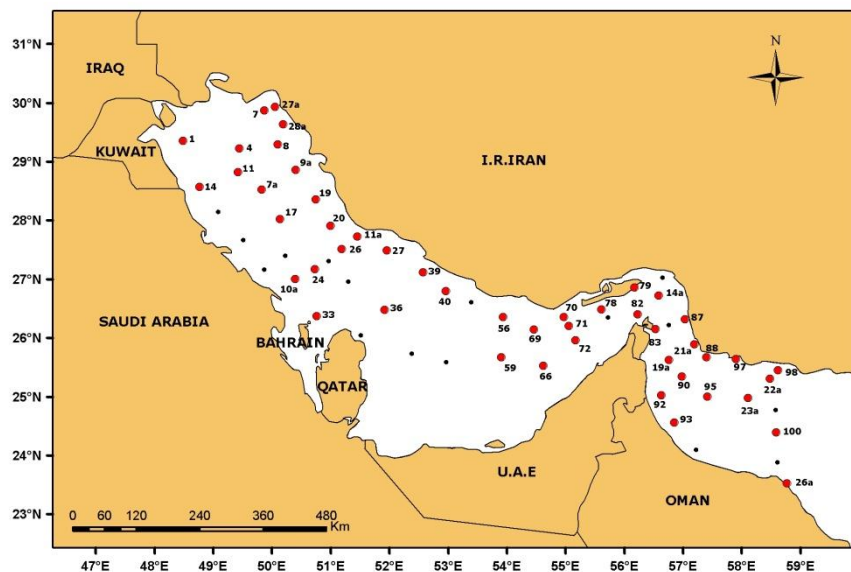
Apical axis 17-21 μm ; perivalvar axis 9-10 μm .

Distribution:

Neritic, boreal to south temperate species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was commonly observed at many sites (refer sites map), often in very large numbers. It was recorded as bloom-forming at some localities; blooms with cell concentration of more than 10^6 cells/l were associated with the Strait of Hormuz area (Stations 78 and 79). It has been previously reported from the inner RSA (Simonsen, 1974) and from Kuwaiti waters (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Chaetoceros compressus* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Biddulphiineae

Family: Chaetocerotaceae Ralfs in Pritchard

Genus: *Chaetoceros* Ehrenberg

Species: *curvisetus*

Scientific name: *Chaetoceros curvisetus* Cleve

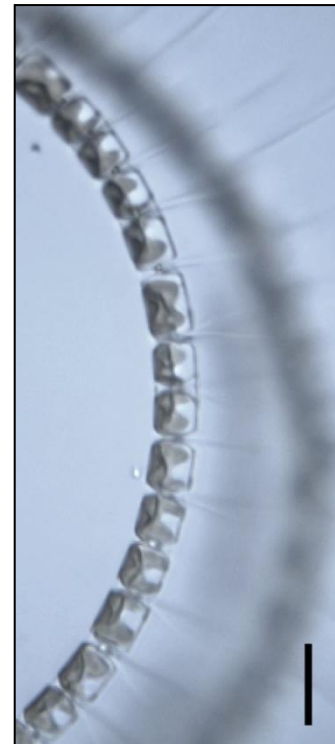
Plate A40: a-c (Annex A)

References:

Pavillard, 1925: p. 51, Fig. 82; Hustedt, 1930: p. 739, Fig. 426; Cupp, 1943: p. 138, Fig. 93; Hendey, 1964: p. 133, Pl. XVII: 6; Simonsen, 1974: p. 30; Priddle and Fryxell, 1985: p. 44-45; Ricard, 1987: p. 207, 215, Figs. 475, 476, 526, 527; Throndsen *et al.*, 2007: p. 172.

Description:

Chains spirally curved, without distinct terminal cells, 7-30 μm wide. Cells four-cornered in broad girdle view, adjacent cells connected by conspicuous corners. Valve mantle usually low, higher at corners of apical axis, very small notch at junction with girdle band. Apertures rhombic, oval, or circular. Setae arising from corners of cells, all bent toward same side of chain - toward outside of curved axis of spiral. Chromatophores one per cell with large central pyrenoid. Resting spores central, smooth, surrounded by thickened girdle of mother cell, more or less rounded valves, without spines; on margin of primary valve, a row of delicate puncta (Cupp, 1943).

**Dimensions:**

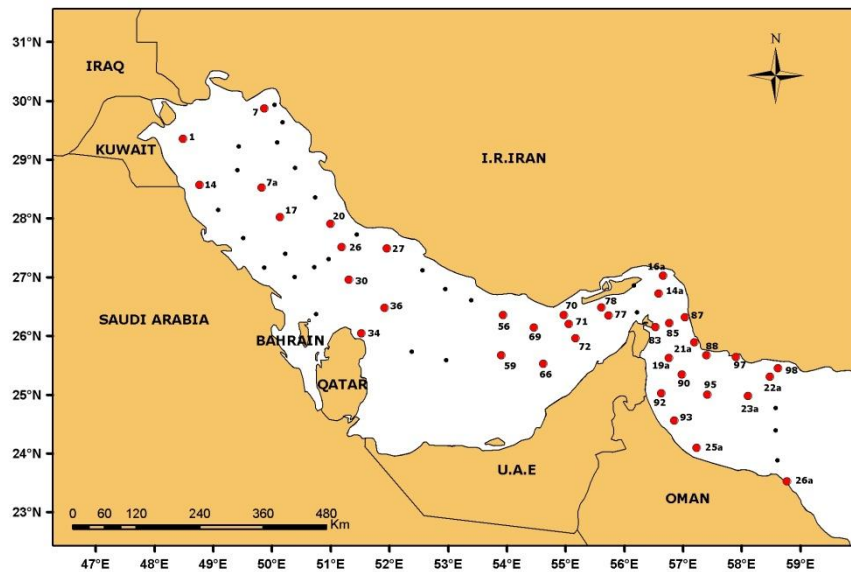
Apical axis 9-11 μm ; perivalvar axis 10-13 μm .

Distribution:

Neritic, south temperate species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was frequently observed at various sites (refer sites map), often in very large numbers. It was recorded as bloom-forming at some localities; blooms with cell concentration of more than 10^6 cells/l were associated with the Sea of Oman (Stations 88, 25a, and 92). It has been previously reported from the Indian Ocean (Simonsen, 1974) and from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Chaetoceros curvisetus* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Biddulphiineae

Family: Chaetocerotaceae Ralfs in Pritchard

Genus: *Chaetoceros* Ehrenberg

Species: *decipiens*

Scientific name: *Chaetoceros decipiens* Cleve

Plate A37: e-g (Annex A)

Synonym:

Chaetoceros grunowii Schütt

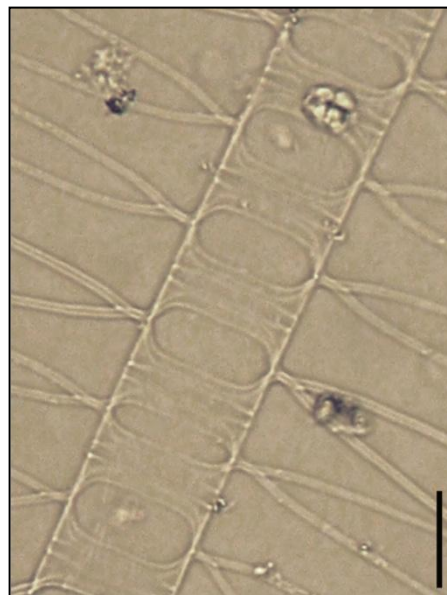
References:

Pavillard, 1925: p. 44, Fig. 70 A; Hustedt, 1930: p. 676, Fig. 383; Cupp, 1943: p. 115, Fig. 70-A, 70-B: a, b; Crosby and Wood, 1958: p. 516, Pl. 37: 44; Hendey, 1964: p. 123, Pl. XII:

2; Simonsen, 1974: p. 30; Ricard, 1987: p. 203, 209, Figs. 450, 495-499; Throndsen *et al.*, 2007: p. 169.

Description:

Cells 9-84 µm wide, four-cornered in broad girdle view, with sharp corners touching those of adjacent cell. Chains straight, stiff, more or less flattened, usually many-celled. Apertures varying in size and shape according to season of year: in winter small, linear to lanceolate; in summer and autumn, larger, elliptical or circular. Setae without a basal portion, arising at corners of valves perpendicular to chain axis, fusing together in pairs for some distance, the fused portion two or three times as long as diameter of setae; terminal setae shorter and thicker than others,



first directed obliquely outward, then bent, so that outer half is nearly parallel to chain axis. Setae are without special sculpturing or with very fine spines and puncta; sometimes with dots near the extremities. Occasionally so, heavily punctuated, they resemble those of *C. lorenzianus*. Chromatophores are 4-10 per cell. No resting spores known (Cupp, 1943).

Dimensions:

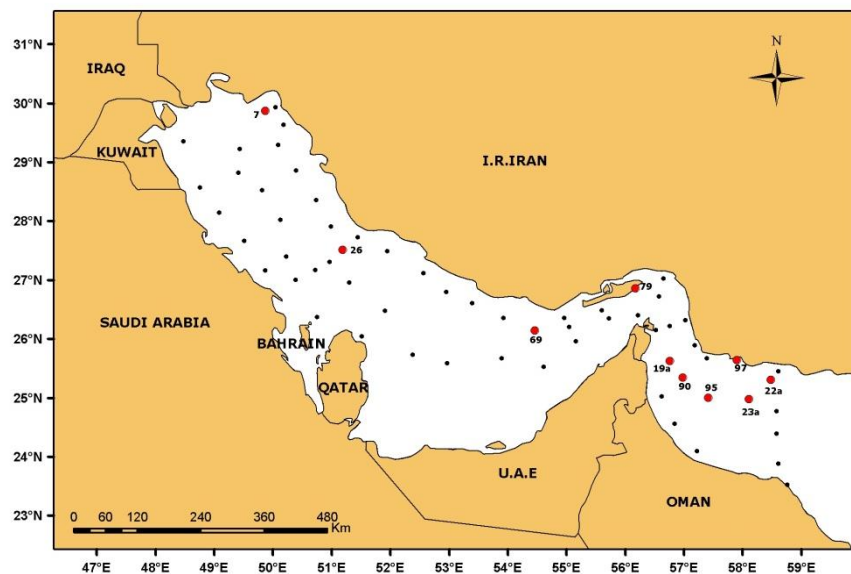
Apical axis 21-35 µm; perivalvar axis 19-21 µm.

Distribution:

Oceanic species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at few sites (refer sites map), usually in small numbers; however, it was quite abundant at some localities; maximum abundance (1.5×10^3 cells/l) was associated with the central part of the inner RSA (St. 26). It has been previously reported from the Indian Ocean (Simonsen, 1974) and from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Chaetoceros decipiens* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Biddulphiineae

Family: Chaetocerotaceae Ralfs in Pritchard

Genus: *Chaetoceros* Ehrenberg

Species: *denticulatus*

Scientific name: *Chaetoceros denticulatus* Lauder

Plate A41: a-f (Annex A)

Synonyms:

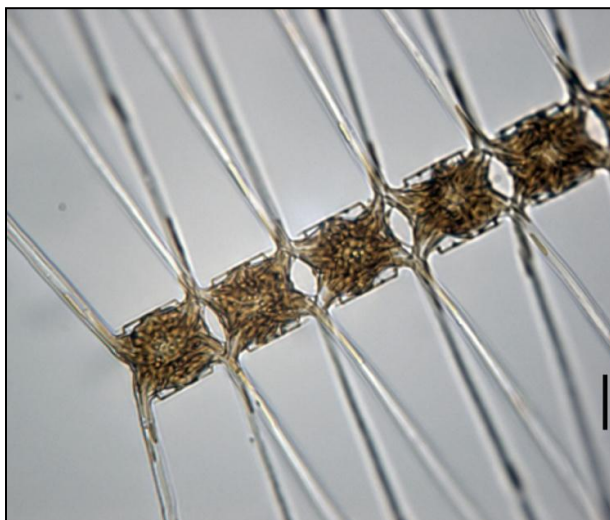
Chaetoceros denticulatus f. *angusta* Hustedt; *Chaetoceros denticulatus* f. *lata* Hustedt;
Chaetoceros nanodenticulatus Okamura.

References:

Allen and Cupp, 1935: p. 134, Fig. 53; Crosby and Wood, 1958: p. 516, Pl. 37: 45;
Simonsen, 1974: p. 31.

Description:

Cells in straight chains, ends different; apertures very small, central; setae arising close to valve center, at first almost parallel with chain axis, then with an elbow, turning at right angles, with distinct tooth on lower setae; setae with spines; chromatophores numerous. Width 25-30 μm (Crosby and Wood, 1958).



Dimensions:

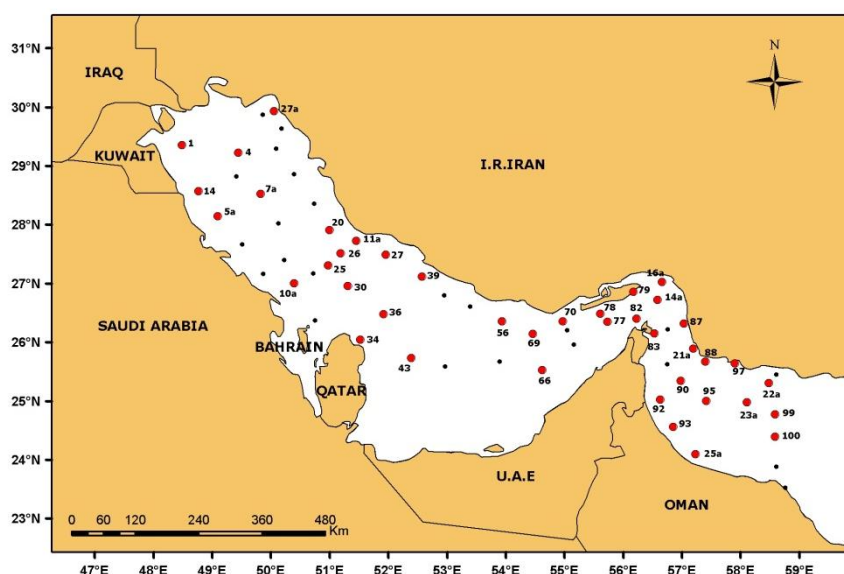
Apical axis 28-33 μm ; perivalvar axis 20-22 μm .

Distribution:

Typical species in tropical areas of the Indian Ocean with neritic preference.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was frequently observed at various sites (refer sites map), often in large numbers; maximum abundance (3.8×10^3 cells/l) was associated with the Iranian coast in the central part of the inner RSA (St. 27). Species has been previously reported from the inner RSA (Simonsen, 1974) and from Kuwaiti waters (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Chaetoceros denticulatus* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Biddulphiineae

Family: Chaetocerotaceae Ralfs in Pritchard

Genus: *Chaetoceros* Ehrenberg

Species: *diversus*

Scientific name: *Chaetoceros diversus* Cleve

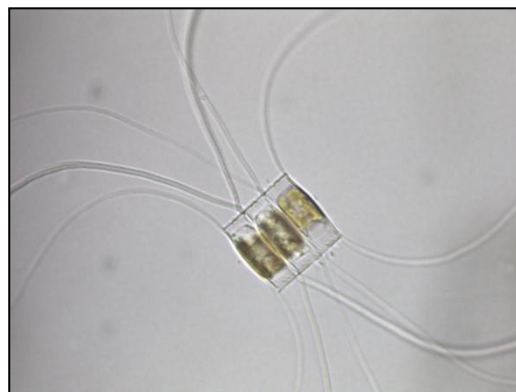
Plate A43: e-h (Annex A)

References:

Hustedt, 1930: p. 717, Fig. 409; Allen and Cupp, 1935: p. 141, Fig. 71; Cupp, 1943: p. 132, Fig. 87; Simonsen, 1974: p. 31.

Description:

Chains straight, not twisted, usually short; cells with elliptical valve surface and apical axis, usually 8-12 μm long; valves flat or slightly raised in the center, with high valve mantle, with small, but distinct notch at junction with girdle; girdle-band zone small in resting cells; setae arising from the corners of the cell, without basal part. Apertures very narrow, slitlike; setae within chains of two kinds: (1) thin setae more or less curved, often straight, and usually slightly turned toward the chain ends; and (2) heavy setae, almost club-shaped increasing in thickness from the base out, then becoming thinner again near the ends. The first two-thirds of setae is almost straight and at a sharp angle from the chain axis, then turning gradually and at obtuse angle toward one or the other end of the chain, and running almost parallel to the chain axis in the outer part. The thicker setae are clearly angular and beset on the corners with fine, spirally arranged little teeth. Terminal setae are always thin and differ from others in position - at first more or less U-shaped, in outer part nearly parallel to chain axis. Number of pairs of heavy setae in a chain, various and seem to conform to no rule. Chromatophores one in each cell, on girdle side. Resting spores unknown (Cupp, 1943).



Dimensions:

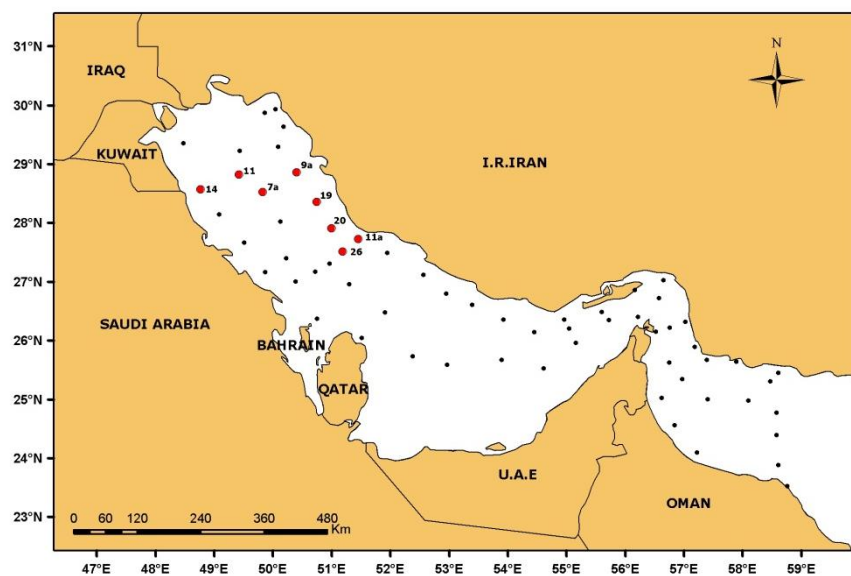
Apical axis 11-14 µm; perivalvar axis 9-12 µm.

Distribution:

Neritic, tropical and subtropical species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at few sites in inner RSA (refer sites map), usually in small numbers; however, it was quite abundant at some localities; maximum abundance (1.5×10^3 cells/l) was associated with the northwestern part of the inner RSA (St. 7a). It has been previously reported from the inner RSA (Simonsen, 1974) and from Kuwaiti waters (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Chaetoceros diversus* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Biddulphiineae

Family: Chaetocerotaceae Ralfs in Pritchard

Genus: *Chaetoceros* Ehrenberg

Species: *eibonii*

Scientific name: *Chaetoceros eibonii* Grunow

Plate A38: d-f (Annex A)

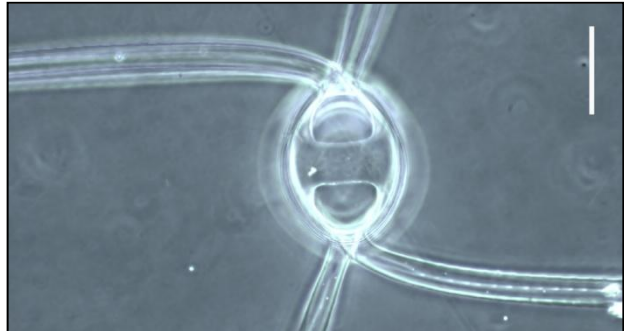
References:

Cupp, 1943: p. 106, Fig. 61; Hendey, 1964: p. 121, Pl. XVII: 5.

Description:

Cells cylindrical, broadly elliptical in valve view; chains straight, not twisted,

25-50 μm broad. Apertures rather flat, hexagonal. Valve surface flat; mantle moderately low, one-third the length of cell or less with shallow constriction at suture with girdle. Valves with minute, hardly visible spine in center; setae arising from near corner of cell, crossing each other very near bases, curved outward from apical plane, half of them nearly parallel to transapical axis. Setae armed with minute spines, farther out with fine striations, 20-22 in 10 μm , hexagonal in cross section (Cupp, 1943).



Dimensions:

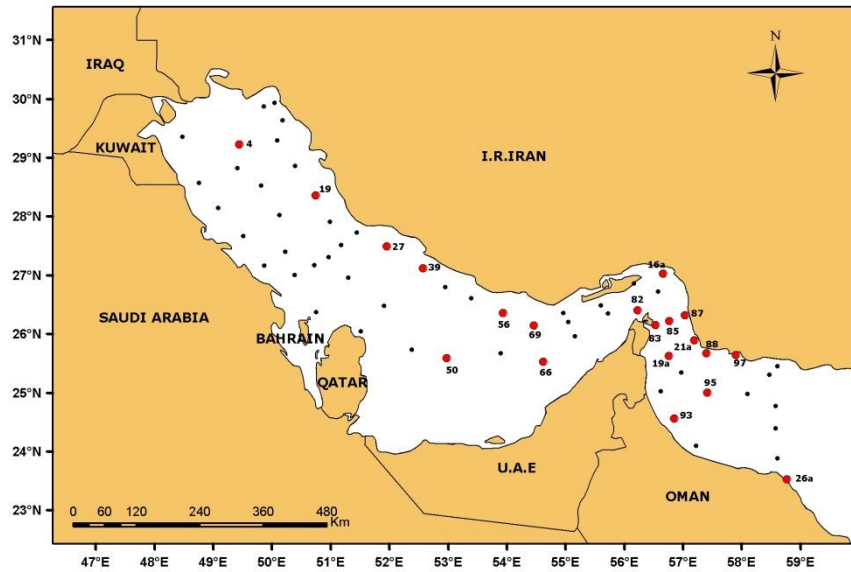
Apical axis 30-33 μm ; perivalvar axis 24-27 μm .

Distribution:

Neritic, tropical and temperate species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at different sites (refer sites map), usually in small numbers; however, it was quite abundant at some localities; maximum abundance (1.3×10^4 cells/l) was associated with the Sea of Oman (St. 88).



Sites of occurrence of *Chaetoceros eibenii* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Biddulphiineae

Family: Chaetocerotaceae Ralfs in Pritchard

Genus: *Chaetoceros* Ehrenberg

Species: *lauder*

Scientific name: *Chaetoceros lauder* Ralfs

Plate A40: d-f (Annex A)

Synonym:

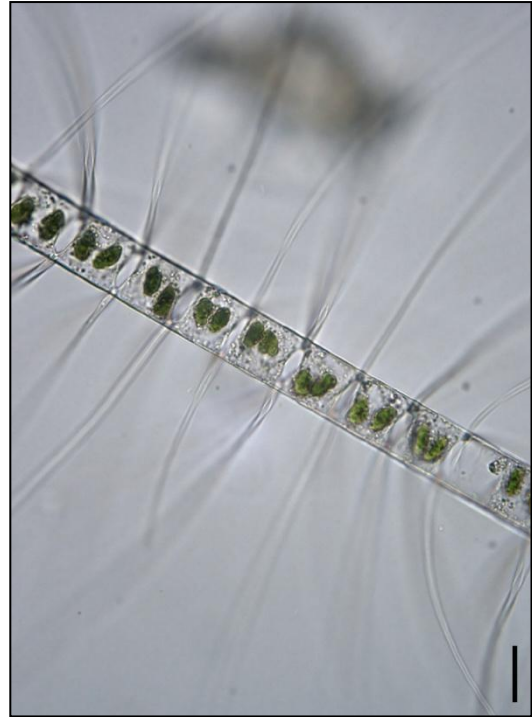
Chaetoceros weissflogii Schütt

References:

Pavillard, 1925: p. 45, Fig. 71; Hustedt, 1930: p. 683, Fig. 387; Allen and Cupp, 1935: p. 137, Fig. 59; Cupp, 1943: p. 118, Fig. 73; Crosby and Wood, 1958: p. 517, Pl. 37: 51; Hendey, 1964: p. 125, Pl. XIII: 3; Ricard, 1987: p. 203, Fig. 455.

Description:

Cells rectangular, united to form straight or twisted chains; cells deep, with shallow valve mantle and wide girdle; valve surface almost flat; straight setae emerge from the corners of the valves at right angles to the chain axis. Foramina narrow, linear to linear-elliptic; diameter of valve 22-50 μm (Hendey, 1964).

**Dimensions:**

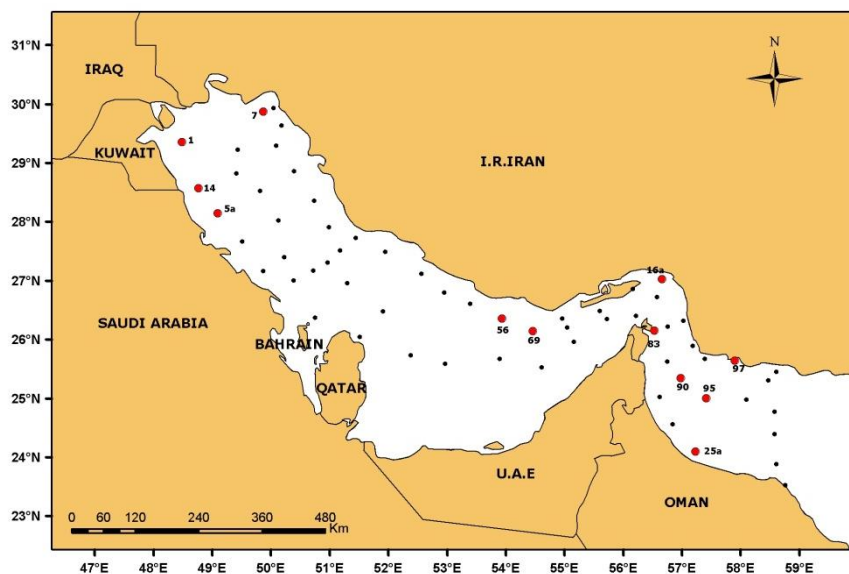
Apical axis 19-22 μm ; perivalvar axis 18-20 μm .

Distribution:

Neritic, south temperate form.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at few sites (refer sites map), usually in small numbers; however, it was quite abundant at some localities; maximum abundance (7.8×10^3 cells/l) was associated with Kuwaiti waters in the northwestern part of the inner RSA (Stations 1 and 14).



Sites of occurrence of *Chaetoceros lauderi* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Biddulphiineae

Family: Chaetocerotaceae Ralfs in Pritchard

Genus: *Chaetoceros* Ehrenberg

Species: *lorenzianus*

Scientific name: *Chaetoceros lorenzianus* Grunow

Plate A42: a-h (Annex A)

Synonym:

Chaetoceros cellulosum Lauder

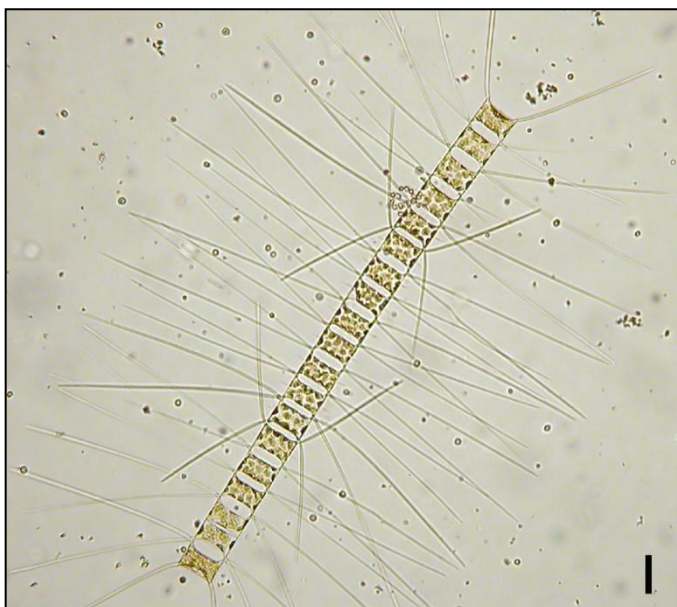
References:

Pavillard, 1925: p. 45, Fig. 70 B; Hustedt, 1930: p. 680, Fig. 385; Allen and Cupp, 1935: p. 136, Fig. 58; Cupp, 1943: p. 117, Fig. 71; Crosby and Wood, 1958: p. 517, Pl. 38: 52;

Hendey, 1964: p. 124, Pl. XVI: 1; Simonsen, 1974: p. 31; Ricard, 1987: p. 203, Figs. 452, 453; Throndsen *et al.*, 2007: p. 169.

Description:

Cells 7-48 μm wide, rectangular in broad girdle view; chains straight, stiff; apertures elliptical to oval. Valve surface flat or slightly elevated in center. Girdle zone usually short except in cells containing resting spores. Setae fused only at point of exit from margin; with very distinct transverse striae; terminal setae, diverging for their entire length. Chromatophores



are large, platelike, 4-10 per cell. Resting spores with primary valve bearing two conical protuberances, each of which terminates in a solid dichotomously branched process. Secondary valve smooth (Cupp, 1943).

Dimensions:

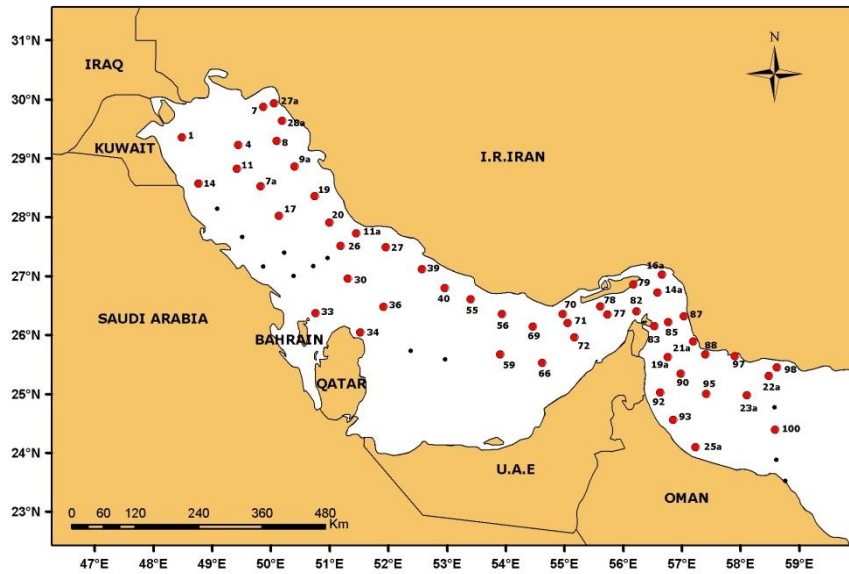
Apical axis 10-33 μm ; perivalvar axis 17-22 μm .

Distribution:

Neritic, tropical and temperate species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, it was one of the commonest species occurred at various sites in the RSA (refer sites map) and was encountered in 63.4% of the samples. Species was observed often in large numbers; maximum abundance (2.3×10^5 cells/l) was associated with the Iranian coast in the central part of the inner RSA (St. 27). Species has been previously reported from the inner RSA (Simonsen, 1974) and from Kuwaiti waters (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Chaetoceros lorenzianus* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Biddulphiineae

Family: Chaetocerotaceae Ralfs in Pritchard

Genus: *Chaetoceros* Ehrenberg

Species: *messanensis*

Scientific name: *Chaetoceros messanensis* Castracane

Plate A43: a-d (Annex A)

Synonym:

Chaetoceros furca Cleve

References:

Pavillard, 1925: p. 50, Fig. 79; Hustedt, 1930: p. 719, Fig. 410; Cupp, 1943: p. 134-135, Figs. 89-A, 89-B; Crosby and Wood, 1958: p. 517, Pl. 34: 48; Hendey, 1964: p. 129, Pl. XII: 3; Simonsen, 1974: p. 31; Ricard, 1987: p. 205, Fig. 468.

**Description:**

Chains straight, not twisted; elliptical valves; apical axis 9-33 μm in length. Cells rectangular with conspicuous corners by which adjacent cells touch each other. Apertures fairly wide, linear-six-sided to almost round. Valve mantle low, without distinct notch at junction with girdle band. Setae thin. Terminal setae strongly diverging, unlike, usually one directed backward from the chain. Some inner setae fused for about two-thirds their length, so that basal part is only a single seta which forks at its second third. These forked horns are thicker than the others and with spirals of conspicuous small spines; sometimes with long hairlike extensions. One chromatophore, placed near girdle (Cupp, 1943).

Dimensions:

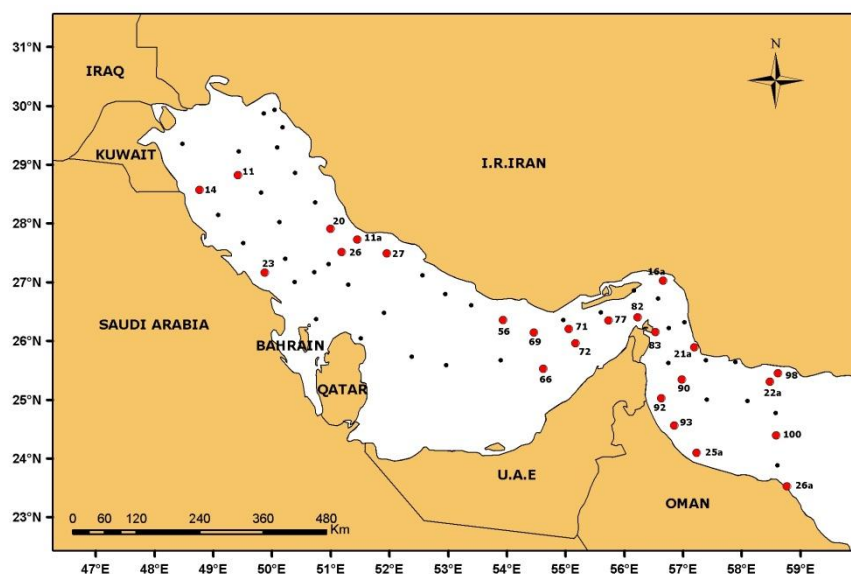
Apical axis 16-19 μm ; perivalvar axis 20-23 μm .

Distribution:

Oceanic, tropical and subtropical species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at various sites (refer sites map), usually in small numbers; however, it was quite abundant at some localities; maximum abundance (1.8×10^4 cells/l) was associated with the Sea of Oman (St. 25a). It has been previously reported from the inner RSA (Simonsen, 1974).



Sites of occurrence of *Chaetoceros messanensis* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Biddulphiineae

Family: Chaetocerotaceae Ralfs in Pritchard

Genus: *Chaetoceros* Ehrenberg

Species: *peruvianus*

Scientific name: *Chaetoceros peruvianus* Brightwell

Plate A44: a-e (Annex A)

Synonyms:

Chaetoceros peruvio-atlanticum Karsten; *Chaetoceros convexicornis* Margin; *Chaetoceros peruvianum* var. *currens* H. Pérégallo.

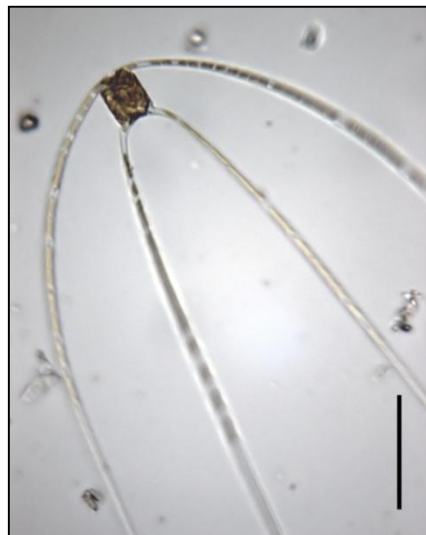
References:

Pavillard, 1925: p. 42, Fig. 67; Hustedt, 1930: p. 670-673, Fig. 379-381; Allen and Cupp, 1935: p. 135-136, Figs. 56, 57; Cupp, 1943: p. 113, Fig. 68 a-c; Crosby and Wood, 1958: p.

518, Pl. 34: 49; Hendey, 1964: p. 123, Pl. IX: 3; Simonsen, 1974: p. 31; Priddle and Fryxell, 1985: p. 40-41; Ricard, 1987: p. 203, Fig. 448.

Description:

Cells usually solitary, seldom building short chains, 16-32 μm broad. Valves elliptical; valves unlike, the upper rounded, lower flat, both with similarly constructed valve mantles which vary greatly from one-sixth to equal the length of the apical axis; on girdle-band margin with hollow channel-like groove of varying size, but always very distinct. Setae of upper valve, arising from near center, turning sharply and running backward in more or less wide, outwardly convex curves after short basal region. At the end, more or less divergent to convergent. Setae of lower valve springing from near margin, slightly convex toward outside, more nearly parallel to chain axis than those of upper valve. At end, more or less divergent or even convergent; all setae strong, 3-5 μm thick, four-sided, with strong spines, striated, 20-22 striae in 10 μm (Cupp, 1943).



Harmful Effect:

Non-toxic bloom-forming species; no harmful incidents have been reported, but species may be regarded as potentially harmful due to its morphology (Hansen *et al.*, 2001).

Taxonomic Remarks:

Cells of this species may be different in size. Smaller specimens have been described as separate species form - *Chaetoceros peruvianus* Brightwell f. *gracilis* (Schröder) Hustedt.

Dimensions:

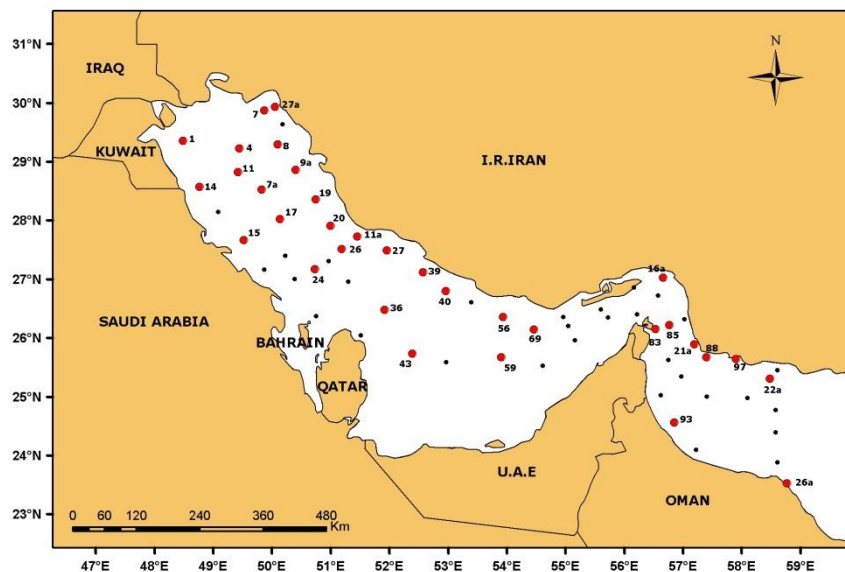
Apical axis 18-22 μm ; pervalvar axis 25-27 μm .

Distribution:

Oceanic; in south temperate to warmer seas.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was frequently observed at various sites (refer sites map), often in large numbers; maximum abundance (1.4×10^4 cells/l) was associated with Kuwaiti waters in the northwestern part of the inner RSA (St. 14). Species has been previously reported from the inner RSA (Simonsen, 1974) and from Kuwaiti waters (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Chaetoceros peruvianus* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Biddulphiineae

Family: Chaetocerotaceae Ralfs in Pritchard

Genus: *Chaetoceros* Ehrenberg

Species: *pseudocurvisetus*

Scientific name: *Chaetoceros pseudocurvisetus* Mangin

Plate A45: a-g (Annex A)

References:

Pavillard, 1925: p. 52, Fig. 83; Hustedt, 1930: p. 741, Fig. 427; Allen and Cupp, 1935: p. 141, Fig. 73; Cupp, 1943: p. 139, Fig. 94; Hendeey, 1964: p. 134, Pl. XVIII: 1.

Description:

Cells compressed, 13-19 μm broad. Apertures lenticular, slightly fused at insertion of setae. Four protuberances appear on each valve connected with similar knobs on adjacent cells. Valve face rectangular with bent angles; setae joined at insertion. Valve mantle high, without definite notch at junction with girdle band; girdle zone small in resting cells. One chromatophore per cell. In general appearance setae similar to those of *C. curvisetus* (Cupp, 1943).

**Dimensions:**

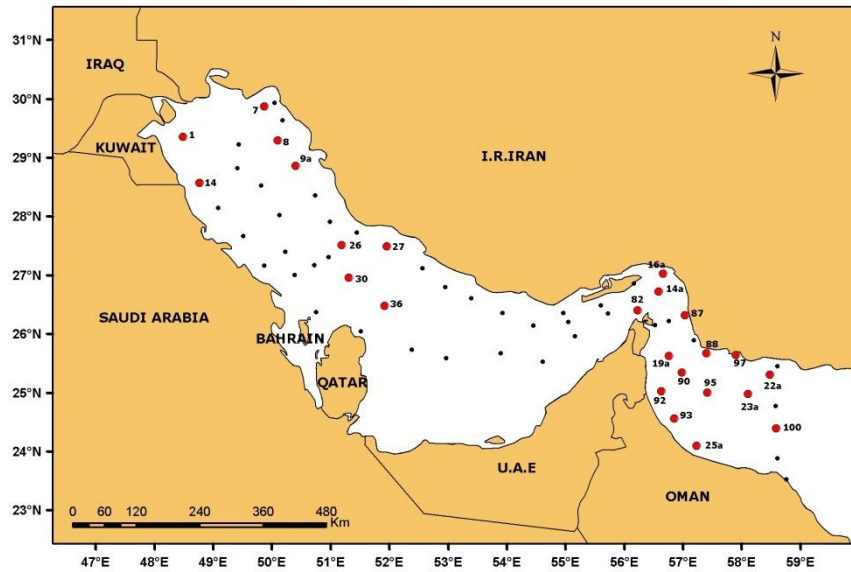
Apical axis 10-13 μm ; pervalvar axis 18-19 μm .

Distribution:

Neritic, tropical and subtropical species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at various sites (refer sites map), usually in small numbers; however, it was very abundant at some localities; maximum abundance (1.4×10^5 cells/l) was associated with Kuwaiti waters in the northwestern part of the inner RSA (St. 1). It has been previously reported from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Chaetoceros pseudocurvisetus* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Biddulphiineae

Family: Chaetocerotaceae Ralfs in Pritchard

Genus: *Chaetoceros* Ehrenberg

Species: *socialis*

Scientific name: *Chaetoceros socialis* Lauder

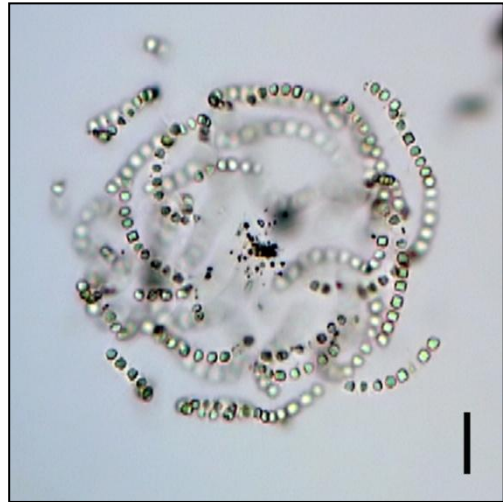
Plate A46: a-f (Annex A)

References:

Hustedt, 1930: p. 752, Fig. 435; Cupp, 1943: p. 143, Fig. 100; Crosby and Wood, 1958: p. 518, Pl. 38: 57; Hendey, 1964: p. 136, Pl. XV: 3; Priddle and Fryxell, 1985: p. 52-53; Ricard, 1987: p. 207, 217, Figs. 484, 485, 534; Throndsen *et al.*, 2007: p. 173.

Description:

Chains short, curved, many united in large, slimy, circular colonies, held together by slime, or mucilaginouslike substance, and often by some very fine long setae which are felted together. Cells 6-12 μm wide, in broad girdle view four-cornered, corners not touching those of adjacent cells. Apertures rather long, slightly narrower in the center. Setae hairlike, arising from corners of the cell, short basal part. Three setae of two adjacent



valves are short, fourth, very long and entwined with long setae of adjacent cells to hold the chains in colonies. Long setae not always present. One chromatophore on girdle side. Resting spores central or near central, smooth on both valves (Cupp, 1943).

Harmful Effect:

Non-toxic bloom-forming species. Harmful effect could just as well be caused by its presence in mucilage colonies as by the setae (Hallegraeff *et al.*, 1995).

Dimensions:

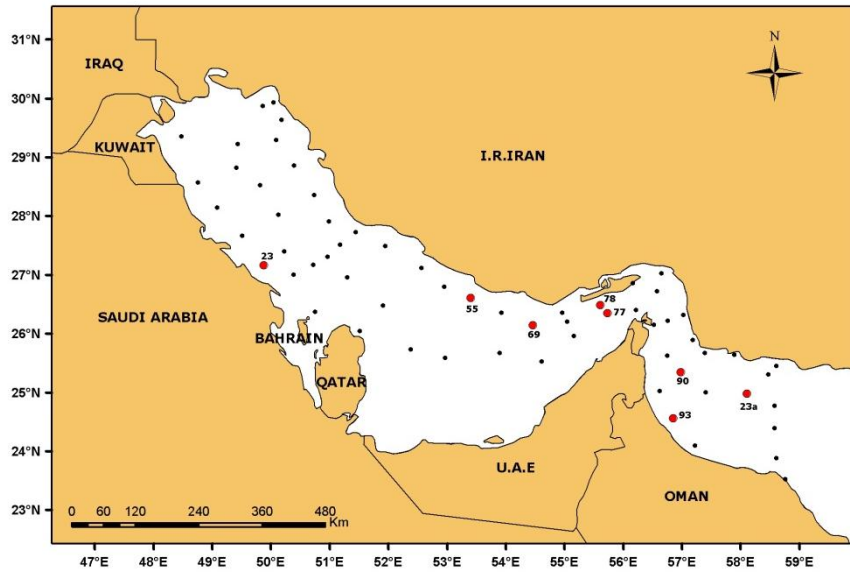
Apical axis, 2-3 μm ; perivalvar axis, 5-6 μm .

Distribution:

Neritic, temperate species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at few sites (refer sites map), usually in small numbers; however, it was very abundant at some localities; maximum abundance (5.7×10^5 cells/l) was associated with the southern part of the inner RSA (St. 78). It has been previously reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Chaetoceros socialis* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Biddulphiineae

Family: Chaetocerotaceae Ralfs in Pritchard

Genus: *Chaetoceros* Ehrenberg

Species: *tortissimus*

Scientific name: *Chaetoceros tortissimus* Gran

Plate A46: g-i (Annex A)

References:

Hustedt, 1930: p. 751, Fig. 434; Cupp, 1943: p. 142, Fig. 99; Hendey, 1964: p. 135, Pl. XI: 2; Ricard, 1987: p. 207, Fig. 483.

Description:

Chains straight or slightly bent, loose, very strongly curved around chain axis, without distinct terminal setae. Cells 14-20 μm broad. Setae thin, arising a little way inside corners,

about at right angles to chain axis, going in all directions. Cell wall weakly siliceous; cells in broad girdle view rounded-rectangular; valves with slightly convex valve surface, touching in the middle, not at corners, therefore apertures are apparent only at corners. No notch at margin of girdle band. Chromatophores one, lying in girdle region. Resting spores unknown (Cupp, 1943).

Dimensions:

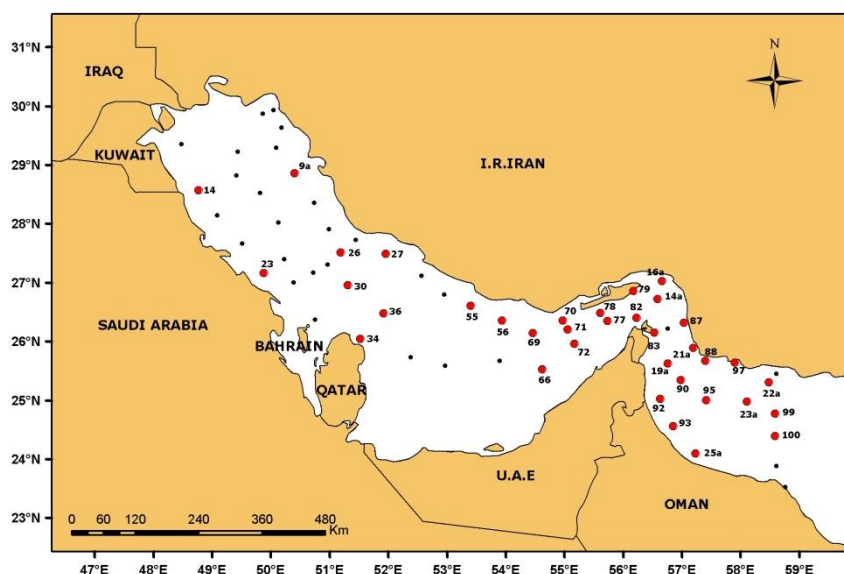
Apical axis 21-25 μm ; perivalvar axis 9-11 μm .

Distribution:

Neritic, temperate species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at various sites (refer sites map), often in very large numbers. It was recorded as bloom-forming at some localities; blooms with cells concentration more than 10^6 cells/l were associated with the Strait of Hormuz area and the southern part of the inner RSA (Stations 14a, 56, and 70). It has been previously reported from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Chaetoceros tortissimus* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Biddulphiineae

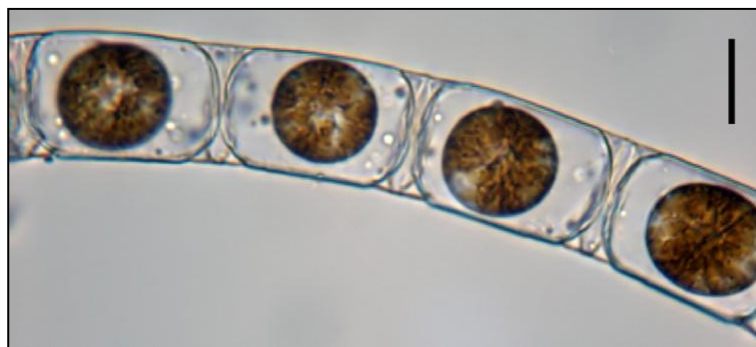
Family: Lithodesmiaceae H. and M. Péragallo *emend* Simonsen

Genus: *Bellerochea* Van Heurck *emend* von Stosch

Cells usually united to form chains so that the valves are more or less in contact over the whole surface, except for small foramina near the margins. Cells rectangular in girdle view, narrow. Valves bipolar, lanceolate or triangular, with concave undulating sides. Valve apices slightly produced; valve surface very weakly siliceous, with a central projection and a circlet of fine spinulae around the margin. Chromatophores numerous small spherical bodies scattered throughout the cell (Hendey, 1964).

Scientific name: *Bellerochea horologicalis* von Stosch

Plate A47: a-d (Annex A)



References:

Ricard, 1987: p. 219, Figs. 545, 546; Hasle and Syvertsen, 1997: p. 229, Pl. 48.

Description:

Ribbons, curved in transapical plane or straight; cells biangular, intercellular space dumbbell shaped; costae partly continuous. Length of perivalvar axis 40-54 μm , apical axis 28-98 μm , transapical axis 25-32 μm ; mantle costae 23-27 in 10 μm (Hasle and Syvertsen, 1997).

Dimensions:

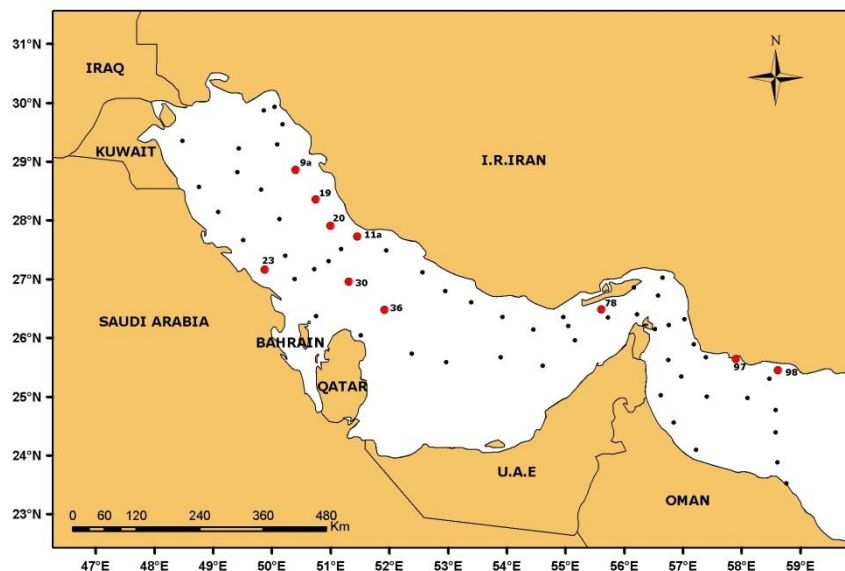
Cells length 33-38 μm ; width 20-22 μm .

Distribution:

Warm-water species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at few scattered stations (refer sites map) in small numbers; maximum abundance (8.6×10^2 cells/l) was associated with the Iranian coast in the central part of the inner RSA (St. 20). It has been previously reported from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Bellerochea horologicalis* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Biddulphiineae

Family: Lithodesmiaceae H. and M. Pérégallo *emend* Simonsen

Genus: *Ditylum* Bailey

Cells elongated, prismatic to box-shaped. Solitary, except immediately after division. Valves three- to four cornered, seldom bipolar, with a strong central siliceous hollow spine, and a marginal ridge, strengthened by ribs. Intercalary bands, more or less numerous. Valve surface more or less waved, with usually poorly developed humps on the corners. In the central part, a usually three-cornered elevated region, the margin often has a circle of short perivalvar-directed spines. Outer valve margin more or less strongly waved, giving the appearance of lines running from valve to valve. Cell wall weakly siliceous; valve membrane, delicately areolated-punctated. Chromatophores are numerous and small (Cupp, 1943).

Scientific name: *Ditylim brightwellii* (West) Grunow *ex* Van Heurck

Plate A48: a-e (Annex A)

Synonyms:

Triceratium brightwellii West; *Ditylum trigonum* Bailey; *Ditylum inaequale* Bailey

References:

Pavillard, 1925: p. 53, Fig. 91; Hustedt, 1930: p. 786, Figs. 457-459; Cupp, 1943: p. 148, Fig. 107-A, 107-B; Crosby and Wood, 1958: p. 510, Pl. 36: 27; Hendey, 1964: p. 111, Pl. V: 1; Ricard, 1987: p. 219, Figs. 552-554; Throndsen *et al.*, 2007: p. 181.

Description:

Cells triangular in space; somewhat like a prism; angles often rounded, giving a cylindrical appearance. Cells three to eight times longer than broad. Valves small, undulate, furnished with a corona of short, but stout spines surrounding one large central spine. Central spine straight; central area of valve often raised, hyaline. Girdle elongated. Lebour (1930) described the connecting zone as composed of scale-like intercalary bands. Chromatophores: numerous cocciform bodies, usually grouped toward the center of the cell. Cells very weakly siliceous; diameter of valve 28-46 µm; perivalvar axis 80-130 µm; length of spine 20-50 µm (Hendey, 1964).



Dimensions:

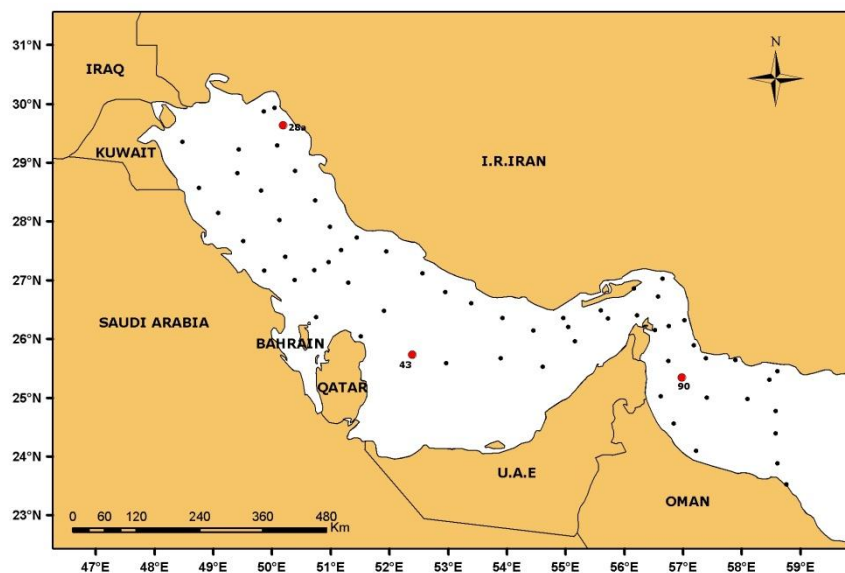
Cells length 85-103 μm ; diameter 28-32 μm .

Distribution:

Neritic, south temperate species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at few sites (refer sites map), usually in small numbers; however, it was quite abundant at some localities; maximum abundance (1.8×10^3 cells/l) was recorded off Qatar (St. 43). It has been previously reported from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Ditylim brightwellii* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Biddulphiineae

Family: Lithodesmiaceae H. and M. Pérégallo *emend* Simonsen

Genus: *Lithodesmium* Ehrenberg

Cells united in usually long; straight chains with concealed apertures. Valves three-cornered; valves with marginal perivalvar-directed membrane by which adjacent cells are joined; long, thin, hollow spine in center of valve. Intercalary bands present, collarlike. Chromatophores numerous and small (Cupp, 1943).

Scientific name: *Lithodesmium undulatum* Ehrenberg

Plate A48: f-h (Annex A)

References:

Pavillard, 1925: p. 54, Fig. 93; Hustedt, 1930: p. 790, Fig. 461; Cupp, 1943: p. 150, Fig. 108; Crosby and Wood, 1958: p. 509, Pl. 36: 22; Hendey, 1964: p. 111, Pl. VI: 6; Hendey, 1970: p. 119; Ricard, 1987: p. 219, Figs. 541-544; Throndsen *et al.*, 2007: p. 181.



Description:

Chains straight, 35-68 μm broad. Valves three-cornered with undulating margin; valve mantle high, fairly flat valve surface; long, thin, hollow spine in center of valve. Cell wall weakly siliceous, areolated-punctated on valves, intercalary bands, girdle bands, and connective membrane. Central hyaline area on valve; on valve surface, about 18 radial rows in 10 μm , with 17-20 areolae in 10 μm on rows. Structure of girdle bands and intercalary bands are more delicate, 22-25 areolae in 10 μm . Connective membrane is usually with coarser areolae, 10-14 in 10 μm , often even in the same colony, more delicate (Cupp, 1943).

Dimensions:

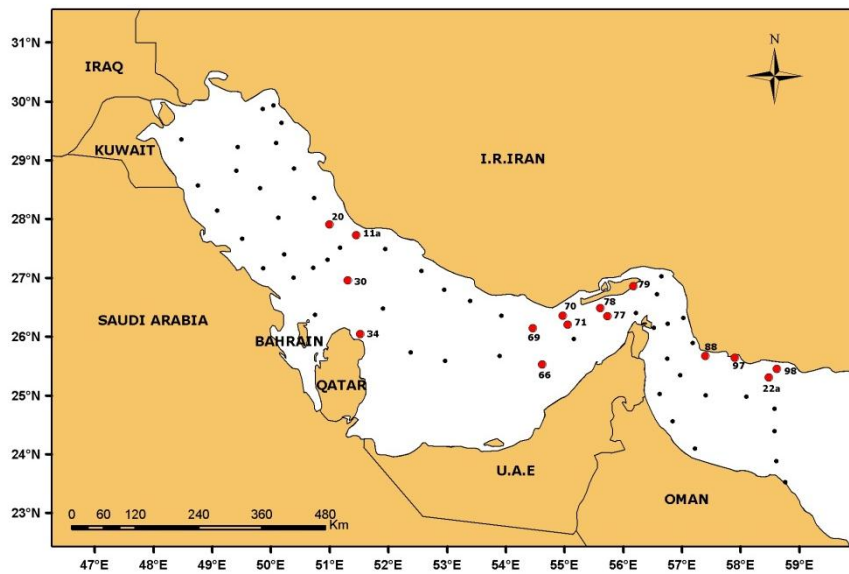
Cells length 44-52 μm ; width 38-41 μm .

Distribution:

Neritic, south temperate species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at few sites (refer sites map), usually in small numbers; maximum abundance (3.1×10^2 cells/l) was associated with the Sea of Oman (St. 98). It has been previously reported from Kuwaiti shore (Hendey, 1970).



Sites of occurrence of *Lithodesmium undulatum* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Biddulphiineae

Family: Lithodesmiaceae H. and M. Pérégallo *emend* Simonsen

Genus: *Streptotheca* Shrubsole (= *Heliotheca* Ricard)

Cells extremely flat, with square outline, sometimes three-cornered; united by valve faces, leaving very little, if any, aperture. Cell wall very weakly siliceous; chains strongly twisted; valves narrowly elliptical with a rudimentary central knob. Chromatophores are numerous small granules (Cupp, 1943). A second generic name published by Ricard (1987), *Heliotheca*, is a validly published substitute name for *Streptotheca* Shrubsole 1890 (type: *S. tamesis* Shrubsole). However, *Streptotheca* Shrubsole remains currently used (Round *et al.*, 1990).

Scientific name: *Streptotheca indica* Karsten

Plate A47: h-j (Annex A)

References:

Allen and Cupp, 1935: p. 143, Fig. 77; Crosby and Wood, 1958: p. 512, Pl. 36: 33.

Description:

Cells in chains, united by valves which have a slight central depression; tripartite in valve view, twisted on pervalvar axis. Dimensions: $200 \times 50 \times 20 \mu\text{m}$ (Crosby and Wood, 1958).

Dimensions:

Cells length $100\text{--}110 \mu\text{m}$; width $70\text{--}80 \mu\text{m}$.

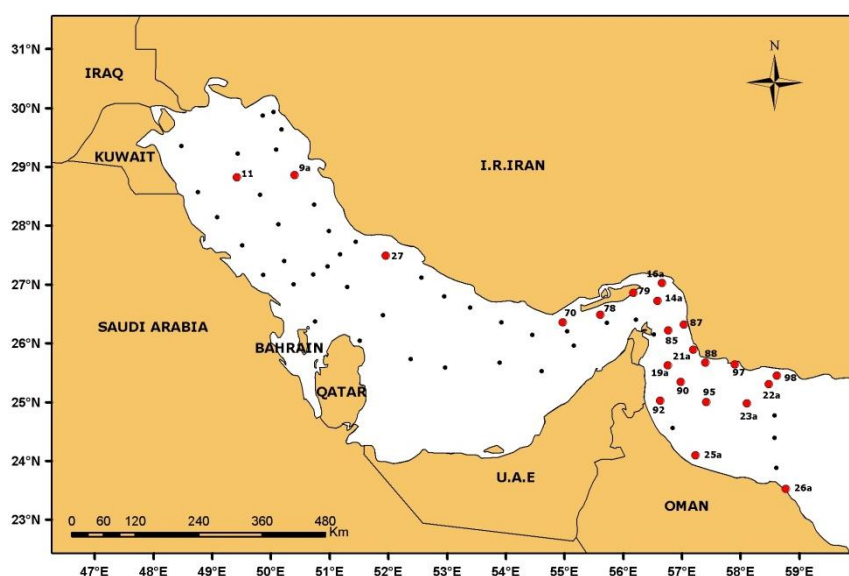


Distribution:

Typical species in tropical areas of the Indian Ocean (Allen and Cupp, 1935). It has been reported also from Australia and New Zealand (Crosby and Wood, 1958).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at few scattered sites (refer sites map), usually in small numbers; however, it was quite abundant at some localities; maximum abundance (1.9×10^3 cells/l) was recorded in the Sea of Oman (St. 98).



Sites of occurrence of *Streptotheca indica* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Biddulphiineae

Family: Lithodesmiaceae H. and M. Péragallo *emend* Simonsen

Genus: *Streptotheca* Shrubsole (= *Heliotheca* Ricard)

Species: *tamesis*

Scientific name: *Streptotheca tamesis* Shrubsole

Plate A47: e-g (Annex A)

Synonym:

Helicotheca tamesis (thamensis) (Shrubsole) Ricard

References:

Pavillard, 1925: p. 53, Fig. 90; Hustedt, 1930: p. 780, Fig. 455; Cupp, 1943: p. 148, Fig. 106; Crosby and Wood, 1958: p. 512, Pl. 36: 32; Hendey, 1964: p. 113, Pl. VII: 2; Ricard, 1987: p. 219, Figs. 549, 550 (as *Helicotheca tamesis*); Throndsen *et al.*, 2007: p. 182 (as *Helicotheca tamesis*).

Description:

Cells twisted so that chains are spiral; one end of cell in relation to the other twisted about 90°. Cells almost flat, square. Apical axis 60-98 µm long. Valves not quite flat but, with two deeply placed knobs which fit into corresponding depressions in the adjacent cells. Nucleus central. Chromatophores numerous, small roundish plates, more or less radiate in the cell (Cupp, 1943).

Dimensions:

Cells length 140-160 µm; width 120-140 µm.

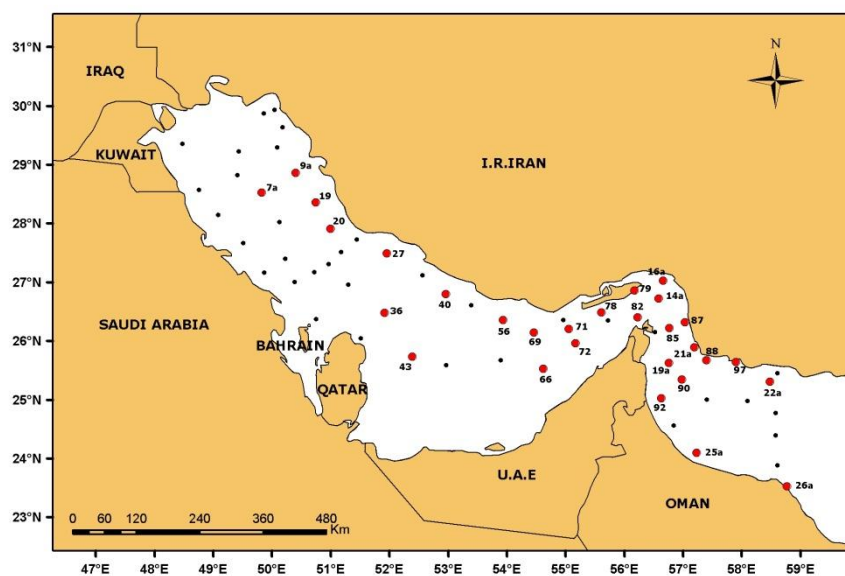


Distribution:

Neritic species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at various sites (refer sites map), usually in small numbers; maximum abundance (1.4×10^2 cells/l) was recorded in the Sea of Oman (St. 88). It has been previously reported from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009, as *Helicotheca thamensis*).



Sites of occurrence of *Streptotheca tamesis* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Biddulphiineae

Family: Epodiscaceae Kützing

Genus: *Odontella* C.A. Agardh

Cells with shorter or longer horns, each with a top plate perforated by closely packed holes (ocellus) through which mucus is extruded. Straight chains (cells united by both horns) or

zigzag chains (cells united by one horn) are observed. Valves elliptical or lanceolate. Two labiate processes per valve, usually with long external tubes are present. Many small chloroplasts (Thronsdén *et al.*, 2007).

Sites of occurrence in RSA:

In Winter 2006 Cruise, the genus *Odontella* combines with three species. Species of this genus were occasionally observed in the RSA phytoplankton, but in low concentration (not more than 4.9×10^2 cells/l; 1% of total phytoplankton abundance). Relatively higher abundance of *Odontella* spp. ($> 10^2$ cells/l) was mostly associated with the waters of the Sea of Oman.

Scientific name: *Odontella aurita* (Lyngbye) C.A. Agardh

Plate A49: a-d (Annex A)

Synonym:

Biddulphia aurita (Lyngbye) Brébisson *et* Godey

References:

Hustedt, 1930: p. 847, Fig. 501 (as *Biddulphia aurita*);
Cupp, 1943: p. 161, Fig. 112 (as *Biddulphia aurita*); Crosby
and Wood, 1958: p. 504, Pl. 33: 33 (as *Biddulphia aurita*);
Hendey, 1964: p. 103, Pl. XXIV: 6 (as *Biddulphia aurita*);
Hendey, 1970: p. 117 (as *Biddulphia aurita*); Simonsen,
1974: p. 27; Witkowski *et al.*, 2000: p. 36, Pl. 8: 12, 13; 9:
1-3; Thronsdén *et al.*, 2007: p. 176.

Description:

Cells united in straight or zigzag chains. Valves elliptical-lanceolate, with obtuse processes inflated at the base. Center part of valve convex, more or less flattened at the top from which usually more or less long spines project. Spines sometimes absent or several. Girdle zone is sharply differentiated from the valve zone by a clear depression. Cell wall strongly siliceous, areolated-punctated. Areolae 8-10 in 10 μ m, on the valve in radial rows. On the girdle band in perivalvar rows, 7-



10 rows in 10 μm , with 8-14 puncta or areolae in 10 μm ; a very variable species. Length of apical axis 12-97 μm ; with a number of small spines on valves in warmer-water specimen (Cupp, 1943).

Dimensions:

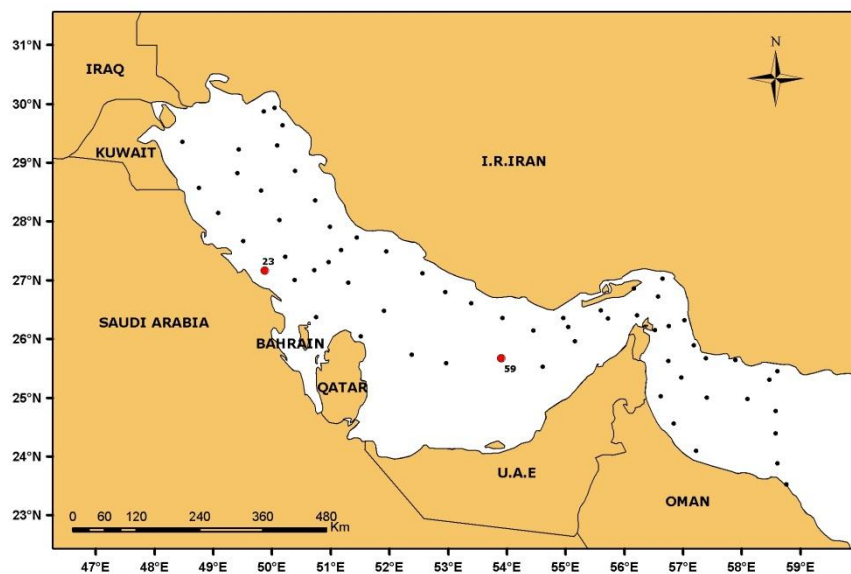
Cells length 37-42 μm ; width 25-28 μm .

Distribution:

Neritic and littoral species, widely distributed.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at two sites (refer sites map) in small numbers. It has been previously reported from the Indian Ocean (Simonsen, 1974) and from Kuwaiti shore (Hendey, 1970) and coastal waters (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Odontella aurita* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Biddulphiineae

Family: Epodiscaceae Kützing

Genus: *Odontella* C.A. Agardh

Species: *mobiliensis*

Scientific name: *Odontella mobiliensis* (Bailey) Grunow

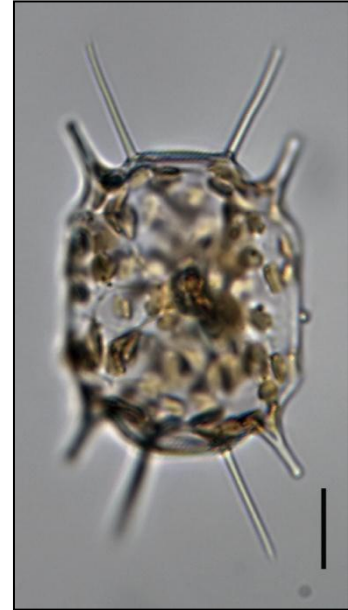
Plate A49: e-h (Annex A)

Synonym:

Biddulphia mobiliensis Bailey

References:

Pavillard, 1925: p. 55, Fig. 96 (as *Biddulphia mobiliensis*);
Hustedt, 1930: p. 841, Fig. 495 (as *Biddulphia mobiliensis*);
Allen and Cupp, 1935: p. 145, Fig. 80 (as *Biddulphia mobiliensis*);
Cupp, 1943: p. 153, Fig. 110 (as *Biddulphia mobiliensis*);
Crosby and Wood, 1958: p. 503, Pl. 36: 19 (as *Biddulphia mobiliensis*);
Hendey, 1964: p. 104 Pl. XX: 3 (as *Biddulphia mobiliensis*);
Hendey, 1970: p. 116 (as *Biddulphia mobiliensis*);
Simonsen, 1974: p. 27; Ricard, 1987: p. 201, Figs. 432, 433; Throndsen *et al.*, 2007: p. 176.



Description:

Cells single or rarely united in short straight chains by the long spines. Length of apical axis 45-157 μm ; valves elliptical-lanceolate, convex, with a flat or nearly flat central part; valve processes slender, arising inside the margin of the valve, directed diagonally outward. Two long spines are placed far apart, but about equally far from the processes, directed obliquely outward, straight or often bent abruptly in their outer part. Cells relatively thin-walled, without a sharp constriction between valve and girdle zone. Sculpturing fine, reticulate, 14-16 areolae in 10 μm on valve and valve mantle, 17-18 on girdle band. Auxospores formed as large bladders from the separation of the valves, with much larger cells inside. Microspores are observed (Cupp, 1943).

Dimensions:

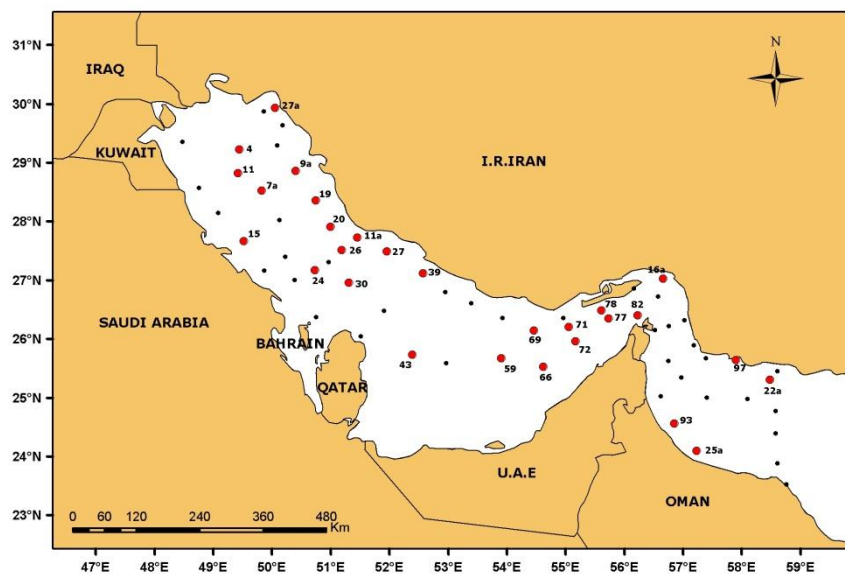
Cells length 65-70 μm ; width 47-55 μm .

Distribution:

Neritic, truly planktonic; temperate and south temperate species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at various sites (refer sites map), usually in small numbers; maximum abundance 102 cells/l) was associated with Iranian coast in the central part of the inner RSA (St. 27). It has been previously reported from the inner RSA (Simonsen, 1974) and from Kuwaiti shore (Hendey, 1970) and coastal waters (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Odontella mobilensis* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Biddulphiineae

Family: Epodiscaceae Kützinger

Genus: *Odontella* C.A. Agardh

Species: *sinensis*

Scientific name: *Odontella sinensis* (Greville) Grunow

Plate A50: a-f (Annex A)

Synonym:

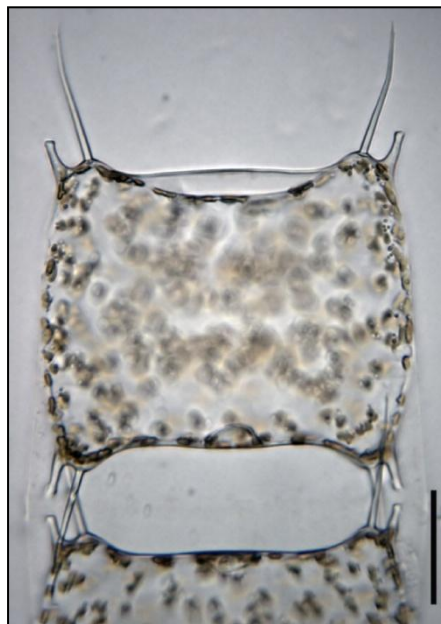
Biddulphia sinensis Greville

References:

Hustedt, 1930: p. 839, Fig. 493 (as *Biddulphia sinensis*); Allen and Cupp, 1935: p. 146, Fig. 81 (as *Biddulphia sinensis*); Hendey, 1964: p. 105, Pl. XX: 1 (as *Biddulphia sinensis*); Simonsen, 1974: p. 27; Throndsen *et al.*, 2007: p. 176.

Description:

Cells solitary or united by their spines to form loosely connected colonies. In girdle view, the frustule is shaped not unlike a pillow, being about 2-2.5 times as long as it is broad. Weakly siliceous. Valves elliptical, having apices furnished with short processes; valve surface slightly concave, bearing two spines which originate close to the base of the processes. Spines long, equal to or a little longer than the apical length of the valve (i.e., the width of the frustule when lying in girdle view). Chromatophores: numerous small irregular bodies scattered throughout the cell. Apical axis of valve 120-260 µm; transapical axis of valve 60-80 µm; length of cell up to 300 µm (Hendey, 1964).



Dimensions:

Cells length 95-180 µm; width 80-150 µm.

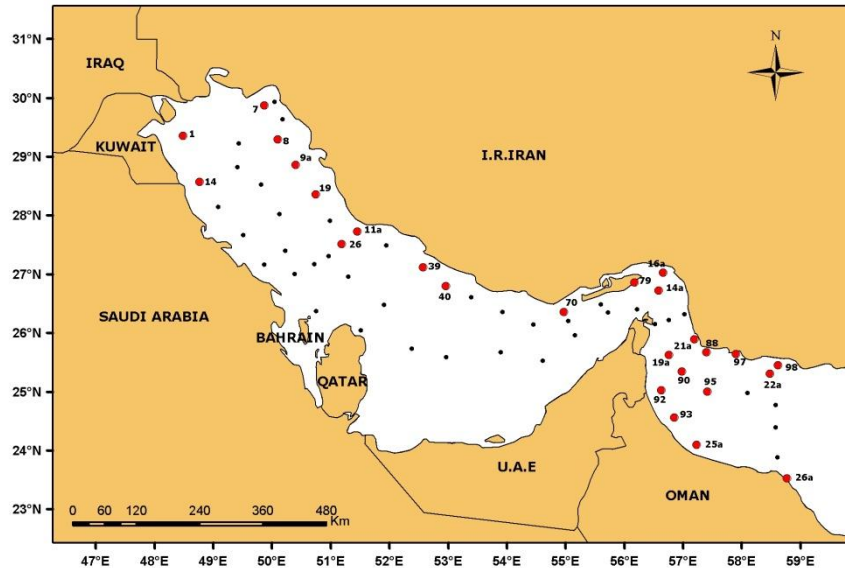
Distribution:

Truly planktonic species, widely spread in temperate and warm waters.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at different sites (refer sites map), usually in small numbers; maximum abundance (4.9×10^2 cells/l) was recorded in the Sea of Oman (St.

98). It has been previously reported from the inner RSA (Simonsen, 1974) and from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Odontella sinensis* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Biddulphiineae

Family: Epodiscaceae Kützing

Genus: *Biddulphia* Gray

Cells box-shaped to cylindrical. Valves elliptical, with two poles or three- or four-sided (rarely five-sided). At the corners or at the ends of the apical axis, more or less strongly developed processes or horns may be present, or with distinct corners, usually with transapical grooves so that valve surface is more or less strongly humped. Very fine slime pores are usually present on end surfaces of processes or on corners of the valves, forming slime cushions which hold the cells together in straight or zigzag chains. Girdle zone is sharply differentiated from valve zone, cylindrical or prism-shaped, with numerous cross striations. Intercalary bands are indistinct if present. Chromatophores are numerous, small, lying against the cell

wall. Nucleus central. Cell wall strongly siliceous, usually with distinct areolae or granules. Auxospores formed; flagellated microspores known in a few species (Cupp, 1943).

Scientific name: *Biddulphia pulchella* Gray

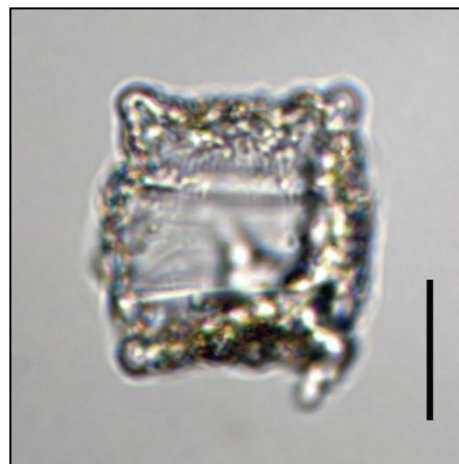
Plate A50: i (Annex A)

Synonym:

Biddulphia biddulphiana (Smith) Boyer

References:

Cupp, 1943: p. 152, Fig. 109; Crosby and Wood, 1958: p. 504, Pl. 33: 32; Hendey, 1964: p. 101, Pl. XXV: 1; Simonsen, 1974: p. 34; Ricard, 1987: p. 177, Figs. 254-264; Witkowski *et al.*, 2000: p. 25, Pl. 8: 8, 9.



Description:

Valves elliptical, convex, divided transversely by two to six ribs, sides undulating. Length along apical axis is 50-70 µm. A globular process at each end of apical axis is constricted at the base. Two or three short spines, usually present near center of valve; very fine pores on rounded corner processes, about 20 areolae or puncta in 10 µm. Valve surface with 3½-5 areolae in 10 µm, smaller near the valve center; valve mantle high, deep furrow at junction with girdle zone, 4-5 areolae in 10 µm near edge. Girdle band similarly areolated, 5-6 in 10 µm (usually slightly more delicate), in nearly parallel lines (Cupp, 1943).

Dimensions:

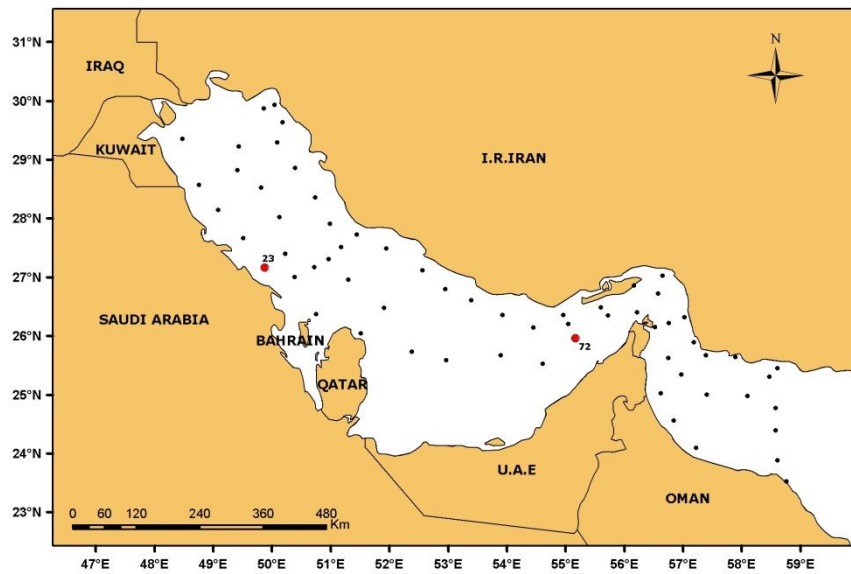
Cells length 45 µm; width 40 µm.

Distribution:

Found occasionally in plankton samples, but a bottom form.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at two sites (refer sites map) and in small numbers. It has been previously reported from the Indian Ocean (Simonsen, 1974) and from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Biddulphia pulchella* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Biddulphiineae

Family: Epodiscaceae Kützinger

Genus: *Biddulphia* Gray

Species: *tuomeyi*

Scientific name: *Biddulphia tuomeyi* (Bailey) Roper

Plate A50: g, h (Annex A)

Synonyms:

Biddulphia tridens Boyer; *Zygoceros tuomeyi* Bailey

References:

Hustedt, 1930: p. 835, Fig. 491; Hendey, 1970: p. 117; Simonsen, 1974: p. 34; Ricard, 1987: p. 177, Fig. 269.

Description:

In girdle view, the apical bosses are produced well above the level of the rest of the valve surface, and may be two or three times as high as the section immediately next to it. Length 84-90 μm (Hendey, 1970).

Dimensions:

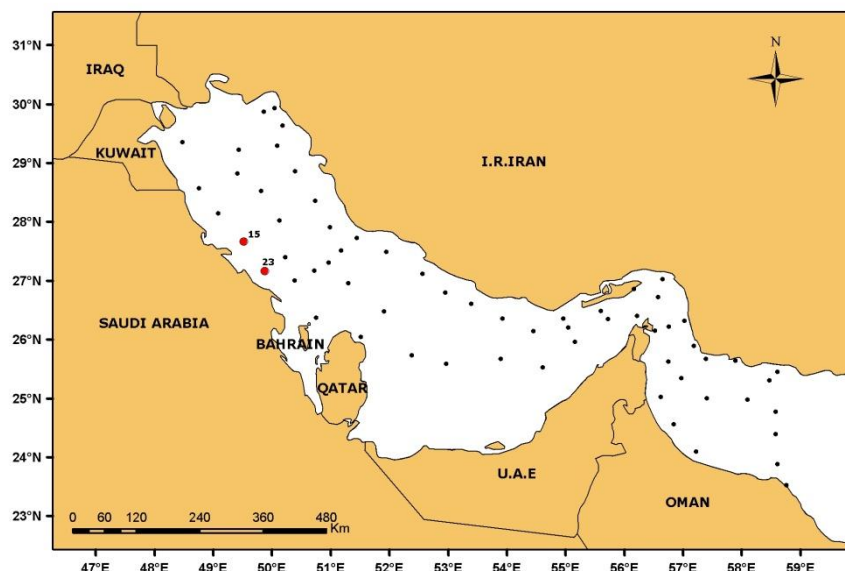
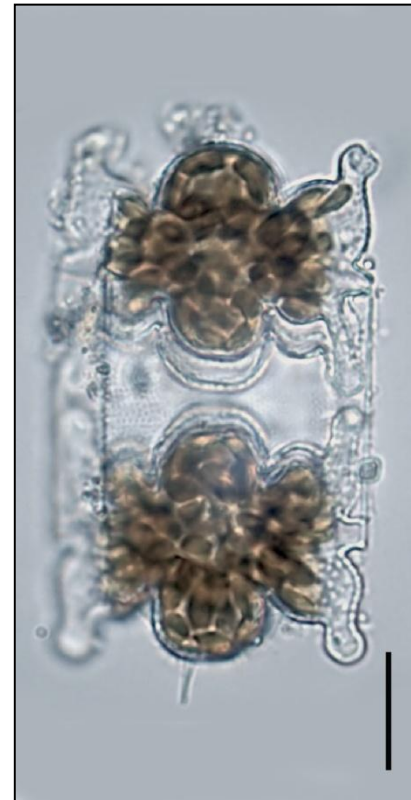
Cells length 51-65 μm ; width 38-46 μm .

Distribution:

Benthic littoral form.

Sites of occurrence in RSA:

This species was encountered at two sites (refer sites map) and in small numbers. It has been previously reported from the inner RSA (Simonsen, 1974) and from Kuwaiti shore (Hendey, 1970).



Sites of occurrence of *Biddulphia tuomeyi* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Biddulphiineae

Family: Triceratiaceae (Schütt) Lemmermann

Genus: *Triceratium* Ehrenberg

The sides of the cell are usually straight or sometimes very slightly convex. The angles are furnished with stout cornutate processes. The valve surface is covered with a regular hexagonal loculation. The loculi are usually open upon the outer surface, while the lower wall or floor is furnished with poroids. The valve mantle is narrow. The girdle is always simple and finely punctate. Small spines are usually present on the valve surface at the point of confluence of the walls of the loculi, and are often developed at the margin of the valve where they have the appearance of a palisade (Hendey, 1964).

Scientific name: *Triceratium robertsonianum* Greville

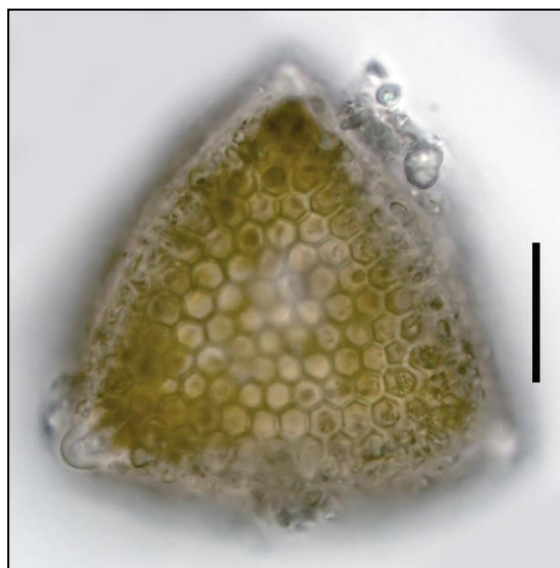
Plate A50: j, k (Annex A)

References:

Hustedt, 1930: p. 803, Fig. 466; Crosby and Wood, 1958: p. 506, Pl. 33: 36; Hendey, 1970: p. 118; Simonsen, 1974: p. 28.

Description:

The strongly siliceous triangular valves have convex sides and a convex valve surface. The angles of the valve are furnished with stout processes. Valve surface strongly areolate, areolae hexagonal, entire over the whole surface. Length of side 80-120 μm (Hendey, 1970).



Dimensions:

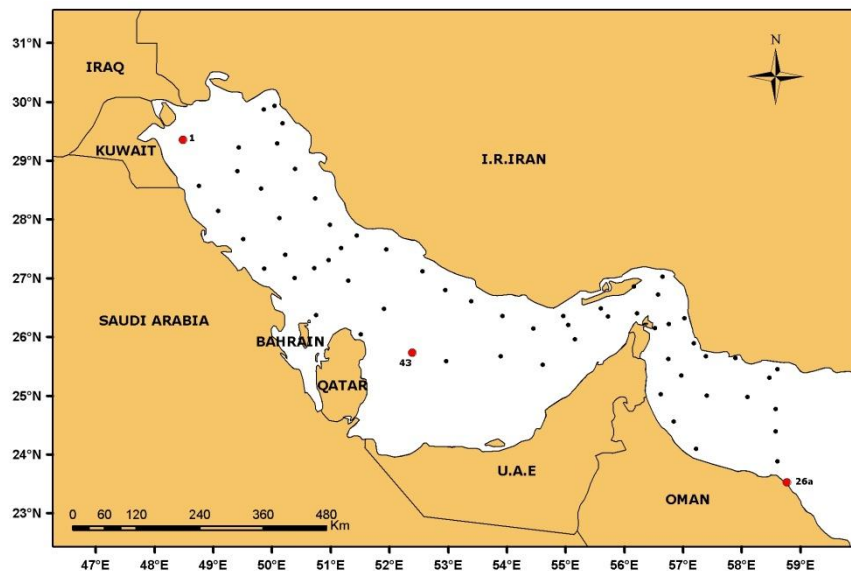
Side length 70-75 µm.

Distribution:

Preliminary benthic species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was present in small numbers at three stations (refer sites map). It has been previously reported from the Indian Ocean (Simonsen, 1974) and from Kuwaiti shore (Hendey, 1970).



Sites of occurrence of *Triceratium robertsianum* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Fragilariineae

Family: Licmophoraceae Kützing

Genus: *Licmophora* Agardh

Cells with wedge-shaped girdle-band side and wedge- or club-shaped valve. Two intercalary bands in resting cells, with a more or less long penetrating septum on the head pole. Valves with transapical punctated striae, seldom with weak transapical ribs and extremely delicately punctated intercalary space. Pseudoraphe usually distinct, often developed as a strong siliceous rib. Chromatophores are numerous small granules or a few larger plates. Auxospore formation, so far as known, consists of one asexual auxospore in one mother cell. Littoral marine species are held to the substrate by a shorter or longer, often branched gelatinous stalk (Cupp, 1943).

Scientific name: *Licmophora abbreviata* Agardh

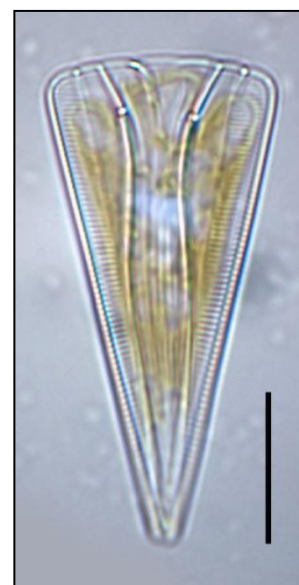
Plate A51: a-c (Annex A)

References:

Cupp, 1943: p. 177, Fig. 127; Witkowski *et al.*, 2000: p. 63, Pl. 20: 3-5.

Description:

Cells in girdle view usually strongly wedge-shaped with moderately rounded upper corners, deeply penetrating septa, and more or less strongly waved intercalary bands. Valves narrow club-shaped, with wide, usually somewhat wedge-shaped rounded head and more acute rounded foot pole. In the lower part slightly concave. Apical axis 40-80 μm long; transapical axis 4-8 μm ; transapical striae fairly strong, on the base, 10-12 in 10 μm , in the upper part of the valve becoming weaker, near the upper (head) pole 13-16 in 10 μm . Pseudoraphe narrow, but distinct (Cupp, 1943).



Dimensions:

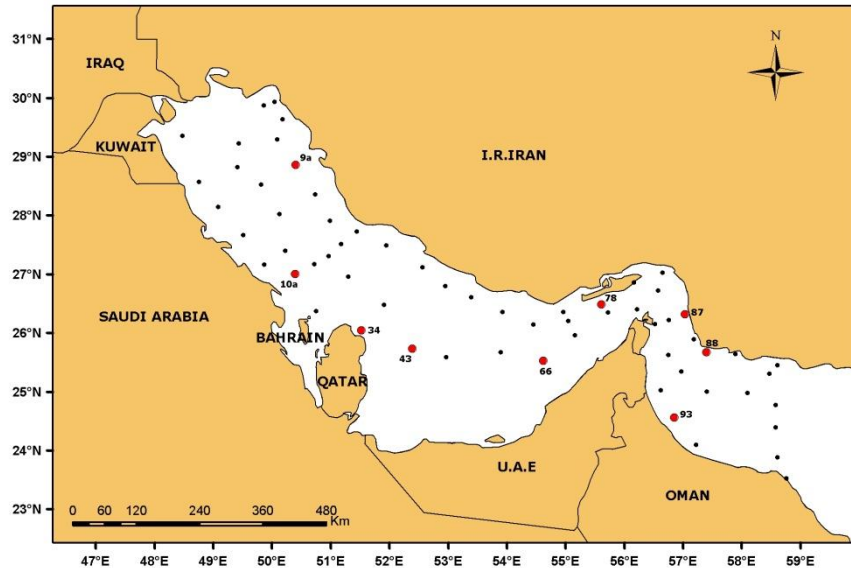
Cells length 65-90 μm ; width 8-13 μm .

Distribution:

Widespread littoral, but often found in plankton collections.

Sites of occurrence in RSA:

In Winter 2006 Cruise, it was present in small numbers at scattered stations (refer sites map).



Sites of occurrence of *Licmophora abbreviata* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Fragilariineae

Family: Fragilariaceae Greville

Genus: *Synedra* Ehrenberg

Frustules elongated, narrow; valve linear, isopolar, lanceolate with rounded or capitate ends. Axial area narrow – some species have a clear transverse central area. Striae parallel, with simple areolate structure in single rows - continuing on to the mantle. Pore field is present at each pole (John, 2000).

Scientific name: *Synedra* sp.

Plate A51: j, k (Annex A)

Description:

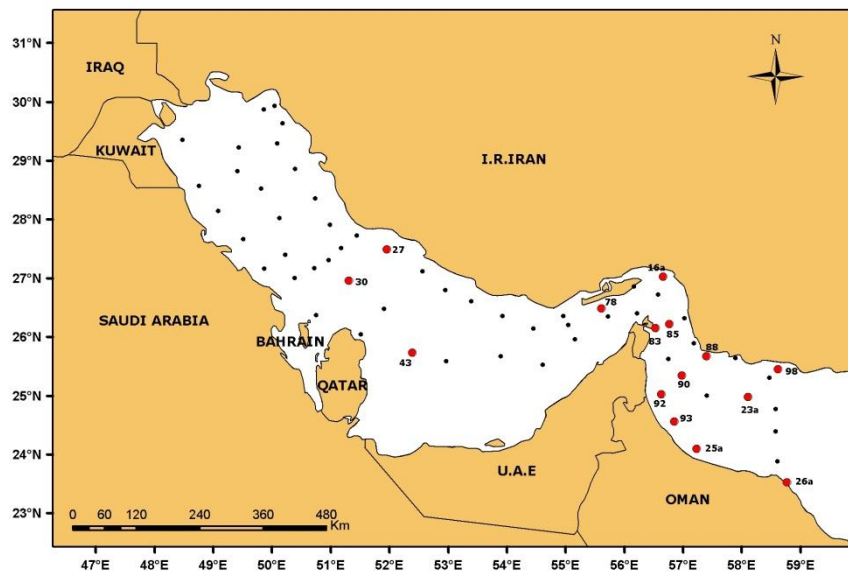
Valve linear with rounded ends; axial area narrow; striae parallel; in single rows.

Dimensions:

Cells length 280-340 μm ; width 9-11 μm .

Sites of occurrence in RSA:

In Winter 2006 Cruise, it was present in small numbers at scattered stations (refer sites map).



Sites of occurrence of *Synedra* sp. in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Fragilariineae

Family: Thalassionemataceae Round in Round *et al.*

Genus: *Thalassionema* Grunow

Cells forming zigzag bands or star-shaped colonies; adjacent cells united to each other by small gelatinous cushions on one cell end, in girdle view, linear. Intercalary bands and septa are absent. Valves linear to narrow lancet-shaped; valves with numerous tiny spines on the margin placed at regular intervals; cell wall otherwise structureless. Chromatophores are more or less numerous small granules; only one species; pelagic, marine (Cupp, 1943).

Scientific name: *Thalassionema nitzschioides* (Grunow) Mereschkowsky

Plate A51: d, e (Annex A)

Synonyms:

Thalassiothrix nitzschioides (Grunow) Grunow; *Synedra nitzschioides* Grunow

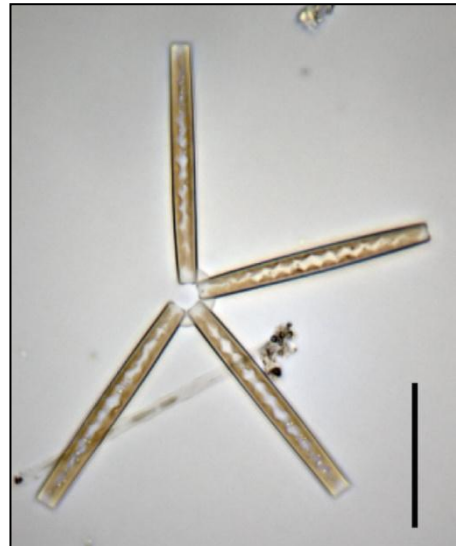
References:

Allen and Cupp, 1935: p. 153, Fig. 96 (as *Thalassiothrix nitzschioides*); Cupp, 1943: p. 182, Fig. 133; Hendey, 1964: p. 165; Hendey, 1970: p. 127; Simonsen, 1974: p. 37; Ricard, 1987: p. 223, Figs. 583-586; Throndsen *et al.*, 2007: p. 186.

Description:

Cells in girdle view narrow linear are, often slightly curved. Valves narrow linear with parallel sides and bluntrounded ends. Length 30-80 μm ; width 2-3.5 μm .

Marginal spines small, 10-12 in 10 μm . Valves otherwise without sculpturing. Cells united into star-shaped colonies or zigzag bands, frequently both types within a colony (Cupp, 1943).



Dimensions:

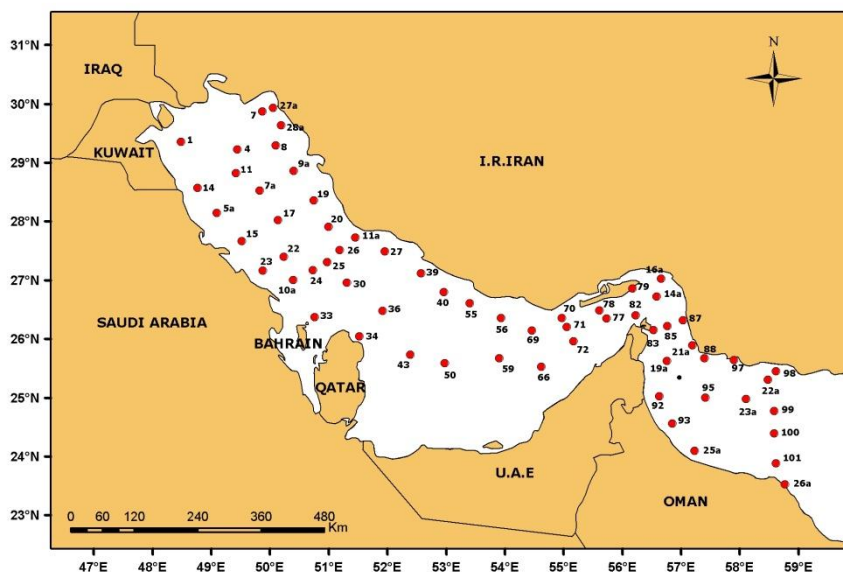
Cells length 35-49 μm ; width 3-4 μm .

Distribution:

Cosmopolitan, predominantly neritic species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred over most of the sampling sites (refer sites map), encountered in 82.7 % of the samples, often in large numbers; maximum abundance (3.1×10^4 cells/l) was associated with Kuwaiti waters in the northwestern part of the inner RSA (St. 1). It has been previously reported from the inner RSA (Simonsen, 1974) and from Kuwaiti shore (Hendey, 1970) and coastal waters (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Thalassionema nitzschioides* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Fragilariineae

Family: Thalassionemataceae Round in Round *et al.*

Genus: *Thalassiothrix* Cleve *et* Grunow

Cells living singly or forming star-shaped colonies, zigzag bands, or bunches, united to one another by a gelatinous cushion on the end of the cell. In girdle view narrow linear. Intercalary bands and septa are absent. In valve view linear or slightly lancet-shaped ends, unlike. Valve borders similar to those of preceding genus, often beset with small spines;

valve surface with short marginal striae or structureless. Chromatophores are more or less numerous small granules. Pelagic marine forms. This genus contains the longest diatoms known at the present time; often present in large masses in the plankton (Cupp, 1943).

Scientific name: *Thalassiothrix frauenfeldii* Grunow

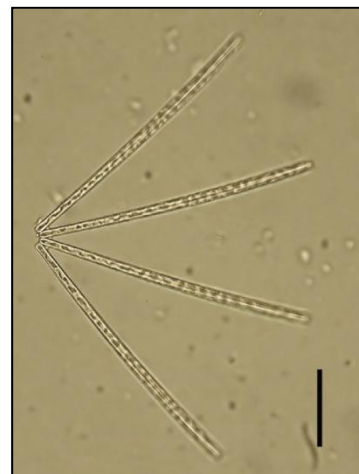
Plate A51: f, g (Annex A)

References:

Pavillard, 1925: p. 59, Fig. 106 A; Allen and Cupp, 1935: p. 153, Fig. 97; Cupp, 1943: p. 185, Fig. 135; Hendey, 1964: p. 165; Simonsen, 1974: p. 37, Pl. 24: 4.

Description:

Cells united into star-shaped colonies or zigzag bands; in girdle view linear. Valves very narrow linear, ends distinct, but only slightly unlike; one end blunt-rounded, near the other end usually widened then decreased to form a wedge-shaped point. Valves 90-210 µm long; 2-4 µm wide. Marginal spines small but regular, 6-9 in 10 µm. Valves are otherwise structureless (Cupp, 1943).



Dimensions:

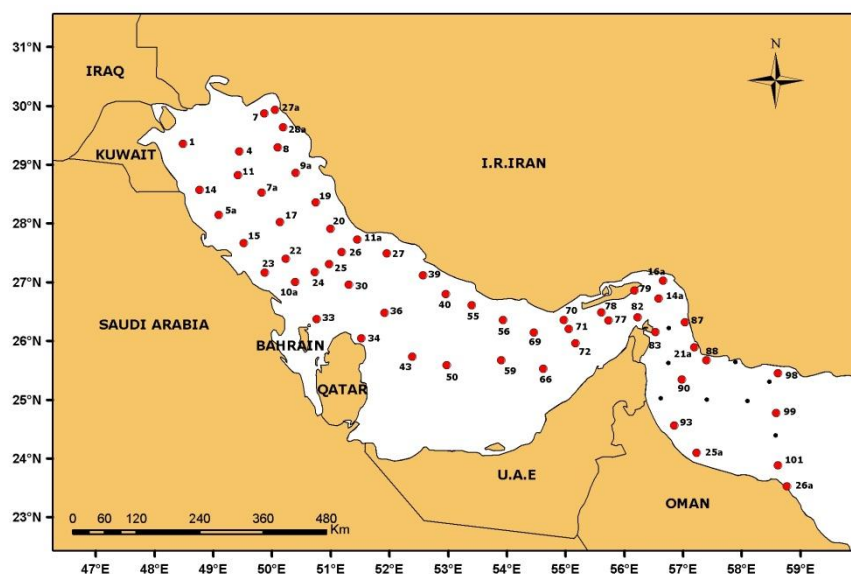
Cells length 110-140 µm; width 3-4 µm.

Distribution:

Oceanic, south temperate species; widespread distribution.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was commonly observed at various sites (refer sites map), often in large numbers; maximum abundance (3.6×10^3 cells/l) was associated with the central part of the inner RSA (St. 43). Species has been previously reported from the inner RSA (Simonsen, 1974) and from Kuwaiti waters (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Thalassiothrix frauenfeldii* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Fragilariineae

Family: Thalassionemataceae Round in Round *et al.*

Genus: *Thalassiothrix* Cleve *et* Grunow

Species: *longissima*

Scientific name: *Thalassiothrix longissima* Cleve *et* Grunow

Plate A51: h, i (Annex A)

References:

Pavillard, 1925: p. 60, Fig. 106 B; Cupp, 1943: p. 184, Fig. 134; Hendey, 1964: p. 165; Simonsen, 1974: p. 38; Throndsen *et al.*, 2007: p. 186.

Description:

Cells four-sided, very long and more or less curved, threadlike, usually living singly; valves very narrow linear, ends slightly narrowed, more so on one end than on the other. Length 1-4 mm, width 3-6 μm ; corners of the valves beset with delicate spines, about 3 in 10 μm in the middle part of the cell, fewer toward the ends or entirely absent. Sometimes the entire cell is without marginal spines. Membrane is with short marginal ribs, 14-16 in 10 μm . Mucilage pore near the ends (Cupp, 1943).

Dimensions:

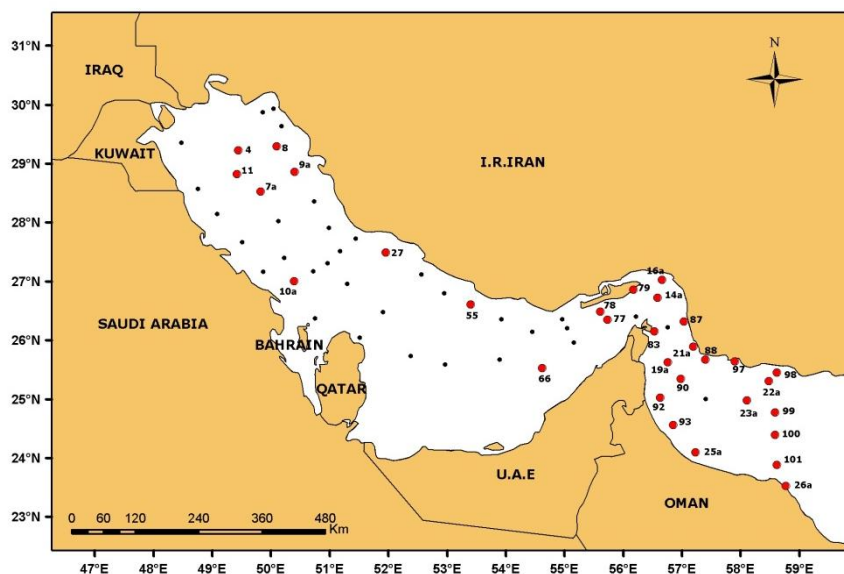
Cells length 740-920 μm ; width 3-4 μm .

Distribution:

Cosmopolitan oceanic species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at different sites (refer sites map), usually in small numbers; maximum abundance (9.9×10^2 cells/l) was associated with the Sea of Oman (St. 26a). It has been previously reported from the inner RSA (Simonsen, 1974) and from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Thalassiothrix longissima* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Naviculaceae Kützinger

Genus: *Caloneis* Cleve

Cells solitary, free; valves linear, linear-lanceolate to lanceolate-rhombic, more or less convex; valve surface striate; striae crossed by one or more longitudinal lines. Chromatophores: usually two (Hendey, 1964).

Scientific name: *Caloneis liber* (Smith) Cleve

Plate A51: l-n (Annex A)

Synonym:

Navicula liber Smith

References:

Hendey, 1970: p. 151; Ricard, 1987: p. 243, Fig. 765; Witkowski *et al.*, 2000: p. 166, Pl. 152: 9.

Description:

Valves elongate to elongate-elliptic with rounded apices, 50-90 μm long, 9-11 μm broad. Raphe slightly undulated, external central endings moderately distant, axial area narrow, central area small, circular. Transapical striae parallel, 18 in 10 μm , midway between raphe and valve margin crossed by longitudinal line (Witkowski *et al.*, 2000).

**Dimensions:**

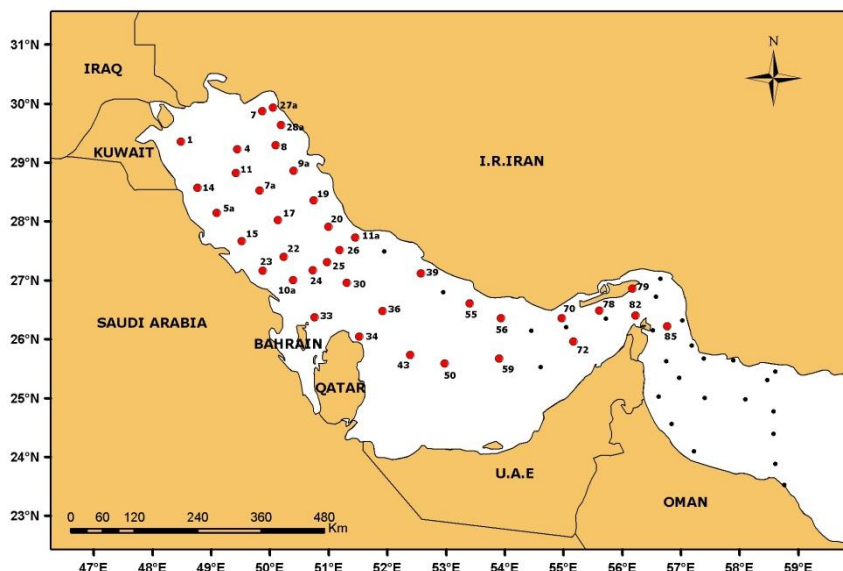
Cells length 75-96 μm ; width 16-18 μm .

Distribution:

Mainly littoral cosmopolitan species, but is occasionally found in the plankton.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at different sites (refer sites map), usually in small numbers; maximum abundance (2.2×10^2 cells/l) was associated with northwestern part of the inner RSA off Saudi Arabia (St. 15). It has been previously reported from Kuwaiti shore (Hendey, 1970).



Sites of occurrence of *Caloneis liber* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Naviculaceae Kützing

Genus: *Diploneis* Ehrenberg

Cells solitary, free; valves elliptical or linear-elliptic, with or without a median constriction; apices rounded or broadly cuneate. Central nodule is prominent, often large, quadrate and strongly formed; central area small, reduced, and produced to form longitudinal extensions usually described as horns, which lie upon either side of the raphe, and enclose it as solid ribs. Beyond the horns are thinner, usually narrow, depressed areas, usually referred to as the furrows. These may be hyaline and structureless, or may contain a row of large puncta, or

may be crossed by faintly transverse costae. Beyond the furrows on each side of the raphe there is, in some species, a more or less lunate area in each segment (that is, above and below the transapical axis) which is usually referred to as the lunula. This may be crossed by costae or alveoli which may or may not bear a single or double row of puncta. These are frequently more strongly developed, close to the valve margin. In some species, transverse costae may be absent. Chromatophores: usually two deeply crenulate bodies that lie along the girdle (Hendey, 1964).

Scientific name: *Diploneis didyma* (Ehrenberg) Cleve

Plate A52: a, b (Annex A)

Synonym:

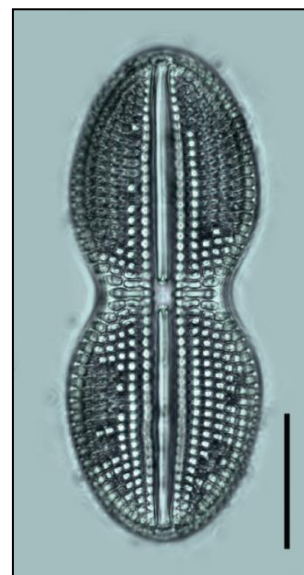
Navicula (Pinnularia) didymus Ehrenberg

References:

Hendey, 1964: p. 226, Pl. XXXII: 12.

Description:

Valves panduriform, slightly constricted in the middle, dividing the valve surface into two tongue-shaped segments. The central nodule is subquadrate or sometimes almost circular, and produced to form two horns, one on either side of the raphe or median line. Valve surface costate, transverse in the middle, but in slightly curving, radiating lines toward the apices and crossed by numerous undulating longitudinal lines; length of valve 50-90 µm; breadth 17-36 µm (Hendey, 1964).



Dimensions:

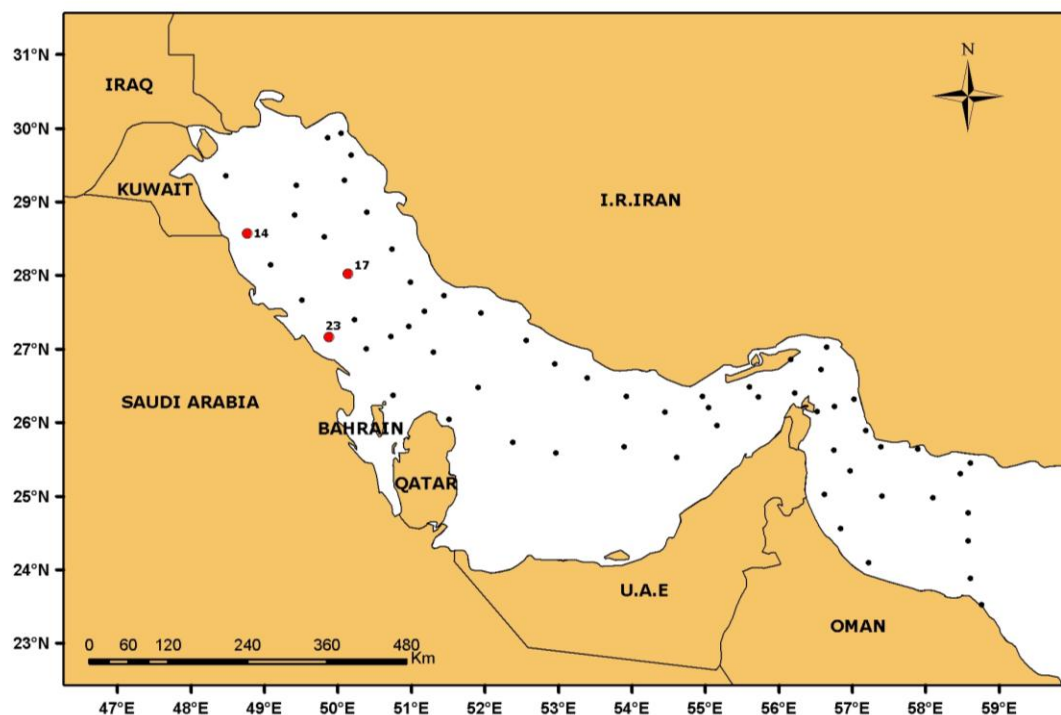
Cells length 60-74 µm; width 25-28 µm.

Distribution:

Mainly, littoral species, but is frequently found in the plankton.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was commonly observed at 3 stations (refer sites map), often in large numbers and also occurred at few stations in Transects 3 and 8; maximum abundance (5×10^3 cells/l) was associated with the northwestern part of the inner RSA off Saudi Arabia (St. 23).



Sites of occurrence of *Diploneis didyma* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Naviculaceae Kützinger

Genus: *Diploneis* Ehrenberg

Species: *weissflogii*

Scientific name: *Diploneis weissflogii* (Schmidt) Cleve

Plate A52: c, d (Annex A)

Synonyms:

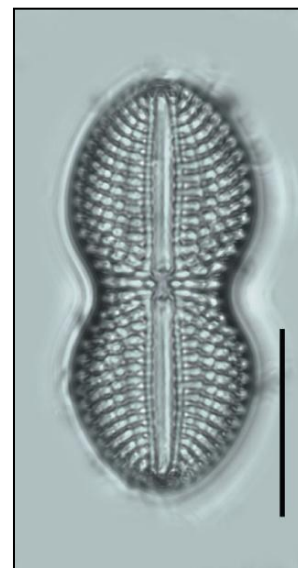
Navicula diversa Greville; *Navicula weissflogii* Schmidt

References:

Allen and Cupp, 1935: p. 155, Fig. 100 (as *Navicula weissflogii*); Hendeby, 1970: p. 141;
Witkowski *et al.*, 2000: p. 197, Pl. 92: 4, 5; 94: 12, 13.

Description:

Valves linear-elliptic in outline with relatively deeply constricted valve margins and broadly rounded apices, 27-110 µm long; 11-35 µm broad (7-25 µm broad in the middle). Central nodule small, apically elongated, raphe sternum furrows close together and parallel, longitudinal canals linear, slightly convex toward the valve margins; transapical striae robust, slightly radiate, 7-8 in 10 µm; crossed by straight or slightly wavy longitudinal ribs (Witkowski *et al.*, 2000).

**Dimensions:**

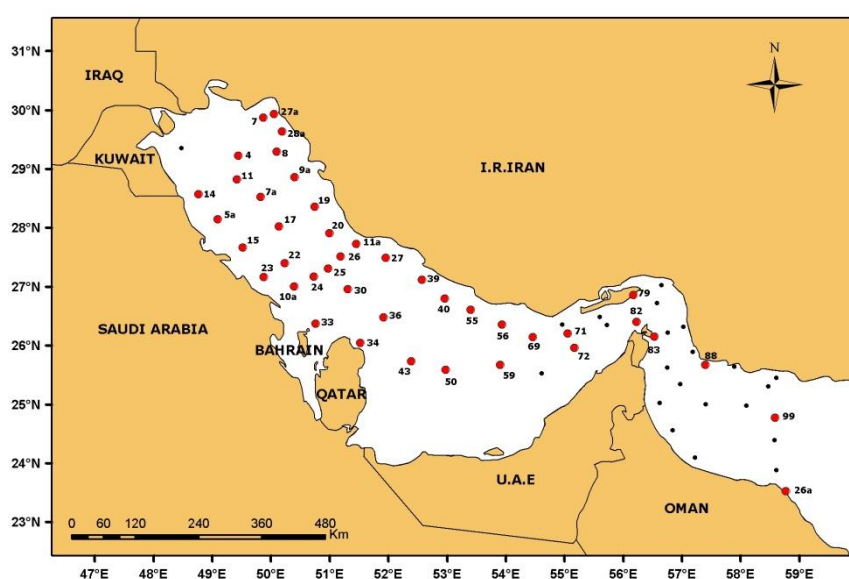
Cells length 35-41 µm; width 17-19 µm.

Distribution:

Mainly littoral species, but is frequently found in the plankton.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at various sites (refer sites map), usually in small numbers; however, it was quite abundant at some localities; maximum abundance (3.4×10^3 cells/l) was associated with the northwestern part of the inner RSA (St. 25). Species has been previously reported from Kuwaiti shore (Hendey, 1970) and coastal waters (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Diploneis weissflogii* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Naviculaceae Kützing

Genus: *Ephemera* Paddock

Species: *planamembranacea*

Scientific name: *Ephemera planamembranacea* (Hendey) Paddock

Plate A52: e-j (Annex A)

Synonym:

Navicula planamembranacea Hendey

References:

Hendey, 1964: p. 188, Fig. 8.

Description:

Cells usually solitary; valves highly vaulted and flattened in transapical plane. Raphe separating the valve face into two unequal parts; central nodule slightly depressed, usually with four stronger and more widely spaced interstriae, reaching valve margin and producing the impression of a pseudo-stauros (Hendey, 1964). Small raphe fins near valve ends and one on each side of the central nodule. Numerous small and rounded chloroplasts. Pervalvar axis 15-30 µm, apical axis 66-90 µm, transapical axis 8-10 µm, transapical striae 28-30 in 10 µm (Hasle and Syvertsen, 1997).



Dimensions:

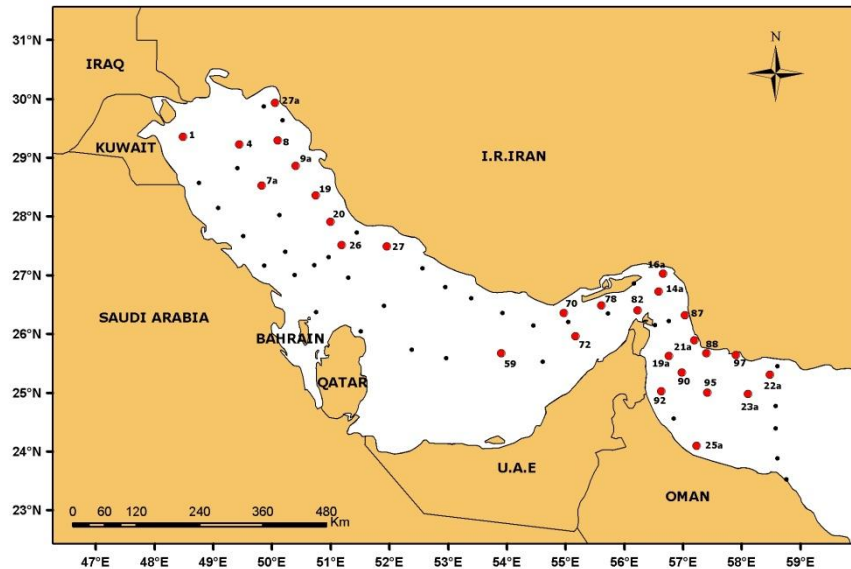
Cells length 47-72 µm; width 35-40 µm.

Distribution:

Species has been previously reported from north Atlantic Ocean.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at various sites (refer sites map), usually in small numbers; however, it was quite abundant at some localities; maximum abundance (1.4×10^3 cells/l) was associated with the Sea of Oman (St. 25a).



Sites of occurrence of *Ephemera planamembranacea* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Naviculaceae Kützing

Genus: *Gyrosigma* Hassall

Valves linear or lanceolate; usually sigmoid; axial area very narrow. Central area small; striae punctate, in transverse and longitudinal rows. Chromatophores two, in long and narrow bands, one on each valve, the margins serrated in marine forms. Pyrenoids are present in all species (Cupp, 1943).

Scientific name: *Gyrosigma balticum* (Ehrenberg) Cleve

Plate A56: g-I (Annex A)

Synonyms:

Navicula baltica Ehrenberg; *Pleurosigma balticum* (Ehrenberg) Smith

Reference:

Hendey, 1964.

Description:

Valves linear, sides more or less parallel in the middle, sigmoid toward the ends, with obtuse apices. Apical nodules small. Axial area very narrow, raphe sigmoid, central, having the same sigmoid curvature as the valve margin, particularly toward the ends, but often curved or flexuose as it approaches the central nodule. Central area is small, elliptical, sometimes slightly oblique. Valve surface striate; striae finely punctuate, and arranged in transverse and longitudinal lines. Transverse and longitudinal striae equidistant, about 11-13 in 10 μm ; striae distinct; girdle narrow, plain. Chromatophores two dentate plates lying under the valves. Size very variable, especially in length; 236-500 μm , mostly between 280-330 μm ; breadth 28-32 μm (Hendey, 1964).



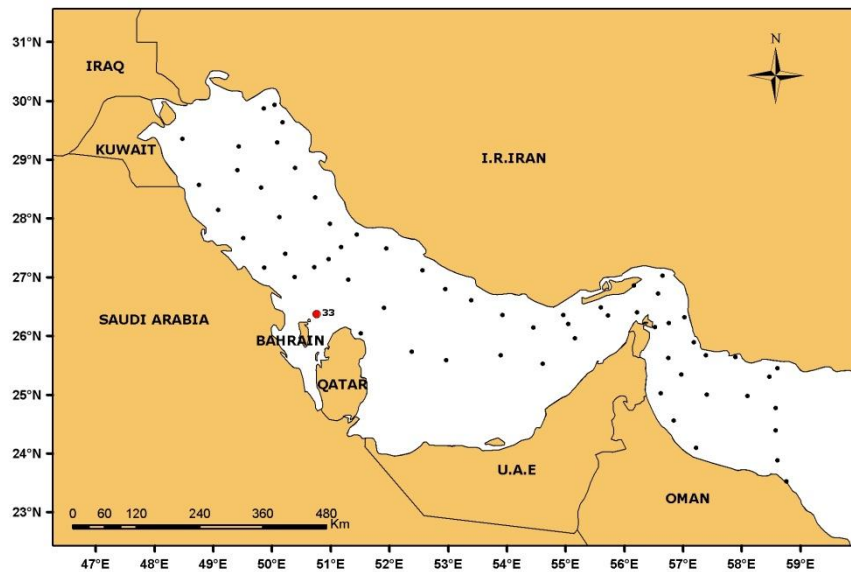
Dimensions:

Cells length 240-300 μm ; width 30-33 μm .

Distribution:

Mainly littoral species, but is frequently found in the plankton.

Sites of occurrence in RSA: In Winter 2006 Cruise, it was present in small numbers at one station (refer site map).



Site of occurrence of *Gyrosigma balticum* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Naviculaceae Kützinger

Genus: *Haslea* Simonsen

The cells have a thin membrane, outline spindle-shaped with acute ends and convex sides, rarely parallel in the middle. Raphe straight, with small, approximate central pores and little developed apical pores; axial and central areas, inconspicuous. The structure of the valve consists of transapical, parallel, and straight apical rows of areolae. The areolae are on the outside covered by a thin, siliceous membrane which has a slit of apical direction in each areola (Simonsen, 1974).

Scientific name: *Haslea* sp. aff. *Haslea balearica*

Plate A53: a-d (Annex A)

Reference:

Witkowski *et al.*, 2000: p. 739, Pl. 148: 1, 1a.

Description:

Valves delicate, narrowly-lanceolate with acute apices. Raphe straight; transapical striae in LM barely resolvable.

Dimensions:

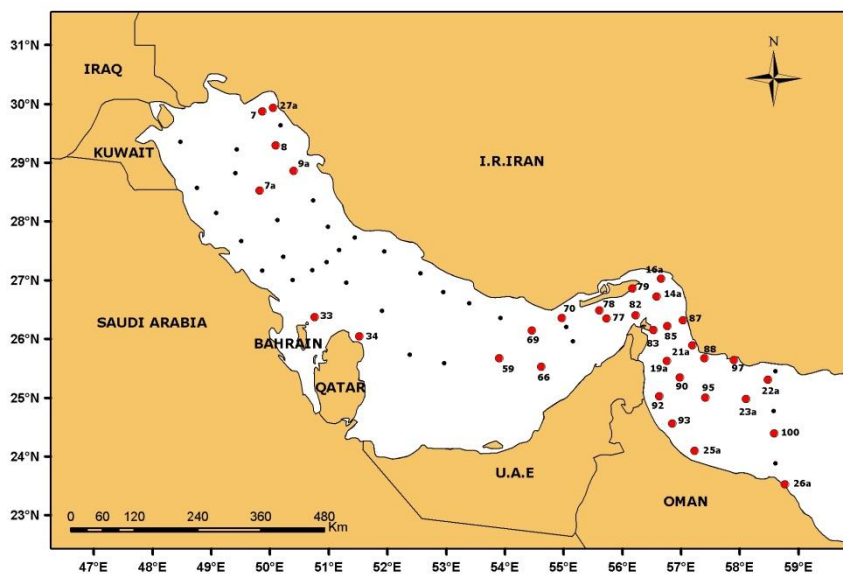
Cells length 120-135 μm ; width 12-15 μm .

Taxonomical Remarks:

Species is similar with illustrations of Witkowski *et al.* (2000) for *Haslea* spec. cf. *balearica* from Mediterranean waters (p. 739, Pl. 148: 1, 1a).

**Sites of occurrence in RSA:**

In Winter 2006 Cruise, this species was observed at various stations (refer sites map), although never in large numbers; maximum abundance (3.6×10^2 cells/l) was associated with the Sea of Oman (St. 25a).



Sites of occurrence of *Haslea* sp. in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Naviculaceae Kützing

Genus: *Lyrella* Snoeijs

Species: *abrupta*

Scientific name: *Lyrella abrupta* (Gregory) Mann *ex* Round *et al.*

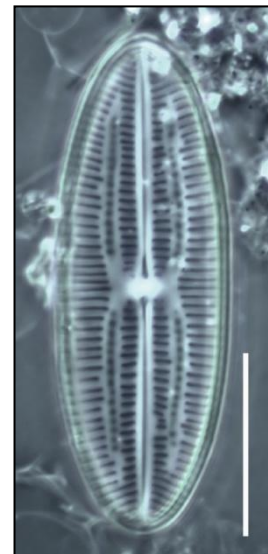
Plate A51: o (Annex A)

Synonyms:

Navicula abrupta (Gregory) Donkin; *Navicula lyra* var. *abrupta* Gregory

References:

Hendey, 1964: p. 210, Pl. XXXIII: 12 (as *Navicula abrupta*);
Hendey, 1970: p. 135 (as *Navicula abrupta*); Simonsen, 1974: p. 41
(as *Navicula abrupta*).



Description:

Valves elliptic-lanceolate, with rounded apices; axial area straight, wider at the middle distance, constricted near the central nodule. Valve surface furnished with striae that are interrupted by the lateral extensions of the central area. These lateral extensions are not truly lyrate, and converge to terminate well before the apices of the valve are reached. Striae punctate, slightly radiate. Length of valve 38-60 μm , breadth 16-28 μm (Hendey, 1964).

Dimensions:

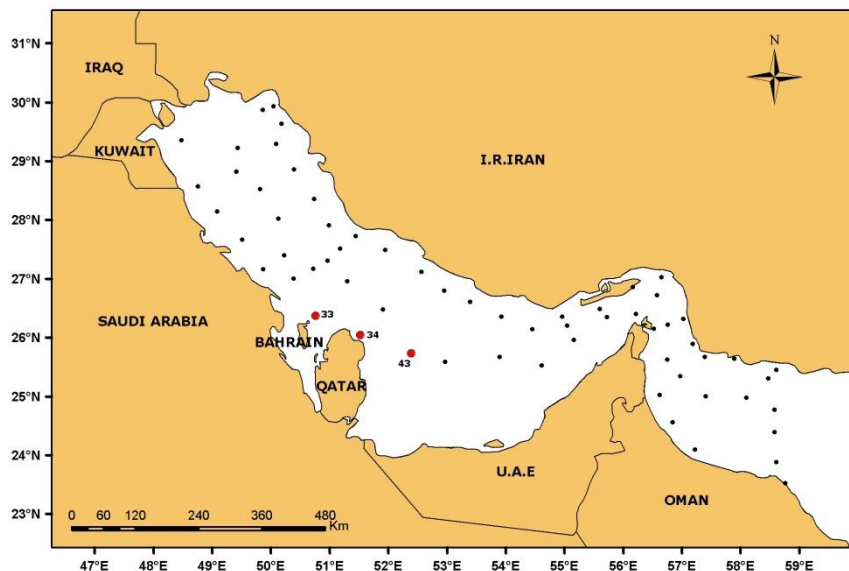
Cells length 52 μm ; width 18 μm .

Distribution:

Common in littoral zone and widely distributed species; it occasionally is reported in plankton.

Sites of occurrence in RSA:

In Winter 2006 Cruise, it was present in very small numbers at three stations (Stations 33, 34, and 43) in the central part of the inner RSA (refer sites map). Species has been previously reported (as *Navicula abrupta*) from the Indian Ocean (Simonsen, 1974) and from Kuwaiti shore (Hendey, 1970) and waters (Al-Kandari *et al.*, 2009 – as *Lyrella cf. abrupta*).



Sites of occurrence of *Lyrella abrupta* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Naviculaceae Kützing

Genus: *Mastogloia* Thwaites

Cells single with two plastids – each placed toward the pole. Valves lanceolate, elliptic, rostrate or capitate. Striae of single or two rows of areolae in some species, interrupted by a lyrate hyaline area. Central raphe endings, expanded, and terminal fissures, hooked. The girdle band (valvocopula) is close to the valve with chambers (John, 2000).

Scientific name: *Mastogloia* sp.

Plate A51: q (Annex A)

Description:

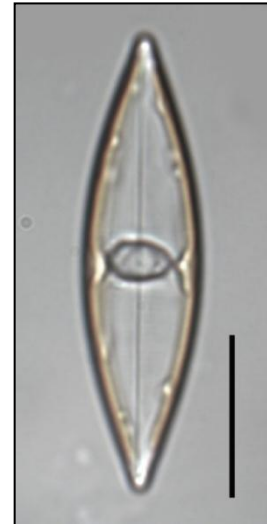
Valves linear-lanceolate, with weakly convex sides and acute apices; valve surface finely striate. Raphe straight.

Dimensions:

Cells length 45-52 μm ; width 14-15 μm .

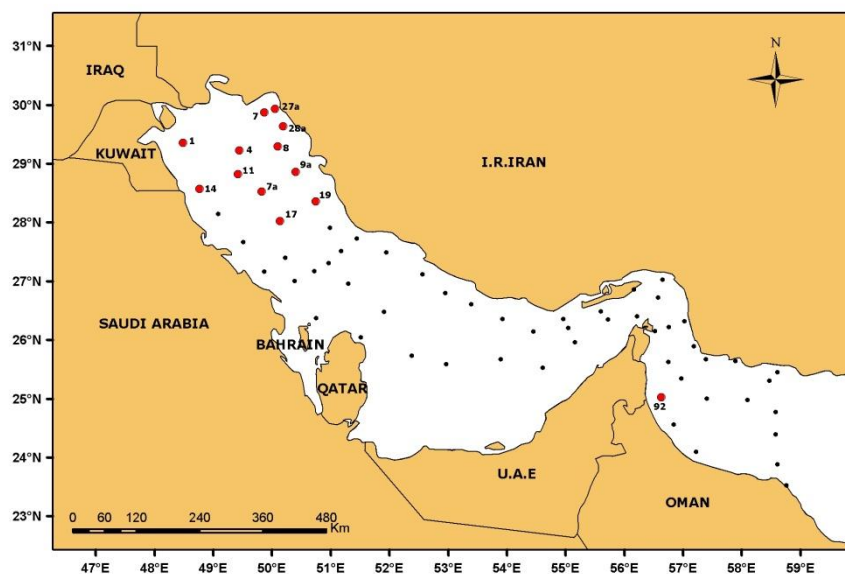
Distribution:

Species of this genus are commonly observed in littoral zone; it is occasionally reported in plankton.



Sites of occurrence in RSA:

In Winter 2006 Cruise, it was present in small numbers at scattered stations (refer sites map).



Sites of occurrence of *Mastogloia* sp. in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Naviculaceae Kützing

Genus: *Meuniera* P.C. Silva

Species: *membranacea*

Scientific name: *Meuniera membranacea* (Cleve) P.C. Silva

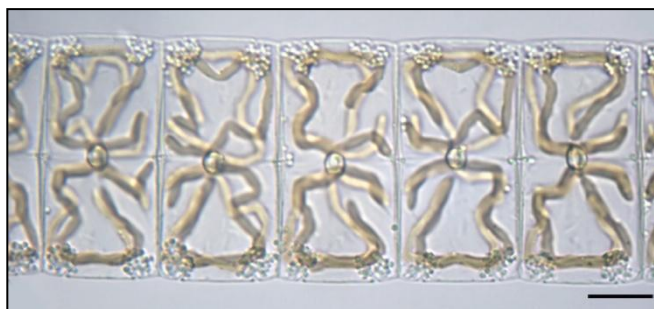
Plate A54: a-e (Annex A)

Synonyms:

Navicula membranacea Cleve;

Stauropsis membranacea (Cleve)

Meunier; *Stauroneis membranacea*
(Cleve) Hustedt.



References:

Pavillard, 1925: p. 61, Fig. 109 (as *Navicula membranacea*); Cupp, 1943: p. 193, Fig. 142 (as *Navicula membranacea*); Hendey, 1964: p. 221, Pl. XXI: 3 (as *Stauroneis membranacea*); Simonsen, 1974: p. 40 (as *Stauroneis membranacea*); Throndsen *et al.*, 2007: p. 188.

Description:

Cells delicate, thin-walled united into short, straight chains; 30-50 μm wide. In girdle view rectangular; valves flat or slightly concave in the center, with a thickening in the middle at right angles to the raphe. In valve view, cells are narrow elliptical and acute. Girdle zone striated; no structure is visible. Central nodule dilated into a narrow stauros that reaches to the margin. Notches at point of union of valve mantle and girdle. Chromatophores two, drawn out like a ribbon. Several pyrenoids are present (Cupp, 1943).

Dimensions:

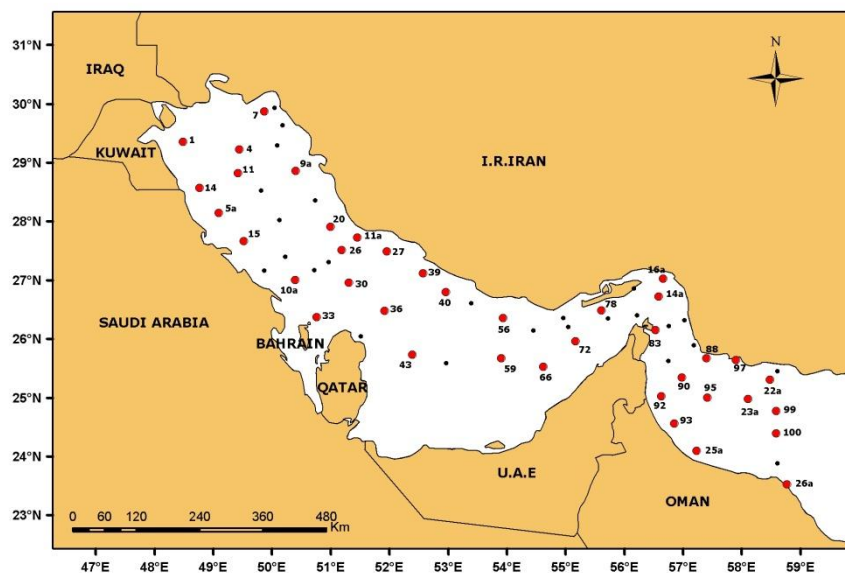
Cells length 60-75 μm ; width 38-46 μm .

Distribution:

Neritic, truly planktonic species of wide distribution.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at various sites (refer sites map), often in large numbers; maximum abundance (3.4×10^3 cells/l) was associated with the Iranian coast in the central part of the inner RSA (St. 27). It has been previously reported (as *Stauroneis membranacea*) from the inner RSA (Simonsen, 1974) and from Kuwaiti waters (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Meuniera membranacea* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Naviculaceae Kützinger

Genus: *Petroneis* Stickle *et Mann ex Round et al.*

Scientific name: *Petroneis granulata* (Bailey) Mann *ex Round et al.*

Plate A51: p (Annex A)

Synonyms:

Navicula granulata Bailey; *Navicula polysticta* Greville; *Navicula brasiliensis* Grunow; *Navicula baileyana* Schmidt; *Navicula javanesis* Leudiger-Fortmorel.

References:

Hendey, 1964: p. 208, Pl. XXXI: 6 (as *Navicula granulata*); Hendey, 1970: p. 133 (as *Navicula granulata*); Ricard, 1987: p. 239, Fig. 726 (as *Navicula granulata*); Witkowski *et al.*, 2000: p. 327, Pl. 97: 1, 2.

Description:

Valves elliptic-lanceolate with obtusely rounded rarely slightly rostrate apices, 40-160 μm long, 22-55 μm broad. Raphe straight, extremely central endings expanded, apical endings hooked to one side, axial area narrow, between valve center and apices slightly widened; central area small, irregularly circular to transverse expanded. Transapical striae coarsely punctate; radiate throughout, 8-12 in 10 μm ; puncta along the valve margin, distinctly more dense than in the middle (Witkowski *et al.*, 2000).

**Dimensions:**

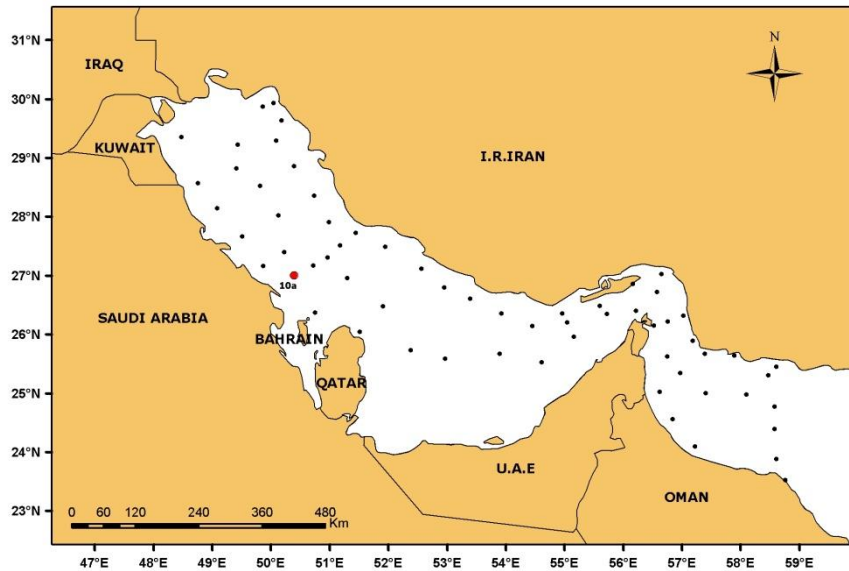
Cells length 104 μm ; width 35 μm ; transapical striae 11 in 10 μm .

Distribution:

Mainly littoral species, but is frequently found in the plankton.

Sites of occurrence in RSA:

In Winter 2006 Cruise, it was found in small numbers at one locality (St. 10a) in the northwestern part of the inner RSA (refer site map). Species has been previously reported (as *Navicula granulata*) from Kuwaiti shore (Hendey, 1970).



Site of occurrence of *Petroneis granulata* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Naviculaceae Kützing

Genus: *Plagiotropis* Pfitzer emend Paddock

Valves similar to those of *Navicula*, but very convex. Lanceolate, acute, usually with a wing or longitudinal band on one or both sides. Median line straight, not sigmoid, on a central or excentric keel; raphe at edge of keel. Axial area is not evident. Central area small, sometimes transverse. Striae transverse and longitudinal, punctuate; girdle zone simple. Chromatophores are either two or four plates, serrated or indented. Pyrenoids are present. Chromatophores on the girdle band as in most naviculoid diatoms (Cupp, 1943).

Scientific name: *Plagiotropis lepidoptera* (Gregory) Kuntze

Plate A54: i, j (Annex A)

Synonyms:

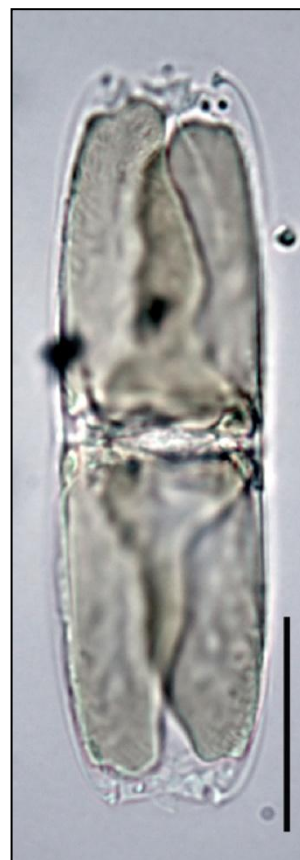
Tropidoneis lepidoptera (Gregory) Cleve; *Amphiprora lepidoptera* Gregory

References:

Cupp, 1943: p. 197, Fig. 149 (as *Tropidoneis lepidoptera*);
Hendey, 1964: p. 256, Pl. XXXVI: 2, 4 (as *Tropidoneis lepidoptera*);
Hendey, 1970: p. 149 (as *Tropidoneis lepidoptera*);
Ricard, 1987: p. 253, Figs. 843-851; Witkowski *et al.*, 2000: p. 338, Pl. 174: 1, 2.

Description:

Cells rectangular, linear-oblong, constricted in the middle. Valves lanceolate, acute or apiculate; central area small or transversely lanceolate. Wing is unilateral, projecting above the central nodule. Striae transverse; length of valves 200-350 μm (Cupp, 1943).

**Dimensions:**

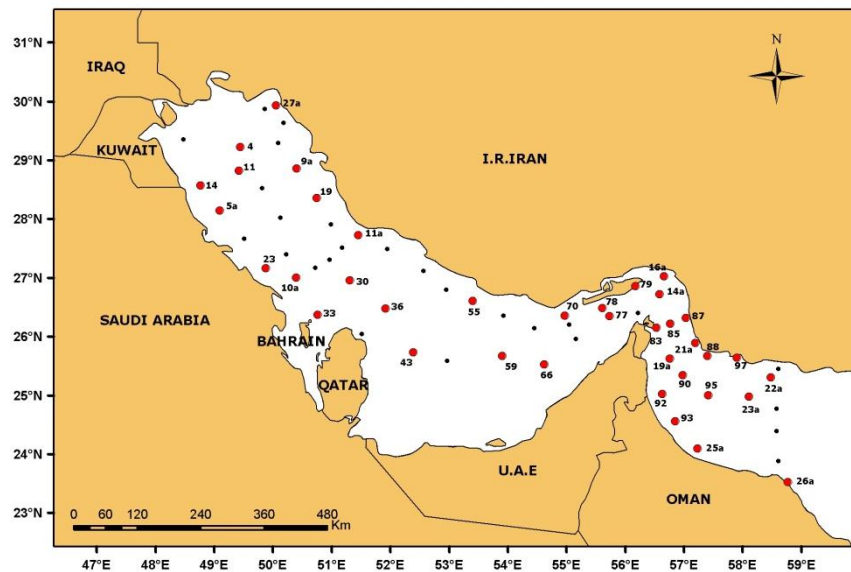
Cells length 180-220 μm ; width 30-32 μm ; transapical striae 20-21 in 10 μm .

Distribution:

Littoral species, but reported occasionally in the plankton.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at various sites (refer sites map), although never in large numbers; maximum abundance (4.3×10^2 cells/l) was associated with the Strait of Hormuz (St. 14a). It has been previously reported (as *Tropidoneis lepidoptera*) from Kuwaiti shore (Hendey, 1970) and coastal waters (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Plagiotropis lepidoptera* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Naviculaceae Kützing

Genus: *Plagiotropis* Pfitzer emend Paddock

Scientific name: *Plagiotropis* sp.

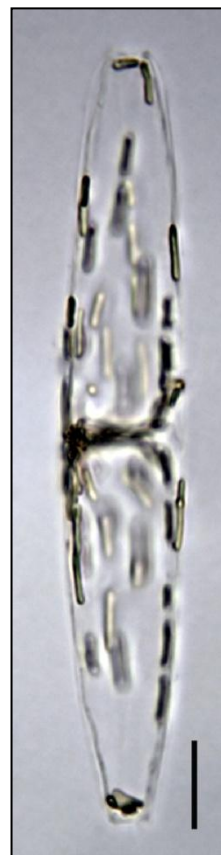
Plate A54: f-h (Annex A)

Description:

Cells linear-oblong, convex in the middle; valves lanceolate, apiculate, with a narrow wings on both sides.

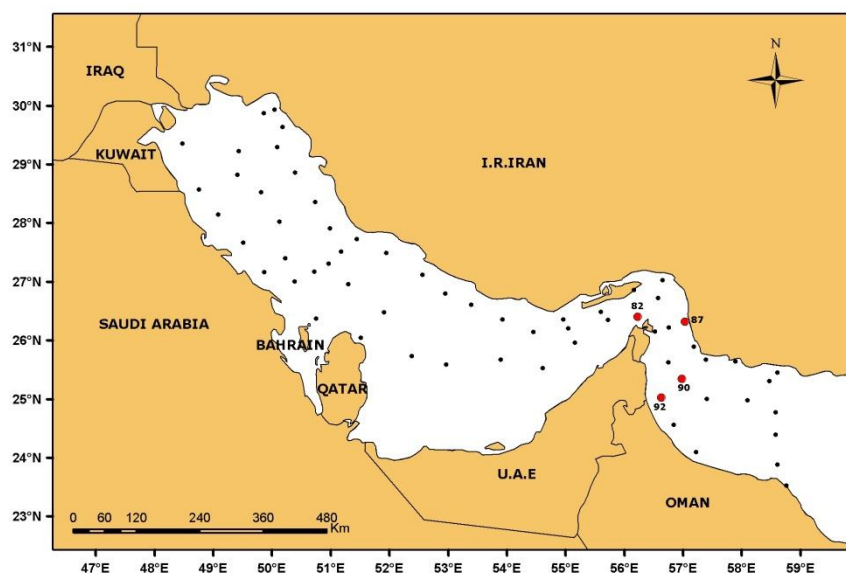
Dimensions:

Cells length 270-300 µm; width 50-55 µm.



Sites of occurrence in RSA:

This species occurred at few stations (refer sites map), usually in small numbers; maximum abundance (1.3×10^2 cells/l) was associated with the Sea of Oman (St. 92).



Sites of occurrence of *Plagiotropis* sp. in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Naviculaceae Kützinger

Genus: *Pleurosigma* Smith

Valves linear to lanceolate, usually sigmoid. Raphe usually sigmoid, central or excentric; striae finely punctate in oblique and transverse lines. Central nodule is usually small and rounded. Cells narrow in girdle view, with narrow connective zone, sometimes twisted or arcuate, or constricted in the middle. Chromatophores usually two bands, one on each valve. Each band is lobed or indented and sometimes differs in opposite valves. Numerous pyrenoids are present in most forms. Littoral or bottom species, are often occurring in the plankton (Cupp, 1943).

Scientific name: *Pleurosigma diverse-striatum* Meister

Plate A55: a-c (Annex A)

Reference:

Hendey, 1970: p. 152, Pl. 6: 62.

Description:

Valve lanceolate, gently sigmoid, with acute apices. Median line more sigmoid than the valve, excentric. Transverse and oblique striae equidistant.

Dimensions:

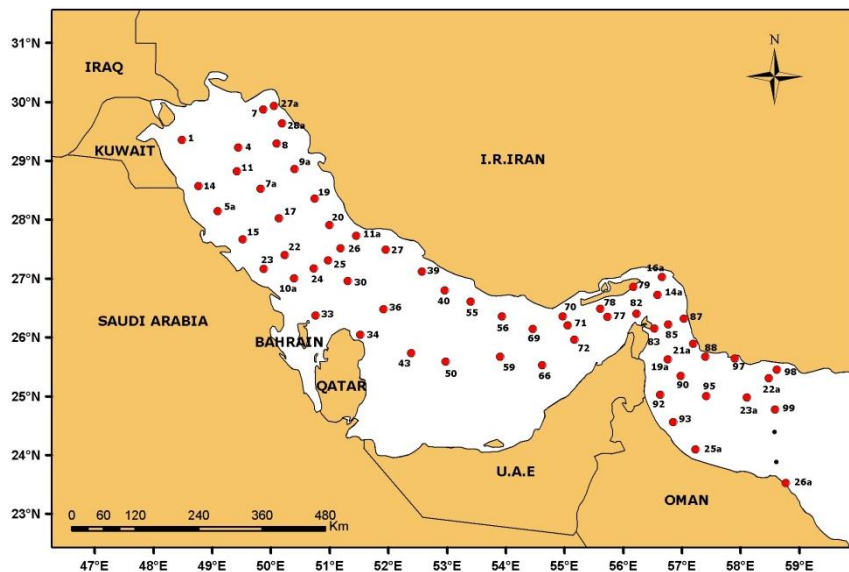
Cells length 98-120 µm; width 20-23 µm.

Distribution:

Mainly littoral species, but is frequently found in the plankton.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at most of the sites (refer sites map), encountered in 83.8 % of the samples, often in large numbers; maximum abundance (3.7×10^3 cells/l) was associated with the Iranian coast in the central part of the inner RSA (St. 11a). Species has been previously reported from Kuwaiti shore (Hendey, 1970) and coastal waters (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Pleurosigma diverse-striatum* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Naviculaceae Kützing

Genus: *Pleurosigma* Smith

Species: *naviculaceum*

Scientific name: *Pleurosigma naviculaceum* de Brébisson

Plate A55: d, e (Annex A)

References:

Allen and Cupp, 1935: p. 156, Fig. 103; Hendey, 1964: p. 243; Simonsen, 1974: p. 46.

Description:

Valves broadly lanceolate, with a slight sigmoid flexure toward the apices; apices acute; polar nodules very small. Raphe is moderately sigmoid, more so than the valve margin; valve surface striate, striae transverse, 18-20 in 10 μm , and oblique 16-18 in 10 μm . The oblique striae are more distant near the center than at the ends, but the terminal striae are at a more acute angle. Length of valve 80-100 μm , breadth 15-20 μm (Hendey, 1964).



Dimensions:

Cells length 70-85 μm ; width 15-18 μm .

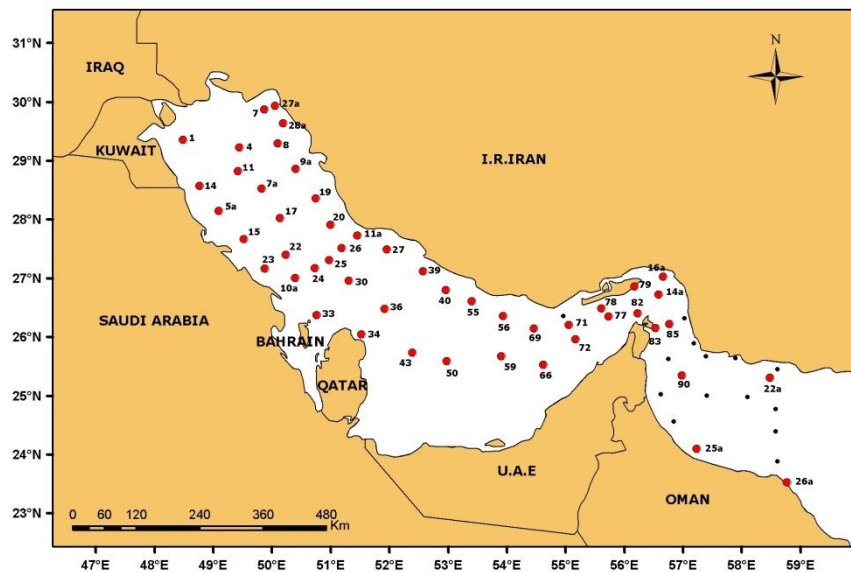
Distribution:

Mainly littoral species, but is frequently found in the plankton.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was commonly observed at various sites (refer sites map), often in large numbers; maximum abundance (3.3×10^3 cells/l) was associated with the

northwestern part of the inner RSA off Saudi Arabia (St. 23). It has been previously reported from the inner RSA (Simonsen, 1974).



Sites of occurrence of *Pleurosigma naviculaceum* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Naviculaceae Kützinger

Genus: *Pleurosigma* Smith

Species: cf. *planctonicum*

Scientific name: *Pleurosigma* cf. *planctonicum* Simonsen

Plate A56: a-c (Annex A)

Reference:

Simonsen, 1974: p. 46, Pl. 30 a-d.

Description:

Valves lanceolate, slightly sigmoid near the ends, with flat valves and very acute, protracted ends, about 300-600 μm long, 40-75 μm wide. Raphe straight, before the ends sigmoid, central in the middle, eccentric toward the ends, central pores very approximate. Axial area very narrow, central area absent. Oblique striae about 30 in 10 μm , crossing each other at an angle of about 60° . Transapical striae always perpendicular to the raphe, about 28-30 in 10 μm in the middle, somewhat wider (ca. 27) near the ends; the striation is hardly visible (Simonsen, 1974).

Dimensions:

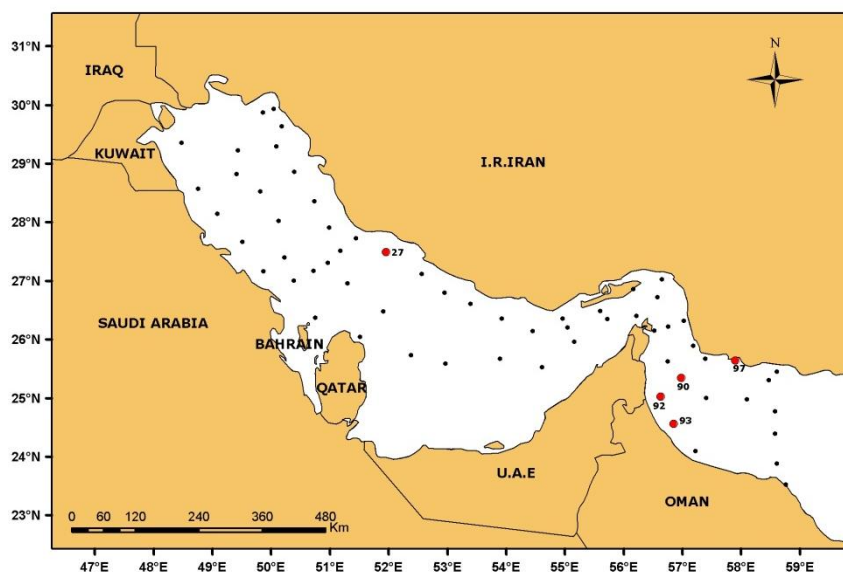
Cells length 300-360 μm ; width 38-44 μm .

Distribution:

Mainly littoral species, but is frequently found in the plankton.

Sites of occurrence in RSA:

In Winter 2006 Cruise, it was present in small numbers at scattered stations (refer sites map). Species has been previously reported from the Indian Ocean and the inner RSA (Simonsen, 1974).



Sites of occurrence of *Pleurosigma* cf. *planctonicum* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Naviculaceae Kützing

Genus: *Pleurosigma* Smith

Species: *strigosum*

Scientific name: *Pleurosigma strigosum* Smith

Plate A55: f-i (Annex A)

Synonym:

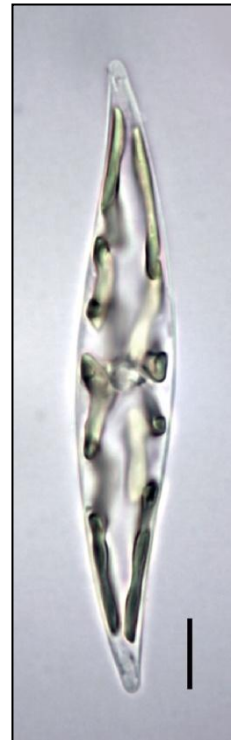
Pleurosigma angulatum v. *strigosa* Van Heurck

Reference:

Hendey, 1964: p. 246, Pl. XXXVI: 7.

Description:

Valves lanceolate, slightly sigmoid, with subobtuse apices. Raphe sigmoid, somewhat eccentric toward the ends; central area small, subcircular. Valve surface striate; striae oblique and transverse. Oblique striae are crossing each other at an angle of about 60°. Striae equidistant, 18-22 in 10 µm. Chromatophores two large plates lying against the valves. Length of valve 164-300 µm, breadth 32-36 µm (Hendey, 1964).



Dimensions:

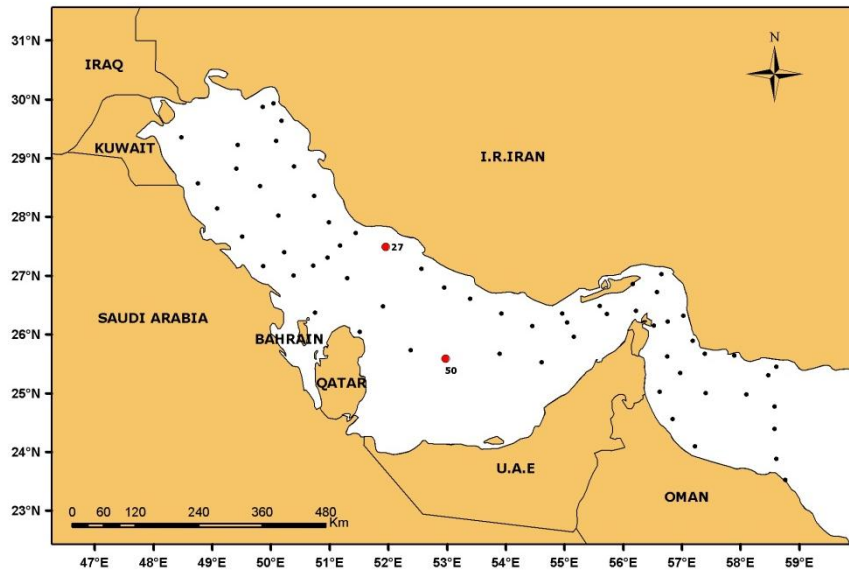
Cells length 120-140 µm; width 28-33 µm.

Distribution:

Mainly littoral species, but is frequently found in the plankton.

Sites of occurrence in RSA:

In Winter 2006 Cruise, it was present in small numbers at two stations (refer sites map).



Sites of occurrence of *Pleurosigma strigosum* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Naviculaceae Kützing

Genus: *Trachyneis* Cleve

Cells solitary, free; valves lanceolate, elliptic-lanceolate to elliptical. Axial area narrow, raphe straight, central area dilated to form an extending stauros which may or may not reach the valve margin. Valve surface areolate, complex, with an outer lamina bearing fine perforations superimposed upon an inner loculate layer. Alveoli oblique, radiate. Girdle is composed of a plan unstriated bands. Chromatophores: two elongated plates, lying along the girdle (Hendey, 1964).

Scientific name: *Trachyneis antillarum* (Cleve et Grunow) Cleve

Plate a57: a-d (Annex A)

Synonym:

Alloioneis antillarum Cleve et Grunow

References:

Hendey, 1970: p. 149, Pl. 4: 44; Simonsen, 1974: p. 43.

Description:

Valve linear-lanceolate with obtuse apices. Raphe eccentric, axial area broad, irregularly linear and unilateral. Central area rounded, unilateral, developed as a rounded area on the narrow side opposite the central nodule. Valve surface coarsely alveolate. Alveoli in longitudinal flexuose or irregular oblique rows. Length 100-120 μm , breadth 29 μm (Hendey, 1970).

Dimensions:

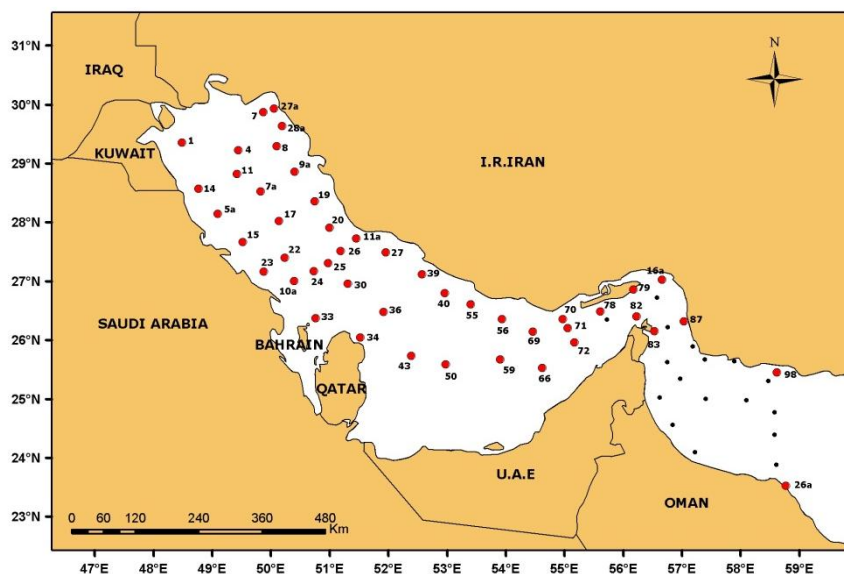
Cells length 76-110 μm ; width 20-27 μm .

Distribution:

Mainly littoral tropical species, but is frequently found in the plankton.

**Sites of occurrence in RSA:**

In Winter 2006 Cruise, this species was commonly observed at various sites (refer sites map), often in large numbers; maximum abundance (1.1×10^3 cells/l) was associated with the northwestern part of the inner RSA off Saudi Arabia (St. 23). It has been previously reported from the inner RSA (Simonsen, 1974) and from Kuwaiti shore (Hendey, 1970) and coastal waters (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Trachyneis antillarum* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Naviculaceae Kützing

Genus: *Trachyneis* Cleve

Species: *debyi*

Scientific name: *Trachyneis debyi* (Leudiger-Fortmorel) Cleve

Plate A57: e-i (Annex A)

Synonyms:

Alloineis debyi Leudiger-Fortmorel; *Trachyneis debyi* var. *osculifera* Cleve;
non *Trachyneis debyi* sensu Cleve, 1894

References:

Hendey, 1970: p. 149; Simonsen, 1974: p. 43, Pl. 27, 28: 1.

Description:

Valves lanceolate; axial area narrow; raphe straight; central area rounded, not reaching the valve margin. Valve surface areolate, complex. Alveoli oblique, radiate. Chromatophores: two elongated plates, lying along the girdle.

Dimensions:

Cells length 180-210 µm; width 22-25 µm.

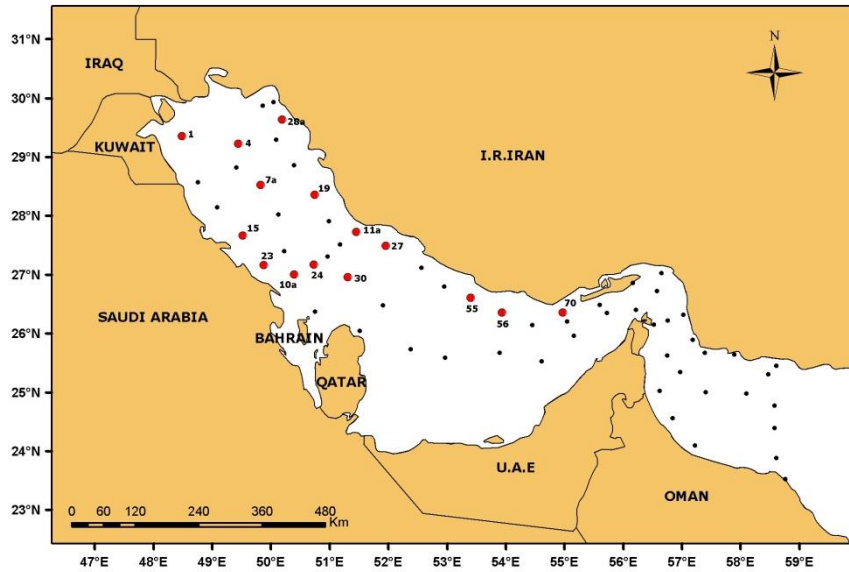
Distribution:

Mainly littoral tropical/subtropical species, but is frequently found in the plankton.

Sites of occurrence in RSA:

In Winter 2006 Cruise, it was present in small numbers at scattered stations only in the inner RSA (refer sites map). It has been previously reported from the inner RSA (Simonsen, 1974) and from Kuwaiti shore (Hendey, 1970).





Sites of occurrence of *Trachyneis debyi* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Catenulaceae Mereschowsky

Genus: *Amphora* Ehrenberg

Cells solitary, generally free-floating, or in tough mucous film adhering to a substratum. A girdle view shows elliptical with truncated flattened ends. Frustules asymmetric, shaped like a third of an orange. Valves not parallel with each other, but with surfaces in planes at an angle one with another. Valves curved or sublunate, and in the complete frustule, the ventral margins lie parallel and close to each other, with the raphes of the two valves in the same focal plane, while the dorsal margins are separated by a very deep development of the girdle. Raphe usually eccentric, lying closer to the ventral margin; valve surface striate, usually punctate; ventral side narrower, and often without structure or with less structure than on the arcuate dorsal side; girdle usually complex, composed of numerous bands that may or may not bear puncta. Chromatophores: very variable, and may be from one to four irregularly shaped plates, or as numerous granules (Hendey, 1964).

Scientific name: *Amphora lineolata* Gregory

Plate A58: d, e (Annex A)

Reference:

Witkowski *et al.*, 2000: p. 142, Pl. 167: 17-19.

Description:

Frustules in girdle view rectangular-elliptic, usually with slightly convex margins, 30-60 μm long; 13-28 μm broad. Valves semilanceolate; ventral margins almost straight with not produced, acutely rounded apices, 3.5-7 μm broad. Raphe biarcuate; external central endings bent toward dorsal side; axial area very narrow; central area absent or very small. Transapical Ostriae on the dorsal and ventral side in the middle radiate, toward apices convergent, 20-25 in 10 μm (Witkowski *et al.*, 2000).

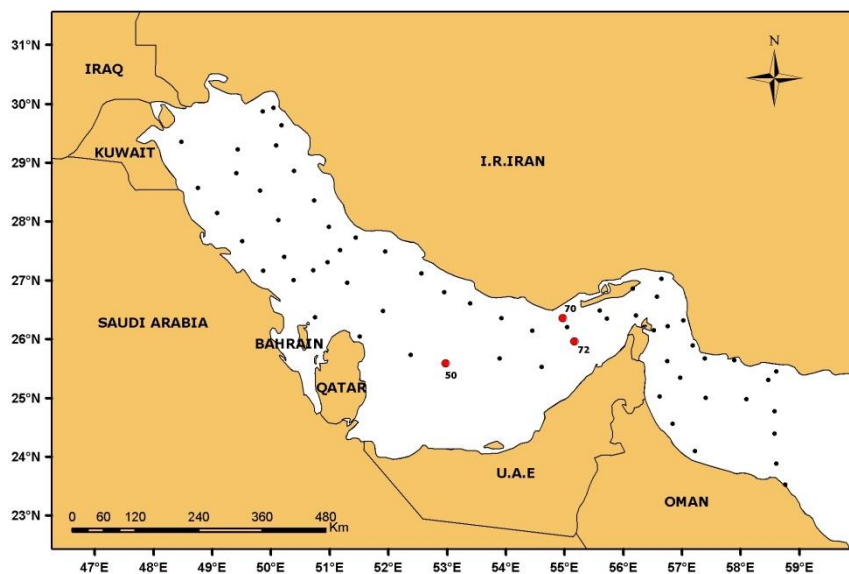


Dimensions:

Cells length 55 μm ; width 12 μm .

Sites of occurrence in RSA:

In Winter 2006 Cruise, it was present in small numbers at three stations (refer sites map).



Sites of occurrence of *Amphora lineolata* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Catenulaceae Mereschkowsky

Genus: *Amphora* Ehrenberg

Species: *ostrearia*

Variety: *ostrearia*

Scientific name: *Amphora ostrearia* Brébisson ex Kützing var. *ostrearia*

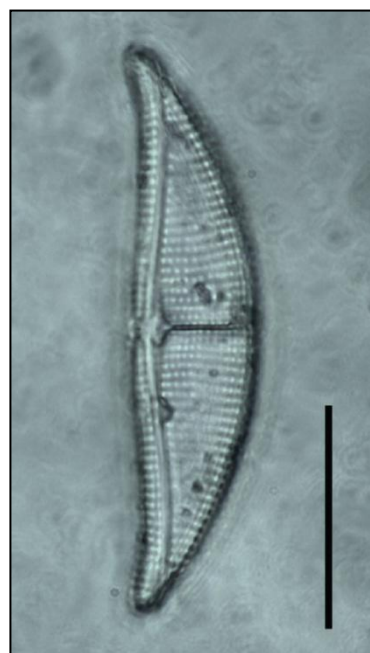
Plate A58: g (Annex A)

References:

Hendey, 1964: p. 266, Pl. XXXVIII: 5; Ricard, 1987: p. 261, Fig. 922; Witkowski *et al.*, 2000: p. 146, Pl. 170: 23.

Description:

Frustules subrectangular or oblong-elliptic, with rounded ends. Valves with arcuate dorsal margins and straight ventral margins; apices acute; valves striate, more clearly marked on the dorsal side; striae 12-16 in 10 µm. Central nodule is dilated transversely to produce a stauros. Girdle is composed of numerous longitudinal narrow bands which appear as lines, striated similar to the valves. Chromatophores: numerous cocciform bodies. Length of valve 56-66 µm (Hendey, 1964).



Dimensions:

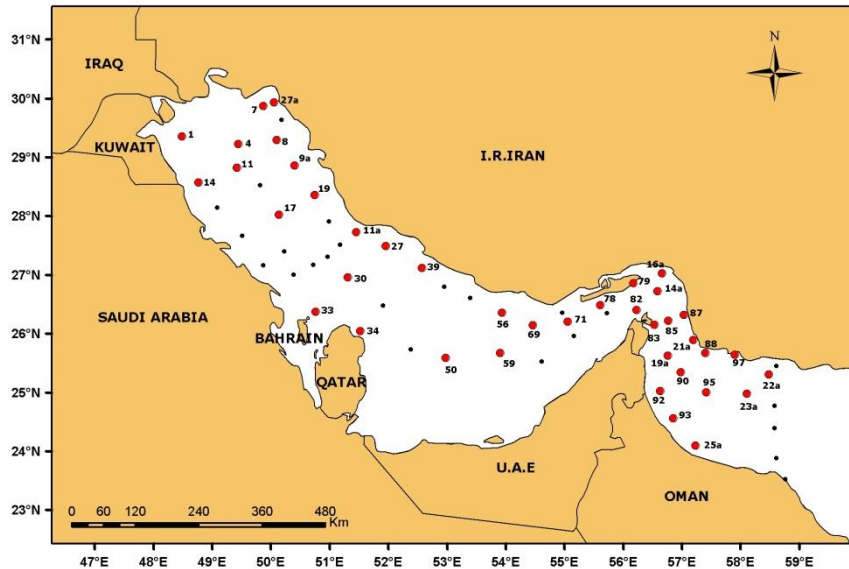
Cells length 45 µm; width 11 µm.

Distribution:

Mainly littoral species, but is frequently found in the plankton.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was frequently observed (refer sites map), often in large numbers; maximum abundance (2.1×10^3 cells/l) was associated with the Sea of Oman (St. 97). It has been previously reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Amphora ostrearia* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Catenulaceae Mereschkowsky

Genus: *Amphora* Ehrenberg

Scientific name: *Amphora* sp.

Plate A58: a-c (Annex A)

Description:

Frustules in girdle view rectangular-elliptic, with slightly convex margins; valves semilanceolate; ventral margins almost straight with not produced, acutely rounded apices.

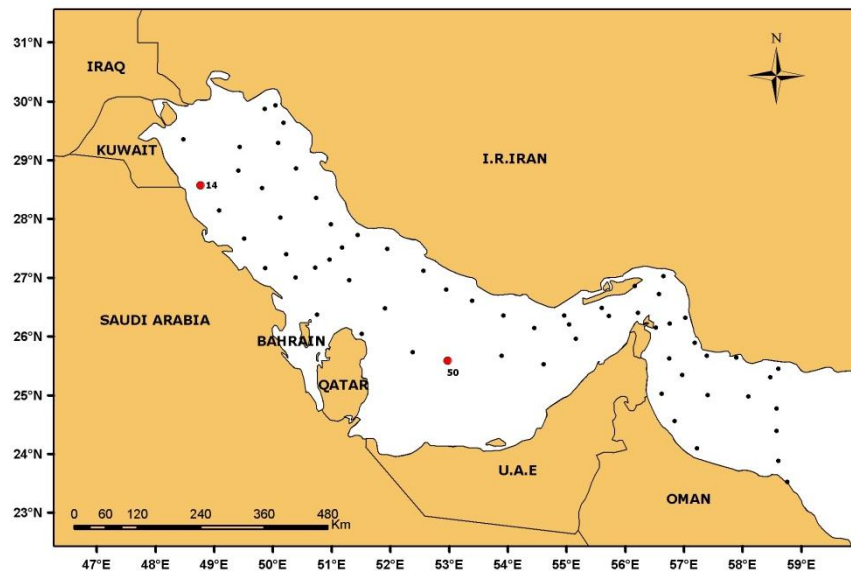


Dimensions:

Cells 60-63 μm long; 13-15 μm broad.

Sites of occurrence in RSA:

In Winter 2006 Cruise, it was present in small numbers at two stations (refer sites map).



Sites of occurrence of *Amphora* sp. in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Bacillariaceae Ehrenberg

Genus: *Bacillaria* Gmelin

Genus is characterized by the presence of a canal raphe. Number of fibulae and striae, and the quotient between them are important characters at species level. Genus *Bacillaria* does not belong to plankton primarily; *B. paxillifera*, however, is often found in samples from shallow areas (Thronsdén *et al*, 2007).

Scientific name: *Bacillaria paxillifera* (O.F. Müller) Hendey

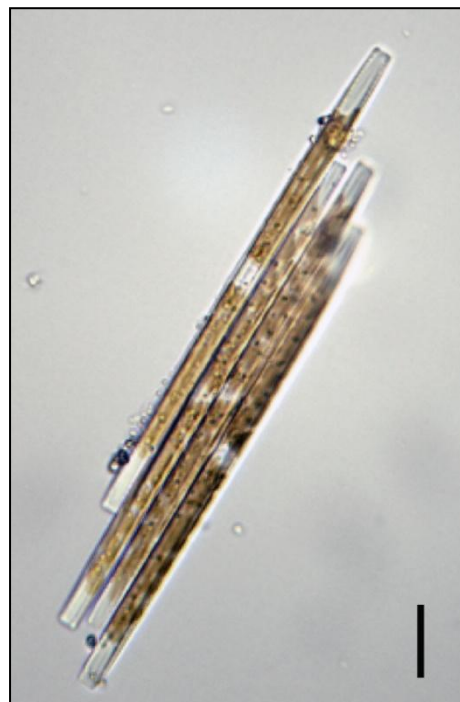
Plate A58: j-l (Annex A)

Synonyms:

Bacillaria paradoxa Gmelin; *Nitzschia paradoxa* (Gmelin) Grunow *ex* Cleve *et* Grunow

References:

Pavillard, 1925: p. 62, Fig. 112 (as *Bacillaria paradoxa*); Allen and Cupp, 1935: p. 161, Fig. 117 (as *Bacillaria paradoxa*); Cupp, 1943: p. 206, Fig. 159 (as *Nitzschia paradoxa*); Hendey, 1964: p. 274, Pl. XXI: 5; Simonsen, 1974: p. 49 (as *Bacillaria paradoxa*); Ricard, 1987: p. 281, Figs. 1125-1128 (as *Bacillaria paradoxa*); Throndsen *et al.*, 2007: p. 192.



Description:

Cells united into movable colonies, the cells sliding along one another. In girdle view rectangular. In valve view linear-lanceolate with produced ends. Keel nearly central. Keel puncta 7-9 in 10 μm . Striae 20-21 in 10 μm . Length of valves 80-115 μm ; width 5-6 μm . Chromatophores small, numerous. Nucleus central (Cupp, 1943).

Dimensions:

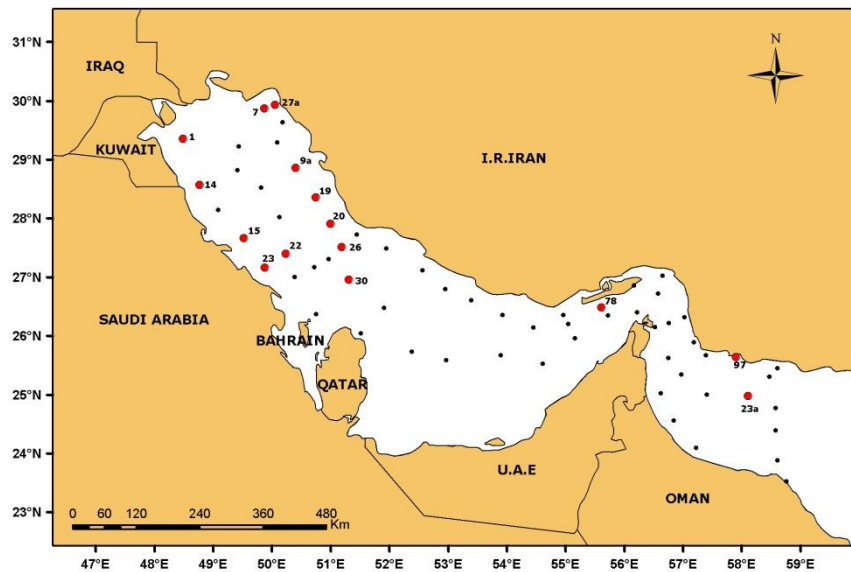
Cells length 120-135 μm ; width 6-7 μm .

Distribution:

Very common in plankton.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred, usually in small numbers, however, it was quite abundant at some localities (refer sites map); maximum abundance (1.2×10^3 cells/l) was associated with Kuwaiti waters in the northwestern part of the inner RSA (St. 1). Species have been previously reported (as *Bacillaria paradoxa*) from the inner RSA (Simonsen, 1974) and from Kuwaiti waters (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Bacillaria paxillefera* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Bacillariaceae Ehrenberg

Genus: *Cylindrotheca* Rabenhorst

Cylindrical, weakly silicified cells with more or less extruded ends (rostra, horns) and numerous, narrow bands. When moving, cells rotate about the length axis. Most of the species do not belong to marine plankton, but are mostly living on and in mud near the coast, except the *C. closterium* which is also found in plankton and epiphytic (Thronsdén *et al.*, 2007).

Scientific name: *Cylindrotheca closterium* (Ehrenberg) Lewin *et* Reimann

Plate A60: h-j (Annex A)

Synonyms:

Nitzschia closterium (Ehrenberg) W. Smith; *Ceratoneis closterium* Ehrenberg

References:

Allen and Cupp, 1935: p. 162, Fig. 122 (as *Nitzschia closterium*); Cupp, 1943: p. 200, Fig. 153 (as *Nitzschia closterium*); Hendey, 1964: p. 283, Pl. XXI: 8 (as *Nitzschia closterium*); Simonsen, 1974: p. 51; Ricard, 1987: p. 279, Figs. 1094, 1095 (as *Nitzschia closterium*); Throndsen *et al.*, 2007: p. 192.

Description:

Cells single, motile. Ends hairlike, flexible; center lanceolate; nucleus central. Chromatophores two, in center only, not in hair-like ends; cells usually bent slightly. Length of valves 25-100 μm . Keel puncta about 7 in 10 μm (Cupp, 1943).

Dimensions:

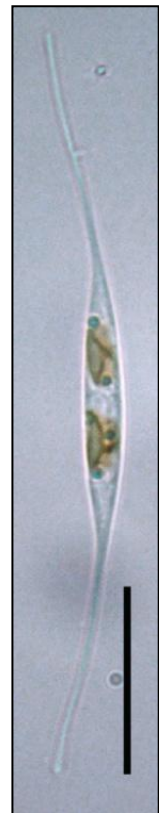
Cells length 55-70 μm ; width 6 μm .

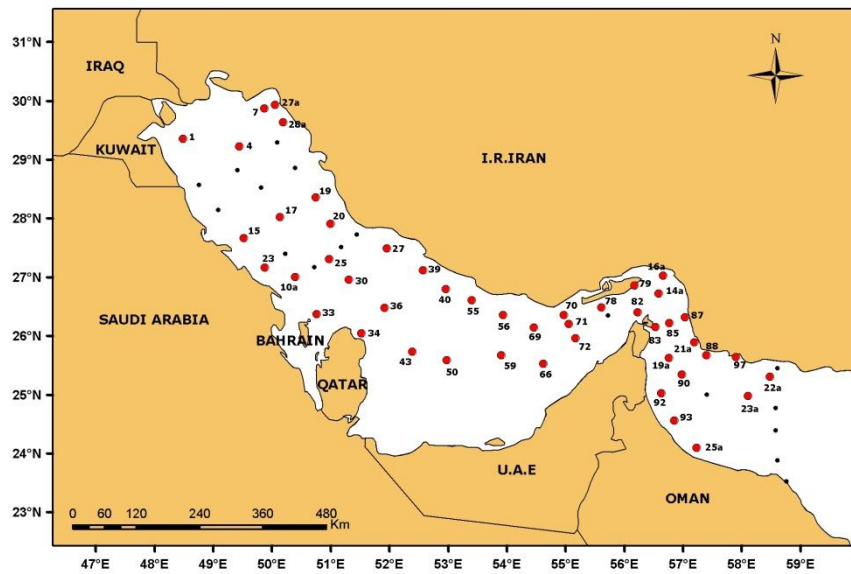
Distribution:

Very common in the littoral zone, frequently in the plankton.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was frequently observed, often in large numbers at various sites (refer sites map); maximum abundance (1.1×10^4 cells/l) was associated with the Sea of Oman (St. 88). It has been previously reported (as *Nitzschia closterium*) from the Indian Ocean (Simonsen, 1974) and from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).





Sites of occurrence of *Cylindrotheca closterium* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Bacillariaceae Ehrenberg

Genus: *Cymatonitzschia* Simonsen

Species: *marina*

Scientific name: *Cymatonitzschia marina* (Lewis) Simonsen

Plate A58: h, i (Annex A)

Synonyms:

Cymatopleura marina Lewis; *Nitzschia antillarum* Meister

References:

Simonsen, 1974: p. 56, Pl. 41: 5-9; Ricard, 1987: p. 281, Figs. 1129, 1130.

Description:

The parapical axis of the valves is conspicuously undulated. The undulation of the two valves of a frustule are opposing each other. the ornamentation consists of irregularly limited areolae or puncta with no particular order in the arrangement. The areolation is limited to the valleys of the valves, so that an areolated depressed transapical zone alternates with an elevated hyaline zone (Simonsen, 1974).

Dimensions:

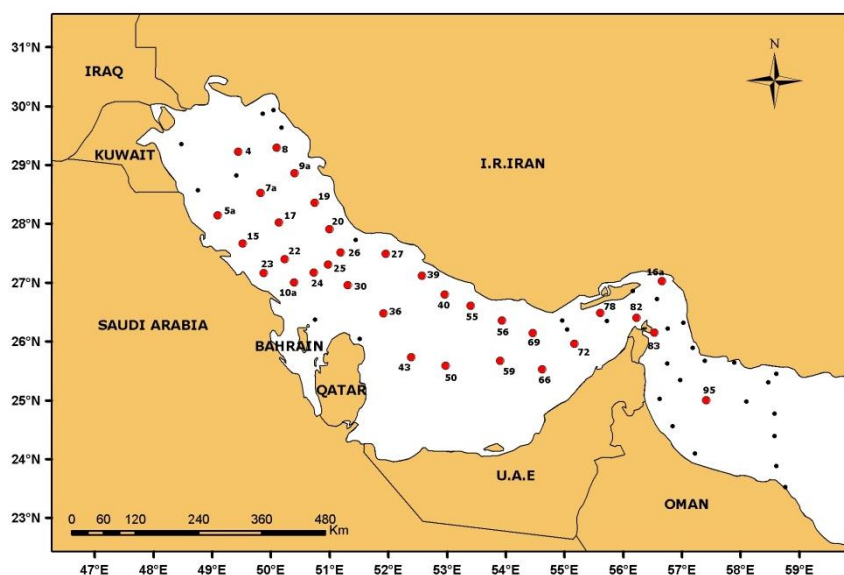
Cells length 40-43 μm ; width 8-9 μm .

Distribution:

It is obviously a tropical species, found in the plankton samples as only allochthonous.

**Sites of occurrence in RSA:**

In Winter 2006 Cruise, this species was frequently observed at various sites (refer sites map), often in large numbers; maximum abundance (4×10^3 cells/l) was associated with central part of the inner RSA (St. 25). It has been previously reported from the inner RSA (Simonsen, 1974).



Sites of occurrence of *Cymatnitzschia marina* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Bacillariaceae Ehrenberg

Genus: *Nitzschia* Hassall

Species: *fluminensis*

Scientific name: *Nitzschia fluminensis* Grunow

Plate A59: d-f (Annex A)

Synonym:

Nitzschia neogena Grunow

Reference:

Witkowski *et al.*, 2000: p. 381, Pl. 202: 6-9.

Description:

Valves lanceolate with produced apices, 130-160 µm long, 13-15 µm broad. Raphe central; fibulae 4-6 in 10 µm, partly prolonged into transapical ribs. Transapical striae punctuate, 14-16 in 10 µm (Witkowski *et al.*, 2000).

Dimensions:

Cells length 85-88 µm; width 12-13 µm; transapical striae 18 in 10 µm; fibulae 6 in 10 µm.

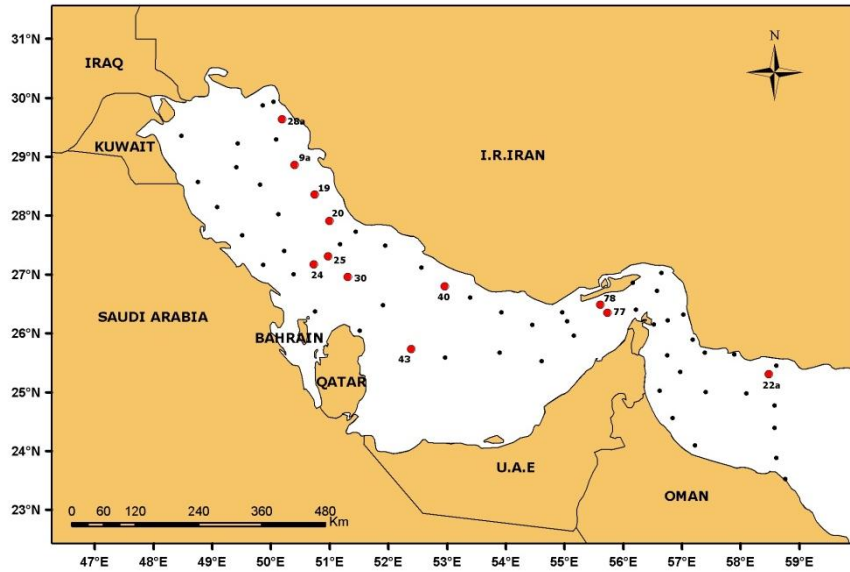
Distribution:

Mainly littoral warm water species, but is found in the plankton.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at few scattered sites (refer sites map), usually in small numbers, however, it was quite abundant at some localities; maximum abundance (4.4×10^3 cells/l) was associated with the southern part of the inner RSA (St. 78). It has been previously reported from Kuwaiti waters (Al-Kandari *et al.*, 2009).





Sites of occurrence of *Nitzschia fluminensis* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Bacillariaceae Ehrenberg

Genus: *Nitzschia* Hassall

Species: *longissima*

Scientific name: *Nitzschia longissima* (Brébisson) Ralfs

Plate A60: k-n (Annex A)

Synonym:

Ceratoneis longissima Brébisson

References:

Pavillard, 1925: p. 62, Fig. 114; Allen and Cupp, 1935: p. 162, Fig. 121; Cupp, 1943: p. 200, Fig. 154; Hendey, 1970: p. 157; Simonsen, 1974: p. 53; Witkowski *et al.*, 2000: p. 391, Pl. 207: 6, 7; Throndsen *et al.*, 2007: p. 200.

Description:

Valves linear-lanceolate. Ends extended into very long horns. Keel puncta 8-14 in 10 μm . Striae about 16 in 10 μm , often difficult to see. Length of valves 125–250 μm . Chromatophores two, in center only, not in hair-like ends (Cupp, 1943). This species is recognized in two varieties: *Nitzschia longissima* v. *longissima*, and *Nitzschia longissima* v. *parva*.

Dimensions:

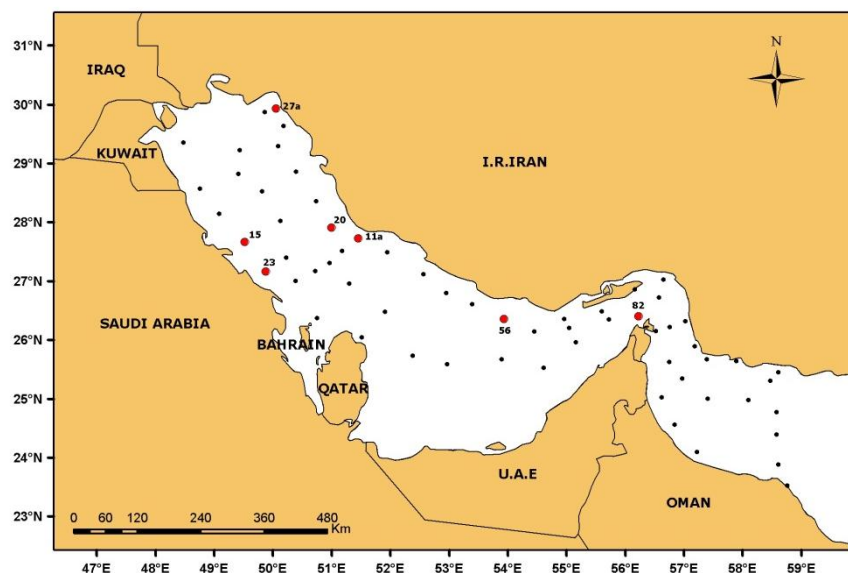
Cells length 130-145 μm ; width 6-8 μm .

Distribution:

Littoral species, frequently found in the plankton.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was present in small numbers at few scattered stations (refer sites map). Species has been previously reported from the inner RSA (Simonsen, 1974) and from Kuwaiti shore (Hendey, 1970) and coastal waters (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Nitzschia longissima* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Bacillariaceae Ehrenberg

Genus: *Nitzschia* Hassall

Species: *lorenziana*

Scientific name: *Nitzschia lorenziana* Grunow

Plate A59: g-i (Annex A)

References:

Allen and Cupp, 1935: p. 162, Fig. 123; Hendey, 1970: p. 158; Simonsen, 1974: p. 53, Pl. 41: 4; Witkowski *et al.*, 2000: p. 392, Pl. 210: 24, 25; 211: 3; 212: 1-3.

Description:

Frustules in girdle view sigmoid. Valves sigmoid narrowly lanceolate with long rostrate acutely rounded apices, (37)50-190 µm long; (3)4-7 µm broad. Raphe eccentric, fibulae evenly spaced, 6-10 in 10 µm, but the median two ones distant, central nodule present; transapical striae 13-19 in 10 µm (Witkowski *et al.*, 2000).

Dimensions:

Cells length 120-130 µm; width 9-10 µm; transapical striae 16-17 in 10 µm; fibulae 8 in 10 µm.

Distribution:

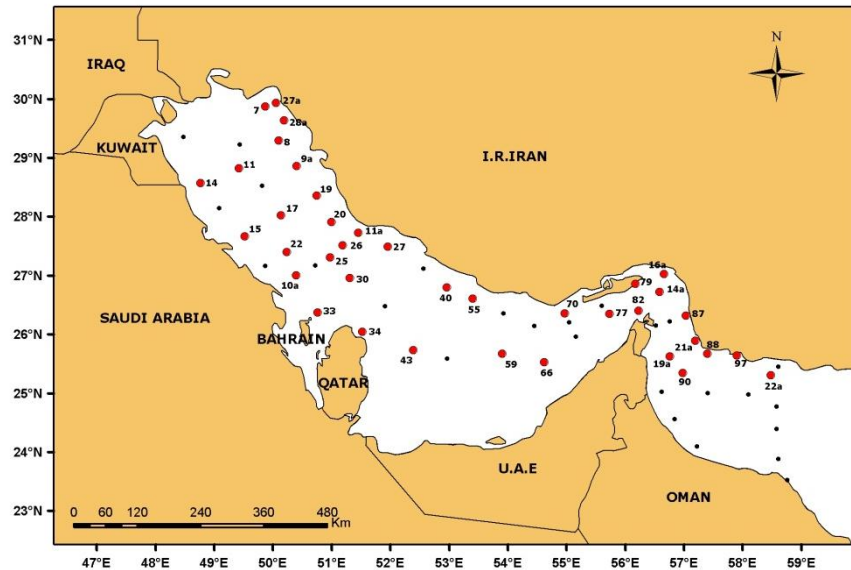
Cosmopolitan benthic species, but occasionally found in plankton.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at various stations (refer sites map), although never in large numbers; maximum abundance (6.6×10^2 cells/l) was associated with the southern part of the inner RSA off the United Arab Emirates (St. 66). It has been



previously reported from the Indian Ocean (Simonsen, 1974) and from Kuwaiti shore (Hendey, 1970) and the coastal waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Nitzschia lorenziana* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Bacillariaceae Ehrenberg

Genus: *Nitzschia* Hassall

Species: *rorida*

Scientific name: *Nitzschia rorida* Giggen

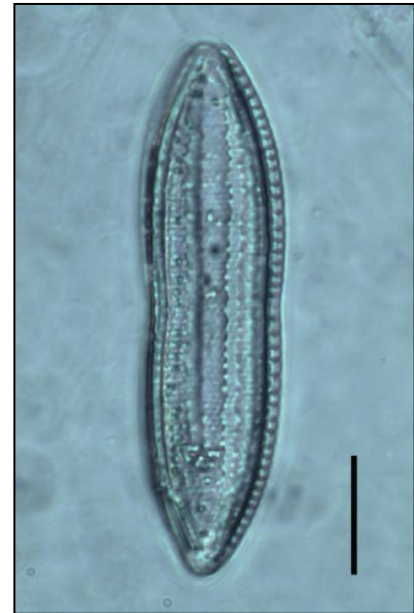
Plate A53: e-g (Annex A)

Reference:

Witkowski *et al.*, 2000: p. 403, Pl. 184: 9-12.

Description:

Valves linear, more or less strongly constricted in the middle with shortly produced rostrate apices, 23-32 μm long, 9-10 μm broad. Raphe strongly eccentric; fibulae transapically elongated, somewhat irregular, 10-12 in 10 μm ; central nodule present. Transapical striae finely punctate arranged in quincunx, 24-27 in 10 μm , interrupted by a distinct apical fold (Witkowski *et al.*, 2000).

**Dimensions:**

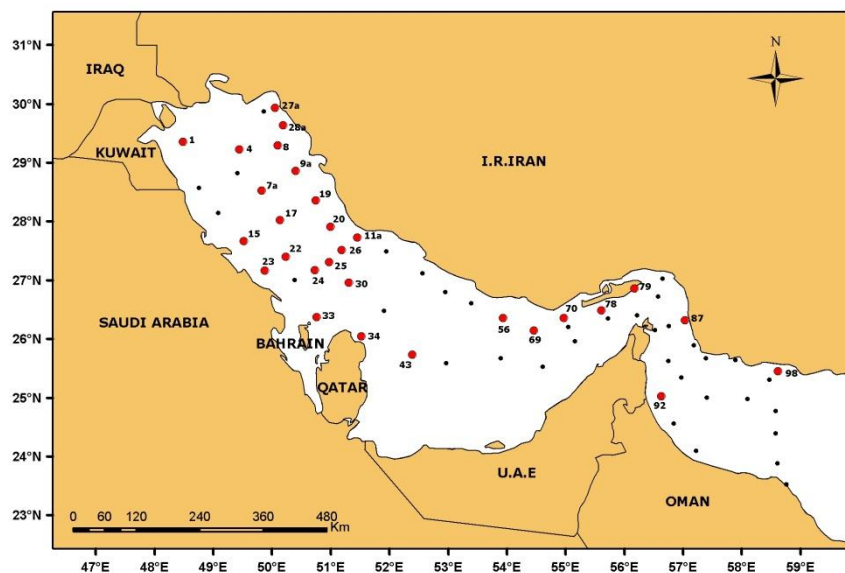
Cells length 37-41 μm ; width 12-13 μm .

Distribution:

Mainly littoral species, but is found in the plankton.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at various sites (refer sites map), usually in small numbers; however, it was quite abundant at some localities; maximum abundance (4.1×10^3 cells/l) was associated with the northwestern part of the inner RSA (St. 9a).



Sites of occurrence of *Nitzschia rorida* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Bacillariaceae Ehrenberg

Genus: *Nitzschia* Hassall

Species: *sigma*

Scientific name: *Nitzschia sigma* (Kützinger) Smith

Plate A59: l, m (Annex A)

Synonym:

Synedra sigma Kützinger

References:

Allen and Cupp, 1935: p. 162, Fig. 120; Hendey, 1964: p. 281, Pl. XLII: 1; Hendey, 1970: p. 158; Simonsen, 1974: p. 55; Witkowski *et al.*, 2000: p. 404, Pl. 206: 1-10.

Description:

Frustules in girdle view strongly sigmoid; valves depending on the position, more or less sigmoid or in the middle part, linear to linear-lanceolate with long cuneate to opposite sides curved apices, 35- ca 1000 μm long; 4-25(26) μm broad. Raphe strongly eccentric; fibulae (3)7-12 in 10 μm , equidistantly spaced; transapical striae (15)19-38 in 10 μm , punctate (Witkowski *et al.*, 2000).



Dimensions:

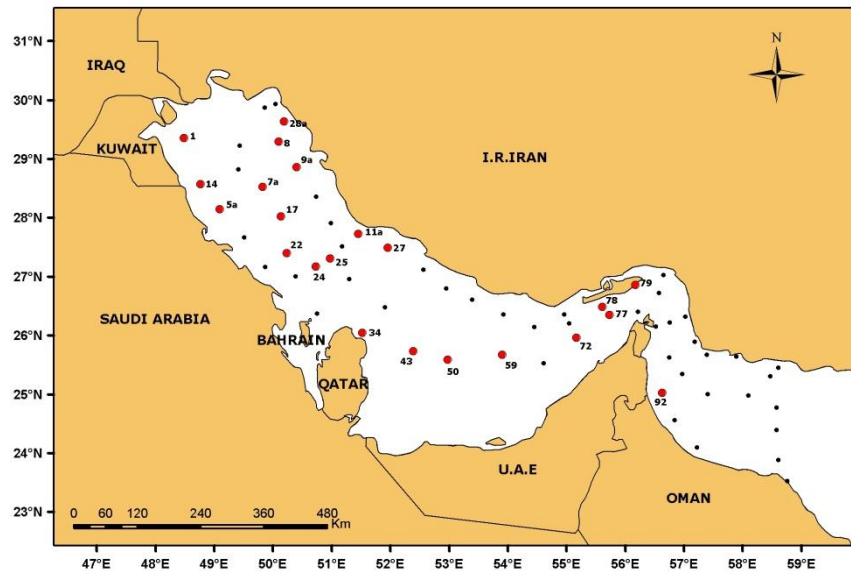
Cells length 120-140 μm ; width 13-15 μm ; transapical striae 22 in 10 μm ; fibulae 5 in 10 μm .

Distribution:

Cosmopolitan benthic marine and extremely euryhaline species, often found in the plankton; it has been previously reported from the Indian Ocean (Simonsen, 1974).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at various stations (refer sites map) in very small numbers. It has been previously reported from Kuwaiti shore (Hendey, 1970; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Nitzschia sigma* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Bacillariaceae Ehrenberg

Genus: *Nitzschia* Hassall

Species: *sigmaformis*

Scientific name: *Nitzschia sigmaformis* Hustedt

Plate A59: j, k (Annex A)

References:

Simonsen, 1974: p. 55, Pl. 40: 5; Witkowski *et al.*, 2000: p. 405, Pl. 206: 19, 20.

Description:

Valves narrow-lanceolate; sigmoid with subacute not capitate apices, 75-170 μm long, 4-5 μm broad. Raphe eccentric; fibulae unevenly spaced, 8-12 in 10 μm ; the median two ones distant; transapical striae ca. 30 in 10 μm , distinctly punctate (Witkowski *et al.*, 2000).

Dimensions:

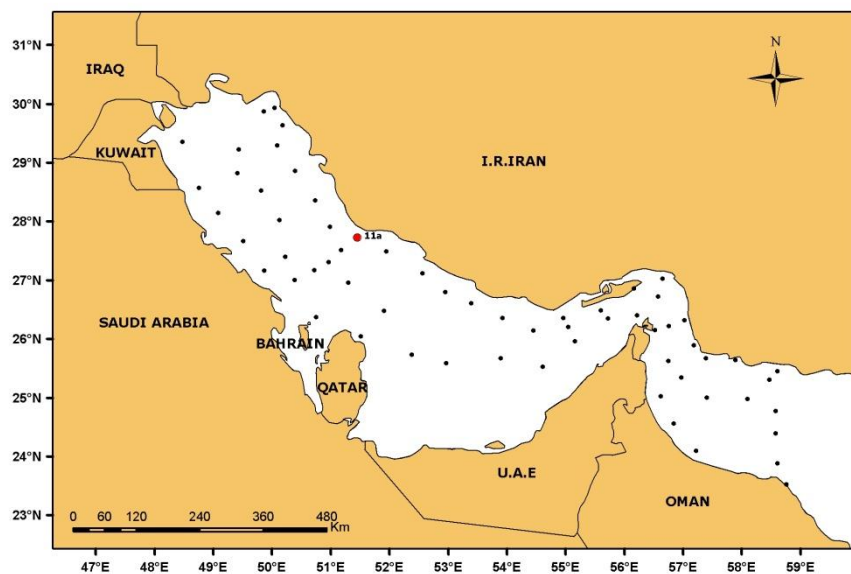
Cells length 220-260 μm ; width 15-17 μm ; transapical striae 14 in 10 μm ; fibulae 5-6 in 10 μm .

Distribution:

Benthic species, only astray in plankton.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at one site associated with the Iranian coast in the central part of the inner RSA (St. 11a) (refer site map) in small numbers with the abundance of 1.1×10^3 cells/l. It has been previously reported from the inner RSA (Simonsen, 1974).



Sites of occurrence of *Nitzschia sigmaformis* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Bacillariaceae Ehrenberg

Genus: *Nitzschia* Hassall

Scientific name: *Nitzschia* sp. 1

Plate A60: a-c (Annex A)

Description:

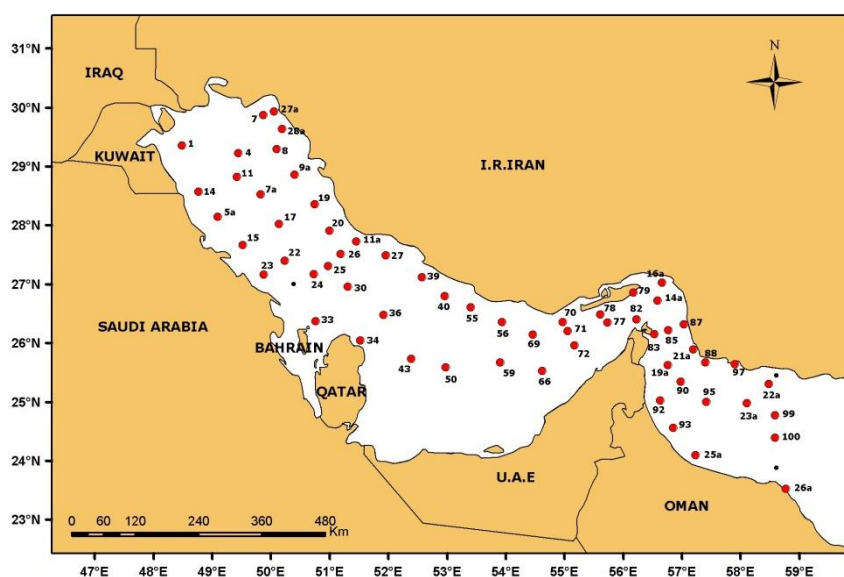
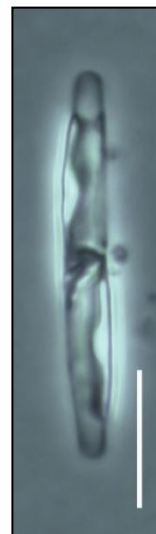
Valves linear-lanceolate with obtusely rounded apices. Fibulae evenly spaced.

Dimensions:

Cells length 21-24 μm ; width 4 μm .

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was commonly observed at various stations (refer sites map), often in large numbers; maximum abundance (10^5 cells/l) was associated with the Iranian coast in the central part of the inner RSA (St. 27).



Sites of occurrence of *Nitzschia* sp.1 in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Bacillariaceae Ehrenberg

Genus: *Nitzschia* Hassall

Scientific name: *Nitzschia* sp. 4

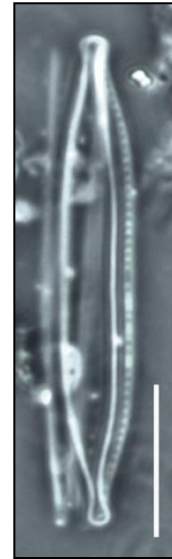
Plate A60: f (Annex A)

Description:

Valves lanceolate, tapering toward apices, which are cuneate, acutely rounded. Raphe strongly eccentric; fibulae evenly spaced; the median two ones distant.

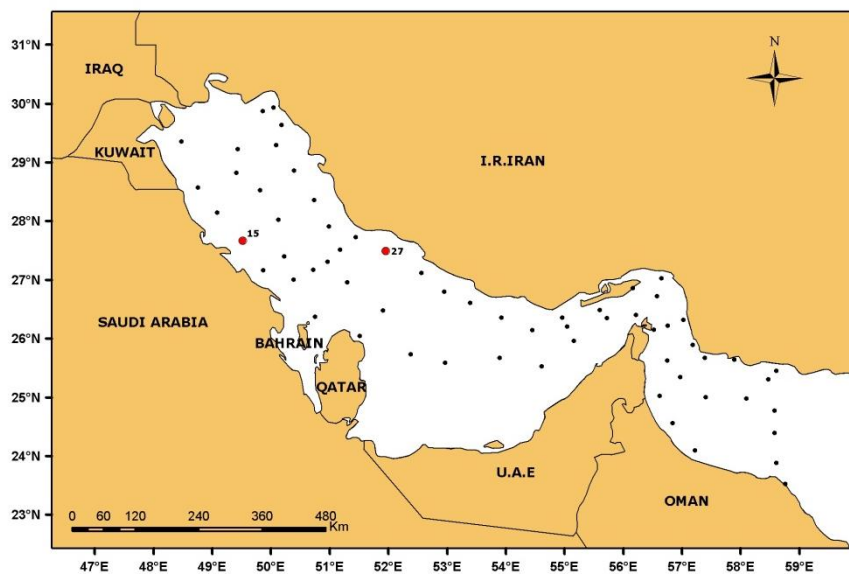
Dimensions:

Cells 20 μm long; 7 μm wide; fibulae 19-20 in 10 μm ;



Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was present in small numbers at two stations (refer sites map).



Sites of occurrence of *Nitzschia* sp. 4 in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Bacillariaceae Ehrenberg

Genus: *Nitzschia* Hassall

Scientific name: *Nitzschia* sp. 5

Plate A60: g (Annex A)

Description:

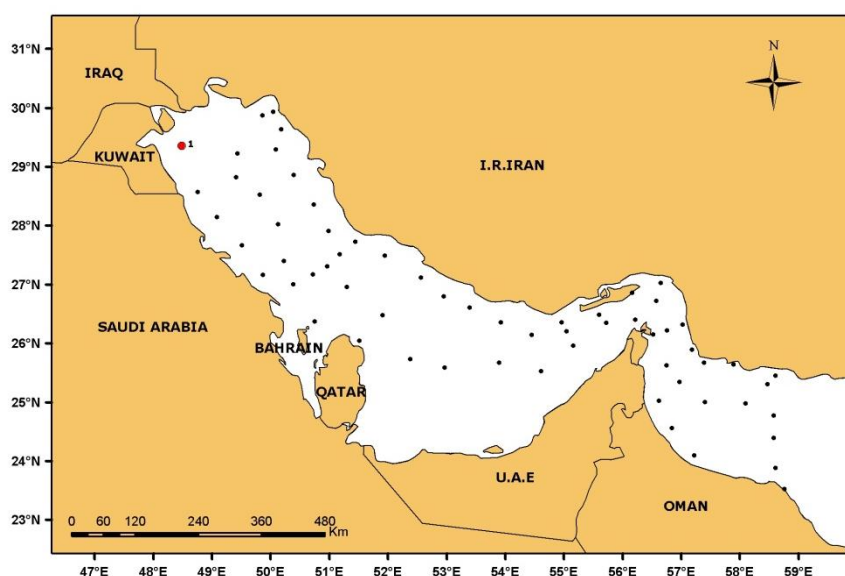
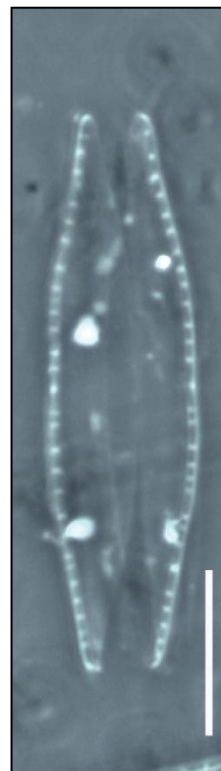
Valves lanceolate with acute, slightly produced, narrowly capitate apices. Raphe eccentric; fibulae unevenly spaced.

Dimensions:

Cells 35 μm long; 6 μm wide; fibulae 10 in 10 μm .

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was present in small numbers at one station (refer site map).



Site of occurrence of *Nitzschia* sp. 5 in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Bacillariaceae Ehrenberg

Genus: *Nitzschia* Hassall

Scientific name: *Nitzschia* sp. 6

Plate A61: a-d (Annex A)

Description:

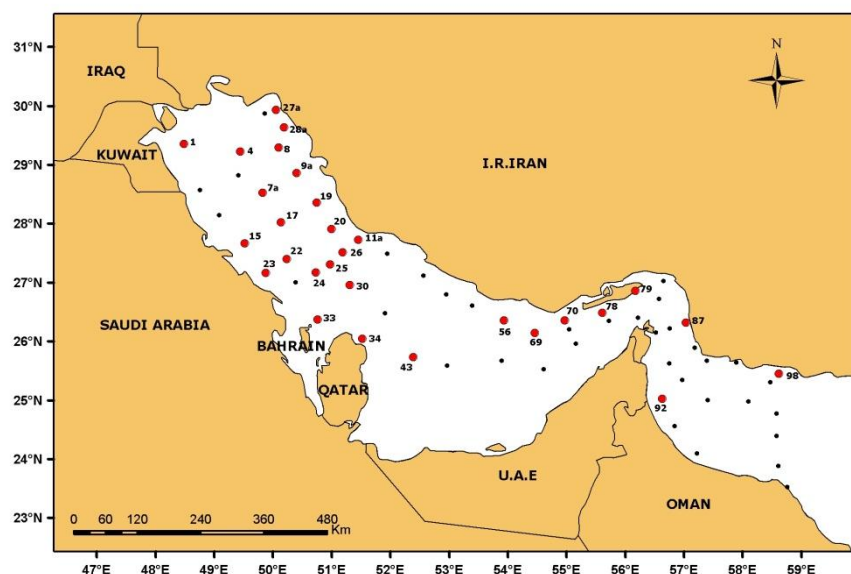
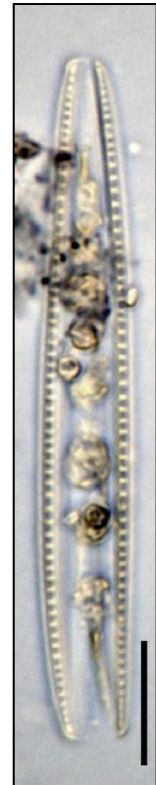
Frustules linear, slightly curved; fibulae evenly spaced.

Dimensions:

Cells 170 μm long, 17 μm wide; fibulae 5 in 10 μm ; transapical striae 22 in 10 μm .

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was present in small numbers at scattered stations (refer sites map).



Sites of occurrence of *Nitzschia* sp. 6 in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Bacillariaceae Ehrenberg

Genus: *Pseudo-nitzschia* H. Pérégallo

Species of *Pseudo-nitzschia* are marine, planktonic diatoms with a worldwide distribution. The genus comprises more than 20 species. It was previously included in *Nitzschia* given the formal rank of section, but following morphological, physiological and genetic investigations of the type species of *Nitzschia* reinstated *Pseudo-nitzschia* at the generic level (Mann, 1986; Hasle, 1994). The shape and symmetry of the cells, cell dimensions, and the detailed morphology of the frustules are important features for identification of *Pseudo-nitzschia* species. Only some of these details can be seen in the LM, and electron microscopy is usually necessary for species examination in order to be accurately identified (Larsen and Nguyen, 2004). Cells united by overlapping ends; raphe is excentric. Cells elongate, rectangular or spindle-shaped in girdle view. Valves narrow lanceolate to linear with rounded or pointed ends. Chains motile as a unit. Transverse interstriae often more than one for each fibula. Chloroplasts two plates lying along the girdle, one in each cell half (Throndsen *et al.*, 2007).

Harmful Effect:

The first incident of amnesic shellfish poisoning (ASP) caused by the toxin domoic acid was documented in 1987 on Prince Edward Island (Bates *et al.*, 1989) coincidently with a bloom of *Pseudo-nitzschia multiseries* (= *Nitzschia pungens* f. *multiseries*). Three people died, and others lost their short-term memory permanently. In September 1991 deaths of pelicans and cormorants in Monterey Bay, California, were caused by *P. australis* (= *Nitzschia pseudoseriata*). The toxin has been concentrated in the gut of filter feeders and the Dungeness crabs, but in the meat of anchovies and razor clams (Fritz *et al.*, 1992). The connection between the occurrence of domoic acid in shellfish and other marine animals and the *Pseudo-nitzschia* species present in the plankton has been studied extensively, and a comprehensive literature on the subject exists (Hallegraeff *et al.*, 1995).

In Winter 2006 Cruise, the genus *Pseudo-nitzschia* includes a few taxa, among them *Pseudo-nitzschia delicatissima* complex, which was the most abundant. The genus contains medium-sized chain-forming diatom algae. When abundant in the RSA, *Pseudo-nitzschia* spp. contributed up to 73 % of the total phytoplankton abundance; the highest concentration reached 5.0×10^5 cells/l. Spatial distribution showed localized occurrence, with high abundance of this genus ($> 10^5$ cells/l) associated with the waters off the Iranian coast in the central part of the inner RSA.

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Bacillariaceae Ehrenberg

Genus: *Pseudo-nitzschia* H. Pérégallo

Complex: *Pseudo-nitzschia delicatissima*

With a few exception the diatoms of this so-called *Pseudo-nitzschia* (*Nitzschia*) *delicatissima* complex (Hasle, 1965) are delicate forms with a very fine structure. Electron microscopy reveals two types of striae structure, either well-defined circular poroids in a varying number of rows or one row of more square poroids. These narrower *Pseudo-nitzschia* species are, like the larger ones, almost indistinguishable in girdle view and have most likely often been confused with *N. delicatissima* as the best known of the complex (Hasle and Syvertsen, 1997).

Principal taxon: *Pseudo-nitzschia delicatissima* (Cleve) Heiden ex Heiden et Kolbe

Plate A61: g-j, (Annex A)

Synonyms:

Nitzschia delicatissima Cleve; *Nitzschia actyrophila* Hasle

References:

Cupp, 1943: p. 204, Fig. 158 (as *Nitzschia delicatissima*); Hendey, 1964: p. 283 (as *Nitzschia delicatissima*); Larsen and Nguyen, 2004: p. 35, Pl. IV: 2, 4, 8; Throndsen *et al.*, 2007: p. 196.

Description:

Valve narrow, linear, acute; cells united into stiff, hair-like chains by the overlapping tips of the cells. Chains usually short, motile; length of valves 32-85 µm; width 1.3-2.8 µm. Keel slightly excentric, keel puncta 14-25 in 10 µm. No striae is visible in LM. Chromatophores two per cell, one on either side of the central nucleus. Asexual auxospore formation is observed (Cupp, 1943). Overlap of cells in chains ca 1/9 of cell length (Throndsen *et al.*, 2007).

Harmful Effect:

Toxic bloom-forming species. Production of toxins was detected. In culture, this species has produced 5-fg domoic acid per cell (Smith *et al.*, 1991). A strain from Canada and one from New Zealand were found to produce domoic acid. Other strains examined so far were found to be nontoxic. The identity of the New Zealand strain was determined only with a probe, but not confirmed morphologically (IOC list, 2002).

Dimensions:

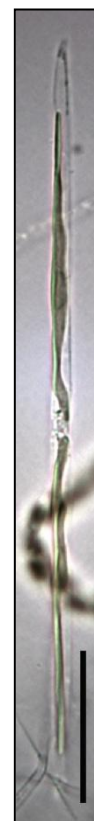
Cells length 79-84 µm; width up to 3 µm; fibulae 20 in 10 µm.

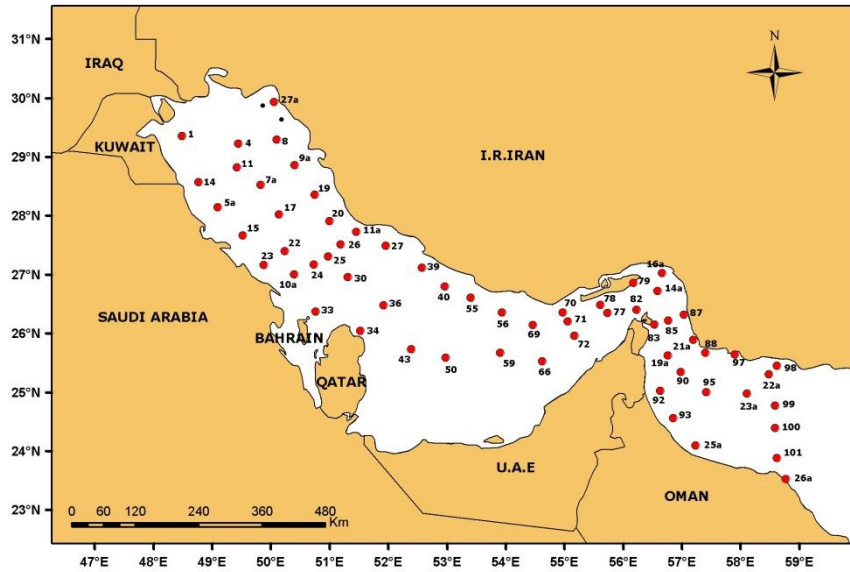
Distribution:

Cosmopolitan species are confined to inshore waters.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at most of the sites studied (refer sites map), encountered in 78.5 % of the samples, often in very large numbers; maximum abundance (4.6×10^5 cells/l) was associated with the central part of the inner RSA (St. 36). It has been previously reported (as *Pseudo-nitzschia delicatissima* group) from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).





Sites of occurrence of *Pseudo-nitzschia delicatissima* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Bacillariaceae Ehrenberg

Genus: *Pseudo-nitzschia* H. Pérégallo

Species: *pungens*

Scientific name: *Pseudo-nitzschia pungens* (Grunow ex Cleve) Hasle

Plate 61: k-o (Annex A)

Synonym:

Nitzschia pungens Grunow ex Cleve

References:

Cupp, 1943: p. 202, Fig. 156 (as *Nitzschia pungens*); Simonsen, 1974: p. 54 (as *Nitzschia pungens*); Ricard, 1987: p. 279, Figs. 1105, 1106 (as *Nitzschia pungens*); Larsen and Nguyen, 2004: p. 43, Pl. VIII: 1-3; Throndsen *et al.*, 2007: p. 197.

Description:

Girdle view: spindle-shaped, many coarse intercalary bands and high perivalvar axis. Fibulae, and/or end of interstriae, distinct. Overlap of cells in chains considerable, ca 1/3 of cell length or more. Valve view: linear to spindle-shaped with distinctly pointed ends (cigar-shaped). Heavily silicified; interstriae visible in water mounts. Fibulae in the same number, less distinct. Striae with two rows of poroids (biseriate), visible with LM under good optical conditions (phase contrast, oil immersion) (Thronsdon *et al.*, 2007). The cell length is 80-116 µm; the width is 2-3.8(4) µm. A central interspace is absent. The number of interstriae and fibulae in 10 µm are (8)-9-12-(13) and 9-13-(15), respectively (Larsen and Nguyen, 2004).

**Harmful Effect:**

Species are regarded to be potentially toxic bloom-forming species. Production of toxins has been detected (Bates *et al.*, 1998; Rhodes *et al.*, 1998; Trainer *et al.*, 1998). It is usually nontoxic, but toxic clones (domoic acid) have been reported from New Zealand and the West Coast of the USA (IOC list, 2002).

Dimensions:

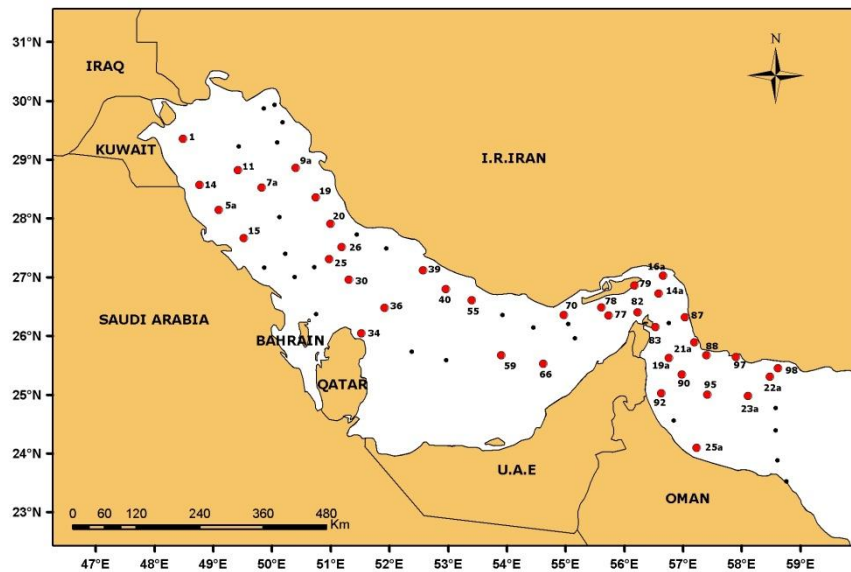
Cells length 88-96 µm; width 4 µm; fibulae 14-15 in 10 µm.

Distribution:

Neritic cosmopolitan species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at various sites (refer sites map), often in large numbers; maximum abundance (4.3×10^4 cells/l) was associated with the central part of the inner RSA (St. 36). It has been previously reported (as *Nitzschia pungens*) from the inner RSA (Simonsen, 1974) and from Kuwaiti waters (Al-Yamani *et al.*, 2004).



Sites of occurrence of *Pseudo-nitzschia pungens* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Bacillariaceae Ehrenberg

Genus: *Pseudo-nitzschia* H. Pérégallo

Complex: *Pseudo-nitzschia seriata/australis*

This group of larger (= wider than 3 μm in valve view) *Pseudo-nitzschia* species has been called the “*Pseudo-nitzschia* (*Nitzschia*) *seriata* complex” (Hasle, 1965). They all have a tendency to appear in girdle view in water mounts, and with *P. pungens* as the only possible exception. The distinction between species can only be seen in valve view. *Pseudo-nitzschia seriata* seems for some obscure reasons to have been regarded by many planktonologists as the only species of this size group appearing in stepped chains. The whole group may have been identified as “*Nitzschia seriata*” on many occasions, and the numerous records of *N. seriata* from all oceans should be regarded with scepticism (Hasle and Syvertsen, 1997). *P. seriata* is predominantly a cold-water species, seems to be restricted to the North Atlantic and

there are no confirmed reports (by EM) south of the latitude 45 N (IOC list, 2002). Therefore, previous reports of *P. seriata* from tropical waters are to be regarded as misidentifications of most probably *Pseudo-nitzschia australis* or other similar, large species.

Principal taxon: *Pseudo-nitzschia* cf. *seriata* (Cleve) H. Pérageallo

Plate A61: p-s (Annex A)

Synonym:

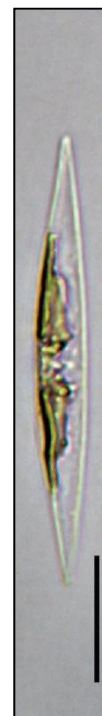
Nitzschia seriata Cleve

References:

Pavillard, 1925: p. 62, Fig. 113 (as *Nitzschia seriata*); Allen and Cupp, 1935: p. 163, Fig. 124 (as *Nitzschia seriata*); Cupp, 1943: p. 201, Fig. 155 (as *Nitzschia seriata*); Hendey, 1964: p. 284, Pl. XXI: 6 (as *Nitzschia seriata*); Ricard, 1987: p. 279, Figs. 1102-1104 (as *Nitzschia seriata*); Throndsen *et al.*, 2007: p. 199.

Description:

Cells spindle-shaped with more or less pointed to moderately rounded ends. United into stiff, hair-like chains by the overlapping points of the cells. Chains motile as a whole. Length of valves 80-140 µm (most commonly 95-115 µm); width 6.2-8 µm (usually 6.5-7 µm). Keel puncta indistinct, obsolete or nearly so, about the same number as the striae. Striae 14-19 in 10 µm; punctate. Chromatophores two per cell, one on each side of the central nucleus (Cupp, 1943). Overlap of cells in chains 1/4 to 1/3 of the cell length (Throndsen *et al.*, 2007).



Harmful Effect:

Toxic bloom-forming species. Several clones of *P. seriata* have been found to produce domoic acid (IOC list, 2002). Domoic acid has been detected in cultures of this species from the Danish waters. In 2005, a bloom of *P. seriata* occurred and was associated with domoic acid in Danish blue mussels (Throndsen *et al.*, 2007). *P. australis* is the most of the domoic acid-producing species of the diatom genus *Pseudo-nitzschia* (IOC list, 2002).

Dimensions:

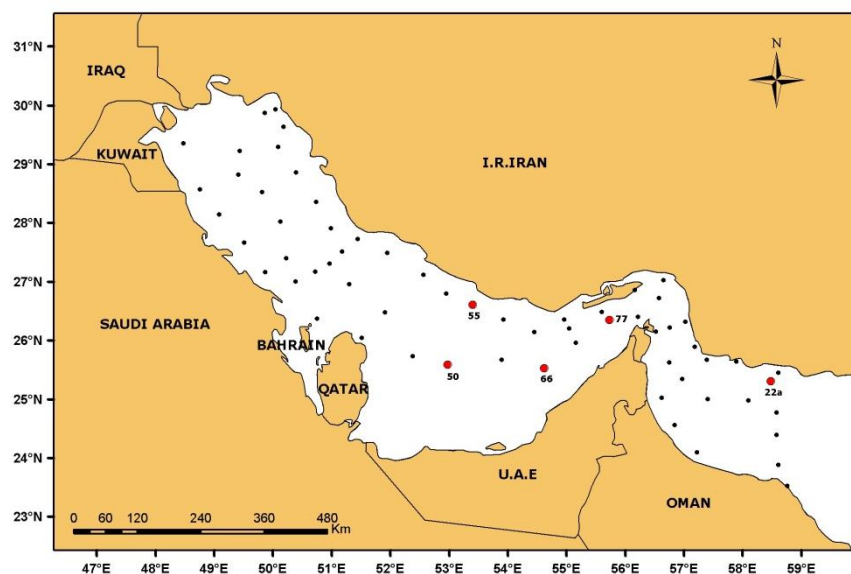
Cells length 85-92 µm; width 7-8 µm.

Distribution:

Neritic species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at few sites (refer sites map), usually in small numbers, however, it was quite abundant at some localities; maximum abundance (2.1×10^4 cells/l) was associated with the southern part of the inner RSA (St. 66). Complex has been previously reported (as *Pseudo-nitzschia seriata* group) from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Pseudo-nitzschia seriata* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Entomoneidaceae Reimer *ex* Patrick *et* Reimer

Genus: *Amphiprora* Ehrenberg

Cells single or in ribbonlike chains; cells constricted in the middle; valves lanceolate, convex, with raphe, central nodule, and a sigmoid keel. One-half of keel lies on each side of the chain axis. Terminal nodules are present. Striae transverse, punctate. Girdle or connective zone is complex, with numerous longitudinal rows of transverse striae. Chromatophores are usually single, along the girdle (Cupp, 1943).

Scientific name: *Amphiprora sulcata* O'Meara

Plate A62: a, b (Annex A)

Synonym:

Amphiprora gigantea var. *sulcata* (O'Meara) Cleve

References:

Allen and Cupp, 1935: p. 159, Fig. 113 (as *Amphiprora gigantea* var. *sulcata*); Cupp, 1943: p. 198, Fig. 151 (as *Amphiprora gigantea* var. *sulcata*); Simonsen, 1974: p. 45 (as *Amphiprora sulcata*).

Description:

Cells strongly constricted; keel with a hyaline margin, broader toward the ends. Junction line curved like a bow; keel with puncta forming obliquely decussating rows, 14-16 in 10 μm .

Striae of the valve curved, divergent from the central nodule, 12-14 in 10 μm , not decussating. Median line strongly sigmoid. Connecting zone with numerous longitudinal divisions. Striae on connective zone transverse, 21-24 in 10 μm . Length of valves 95-120 μm (Cupp, 1943).

Dimensions:

Cells length 95-110 μm ; width 38-40 μm ; transapical striae 12 in 10 μm .

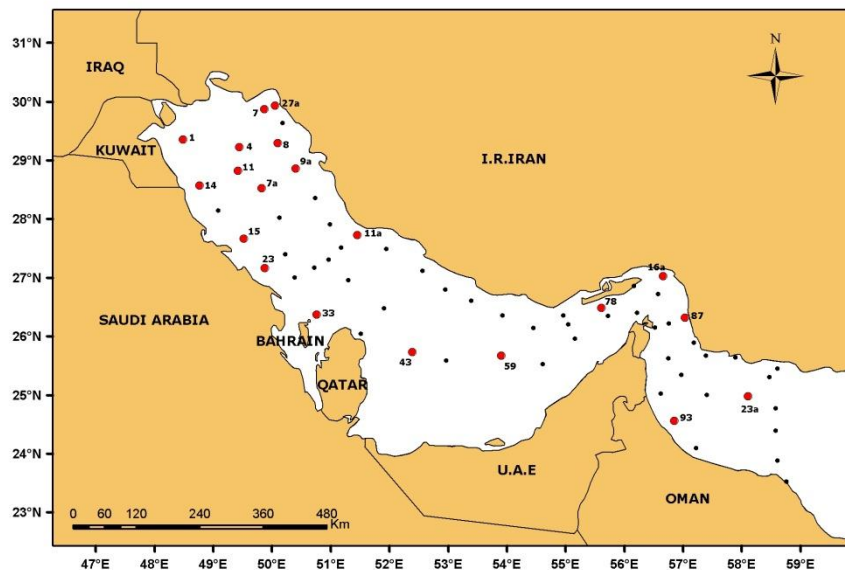
Distribution:

Marine littoral species.



Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at few sites in small numbers (refer sites map). It has been previously reported from the Indian Ocean (Simonsen, 1974; as *Amphiprora sulcata*) and from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Amphiprora sulcata* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Surellaceae Kützing

Genus: *Surirella* Turpin

Cells single. In girdle view linear or wedge-shaped. Valves linear, elliptical or oval, sometimes constricted. Costae long or short, extending toward the center, but not quite to it, with intermediate striae more or less evident. Central space linear or lanceolate, often obscure. Valves with a longitudinal central pseudoraphe and marginal, more or less elevated,

undulated keel, produced into winglike expansions containing the raphe on each side. Pseudoraphes of the two valves are parallel. Raphe difficult to see. Distinct canal pores are usually visible. Valve surface nearly flat; rarely spirally twisted. Bottom and littoral forms are found occasionally in the plankton (Cupp, 1943).

Scientific name: *Surirella fastuosa* (Ehrenberg) Kützing

Plate A62: e-g (Annex A)

Synonym:

Navicula fastuosa Ehrenberg

References:

Hendey, 1964: p. 288, Pl. XL: 4; Hendey, 1970: p. 159;
Simonsen, 1974: p. 56; Ricard, 1987: p. 265, Figs. 951-961;
Witkowski *et al.*, 2000: p. 414, Pl. 215: 1-3; 216: 4.

Description:

Cell solitary, cuneate, with rounded angles. Valves broadly ovate; marginal alae small. Costae few, 1-2 in 10 μm , dilated toward the margin, and becoming narrow as they proceed toward the broadly lanceolate central area. Valve surface striate, striae evident at the margin, and in a narrow band about halfway between the margin and the center of the valve. This narrow striate zone is almost parallel with the valve margin. Length of valve 60-130 μm , length/bread ratio about 1.5:1 (Hendey, 1964).



Dimensions:

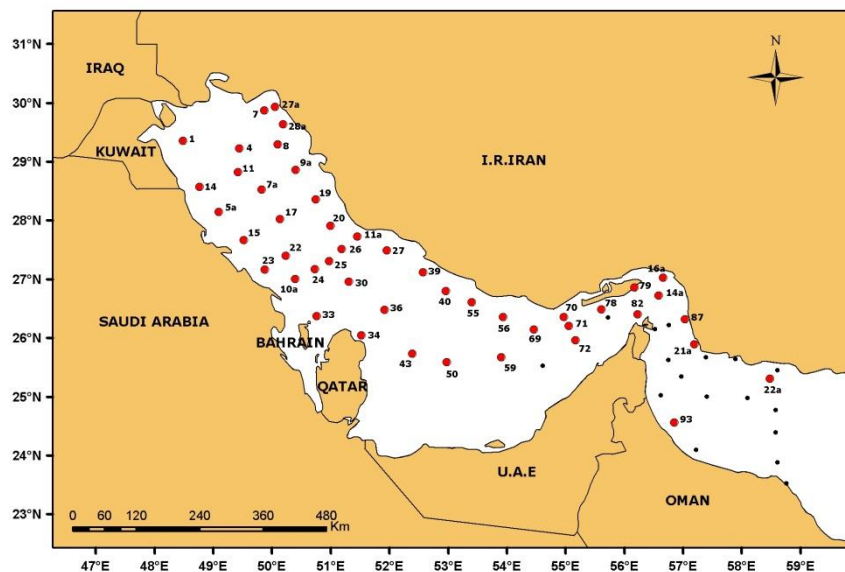
Cells length 65-82 μm ; width 45 μm .

Distribution:

Marine littoral species, frequent in harbors and estuaries; found occasionally in plankton collections.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at many sites (refer sites map), often in large numbers; maximum abundance (4.3×10^3 cells/l) was associated with the Iranian coast in the central part of the inner RSA (St. 11a). It has been previously reported in the inner RSA from Kuwaiti shore (Hendey, 1970) and coastal waters (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Surirella fastuosa* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Surellaceae Kützing

Genus: *Petrodictyon* Mann *ex* Round *et al.*

Scientific name: *Petrodictyon gemma* (Ehrenberg) Mann *ex* Round *et al.*

Plate A62: c, d (Annex A)

Synonym:

Surirella gemma Ehrenberg

References:

Hendey, 1970: p. 158 (as *Surirella gemma*); Ricard, 1987: p. 265, Figs. 963, 964 (as *Surirella gemma*); Witkowski *et al.*, 2000: p. 413, Pl. 216: 8, 9.

Description:

Frustules heteropolar in girdle view; rectangular to trapezoid. Valves oval, elliptic-oval to linear-oval with slightly to moderately convex margins and broadly to cuneately rounded apices, 70-140 μm long, 30-55 μm broad. Fibulae connected to long narrow transapical ribs, 20-30 in 100 μm . Transapical ribs are fused in the middle to form a narrow slightly wavy, longitudinal sternum. Transapical striae uniseriate, punctate, 18-25 in 10 μm ; puncta 22-30 in 10 μm (Witkowski *et al.*, 2000).

**Dimensions:**

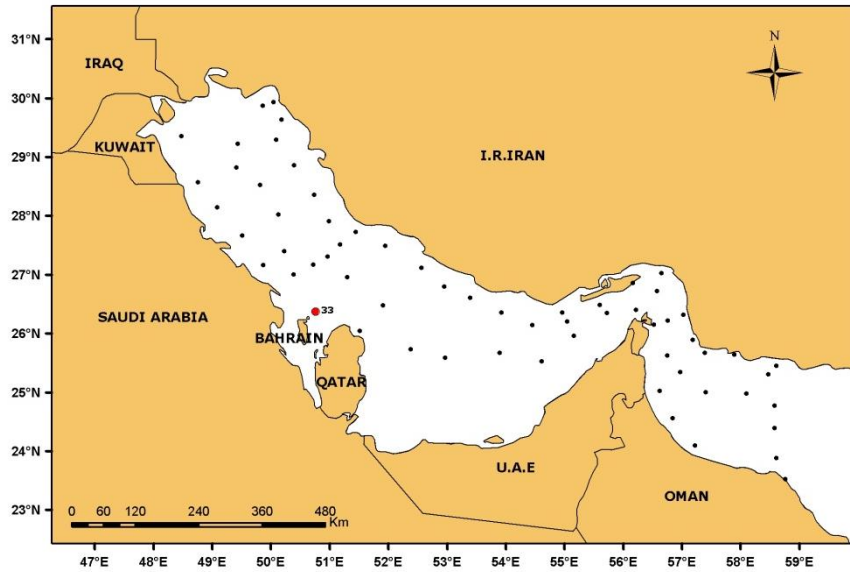
Cells length 85-92 μm ; width 33-35 μm .

Distribution:

Marine littoral species; found occasionally in the plankton collections.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was present in small numbers at one station (refer site map). It has been previously reported in the inner RSA (as *Surirella gemma*) from Kuwaiti shore (Hendey, 1970).



Site of occurrence of *Petrodictyon gemma* in RSA

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Surellaceae Kützing

Genus: *Campylodiscus* Ehrenberg

Cells solitary. Valves circular or nearly so, but bent slightly saddle-shaped. The girdle view is therefore complex, and numerous shapes are obtained, according to the position in which the cell is lying. Valve surface usually costate or bearing folds, which radiate toward the central space which is usually broadly elliptical or linear; the axis of the central space gives a certain amount of polarity to the valve structure. The axes of the two valves usually cross at right angles. The central space may be hyaline, striate or punctate (Hendey, 1964).

Scientific name: *Campylodiscus* sp.

Plate A62: h (Annex A)

Description:

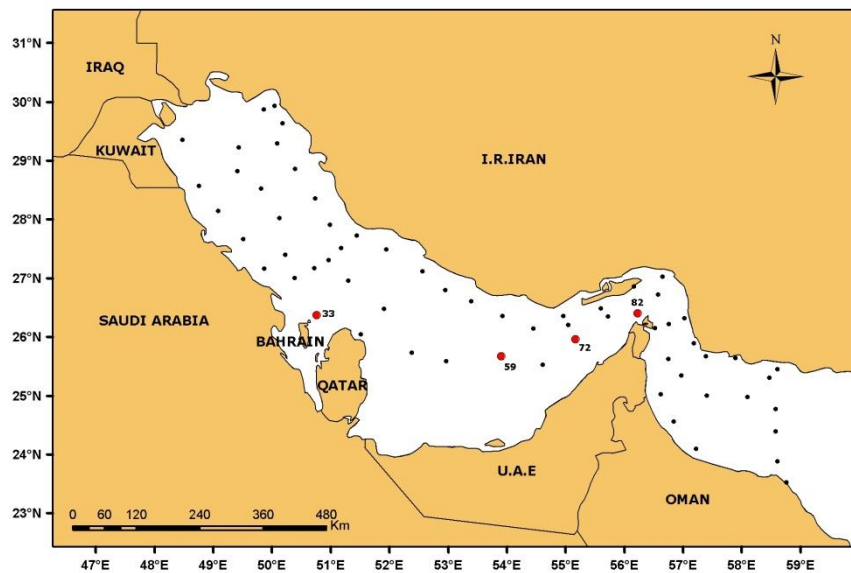
Valves circular, bent slightly saddle-shaped. Valve surface costate, costae radiate towards the central space which is broadly linear; the axis of the central space gives a certain amount of polarity to the valve structure. The central space hyaline.

Dimensions:

Cells length 48-55 μm ; width 48-52 μm .

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was present in small numbers at few scattered stations (refer sites map).



Sites of occurrence of *Campylodiscus* sp. in RSA

5.2.1 Division: Chromophyta

5.2.1.4 Class: Class Dinophyceae West *et. Fritch*, 1927

Dinoflagellates are one of the most important components in plankton. They are small single-celled organisms, which swim freely in water with a forward spiraling motion propelled by dimorphic flagella: one flagellum oriented around the cell, and the other at directed posterior. Cells have plates as a cell covering, and numerous cellular structures: chloroplasts mitochondria and nucleus, which set them apart from other groups of land plants belonging to microscopic algae. Many dinoflagellates are primary producers of food in the aquatic food webs. Dinoflagellates are an integral part of the first link in the aquatic food chain: the initial transfer of light energy to chemical energy (photosynthesis). Almost all other organisms are dependent upon this energy transfer for their subsequent existence. This group of microorganisms comprises a large number of unusual algal species of many shapes and sizes. Dinoflagellate species are adapted to a variety of habitats: from pelagic to benthic, from temperate to tropical seas, and from estuaries to freshwater. Many species are cosmopolitan and can survive in variety of habitats: in the plankton, or attached to sediments, sand, corals, or macroalgal surfaces. Some species produce resting cysts that can survive in sediments for an extended period of time, and then germinate to initiate blooms (Spector, 1984). Dinoflagellates exhibit a wide divergence in morphology and size that are essential features used to identify species, as well as surface ornamentation (pores, areolae, spines, ridges, etc.). Armored or thecate species, those that possess a multilayered cell wall, can be distinguished from unarmored or athecate species, which are those that lack a cell wall (Steidinger and Tangen, 1997).

In general, after diatoms, dinoflagellates is regarded as the second significant contributor to the total abundance of phytoplankton. In Winter 2006 Cruise, when dominant, dinoflagellates contributed up to 91 % of the total phytoplankton abundance; the highest concentration reached 4.8×10^5 cells/l. The higher abundance of dinoflagellates ($> 10^5$ cells/l) was recorded throughout the sampled RSA, especially in the southern part of the inner RSA near the coast of the UAE. The major part of dinoflagellate abundance was contributed by small-sized *Gymnodinium*-like flagellates (88 %; 4.7×10^5 cells/l).

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Actiniscles Sournia, 1984

Family: Actiniscaceae Kützing, 1884

Genus: *Achradina* Lohmann, 1920

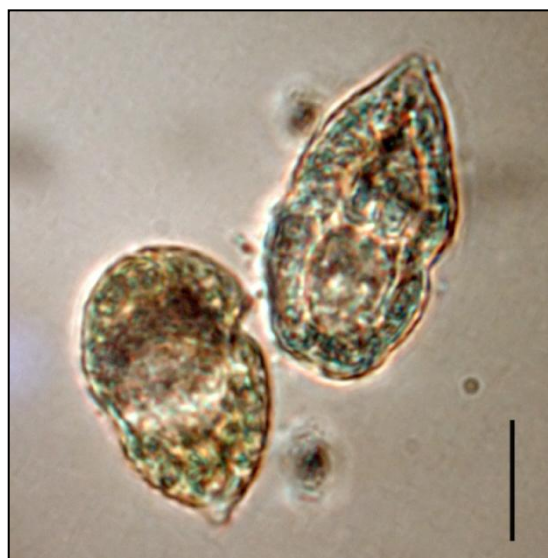
Cells narrowly ovate; slightly dorso-ventrally flattened. Cingulum, straight or slightly oblique; located equatorially or in the first one-third of cell. Sulcus, invisible. Skeleton is not true interior; its structure includes major portion of cytoplasm. It consists of inner silica (?) frame, which may include 1-3 roundish chambers, and surface pellicular reticular-lamellar layer. Chloroplasts are absent (Konovalova, 1998).

Scientific name: *Achradina pulchra* Lohmann

Plate A63: a-c (Annex A)

Synonyms:

Gymnodinium lohmanni Paulsen; *Achradina angusta* Lohmann; *Achradina pulchra* f. *angusta* (Lohmann) Nival; *Achradina reticulata* Lohmann; *Achradina pulchra* f. *reticulata* (Lohmann) Nival; *Achradina sulcata* Lohmann; *Achradina pulchra* f. *sulcata* (Lohmann) Nival; *Achradina pulchra* f. *pulchra* Nival; *Achradina pulchra* f. *aciculata* Nival; *Achradina pulchra* f. *nervosa* Nival; *Achradina pulchra* f. *spatulata* Nival; *Achradina pulchra* f. *truncata* Nival.

**References:**

Lohmann, 1920: p. 138, Fig. 42a; Schiller, 1937: p. 5, Fig. 2a; Nival, 1969: p. 128, Fig. 1; Pl. 1, 2; Konovalova, 1998: p. 82, Fig. 19: 5 a, b.

Description:

Cells small-sized, 16.8-22 μm long, 7-11 μm wide; irregularly narrowly ovate or widely spindle-shaped, slightly dorso-ventrally flattened. Epitheca conical, often with spinule on apex, sometimes, spinule is present also on antapex. Cingulum is poorly defined, straight or slightly oblique, located equatorially or in the first one-third of cell. Hypotheca is roundish or widely conical. Sulcus is invisible. Cell surface is compact, reticulated or reticular-lamellar. Interior skeleton consists of frame, which includes 1-2 (rare 3) roundish or rounded-conical chambers (Konovalova, 1998).

Dimensions:

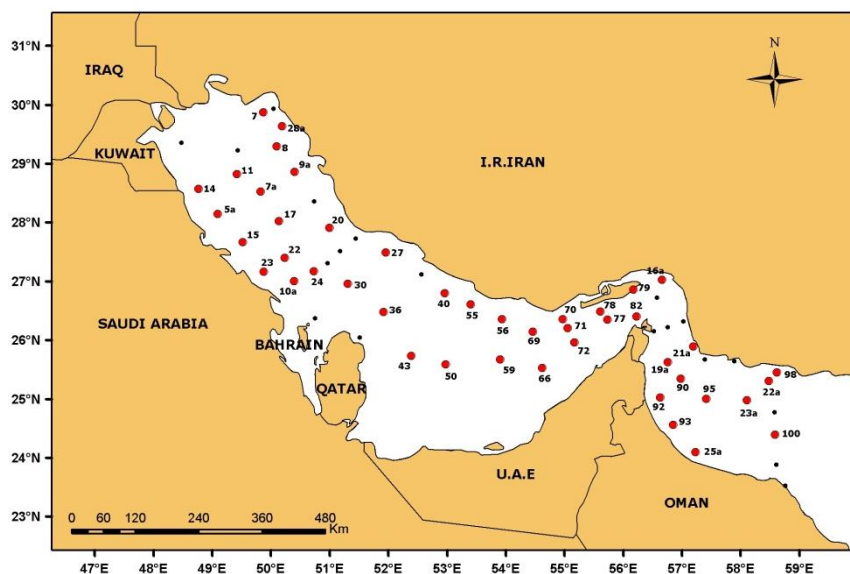
Cells 29-32 μm long; 13-15 μm wide.

Distribution:

Atlantic and Pacific oceans, Black and Mediterranean seas.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was frequently observed at many sites (refer sites map), although never in large numbers; maximum abundance (4.3×10^2 cells/l) was associated with the central part of the inner RSA (St. 50).



Sites of occurrence of *Achradina pulchra* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Actiniscales Sournia, 1984

Family: Actiniscaceae Kützing, 1884

Genus: *Actiniscus* Ehrenberg, 1843

Heterotrophic, cingulum median on the cell; slightly displaced; sulcus extended for some distance at the epicone. A characteristic inner skeleton consists of two star-shaped silica structures with five rays (pentasts) enclosing the central nucleus (Throndsen *et al.*, 2007).

Scientific name: *Actiniscus pentasterias* (Ehrenberg) Ehrenberg

Plate A63: d-i (Annex A)

Synonym:

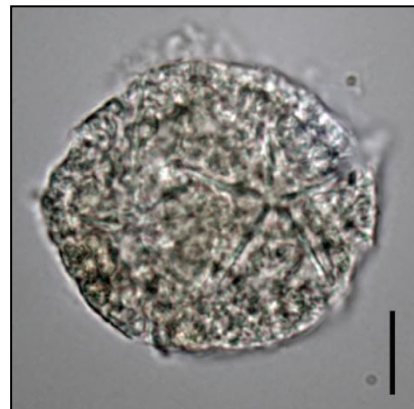
Gymnaster pentasterias Schütt

Reference:

Throndsen *et al.*, 2007: p. 58.

Description:

Cell nearly spherical, often apically-antapically compressed. In ventral view the pentasts can be seen opposing each other with the rays bending to make two half spheres with a diameter approximately one half that of the cell. Diameter 25-50 μm . Disrupt easily upon fixation leaving loose pentasts which may eventually be easily identified (Throndsen *et al.*, 2007).

**Dimensions:**

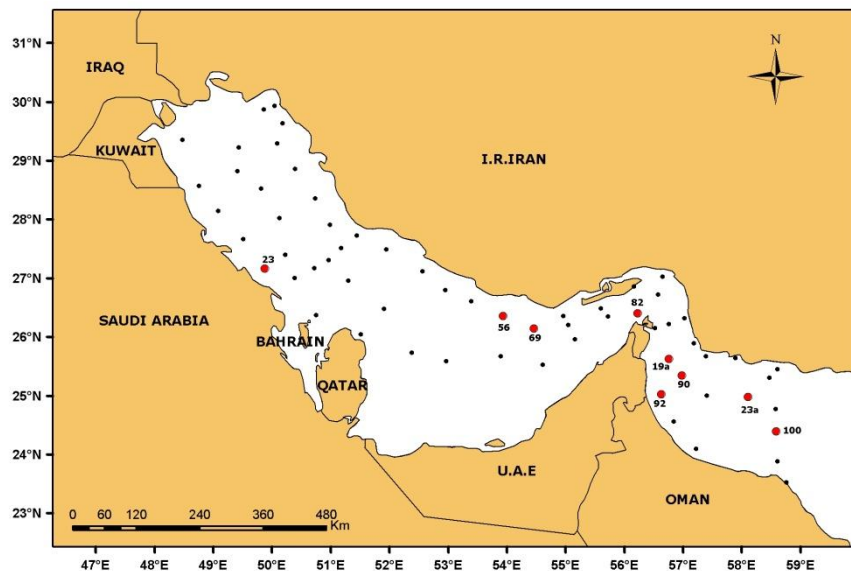
Cells 59-62 μm long; 55-64 μm wide.

Distribution:

Widely distributed.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at scattered stations (refer sites map), never in large numbers; maximum abundance (1.3×10^2 cells/l) was associated with the Sea of Oman (St. 92).



Sites of occurrence of *Actiniscus pentasterias* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Actiniscales Sournia, 1984

Family: Actiniscaceae Kützing, 1884

Genus: *Dicroerisma* Taylor *et* Cattell, 1969

Species: *psilonereiella*

Scientific name: *Dicroerisma psilonereiella* Taylor *et* Cattell

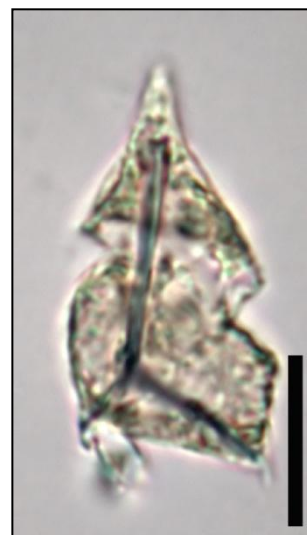
Plate A79: i-l (Annex A)

References:

Taylor and Cattell, 1969: p. 169-172, Pl. 1: 1 a-d; Taylor, 1976: p. 54, Pl. 37: 432; Konovalova, 1998: p. 83, Fig. 19-8.

Description:

Cell oblong, obovoid or pear-shaped, slightly dorsoventrally flattened; 37-42 μm long; 21-25 μm wide. Epitheca conical or roundish-conical; apex extended with obtuse end. Cingulum is equatorial, descending, deep; its borders weakly delineated in ventral side. Hypotheca slightly wider than epitheca with rounded, convex sides; antapex concave. Sulcus border difficult for observation in the central part of ventral side and near antapex. Cell surface smooth; chloroplasts absent, numerous small rounded parietal bodies. Large pusule, located below the cingulum in the left part of cell. Inside mineralized skeleton may be easily observed as inverted Y-shaped tube with brachiferous ends, which extends from apex to antapex (Konovalova, 1998).

**Dimensions:**

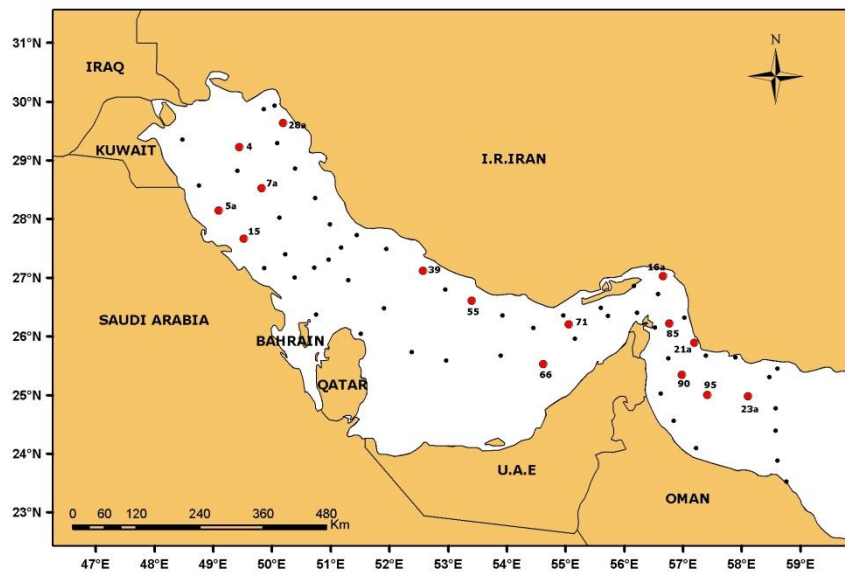
Cells 27-30 μm long; 11-12 μm wide.

Distribution:

Rare species have been found firstly in the Pacific coastal zone of British Columbia (Canada), also reported from the Pacific shores of the Russian Far East. Species have previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred in small numbers at scattered stations (refer sites map).



Sites of occurrence of *Dicroerisma psilonereiella* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Dinophysales Lindermann, 1928

Family: Dinophysaceae Stein, 1883

Genus: *Amphisolenia* Stein, 1883

A genus of very elongated organisms; epitheca reduced to a small cap-like plate; hypotheca drawn out into one or more posterior processes which may be inflated in their upper or mid portion. Transverse lists as in *Dinophysis*, but sulcal list reduced and only running a short distance along the hypotheca. Thecal plates are weakly sculptured (Dodge, 1982).

This genus includes two large-sized heterotrophic rarely observed species. In Winter 2006 Cruise, species of this genus were presented in samples in very low concentrations (< 1% of total phytoplankton abundance; < 50 cells/l). Distribution of this genus was strongly associated with the open deep sea waters of the Sea of Oman, often in middle and bottom layers.

Scientific name: *Amphisolenia bidentata* Schröder

Plate A64: a-l (Annex A)

References:

Wood, 1968: p. 18, Fig. 19; Taylor, 1976: p. 28, Pl. 2: 21, 22; Pl. 3: 21b, 22b; Balech, 1988: p. 239, L. 17: 2, 3.

Description:

Slightly or moderately sigmoid; head two to three times wider than long; epitheca gently convex; midbody fusiform, merging gradually into anterior and antapical portions; antapical twisted ventrally and bent to the right with spinule at elbow; antapex widened truncate with two spinules on left valve, none on right. Length 700-900 μm (Wood, 1968).

Dimensions:

Cells 750-810 μm long; 30-35 μm wide.

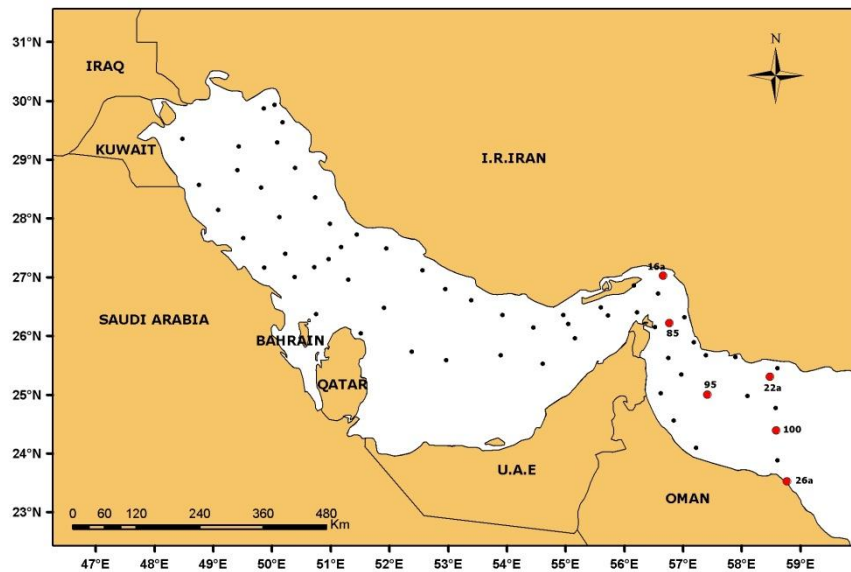
Distribution:

Oceanic, sometimes associated with upwelling; cosmopolitan in warm temperate to tropical waters. Species have previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred in small numbers at scattered stations (refer sites map) in the Sea of Oman, usually in bottom layers.





Sites of occurrence of *Amphisolenia bidentata* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Dinophysales Lindermann, 1928

Family: Dinophysaceae Stein, 1883

Genus: *Amphisolenia* Stein, 1883

Species: *globifera*

Scientific name: *Amphisolenia globifera* Stein

Plate A65: a-g (Annex A)

References:

Wood, 1968: p. 19, Fig. 25; Taylor, 1976: p. 29, Pl. 2: 26, 27; Pl. 3: 26b, 27b; Dodge, 1982: p. 38, Fig. 3 E

Description:

Epitheca very reduced; hypotheca of variable length, widened into a bulge around the center and ending with a rounded knob. Sulcus is less than a quarter of the length of the hypotheca; 200-300 μ m long (Dodge, 1982).

Dimensions:

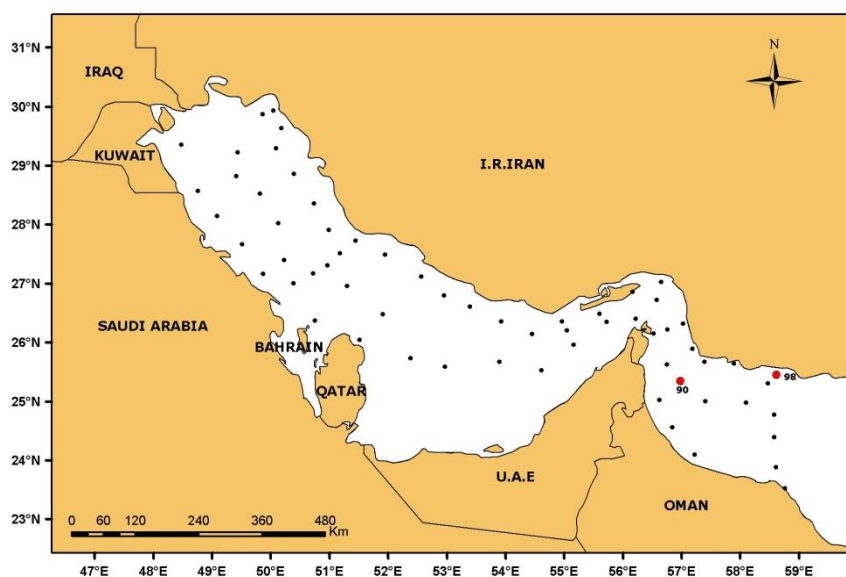
Cells 140 μm long; 12-13 μm wide.

Distribution:

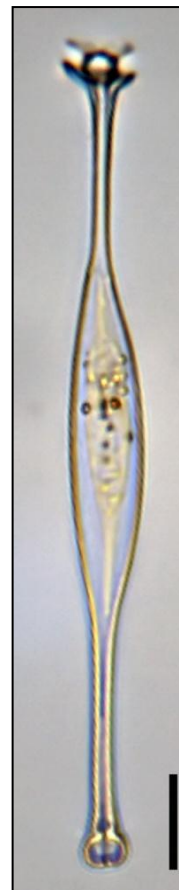
Eupelagic species; cosmopolitan in warm temperate to tropical waters. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at two sites (refer sites map); two specimens were found at two localities in the Sea of Oman one at St. 90 and the other at St. 98 in bottom sampling layer.



Sites of occurrence of *Amphisolenia globifera* in RSA

**Division: Chromophyta**

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Dinophysales Lindermann, 1928

Family: Dinophysaceae Stein, 1883

Genus: *Dinophysis* Ehrenberg, 1839

(= *Phalachroma* Stein, 1883 *partim*.)

Characteristics for the genus are the apical location of the cingulum, the markedly wing-shaped lists along the sulcus and the delimiting list on both sides of the cingulum. Left sulcus list is distinctly larger than the right one, and with three supporting ribs. The cells are laterally flattened and will rest on the side in the LM water mounts. The cell outline in lateral view is the most important distinguishing feature for the species. The surface structure of the theca varies from almost smooth plates to theca plates with distinct surface markings. Species in which the epicone protrudes above the apical cingulum list have been referred to another genus, *Phalacroma*, by some authors. *Dinophysis* comprises species with chloroplasts and species that lack chloroplasts (Throndsen *et al.*, 2007).

In Winter 2006 Cruise, species of *Dinophysis* genus were rare or occasionally found in samples; only *D. caudata* and *D. rotundata* were frequently observed. The genus *Dinophysis* was usually present in low concentrations (less than 6% of total phytoplankton abundance; $< 3.9 \times 10^2$ cells/l). Local peaks ($> 10^2$ cells/l) were sporadically noted throughout the RSA area.

Scientific name: *Dinophysis acuminata* Claparede *et* Lachmann

Plate A66: c-g (Annex A)

Synonyms:

Dinophysis borealis Paulsen; *Dinophysis boehmii* Paulsen;
Dinophysis lachmannii Paulsen

References:

Lebour, 1925: p. 80, Pl. XII: 2 a-c; Wood, 1968: p. 47, Fig. 111; Dodge, 1982: p. 44, Fig. 3H; Balech, 1988: p. 227, L. 5: 5-10; Hallegraeff *et al.*, 1995: p. 304, Figs. 15.23, 15.38 b; Hallegraeff, 2002: p. 81, Fig. 18 A, D; Faust and Gualledge, 2002: p. 23, Pl. 11: 1-6; Throndsen *et al.*, 2007: p. 53.



Description:

Cells oval or often narrow and elongated oval in lateral view. Dorsoventral depth, longest near the middle, about half of the cell length. Epitheca low, flat or weakly convex, invisible in lateral view. Dorsoventral depth of epitheca is 1/3 to 1/2 of hypotheca. Antapex is rounded and smooth, or with two to four knob-shaped small protuberances. Left sulcal list is rather narrow, often coarsely areolate, supported by three ribs, extending to 1/2 to 2/3 of cell length. Thecal plates are thick and areolated. Length: 40-50 µm; dorsoventral depth: 30-40 µm (Hallegraeff *et al.*, 1995).

Harmful Effect:

Species is a producer of okadaic acid, a toxin implicated in diarrhetic shellfish poisoning (DSP) (IOC list, 2002; Cembella, 1989; Lee *et al.*, 1989; Kat, 1985). Its blooms are often associated with toxification of shellfish (Larsen and Moestrup, 1992). Toxicity can vary considerably among seasons and areas where it blooms (Taylor *et al.*, 1995). This species can cause shellfish toxicity at very low cell concentrations (as low as 200 cells/l) (Lassus *et al.*, 1985). Hoshiai *et al.* (1997), however, reported a case of nontoxic mussels in Kesennuma Bay, northern Japan, in the presence of high concentrations of *D. acuminata* cells.

Taxonomical Remarks:

Population of *Dinophysis acuminata* in the RSA was composed of specimens differing somewhat in size, shape and morphology. Among typical cells (as illustrated in Pl. A66: c), some specimens with rightward bending of the left sulcal list were observed (Pl. A66: d, e). Similar variability within *Dinophysis acuminata* from Japanese waters has been described in Abé (1967, p. 44-45, fig. 7).

Dimensions:

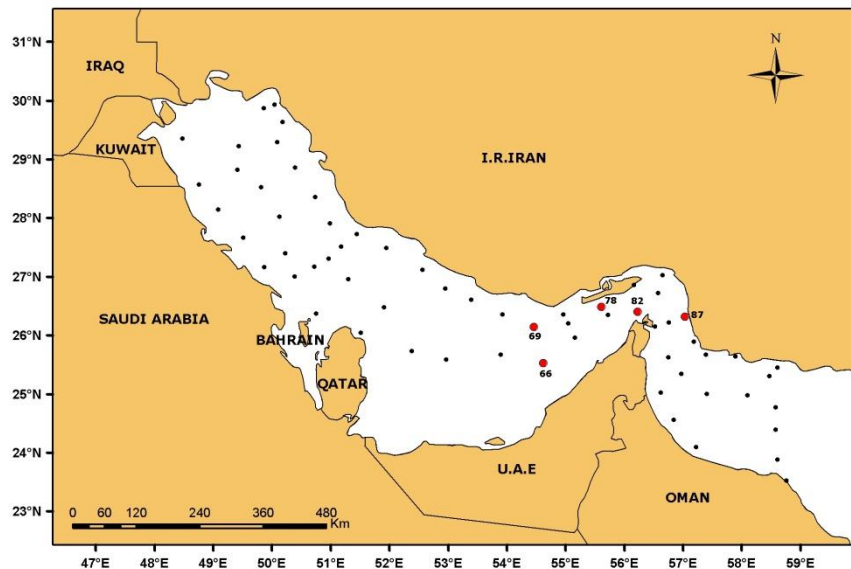
Cells 44 µm long; 30 µm wide.

Distribution:

Widely distributed in temperate waters and seems to appear abundantly in coastal waters, especially eutrophic areas.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred in small numbers at few stations in the southern part of the inner RSA (refer sites map). This species has been previously reported from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004).



Sites of occurrence of *Dinophysis acuminata* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Dinophysales Lindermann, 1928

Family: Dinophysaceae Stein, 1883

Genus: *Dinophysis* Ehrenberg, 1839

(= *Phalachroma* Stein, 1883 *partim.*)

Species: *caudata*

Scientific name: *Dinophysis caudata* Saville-Kent

Plate A67: a-h (Annex A)

Synonyms:

Dinophysis homunculus Stein; *Dinophysis caudata* var. *tripos* (Gourret) Gail; *Dinophysis caudata* f. *acutiformis* Kofoed *et* Skogsberg

References:

Lebour, 1925: p. 82, Fig. 21 c; Wood, 1968: p. 47, Fig. 112; Taylor, 1976: p. 34, Pl. 6: 59; Dodge, 1982: p. 45, Fig. 4 B; Pl. II: d; Dodge, 1985: p. 18; Balech, 1988: p. 230, L. 8: 2, 3; Hallegraeff *et al.*, 1995: p. 306, Figs. 15.25; Faust and Gullledge, 2002: p. 26, Pl. 13: 1-6; Throndsen *et al.*, 2007: p. 54.

**Description:**

Cells large, irregularly subovate with fairly distinctive long ventral projection. Ventral side of hypotheca undulate or straight. Dorsal side straight or slightly concave in the anterior half, and straight or convex, running parallel with the ventral side in the posterior half. Anterior cingular list wide, supported by many ribs, forming a wide and deep funnel-like structure with very low epitheca on the bottom. Left sulcal list almost half of total length, supported by three ribs. Thecal plates thick, areolated. Length: 70-110 μm (Hallegraeff *et al.*, 1995).

Harmful Effect:

This species is a producer of okadaic acid, which is a toxin implicated in DSP (IOC list, 2002). Its blooms, which are associated with mass mortality of fish, were reported in the Gulf of Thailand and the Seto Sea in Japan (Okaichi, 1967). Toxicity of the species was found using specimens collected from the Philippine waters (Hallegraeff *et al.*, 1995).

Dimensions:

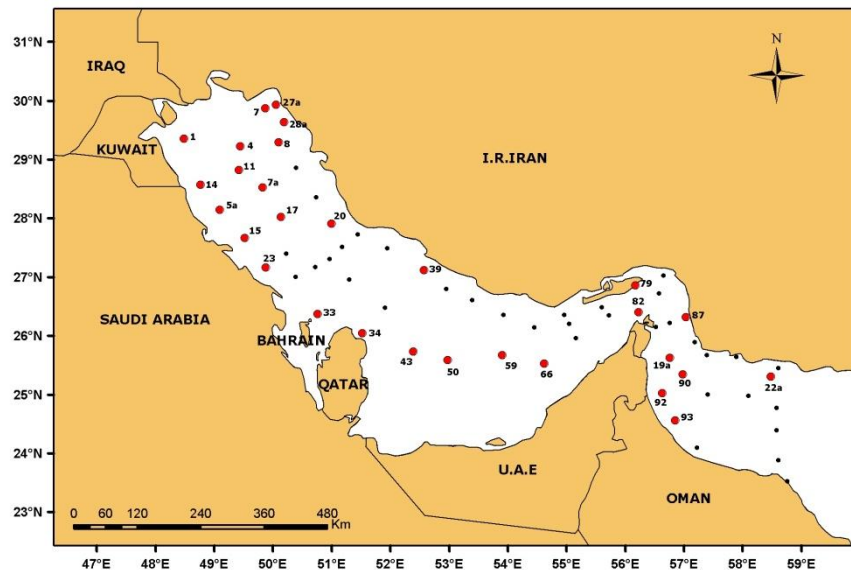
Cells 80-85 μm long; 32-36 μm wide.

Distribution:

Neritic and estuarine in warm temperate to tropical waters, worldwide distribution. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was frequently observed at various sites (refer sites map), although never in large numbers; maximum abundance (3.9×10^2 cells/l) was associated with the Sea of Oman (St. 92). Species has previously been reported from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Dinophysis caudata* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Dinophysales Lindermann, 1928

Family: Dinophysaceae Stein, 1883

Genus: *Dinophysis* Ehrenberg, 1839

(= *Phalachroma* Stein, 1883 *partim.*)

Species: *doryphorum*

Scientific name: *Dinophysis doryphorum* (Stein) Abé

Plate A70: i; 71: a-c (Annex A)

Synonym:

Phalachroma doryphorum Stein

References:

Taylor, 1976: p. 35, Pl. 4: 41, 42; Hansen *et al.*, 2001: p. 28, Pl. 2: B.

Description:

Species is characterized by a distinct triangular ribless posterior spine. The distal end of the spine may be thickened, and the shape may vary from clavate to acute. The cell body is subovate and slightly tapered toward the posterior. The epitheca is raised above the upper circular list. Chloroplasts are absent. Length ca 50 μm (Hansen *et al.*, 2001).

**Dimensions:**

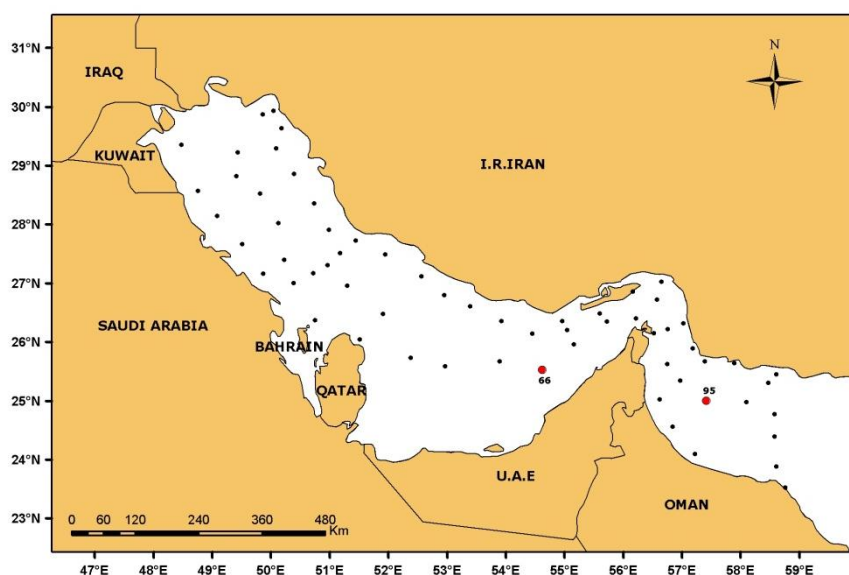
Cells 70-73 μm long; 58-60 μm wide.

Distribution:

Tropical to warm temperate waters. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred in small numbers at two stations (refer sites map).



Sites of occurrence of *Dinophysis doryphorum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Dinophysales Lindermann, 1928

Family: Dinophysaceae Stein, 1883

Genus: *Dinophysis* Ehrenberg, 1839

(= *Phalachroma* Stein, 1883 *partim*.)

Species: *miles*

Scientific name: *Dinophysis miles* Cleve

Plate A68: a-g (Annex A)

References:

Taylor, 1976: p. 38, Pl. 6: 57, 58; Hallegraeff *et al.*, 1995: p. 306, Figs. 15.27.

Description:

Cells very large, antero-posteriorly elongated with two fairly distinctive long antapical and dorsal projections. Ventral side of hypotheca, undulate. Dorsal side concave and smoothly continues to the dorsal projection which runs obliquely backwards. The distal end bends at a right angle, carrying a wing-like unabsorbed remnant of the megacytic zone. Six to eight daughter cells are often attached at the remnant after asexual cell division. Posterior projections are shorter or longer than, or as long as the dorsal process. Angle between the dorsal and posterior projections is at 50-90°. It starts at the base of the third rib. Anterior cingular list is wide, supported by many ribs, forming a narrow funnel-like structure with very low epitheca on the bottom. Thecal plates are thick, round or angular areolated. Length: 125-150 µm (Hallegraeff *et al.*, 1995).

**Harmful Effect:**

It is a producer of dinophysistoxin-1 (DTX-1), a toxin implicated in DSP (IOC list, 2002). Toxicity of the species has been found using specimens collected from the Philippines waters (Hallegraeff *et al.*, 1995).

Dimensions:

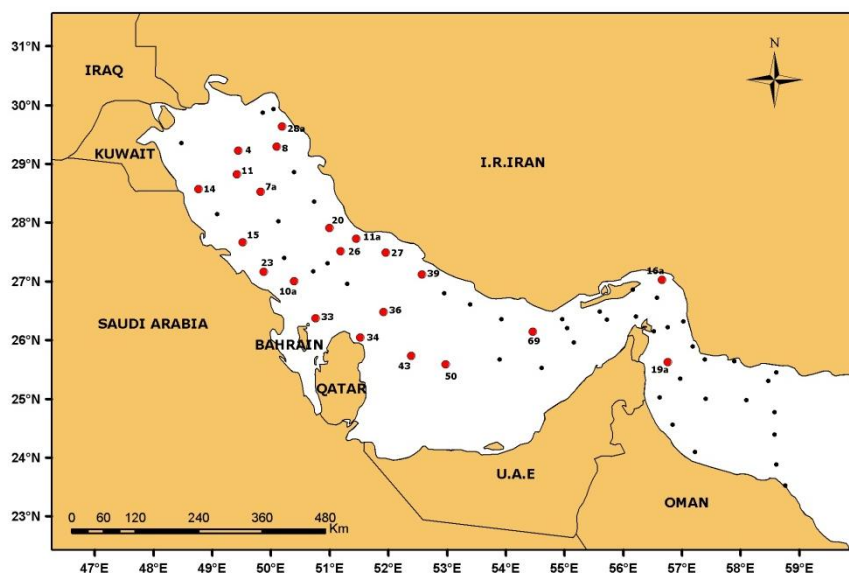
Cells 122-131 μm long; 40-42 μm wide.

Distribution:

Widely distributed in tropical waters; species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred occasionally in small numbers at different stations (refer sites map); maximum abundance (72 cells/l) was associated with the Iranian coast in the northwestern part of the inner RSA (St. 28a). It has previously been reported from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Dinophysis miles* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Dinophysales Lindermann, 1928

Family: Dinophysaceae Stein, 1883

Genus: *Dinophysis* Ehrenberg, 1839

(= *Phalachroma* Stein, 1883 *partim.*)

Species: *mitra*

Scientific name: *Dinophysis mitra* (Schütt) Abé

Plate A69: a-c (Annex A)

Synonyms:

Phalacroma rapa Stein; *Phalacroma mitra* Schütt;
Phalacroma dolichopterygium Jorgensen

References:

Taylor, 1976: p. 39, Pl. 5: 49; Balech, 1988: p. 230, L. 8: 9-11; Hallegraeff *et al.*, 1995: p. 307, Fig. 15.28; Faust and Gullede, 2002: p. 29, Pl. 15: 1-6.



Description:

Cells broad wedge-shaped; dorsal side smoothly convex; ventral side flat or somewhat undulate in anterior half, and slightly concave in posterior half. Epitheca flat or slightly convex; broad ellipsoidal in apical view. As the megacytic zone becomes wide due to cell growth, the epitheca becomes round in apical view and the postero-ventral concavity becomes much less distinct. Dorso-ventral depth of epitheca and hypotheca are almost the same and longest at the base of the second rib. Cingulum is located most anteriorly. Both anterior and posterior cingular lists are narrow, supported by many ribs. Sulcal list is rather short, about half of the total length supported by three short ribs. Thecal plates are thick and coarsely areolated. Length: 56-68 μm , width 48-58 μm (Hallegraeff *et al.*, 1995).

Harmful Effect:

It is a confirmed DSP (diarrhetic shellfish poison) toxin-producing species; it produces Dinophysistoxin-1 (DTX 1) and okadaic acid (OA) (Lee *et al.*, 1989).

Dimensions:

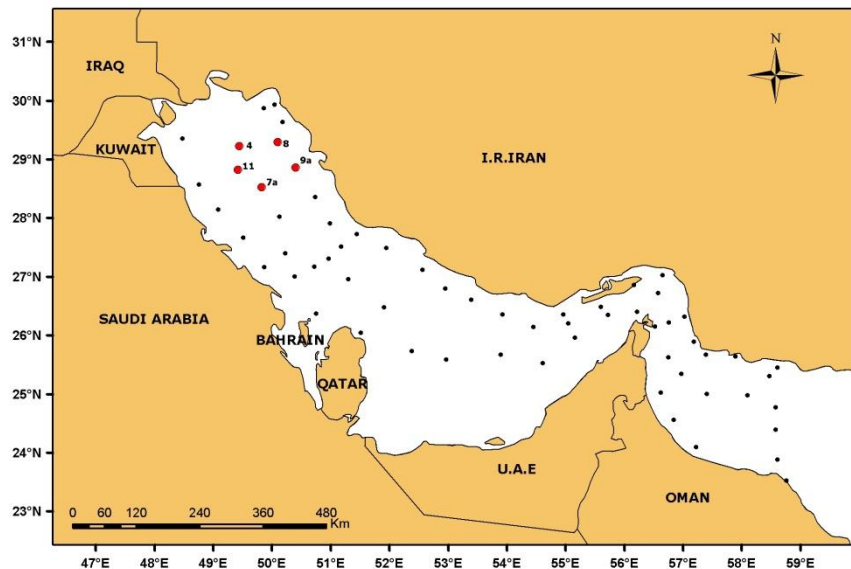
Cells 48 μm long; 42 μm wide.

Distribution:

Widely distributed in temperate waters. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, it occurred in small numbers at scattered stations in the northwestern part of the inner RSA (refer sites map). Species has previously been reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Dinophysis mitra* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Dinophysales Lindermann, 1928

Family: Dinophysaceae Stein, 1883

Genus: *Dinophysis* Ehrenberg, 1839

(= *Phalachroma* Stein, 1883 *partim.*)

Species: *nasutum*

Scientific name: *Dinophysis nasutum* (Stein) Parke *et* Dixon

Plate A66: h-j (Annex A)

Synonyms:

Phalacroma nasutum Stein; *Pseudophalacroma nasutum* Jorgensen

References:

Lebour, 1925: p.75, Figs. 20 a, b (as *Pseudophalacroma nasutum*); Schiller, 1933: p. 55, Fig. 54 (as *Pseudophalacroma nasutum*); Dodge, 1982: p. 51, Fig. 4 G.

**Description:**

Oval or roundish in lateral view with slight constriction at girdle. Epitheca much smaller than hypotheca, domed and not obscured by the cingular lists. Characteristically, the sulcus extends onto the epitheca two-thirds of the distance from the girdle to the apex, and has a rounded end in the epithecal dome. The anterior cingular list together with the posterior list may be supported by very short ribs; the former list being horizontal or inclined anteriorly as much as 45°. The posterior cingular list resembles the anterior one but is narrower. The hypotheca is large and bears no antapical spines or protuberances. The sulcal lists are narrow and inconspicuous with no obvious ribs on the left sulcal list. The sulcus extends halfway down the hypotheca. The theca is covered with coarse poroids which may contain a pore. The girdle plates have rows of poroids arranged horizontally with the middle row each containing a pore; 43-49 µm long; depth of body 38-43 µm (Dodge, 1982).

Dimensions:

Cells 40-42 µm long; 29-30 µm wide.

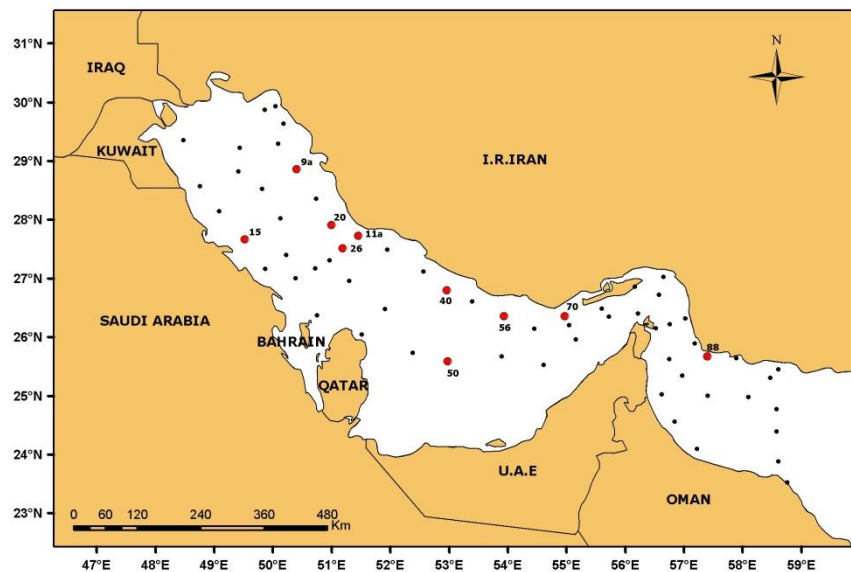
Distribution:

Widely distributed in temperate waters.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at few sites (refer sites map), never in large numbers; maximum abundance (1.4×10^2 cells/l) was associated with the Sea of Oman (St.

88). It has been previously reported (as *Pseudophalacroma nasutum*) from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Dinophysis nasutum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Dinophysales Lindermann, 1928

Family: Dinophysaceae Stein, 1883

Genus: *Dinophysis* Ehrenberg, 1839

(= *Phalachroma* Stein, 1883 *partim.*)

Species: *rapa*

Scientific name: *Dinophysis rapa* (Stein) Abé

Plate A69: d-I (Annex A)

Synonym:

Phalachroma rapa Stein

References:

Schiller, 1933; Fig. 80 (as *Phalacroma rapa*); Taylor, 1976: p. 40, Pl. 5: 48 a, b; Pl. 41: 488; Hansen *et al.*, 2001: p. 31, Pl. 2: G.

Description:

Species is very similar to and may be conspecific with *D. mitra*. However, it may be distinguished from each other by *D. rapa* having a more angular projection of the ventral margin adjacent to the R3 rib of the left sulcal list. As a result, the sulcal area has a straight to concave outline. In *D. mitra* this area is more convexly rounded. Thecal plates are coarsely areolated. Chloroplasts absent. Length ca 70 µm, width ca 80 µm (Hansen *et al.*, 2001).

**Harmful Effect:**

This species was found to produce okadaic acid (IOC list, 2002).

Dimensions:

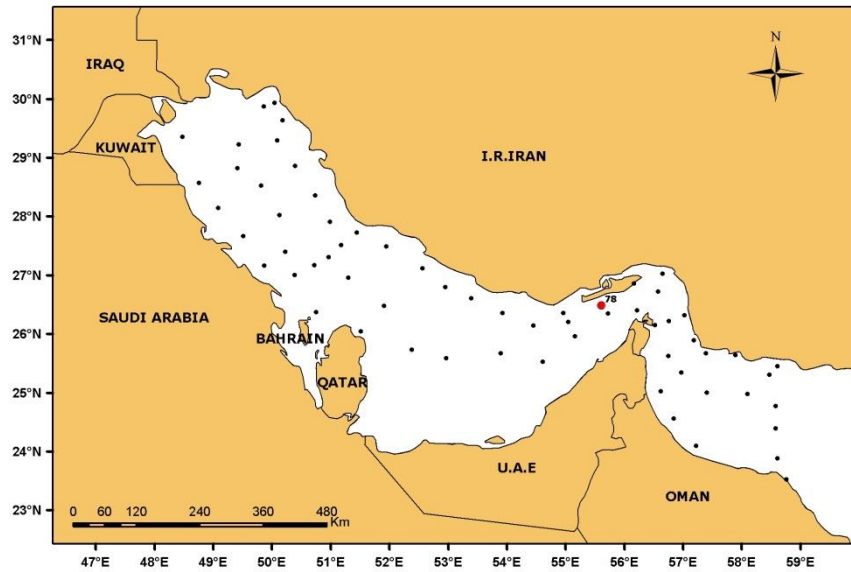
Cells 77 µm long; 67 µm wide.

Distribution:

Worldwide distribution; temperate to tropical waters. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, a single specimen was recorded at one locality in the Strait of Hormuz area (St. 78) (refer site map).



Site of occurrence of *Dinophysis rapa* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Dinophysales Lindermann, 1928

Family: Dinophysaceae Stein, 1883

Genus: *Dinophysis* Ehrenberg, 1839

(= *Phalacroma* Stein, 1883 *partim.*)

Species: cf. *rotundata*

Scientific name: *Dinophysis* cf. *rotundata* Claparede *et* Lachmann

Plate A66: a, b (Annex A)

Synonyms:

Phalacroma rotundatum (Claparede *et* Lachmann) Kofoid *et* Michener; *Phalacroma rotundatum* var. *laevis* (Claparede *et* Lachmann) Jorgensen; *Prodinophysis rotundatum* (Claparede *et* Lachmann) Balech; *Dinophysis whittingae* Balech

References:

Lebour, 1925: p. 78, Pl. XI: 3 a-c (as *Phalacroma rotundatum*); Schiller, 1933: Fig. 60 (as *Phalacroma rotundatum*); Dodge, 1982: p. 55, Fig. 4 I; Pl. II: f; Dodge, 1985: p. 27; Balech, 1988: p. 231, L. 9: 1-4; Hallegraeff *et al.*, 1995: p. 307, Fig. 15.30; Faust and Gualledge, 2002: p. 32, Pl. 17: 1-5; Throndsen *et al.*, 2007: p. 56.

Description:

Cells asymmetrically round-oval in lateral view and ellipsoidal to round in apical view. Epitheca low and fairly evenly rounded; convex, and visible laterally. Both anterior and posterior cingular lists are narrow, lacking any ridges. Sulcal list also is narrow, extending to about 1/2 to 3/5 of total length. The list has three ribs, among which the second one is located nearer the first one. Dorso-ventral depth is largest between base of the second and third ribs. Thecal plates are thick, finely areolated. Protoplasm does not contain chloroplasts, but often has many large food vacuoles. Length: 42-50 μm , dorso-ventral depth: 36-43 μm (Hallegraeff *et al.*, 1995).



Harmful Effect:

It is a toxic species producing the toxin dinophysistoxin-1 (DTX-1), which causes diarrhetic shellfish poisoning (DSP). However, only Japanese strains of this species have been found to produce the toxins. North American strains apparently were reported to be nontoxic (IOC list, 2002). *D. rotundata* is the first heterotrophic dinoflagellate in which toxin productivity has been confirmed (Lee *et al.*, 1989).

Taxonomical Remarks :

Specimen illustrated deviates from typical *Dinophysis rotundata* by being rounded posterior end of the left sulcal list with reduced R3 rib (Plate A66: a, b) against sharply angulated left sulcal list supported by distinct three ribs in *D. rotundata* as illustrated in e.g. Lebour (1925, Pl. XI: 3 a-c), Schiller (1933, fig. 60), Abé (1967, fig. 15), Dodge (1982, fig. 4 I; Pl. II: f), Balech (1988, L. 9: 1-4).

Dimensions:

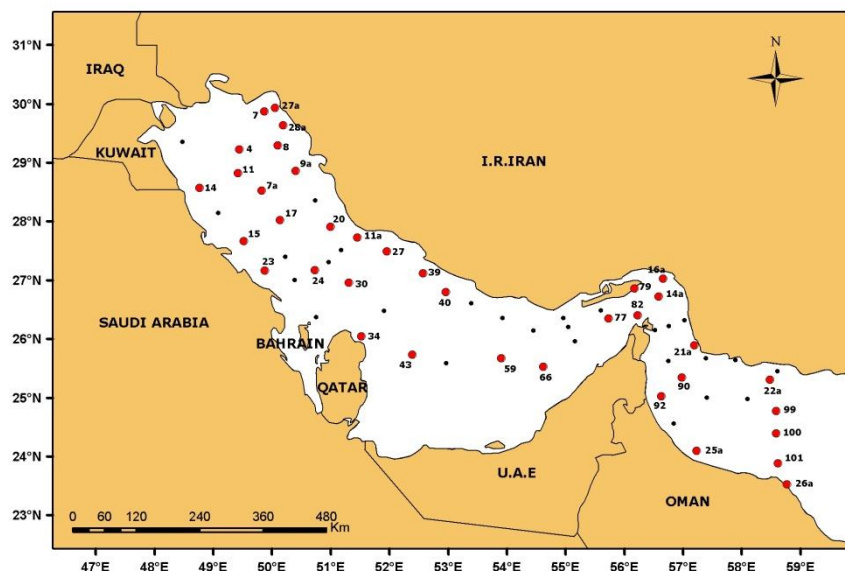
Cells 40-42 μm long; 37-39 μm wide.

Distribution:

Widely distributed in cold and temperate waters.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was frequently observed at various sites (refer sites map), although never in large numbers; maximum abundance (53 cells/l) was associated with the northwestern part of the inner RSA (St. 17). It has been previously reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Dinophysis* cf. *rotundata* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Dinophysales Lindermann, 1928

Family: Dinophysaceae Stein, 1883

Genus: *Dinophysis* Ehrenberg, 1839

(= *Phalachroma* Stein, 1883 *partim.*)

Scientific name: *Dinophysis* sp. 1

Plate A70: f (Annex A)

Description:

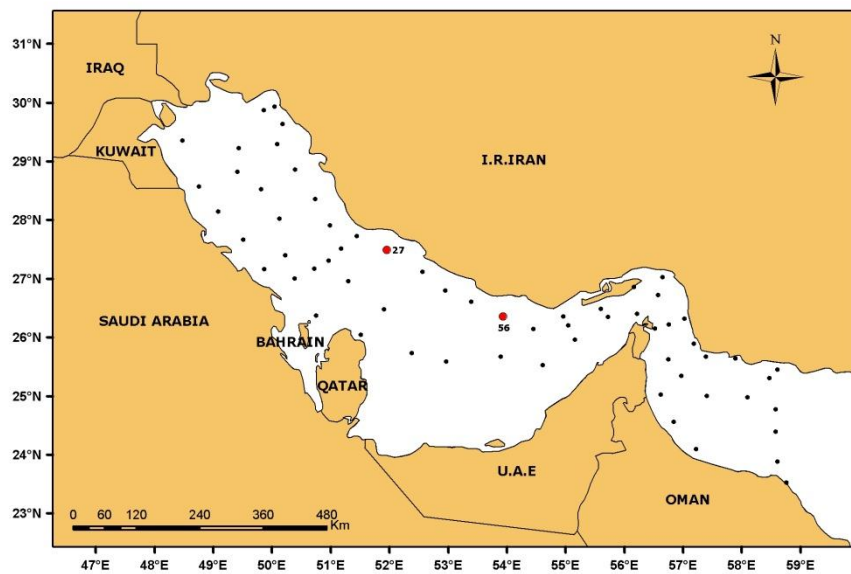
Body in side view circular.

Dimensions:

Cells 30-32 μm long; 27-28 μm wide.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at two sites (refer sites map).



Sites of occurrence of *Dinophysis* sp. 1 in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Dinophysales Lindermann, 1928

Family: Dinophysaceae Stein, 1883

Genus: *Dinophysis* Ehrenberg, 1839

(= *Phalachroma* Stein, 1883 *partim.*)

Scientific name: *Dinophysis* sp. 2

Plate A70: g, h (Annex A)

Description:

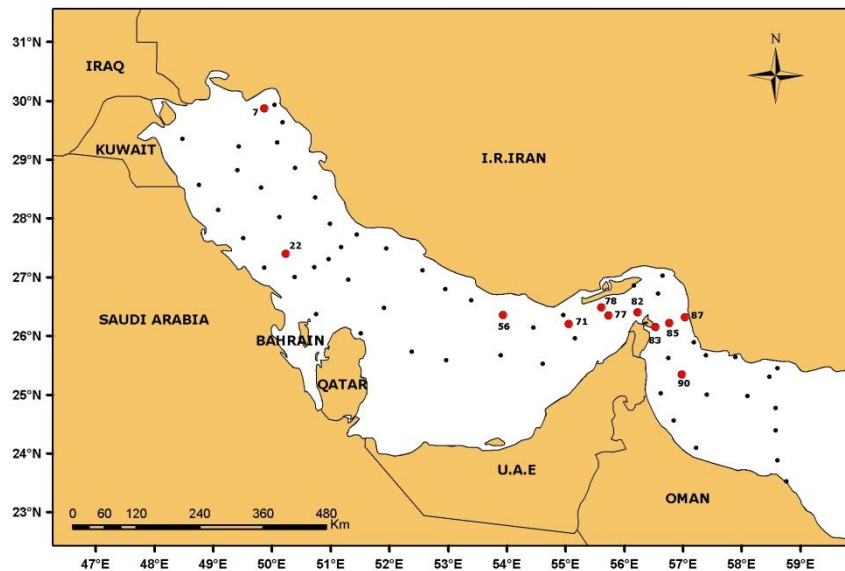
Body in side view ovate.

Dimensions:

Cells 35 μm long; 29 μm wide.

Sites of occurrence in RSA:

In Winter 2006 Cruise, species occurred at few sporadic sites (refer sites map).



Sites of occurrence of *Dinophysis* sp. 2 in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Dinophysales Lindermann, 1928

Family: Dinophysaceae Stein, 1883

Genus: *Dinophysis* Ehrenberg, 1839

(= *Phalachroma* Stein, 1883 *partim*.)

Scientific name: *Dinophysis* sp. 3

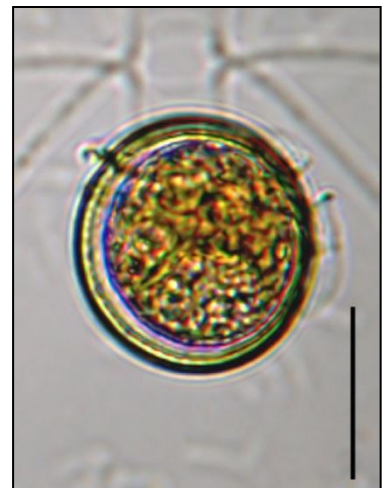
Plate A70: a-e (Annex A)

Description:

Body in side view ovate; epitheca rounded, moderately high; girdle slightly depressed, girdle list narrow; left sulcal list wide, supported by three ribs, extending more than half the length of hypotheca.

Taxonomical Remarks:

Specimens illustrated resemble *Dinophysis rotundata*, however, differ from typical *D. rotundata* by having a wider posteriorly left sulcal list (Plate A70: b-e).

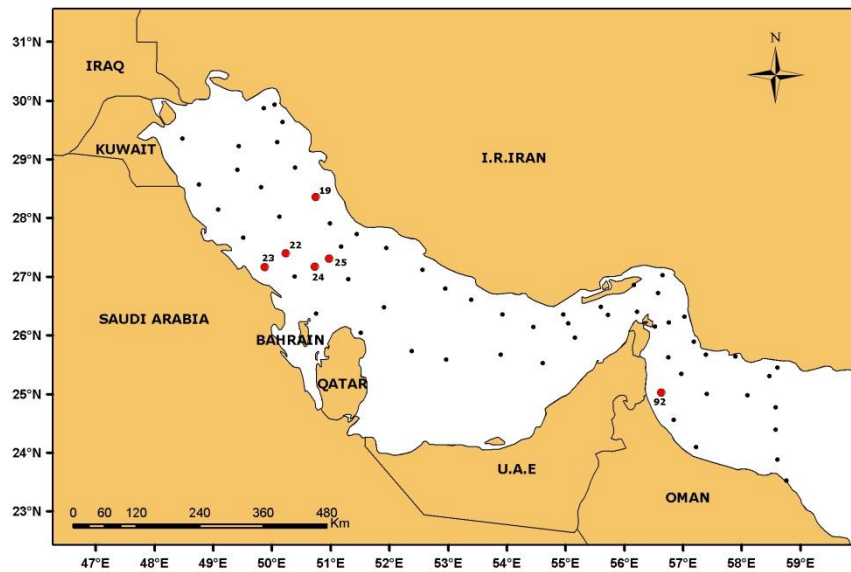


Dimensions:

Cells 50-56 µm long; 42-44 µm wide.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at few sites (refer sites map) and in small numbers.



Sites of occurrence of *Dinophysis* sp. 3 in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Dinophysales Lindermann, 1928

Family: Dinophysaceae Stein, 1883

Genus: *Histioneis* Stein, 1883

(= *Parahistioneis* Kofoid *et* Skogsberg, 1928 *partim.*)

Armored, small to large subcircular, reniform or subreniform, dinophysoid cell bodies with ornate list and rib systems and large cingular chamber; poorly characterized species, but readily a recognizable group. Posterior cingular list is often cup-shaped with largest portion of cingulum being posterior and with vertical support ribs. Anterior cingular area is reduced, sometimes to a funnel with a small anterior cingular list; reduced membraneous right sulcal list, but extensive left sulcal list. Chloroplasts are absent; surface markings of pores to areolae (Steidinger and Tangen, 1997).

Scientific name: *Histioneis costata* Kofoid *et* Michener

Plate A71: d-f (Annex A)

References:

Gomez, 2007.

Description:

Cell body subcircular with ornate list and rib systems and large cingular chamber; characterized by a long R3, the cross-rib extended ventrally and a smooth triangular sail, extended from R2 to R3. Chloroplasts are absent; surface markings of pores.

Dimensions:

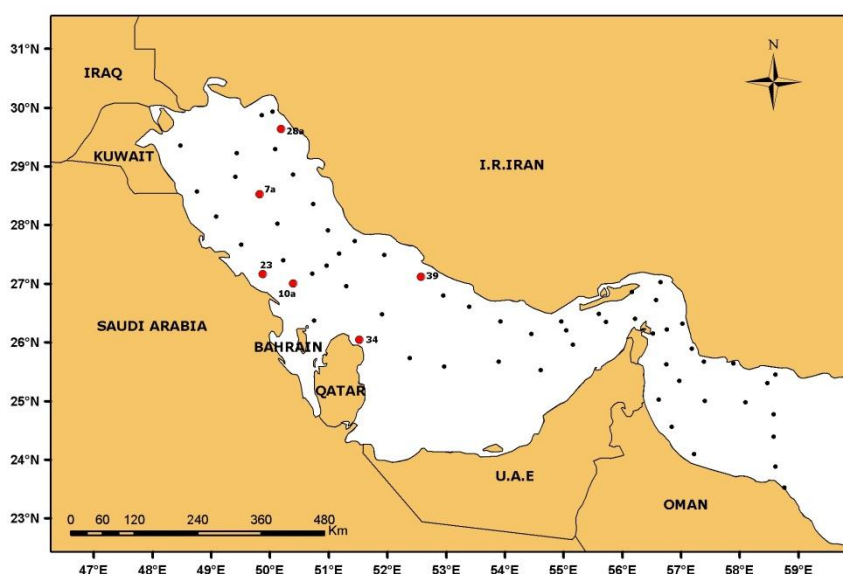
Total length 70-73 μm ; body 30-31 μm long; 30-32 μm wide.

Distribution:

Oceanic species.

**Sites of occurrence in RSA:**

In Winter 2006 Cruise, this species occurred at few sites in the inner RSA (refer sites map) and in small numbers. It has been reported previously from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Histiogammarus costatus* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Dinophysales Lindermann, 1928

Family: Dinophysaceae Stein, 1883

Genus: *Ornithocercus* Stein, 1883

Small to medium-sized circular full body in lateral view with extensive sulcal and cingular list and rib systems that characterize the species. Ribs and lists are formed at the extremities of plates, near sutures. Body surface markings of pores, poroids, or areolae; lacks chloroplasts, but can have photosynthetic symbionts in cingular chamber. Species of this genus can be differentiated by size and shape (Steidinger and Tangen, 1997).

Scientific name: *Ornithocercus magnificus* Stein

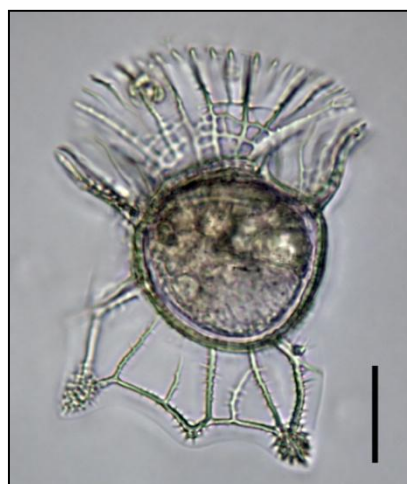
Plate A72: d-I (Annex A)

References:

Wood, 1968: p. 86, Fig. 241; Taylor, 1976: p. 49, Pl. 7: 67-69; Pl. 42: 505 a, b; Dodge, 1985: p. 28; Balech, 1988: p. 236, L. 14: 7, 8.

Description:

Body subcircular; girdle lists large, funnel-shaped, ribbed; left sulcal list ends on dorsal side of body with two posterior lobes; center lobe supported typically by three ribs forming a diamond. Length 40-120 μm (Wood, 1968).

**Dimensions:**

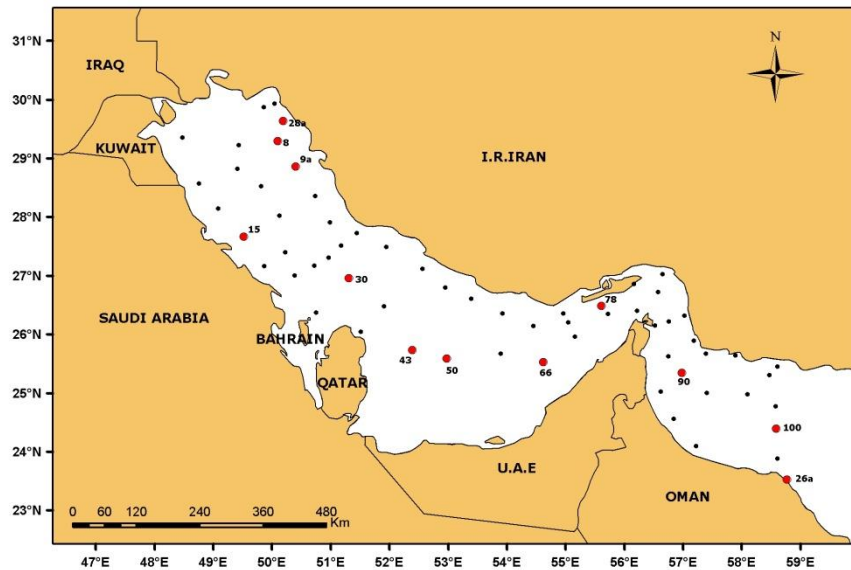
Total length 80-88 μm ; body diameter 38-40 μm .

Distribution:

Oceanic; cosmopolitan in warm temperate to tropical waters. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred in small numbers at scattered stations (refer sites map). Species has previously been reported from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Ornithocercus magnificus* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Dinophysales Lindermann, 1928

Family: Dinophysaceae Stein, 1883

Genus: *Ornithocercus* Stein, 1883

Species: *quadratus*

Scientific name: *Ornithocercus quadratus* Schütt

Plate A72: a-c (Annex A)

References:

Wood, 1968: p. 86, Fig. 242; Taylor, 1976: p. 50, Pl. 8: 77-82; Pl. 42: 499-501; Dodge, 1985: p. 29; Balech, 1988: p. 236, L. 14: 10.

Description:

Body rotund; girdle wider on dorsal side; anterior and posterior girdle lists funnel-shaped with numerous ribs; left sulcal list quadrate, finishing parallel with dorsal plane, usually with a submarginal rib. Length 50-75 μm (Wood, 1968).

**Taxonomical Remarks:**

Population of *Ornithocercus quadratus* in the RSA was composed of specimens differing somewhat in morphology of the left sulcal list. Among typical cells (as illustrated in Pl. A72: c), an immature newly divided specimens with unusual dorsal projection of the left sulcal list were observed (Pl. 72: a, b). Similar variability within *Ornithocercus quadratus* from Indian Ocean has been illustrated in Taylor (1976, Pl. 8: 77-82).

Dimensions:

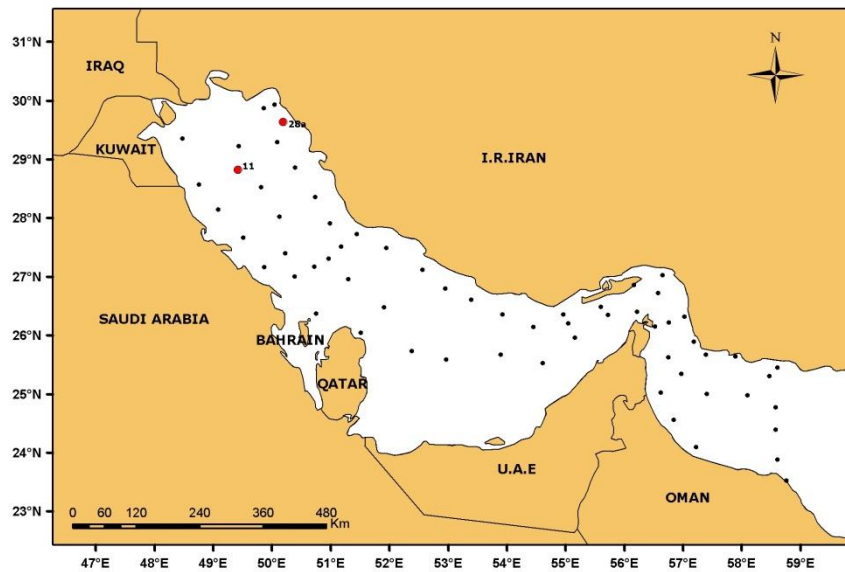
Total length 110-118 μm ; body diameter 48-50 μm .

Distribution:

Oceanic; warm temperate to tropical waters; worldwide distribution. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was present in small numbers at two stations in the northernmost part of the inner RSA (refer sites map).



Sites of occurrence of *Ornithocercus quadratus* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Dinophysales Lindermann, 1928

Family: Dinophysaceae Stein, 1883

Genus: *Ornithocercus* Stein, 1883

Species: *steinii*

Scientific name: *Ornithocercus steinii* Schütt *emend.* Kofoid *et* Skogsberg

Plate A73: a-I (Annex A)

References:

Wood, 1968: p. 86, Fig. 244; Taylor, 1976: p. 52, Pl. 7: 72, 73; Balech, 1988: p. 237, L. 15: 1.

Description:

Body subrotund; girdle wider dorsally than ventrally; anterior girdle list supported by strong ribs, funnel-shaped; posterior list also ribbed; left sulcal list wide, margin rounded, almost

parallel with body, ending dorsally; ribs more or less evenly spaced; last rib reaching margin of ventral-side of wing. Length 50-70 μm (Wood, 1968).

Dimensions:

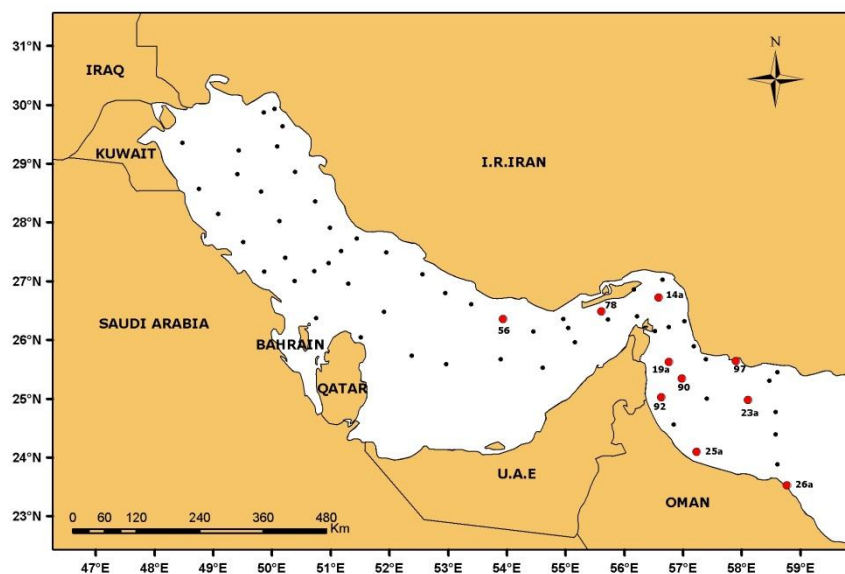
Total length 125-131 μm ; body diameter 60 μm .

Distribution:

Oceanic; cosmopolitan in warm temperate to tropical waters. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was present in small numbers at scattered stations (refer sites map).



Sites of occurrence of *Ornithocercus steinii* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Dinophysales Lindermann, 1928

Family: Dinophysaceae Stein, 1883

Genus: *Sinophysis* Nie *et* Wang

Species: *stenosoma*

Scientific name: *Sinophysis stenosoma* Hoppenrath

Plate A71: g-I (Annex A)

References:

Hoppenrath, 2000: p. 159, fig 4-6; 24-33; Selina and Hoppenrath, 2004: p. 155, Fig. 42-54.

Description:

Cells are oblong ellipsoidal, 37-56 μm long, 21-33 μm wide, with a length/width ratio of 1.43-1.89. They are flattened laterally. The small cylindrical, crown-like epicone is notably small compared with the other *Sinophysis* species, and 5.5-8.0 μm wide (dorsoventrally). It is surrounded by a well-developed smooth girdle list of the hypotheca and slightly tilted back to the dorsal side. The epitheca consists of an outer epithecal list encircling four-fifths of it, with the 'open' area at the right lateral side. This area is closed by a smaller list. In lateral view, two parallel, curved, upright projections are located in the ventral epithecal half. In front of this structure (dorsally) lies a third upright projection encircling one half of it, extending from mid-lateral position on one side to mid-lateral position on the other side. The apical view of the epitheca shows that the third upright projection forms the outer margin of a curved tongue-like flap. The inner margin of the flap is identical with the second upright projection, that means, the two dorsal projections are connected. Epithecical plates were not distinguished. The longish hypocone has nearly parallel side, or is slightly broader in the posterior third, with a rounded antapex. The deep girdle is surrounded by a collar, which is part of the hypothecal plates. The sulcus is located on the right side, partly covered by a narrow list and about half of the cell length. The cell is colorless, and usually contains numerous small colorless granules and large colorless or colored food vacuoles. Chloroplasts were not detected. One large pusule is situated in the anterior half of the hypocone. The spherical nucleus is located posteriorly in the hypocone. The thecal surface is smooth with a distinct pore pattern. There are two pore types: small (0.2-0.3 μm) and large (0.3-0.4 μm). The small pores are randomly distributed over thecal



surface. In addition, small pores are arranged in marginal row. Large pores, single or in small groups, are distributed randomly, but never in the marginal row. The large pore pattern could differ from specimen to specimen (Hoppenrath, 2000).

Dimensions:

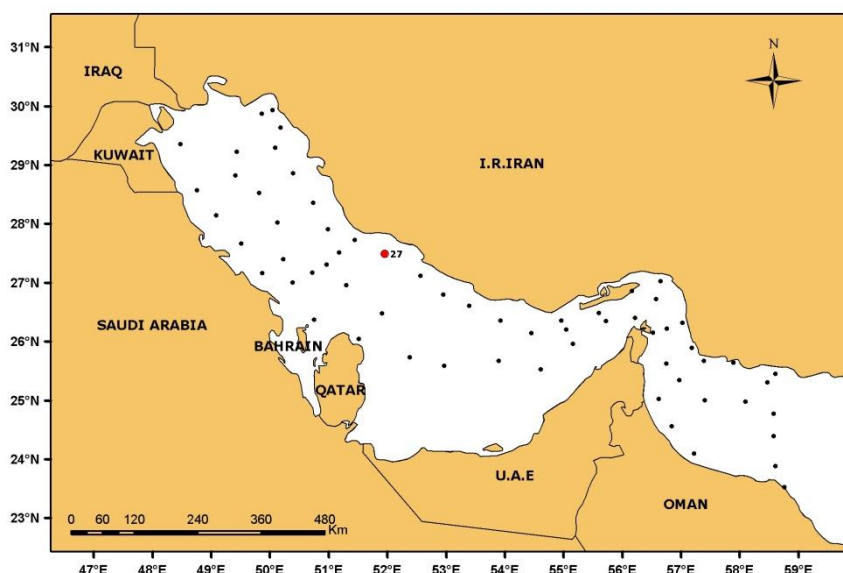
Cell length 34 μm ; width 19 μm .

Distribution:

Species was previously reported from the water column in the North Carolina, USA (Campbell, 1973; as *Sinophysis* aff. *ebriolum* according to Hoppenrath, 2000), from intertidal sandy sediments in the British Isles and the northern France (Saunders and Dodge, 1984; as *Sinophysis ebriolum* according to Hoppenrath, 2000), from marine sediments in the North German Wadden Sea (Hoppenrath, 2000) and from bottom sediments in the northwestern part of the Sea of Japan, Russia (Selina and Hoppenrath, 2004).

Sites of occurrence in RSA:

In Winter 2006 Cruise, a single specimen was found in a sample from the Iranian coast in the central part of the inner RSA (St. 27) (refer site map).



Site of occurrence of *Sinophysis stenosoma* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Dinophysales Lindermann, 1928

Family: Dinophysaceae Stein, 1883

Genus: *Triposolenia* Kofoid

Armored large cells up to 300 μm and similar to *Amphisolenia* in form but with two extensions. Cells with head of epitheca and cingulum; neck and shoulder with the sulcal plates and lists, the central body, and two posteriorly curved extensions, resembling legs. Triangular body with three extensions. Chloroplasts are probably present (Steidinger and Tangen, 1997).

Scientific name: *Triposolenia bicornis* Kofoid

Plate A65: h-k (Annex A)

References:

Schiller, 1933: p. 188, Fig. 182 a-c; Wood, 1968: p. 128, Fig. 400; Taylor, 1976: p. 31, Pl. 3: 33.

Description:

Body subconical; epitheca rounded, low; neck elongate, angled dorsally; antapical horns (extensions) evenly bent toward longitudinal axis; slightly rugose toward ends on outside. Length 150-200 μm (Wood, 1968).

Dimensions:

Total length 95 μm ; body 26 μm long; 38 μm wide.

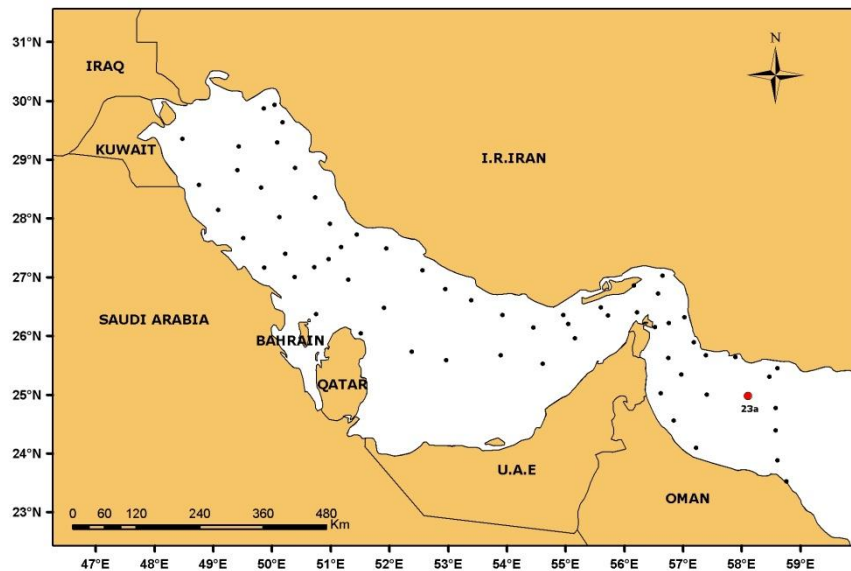
Distribution:

Oceanic; warm temperate to tropical waters. Species has previously been reported from the Indian Ocean (Taylor, 1976).



Sites of occurrence in RSA:

In Winter 2006 Cruise, a single specimen was found in a sample from the Sea of Oman (St. 23a) from the bottom sampled layer (refer site map).



Site of occurrence of *Triposolenia bicornis* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Gymnodiniales Lemmermann, 1910

Family: Gymnodiniaceae Lankester, 1885

Genus: *Akashiwo* Hansen *et* Moestrup, 2000

The genus comprises species without a firm theca, with an evident approximately median cingulum as seen in *Gymnodinium*. The chloroplasts contain peridinin as the principal carotenoid pigment. An apical groove circumscribes the apex clockwise (Thronsdén *et al.*, 2007).

Scientific name: *Akashiwo sanguinea* (Hirasaka) Hansen *et* Moestrup

Plate A76: j (Annex A)

Synonyms:

Gymnodinium splendens Lebour; *Gymnodinium nelsonii* Martin; *Gymnodinium sanguineum* Hirasaka

References:

Faust and Gualledge, 2002: p. 42, Pl. 26: 1-4 (as *Gymnodinium sanguineum*); Hallegraeff, 2002: p. 42, Fig. 10 B; Throndsen *et al.*, 2007: p. 58.

Description:

This athecate species is highly variable in size and shape.

Cells are large, slightly dorso-ventrally flattened and roughly pentagonal. An apical groove is present. Cells range in size from 40-80 μm in length. The epitheca and hypotheca are nearly equal in size. The epitheca is rounded and conical, and the hypotheca is deeply indented by the sulcus creating two posterior lobes. The median cingulum is left-handed and displaced 1-2 times its width. The sulcus does not invade the epitheca, but expands posteriorly into the hypotheca. Cell has numerous large, spindle-shaped, reddish-yellow-brown chloroplasts radiating from the center of the cell. The large nucleus is slightly off-center. Cells can vary from heavily pigmented to pale yellow or nearly colorless (Faust and Gualledge, 2002).

**Harmful Effect:**

A red tide species associated with mortality of fish and invertebrate. Cardwell *et al.* (1979) reported the acute toxicity of this species to larval stages of two species of oysters in Puget Sound, Washington State. Species is believed to be responsible for at least one reported fish mortality event in Peru (Jordan, 1979). Tindall *et al.* (1984) and Carlson and Tindall (1985) reported one isolate of this species to be potentially toxic; however, the toxin principles have yet to be elucidated.

Dimensions:

Cell length 52 μm ; width 27 μm .

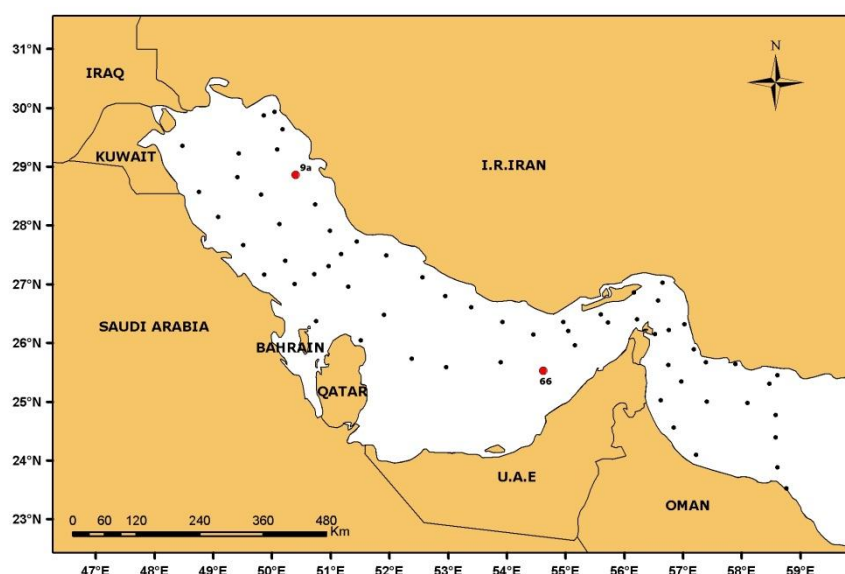
Distribution:

Species are commonly found in temperate to tropical neritic waters (Steidinger and Tangen, 1997). Blooms have been recorded from the coasts of Japan (Hirasaka, 1922; Fukuyo *et al.*,

1990), Australia and New Zealand (Hallegraeff, 1991), and from the Atlantic and Pacific American coasts (Keifer and Lasker, 1975; Bockstahler and Coats, 1993; Voltolina, 1993).

Sites of occurrence in RSA:

In Winter 2006 Cruise, a single specimen was found at each samples collected from Station 9a, and 66 in the inner RSA (refer sites map). It has been previously reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Akashiwo sanguinea* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Gymnodiniales Lemmermann, 1910

Family: Gymnodiniaceae Lankester, 1885

Genus: *Balechina* Loeblich *et* Loeblich III, 1966

Unarmored. Large subellipsoidal cell with thick, rifid theca; linear thecal ridges and aerolations discernible. Circular in cross section. Cingulum median and descending 0.5-2x. Sulcus invaded epitheca. Apex hyaline. Chloroplasts, absent (Steidinger and Tangen, 1997).

Scientific name: *Balechina coerulea* (Dogiel) Taylor

Plate A74: f-I (Annex A)

Synonym:

Gymnodinium coeruleum Dogiel

References:

Wood, 1968: p. 63, Fig. 168 (as *Gymnodinium coeruleum*);

Balech, 1988: p. 223, L. 1: 6 (as *Gymnodinium coeruleum*);

Steidinger and Tangen, 1997: p. 461, Pl. 22.

Description:

Body elongate, biconical to 8-shaped, about twice as long as wide, flattened ventrally; girdle submedian, displaced about two widths; sulcus from apex to antapex, narrow on epicone, widening from girdle to antapex; base indented. Length 100 μm (Wood, 1968).



Dimensions:

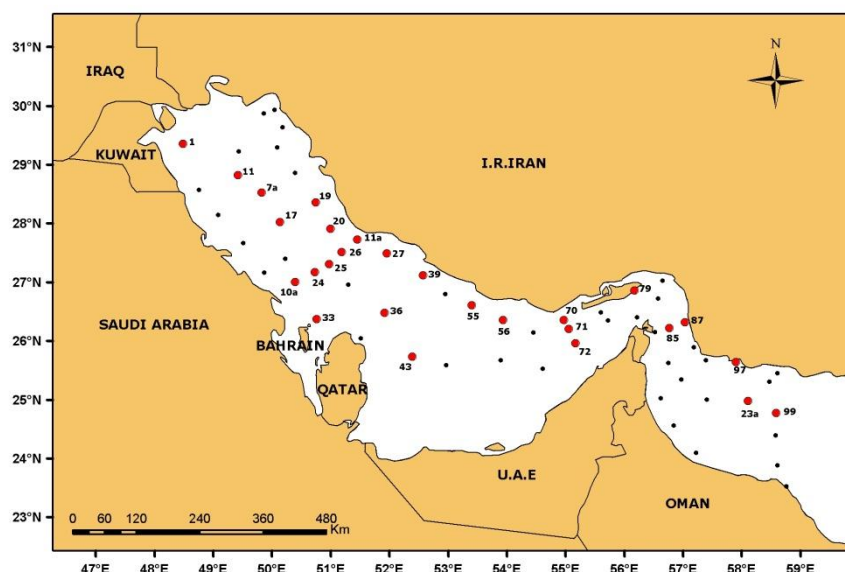
Cells 83-91 μm long; 42-45 μm wide.

Distribution:

Coastal and open waters; warm water species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at various sites (refer sites map), however, never in large numbers.



Sites of occurrence of *Balechina coerulea* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Gymnodiniales Lemmermann, 1910

Family: Gymnodiniaceae Lankester, 1885

Genus: *Cochlodinium* Schütt, 1896

Ovoid to elongate cells with characteristic twist around the length axis one half (180°) to four times, the cingulum being from 1.5 to 5 circumference long, the sulcus 0.5 to 4 circumference. The twist is descending. The amount of twist is very important as a species criterion. Both furrows are usually deeply submerged in the cell body, giving the cell a denticulate outline. The sulcus usually reaches and makes a loop around the apex. Chain-forming species are known. Most of the species in the genus are heterotrophic, but autotrophic species exist. Often large and conspicuous vacuoles; may be observed surrounded by a gelatinous matrix, probably a cyst stage. Morphologically related to some species of *Gyrodinium* with somewhat twisted cell shape and *Nematopsides*, but an ocellus is lacking. The species identification may be difficult in living material and practically impossible in preserved samples. Some species produce toxins (Thronsdon *et al.*, 2007).

Scientific name: *Cochlodinium brandtii* Wulff

Plate A75: a-c (Annex A)

Synonym:

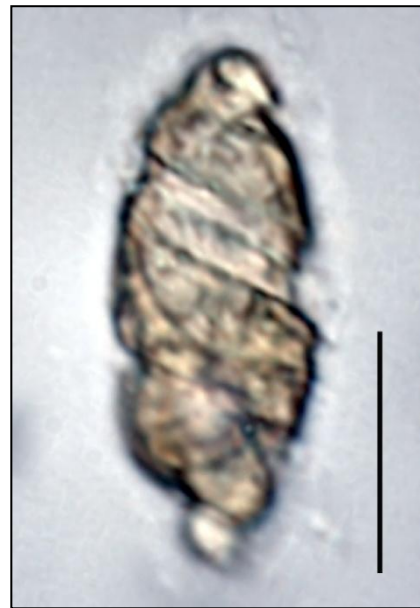
Cochlodinium augustum Kofoed et Swezy

References:

Lebour, 1925: p. 65, Pl. IX: 8; Dodge, 1982: p. 75, Fig. 8 H.

Description:

Cell spindle-shaped with rounded ends. Girdle deeply incised making about 4 turns with a total displacement of over 0.75 of cell length. Sulcus only just entering the epicone but makes over 3 turns between girdle ends; 50-110 µm long (Dodge, 1982).

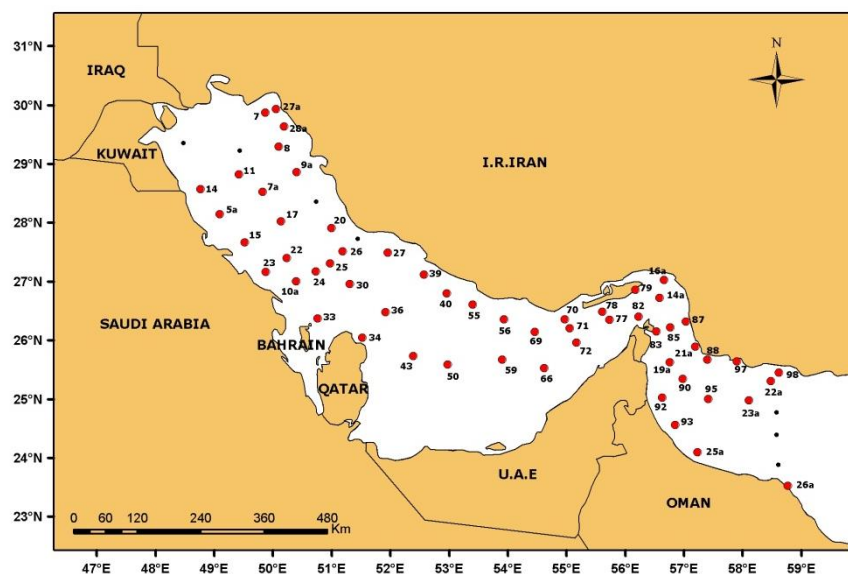


Dimensions:

Cells 49-54 µm long; 19-21 µm wide.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was commonly observed at various sites (refer sites map), often in large numbers; maximum abundance (1.3×10^3 cells/l) was associated with the central part of the inner RSA (St. 50).



Sites of occurrence of *Cochlodinium brandtii* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Gymnodiniales Lemmermann, 1910

Family: Gymnodiniaceae Lankester, 1885

Genus: *Cochlodinium* Schütt, 1896

Species: *polykrikoides*

Scientific name: *Cochlodinium polykrikoides* Margalef

Plate A75: d-f (Annex A)

Synonym:

Cochlodinium heterolobatum Silva

References:

Hallegraeff *et al.*, 1995: p. 286, Fig. 15.3; Faust and Gualledge, 2002: p. 21, Pl. 9: 1-7.

Description:

The cells often form short chains consisting of rarely more than 8 cells. The individual cells are more or less oval, only slightly flattened and with a girdle making 1.8-1.9 turns around the cell, notched at the antapex. An apical groove is present. A red stigma is located on the dorsal side of the episome. There are several band-shaped chloroplasts. The nucleus is located in the episome; length 30-40 μm , width 20-30 μm (Hallegraeff *et al.*, 1995).

**Harmful Effect:**

Species is a serious fishkiller (IOC list, 2002). It may be toxic to juvenile fish, but the toxic principles are unknown (Hallegraeff *et al.*, 1995). *C. polykrikoides* is a known red tide species associated with extensive fish kills and great economic loss in Japanese and Korean waters (Yuki and Yoshimatsu, 1989; Fukuyo *et al.*, 1990; Kim, 1998). However, the actual toxin principles have yet to be elucidated (Taylor *et al.*, 1995). Ho and Zubkoff (1979) suggested that physical contact, not a released toxin, was the cause of oyster larvae

(*Crassostrea virginica*) deformation and mortality during a *C. polykrikoides* red tide in the York River (Virginia, USA).

Dimensions:

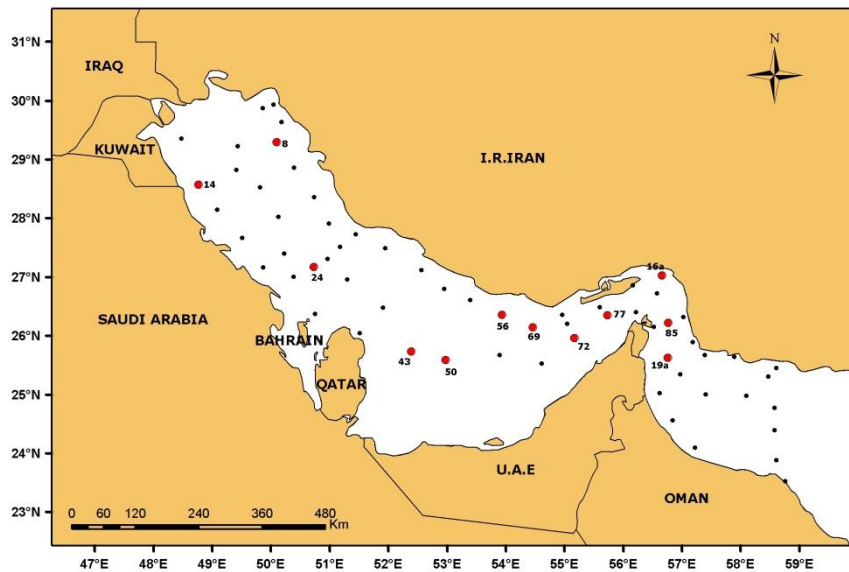
Cells 22-27 µm long; 14-17 µm wide.

Distribution:

Cochlodinium polykrikoides has been reported from the American east coast, Japan where it is widely distributed and often forms harmful blooms, and in Korea and Puerto Rico.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred usually in small numbers at scattered sites (refer sites map), however, it was quite abundant at some localities; maximum abundance (1.7×10^3 cells/l) was associated with the central part of the inner RSA (St. 50).



Sites of occurrence of *Cochlodinium polykrikoides* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Gymnodiniales Lemmermann, 1910

Family: Gymnodiniaceae Lankester, 1885

Genus: *Gymnodinium* Stein, 1878 *emend.* Hansen *et* Moestrup

The genus comprises species without a firm theca, with distinct cingulum which is located about the median on the cell body. The cingulum is circular or slightly displaced, maximum 1/5 of the cell length; the sulcus may continue toward apex as a narrow stripe, and some species have a specific apical groove. Theca is smooth or with longitudinal stripes/ribs. Photosynthetic with chloroplasts or heterotrophic without. Heterotrophic species are often with distinct vacuoles. Most species are with median nucleus. Some species produce resting spores. Life cycle stages of species from other genera may be mistaken for *Gymnodinium*. Closely related to *Gyrodinium*, *Karenia* and *Karlodinium*; present in brackish water and in marine areas. Some species are toxin producers (Thronsdon *et al.*, 2007).

Scientific name: *Gymnodinium catenatum* Graham

Plate A74: a-e (Annex A)

References:

Balech, 1988: p. 223, L. 1: 3, 4, 9; Hallegraeff *et al.*, 1995: p. 288, Figs. 15.5, 15.10 i-j; Hallegraeff, 2002: p. 28, Figs. 7 A, C-H; Faust and Gualledge, 2002: p. 39, Pl. 23: 1-7.

Description:

The cells form chains of usually 4, 8 or 16 cells, occasionally longer. Unfavourable conditions may cause the chains to break up into single cells, and non-chain forming clones possibly also exist. The girdle describes a descending spiral which is displaced up to one fifth of the cell length. The sulcus extends from the antapex to the apex which is also surrounded by a semicircular apical ring. The cells contain numerous chloroplasts with conspicuous pyrenoids. The nucleus is located in the central part of the cell. The reported size ranges are for solitary cells: 34-65 µm long and 27-43 µm wide; for chain-forming cells, 23-60 µm long and 27-43 µm wide, with the terminal cells being about the size of solitary cells (Hallegraeff *et al.*, 1995).



Harmful Effect:

This species is a producer of paralytic shellfish poisoning (PSP) (IOC list, 2002). *G. catenatum* is the only unarmored dinoflagellate known to produce PSP-toxins (Morey-Gaines, 1982; Mee *et al.*, 1986; Hallegraeff *et al.*, 1995). First reports of PSP associated with *G. catenatum* blooms were recorded in Spain (Estrada *et al.*, 1984).

Dimensions:

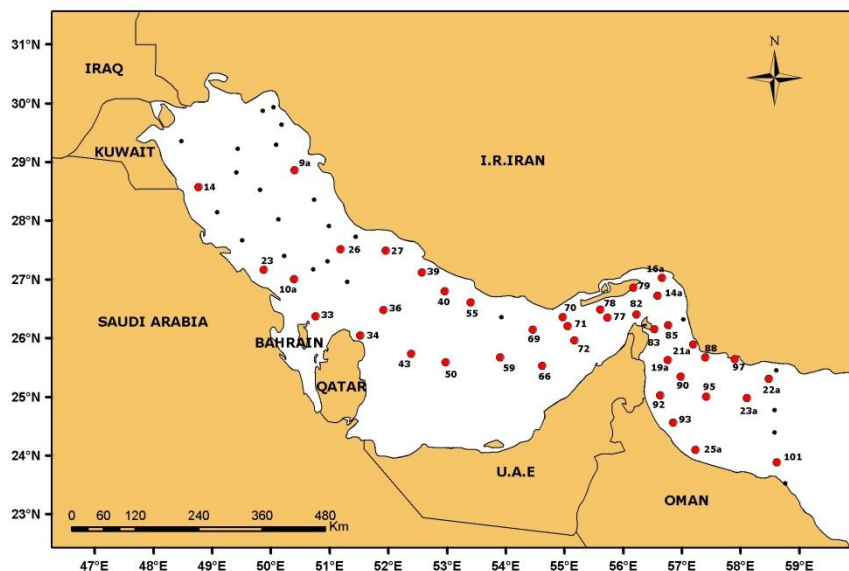
Cells 52-57 µm long; 55-60 µm wide.

Distribution:

Temperate waters of the North America, Europe, Australia and Japan.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at various sites (refer sites map), usually in small numbers, however, it was quite abundant at some localities; maximum abundance (1.2×10^3 cells/l) was associated with the Iranian coast in the central part of the inner RSA (St. 27).



Sites of occurrence of *Gymnodinium catenatum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Gymnodiniales Lemmermann, 1910

Family: Gymnodiniaceae Lankester, 1885

Genus: *Gymnodinium* Stein, 1878 *emend.* Hansen *et* Moestrup

Scientific name: *Gymnodinium* sp. 1

Plate A76: e-I (Annex A)

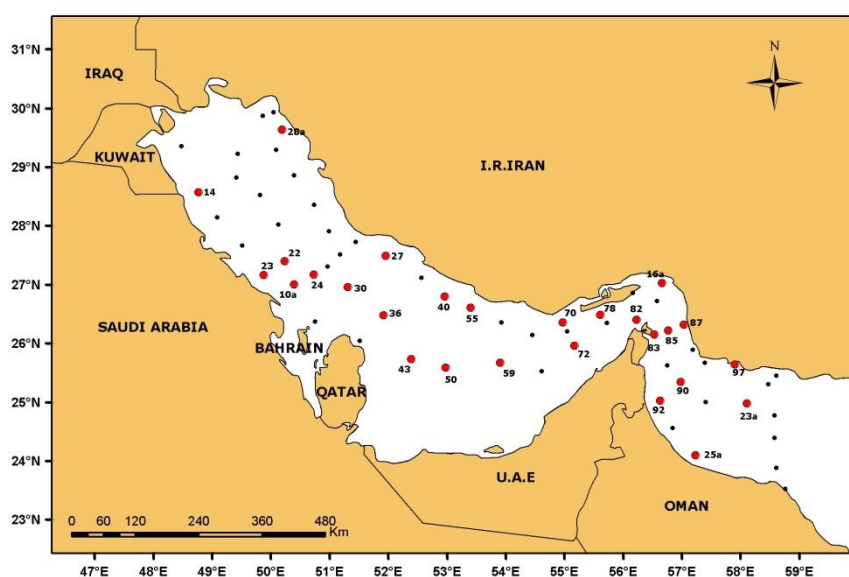
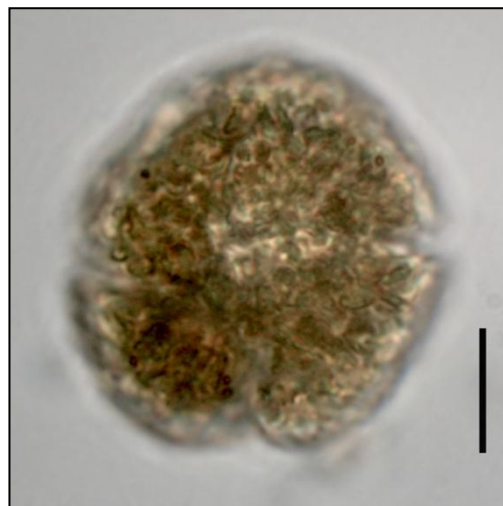
Description: Cells rotund, epicone hemispherical; hypocone slightly depressed antapically. The cingulum is circular, median. Chromatophores large; nucleus median.

Dimensions:

Cells 29-32 µm long; 28-32 µm wide

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at various sites (refer sites map), never in large numbers; maximum abundance (4.3×10^2 cells/l) was associated with the central part of the inner RSA (St. 50).



Sites of occurrence of *Gymnodinium* sp.1 in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Gymnodiniales Lemmermann, 1910

Family: Gymnodiniaceae Lankester, 1885

Genus: *Gymnodinium* Stein, 1878 *emend.* Hansen *et* Moestrup

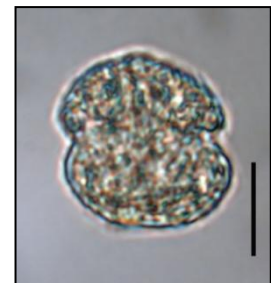
The *Gymnodinium*-like group (Plate A77: a-p; Annex A) combines with at least 11 species of small-sized autotrophic flagellates.

Gymnodinium-like group: **Species 1**

Plate A77: a, b (Annex A)

Description:

Cells rotund. The cingulum is circular, median. Chromatophores small, numerous; nucleus median.



Dimensions:

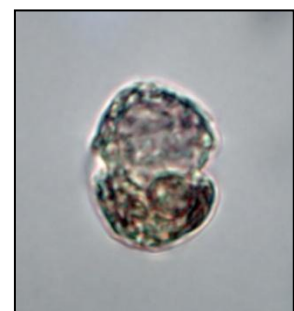
Cells 20 µm long; 19 µm wide.

Gymnodinium-like group: **Species 2**

Plate 77: c (Annex A)

Description:

Cells rotund. The cingulum is circular, median. Chromatophores small, numerous; nucleus is located in epicone.



Dimensions:

Cells 17 µm long; 13 µm wide.

Gymnodinium-like group: **Species 3**

Plate 77: d (Annex A)

Description:

Cells small, rotund. Epicone hemispherical; hypocone skewed, slightly depressed antapically. The cingulum is circular and wide, median. Chromatophores large. Nucleus is located in epicone.

**Dimensions:**

Cells 10 μm long; 7 μm wide.

Gymnodinium-like group: **Species 4**

Plate 77: e (Annex A)

Description:

Cells rotund. Epicone small, hemispherical; hypocone larger than epicone, skewed. Chromatophores small, numerous; nucleus median.

**Dimensions:**

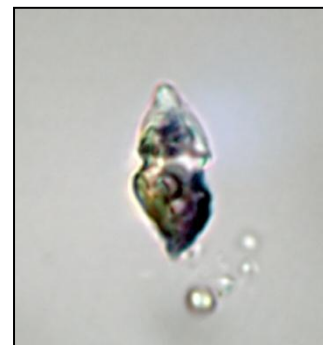
Cells 11 μm long; 9 μm wide

Gymnodinium-like group: **Species 5**

Plate 77: f, g (Annex A)

Description:

Cells ovate. Epicone smaller than hypocone, cell tapering toward ends. The cingulum is circular, submedian. Chromatophores large.

**Dimensions:**

Cells 16 μm long; 7 μm wide.

Gymnodinium-like group: **Species 6**

Plate 77: h, i (Annex A)

Description:

Cells ovate. Epicone smaller than hypocone, cell tapering toward ends. The cingulum is submedian. Chromatophores large; nucleus median.



Dimensions:

Cells 21 μm long; 9 μm wide.

Gymnodinium-like group: **Species 7**

Plate 77: j, k (Annex A)

Description:

Cells rotund. Epicone hemispherical, slightly smaller than hypocone; hypocone slightly depressed antapically. The cingulum submedian. Chromatophores small, numerous. Nucleus is located in hypocone.



Dimensions:

Cells 16 μm long; 13 μm wide.

Gymnodinium-like group: **Species 8**

Plate 77: l (Annex A)

Description:

Cells rotund. Epicone hemispherical, slightly smaller and narrower than hypocone. The cingulum is submedian. Chromatophores small, numerous. Nucleus large, located in hypocone.



Dimensions:

Cells 14 μm long; 11 μm wide.

Gymnodinium-like group: **Species 9**

Plate 77: m (Annex A)

Description:

Cells small, rotund. Epicone hemispherical; hypocone skewed, strongly depressed antapically. The cingulum wide, median. Chromatophores large.

Dimensions:

Cells 11 μm long; 7 μm wide.



Gymnodinium-like group: **Species 10**

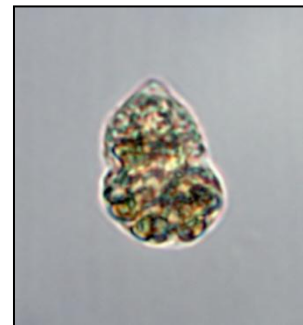
Plate 77: n, o (Annex A)

Description:

Cells ovate. Epicone hemispherical, with acute apical end; hypocone skewed, slightly depressed antapically. The cingulum is circular and wide, median. Chromatophores large.

Dimensions:

Cells 17 μm long; 13 μm wide.



Gymnodinium-like group: **Species 11**

Plate 77: p (Annex A)

Description:

Cells ovate. Epicone hemispherical, smaller and narrower than hypocone. The cingulum wide, submedian. Chromatophores large. Nucleus large, located in hypocone.

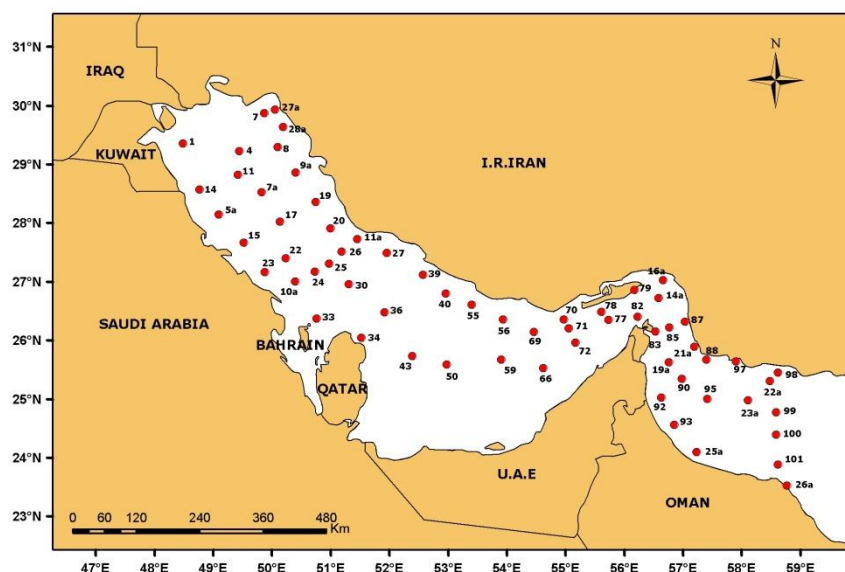
Dimensions:

Cells 11 μm long; 7 μm wide.



Sites of occurrence in RSA:

In Winter 2006 Cruise, species of this group were the commonest dinoflagellates in the material, encountered in 95.3 % of the samples and occurred ubiquitously over most of the area studied in very large numbers (refer sites map) . The higher abundances ($> 10^5$ cells/l) were recorded through all examined area, especially in the southern part in the inner RSA near coast of the UAE.



Sites of occurrence of *Gymnodinium*-like group in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Gymnodiniales Lemmermann, 1910

Family: Gymnodiniaceae Lankester, 1885

Genus: *Gyrodinium* (Kofoid *et* Swezy, 1921 *emend.* Hansen *et* Moestrup)

(=*Gymnodinium* Stein, 1878 *partim.*)

A firm theca is lacking, the cingulum, located about the median on the cell body and is displaced at least 1/5 of the cell length. The sulcus may continue from the apical area to antapex and is twisted in some species, but not more than half the cell width. Most species are heterotrophic; some important species have chloroplasts. The cell shape varies from

elongates, spindle-shaped to ovoid with many features in common with *Gymnodinium*. Resting spores, in some species. Toxin production occurs (Thronksen *et al.*, 2007). Life cycle stages of species from this genus may be mistaken for other genera (see *G. falcatum*).

In Winter 2006 Cruise, species of *Gyrodinium* genus were commonly detected in the samples and some have ubiquitous occurrence (*G. fusiforme*). When abundant, these species contributed up to 11 % of the total phytoplankton abundance; the highest concentration reached up to 9.9×10^3 cells/l. The spatial distribution of this genus was localized. High abundance of this genus ($> 10^3$ cells/l) was strongly associated with the waters of the Sea of Oman.

Scientific name: *Gyrodinium falcatum* Kofoed *et* Swezy

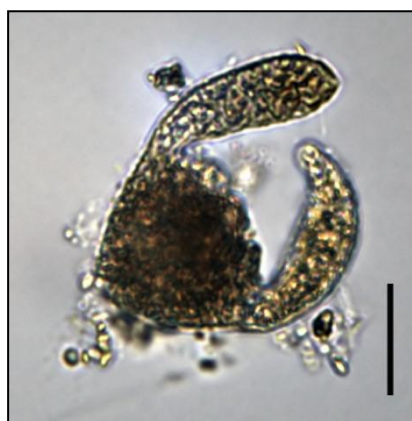
Plate A157: h (Annex A)

Synonym:

Pseliodinium vaubanii Sournia

References:

Dodge, 1982: p. 98, Fig. 11 I.



Description:

A large organism with a rather irregular outline. Epicone slightly larger than hypocone, ending in a rounded projection. Hypocone is hemispherical with a rounded extension. Girdle \pm median is displaced by about one-fifth the length of the cell. Sulcus is rather short and wide. Nucleus is central in position, cell also containing numerous small chloroplasts and oil globules. Size: 80-120 μm long; 65 μm wide (Dodge, 1982).

Taxonomical Remarks:

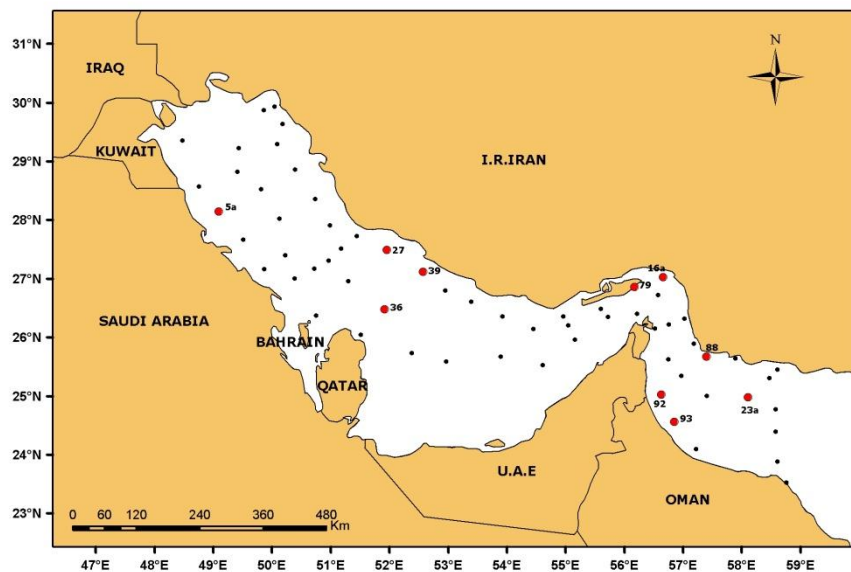
Recent observations on the development of the dinoflagellate *Gyrodinium falcatum* in the natural environment and algal cultures (Konovalova, 2003) showed that the species named *Pseliodinium vaubanii* is a stage of the life cycle of *G. falcatum*.

Dimensions:

Cells 98-112 µm long; 28-30 µm wide.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at few sites (refer sites map), never in large numbers; maximum abundance (2.7×10^2 cells/l) was associated with the Strait of Hormuz area (St. 79).



Sites of occurrence of *Gyrodinium falcatum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Gymnodiniales Lemmermann, 1910

Family: Gymnodiniaceae Lankester, 1885

Genus: *Gyrodinium* (Kofoid *et* Swezy, 1921 *emend.* Hansen *et* Moestrup)

(=*Gymnodinium* Stein, 1878 *partim.*)

Species: *fusiforme*

Scientific name: *Gyrodinium fusiforme* Kofoid *et* Swezy

Plate A78: a, b (Annex A)

Synonyms:

Spirodinium fusus Meunier; *Spirodinium fusus* Conrad

References:

Dodge, 1982: p.100, Fig. 12 A; Throndsen *et al.*, 2007: p. 65.

Description:

Cell with long fusiform body; length 3-4 transdiameters and pointed at both apices. The epicone is slightly smaller than the hypocone, forming a slender cone with straight to concavo-convex sides. The hypocone is also slender and conical. The girdle begins about one third of the length from the apex and descends in a left-handed spiral to about a third of the body length from the antapex. The girdle is shallow and fairly wide, although some illustrations show it as relatively deeply incised. The sulcus is shallow and incompletely described. The nucleus is elliptical and is situated centrally or anteriorly. Chromatophores are probably absent. The cell surface is fairly strongly striate and rodlets are present under it all around the cell; 50-125 µm long; 13-26 µm wide (Dodge, 1982).

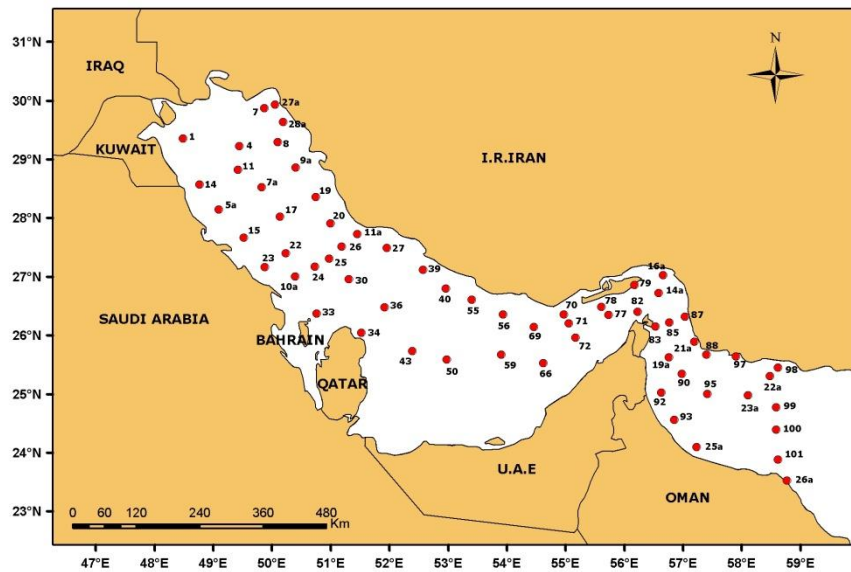


Dimensions:

Cells 69-86 µm long; 20-24 µm wide.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred ubiquitously over most of the studied area (refer sites map), encountered in 94.2 % of the samples, often in large numbers; maximum abundance (8.5×10^3 cells/l) was associated with the southern part of the inner RSA (St. 78).



Sites of occurrence of *Gyrodinium fusiforme* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Gymnodiniales Lemmermann, 1910

Family: Gymnodiniaceae Lankester, 1885

Genus: *Gyrodinium* (Kofoid *et* Swezy, 1921 *emend.* Hansen *et* Moestrup)

(=*Gymnodinium* Stein, 1878 *partim.*)

Species: *spirale*

Scientific name: *Gyrodinium spirale* (Bergh) Kofoid *et* Swezy

Plate A78: f-h (Annex A)

Synonyms:

Gymnodinium spirale Berg; *Spirodinium spirale* Entz

References:

Lebour, 1925: p. 56, Pl. VIII: 1; Wood, 1968: p. 72, Fig. 198; Dodge, 1982: p. 106, Fig. 12 I; Throndsen *et al.*, 2007: p. 66.

Description:

This widely distributed species is the type for the genus. The cell is slender, fusiform, widest posteriorly and tapering toward the anterior. Length of body 2.5 transdiameters; body convex dorsally and subconcave ventrally giving an asymmetrical appearance. The cone-shaped epicone is convex on the left and dorsal sides, but concave on the right and ventral side. The apex is usually blunt, but may be pointed. The hypocone is straight-sided anteriorly; convex posteriorly and deeply notched on the left side of the antapex by the sulcus with the right side forming a rounded lobe which projects beyond the posterior end of the left side. The girdle starts anterior to the midline and steeply spirals to the left with a displacement of about 1.2 transdiameters ending a quarter of the total cell length from the



antapex. The girdle is deeply incised and approximately 4-6 μm wide. The transverse flagellum pore is situated at the anterior junction of the girdle and sulcus, the longitudinal flagellum pore about one girdle width below. The sulcus extends from the apex to the antapex, is narrow anteriorly, widening slightly towards the antapex. The nucleus is ellipsoidal to spherical, situated in the intercingulum area or to the anterior. Pusules may be present at either pore. Chromatophores are absent, plasma colorless, or pale green or pale yellowish brown. The surface is marked with longitudinal striae; 40-200 (50-103) μm long (Dodge, 1982).

Dimensions:

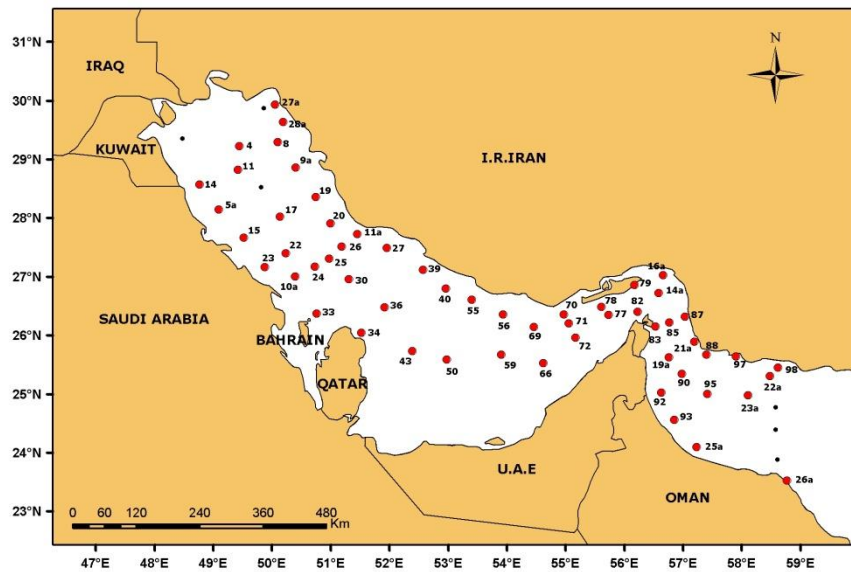
Cells 121-139 μm long; 35-38 μm wide.

Distribution:

Temperate to subtropical waters; cosmopolitan.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was commonly observed at most of the sampling sites (refer sites map), often in large numbers; maximum abundance (2.6×10^3 cells/l) was associated with the Sea of Oman (St. 93).



Sites of occurrence of *Gyrodinium spirale* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Gymnodiniales Lemmermann, 1910

Family: Gymnodiniaceae Lankester, 1885

Genus: *Gyrodinium* (Kofoed *et* Swezy, 1921 *emend.* Hansen *et* Moestrup)
(=*Gymnodinium* Stein, 1878 *partim.*)

Scientific name: *Gyrodinium* sp. 1

Plate A78: c, d (Annex A)

Description:

The cell shape elongates, close to fusiform; the cingulum located about median on the cell body and displaced. Chromatophores are present; nucleus median.

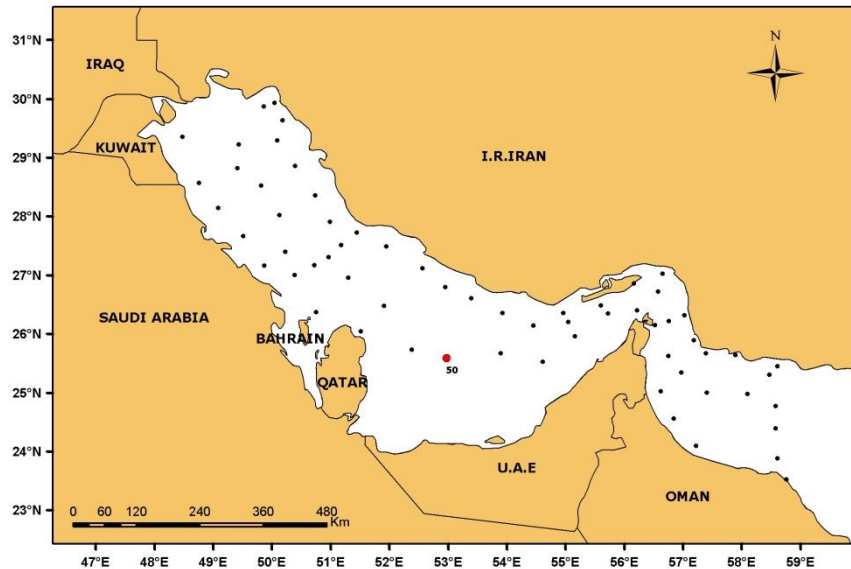
Dimensions:

Cells 41-44 µm long; 19-20 µm wide.



Sites of occurrence in RSA:

This species occurred in small numbers at one site in the inner RSA (refer site map).



Site of occurrence of *Gyrodinium* sp. 1 in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Gymnodiniales Lemmermann, 1910

Family: Gymnodiniaceae Lankester, 1885

Genus: *Gyrodinium* (Kofoid *et* Swezy, 1921 *emend.* Hansen *et* Moestrup)

(=*Gymnodinium* Stein, 1878 *partim.*)

Scientific name: *Gyrodinium* sp. 2

Plate A78: e (Annex A)

Description:

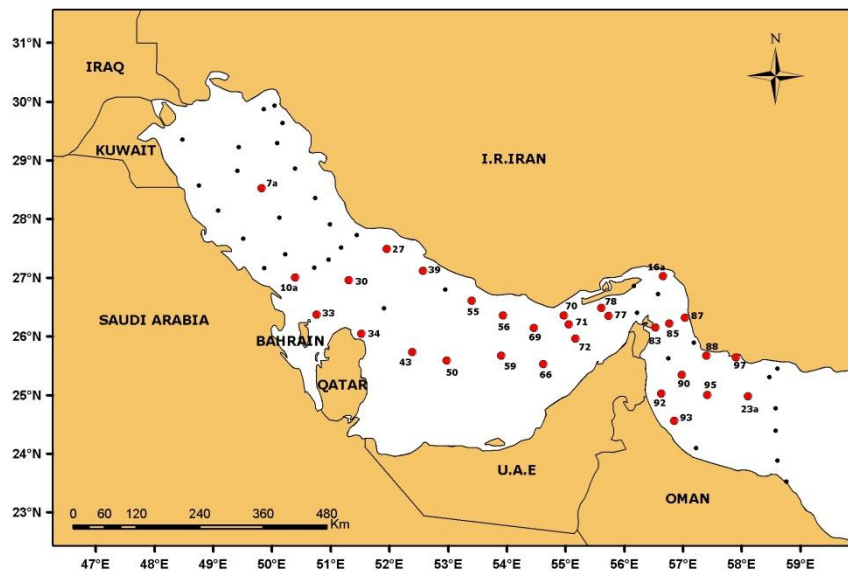
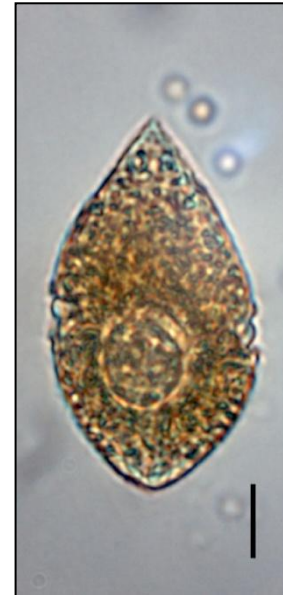
Cells ovate. Epicone slightly larger than hypocone, with acute apical end; hypocone hemispherical. Chromatophores small, numerous; nucleus submedian, located mainly in hypocone.

Dimensions:

Cells 100-107 μm long; 55-61 μm wide

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at few sites (refer sites map), never in large numbers; maximum abundance (2.8×10^2 cells/l) was associated with the central part of the inner RSA (St. 50).



Sites of occurrence of *Gyrodinium* sp. 2 in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Gymnodiniales Lemmermann, 1910

Family: Gymnodiniaceae Lankester, 1885

Genus: *Karenia* Hansen *et* Moestrup, 2000

The genus comprises species without a firm theca, with distinct cingulum located approximately median on the cell body as in *Gymnodinium* and *Gyrodinium*. The chloroplasts contain fucoxanthin or derivatives of this as main carotenoid pigment. Apical groove is straight. Ventral pore is lacking, distinguishing the genus from *Karlodinium*. It is distinguished from similar genera among other criteria by the path of the apical groove and details in fine structure; in brackish water and marine areas. Toxin producing species (Thronsdon *et al.*, 2007).

Harmful Effect:

Karenia spp. produce a series of brevetoxins (neurotoxins). Blooms of these species produce toxins which are toxic to humans and which are transported by air in aerosols from the bloom areas to the coast and are associated with marine animal mortalities and respiratory irritations (Baden, 1983; IOC list, 2002). These toxins are responsible for massive fish kills along the west coast of Florida, in the Gulf of Mexico. Aerosolization of the toxins (noxious air-borne *K. brevis* fragments from sea spray) has been linked to asthma-like symptoms in humans (Baden *et al.*, 1982). Brevetoxins produce neurotoxic shellfish poisoning (NSP) when consumed (Hughes, 1979). These toxins are known to cause human illness and distress; however, the poison is not fatal: no human fatalities have been reported from consumption of *K. brevis*-infected bivalves (Steidinger and Joyce, 1973). So far, NSP has been restricted to the western coast of Florida, but more recently, it has been documented for New Zealand as well (Steidinger *et al.*, 1973; Baden *et al.*, 1982; Taylor *et al.*, 1995).

Scientific name: *Karenia papilionacea* Haywood *et* Steidinger

Plate A76: a-d (Annex A)

References:

Haywood *et al.*, 2004: p. 167-170, figs. 2 e-h, 3 a-f.

Description:

Cells are 18-32 μm long and 18-48 μm wide; 10-15 μm in thickness and dorsally convex and ventrally concave in most cells; thin oval in longitudinal section. The epitheca has a prominent attenuated apical carina, and a short linear apical groove with rolled margins extends vertically to one third of the ventral and dorsal epitheca. The hypotheca is



bilobed and centrally excavated. The cingulum is descending and premedian to median and typically displaced by the cingulum width. The sulcal intrusion onto the epitheca is open, and the sulcus is displaced to the left side of the ventral epitheca adjacent to the apical groove or extends to a point just below and left of the cell's apex. The nucleus is spherical to slightly oval and located in the left hypotheca. The hypotheca has large single lateral pores on both sides adjacent to the cingulum. Chloroplasts are few and large or several and small, peripheral, round to reniform in shape and yellow-green in color (Haywood *et al.*, 2004).

Harmful Effect:

Culture material found to produce brevetoxin (Haywood *et al.*, 2004).

Dimensions:

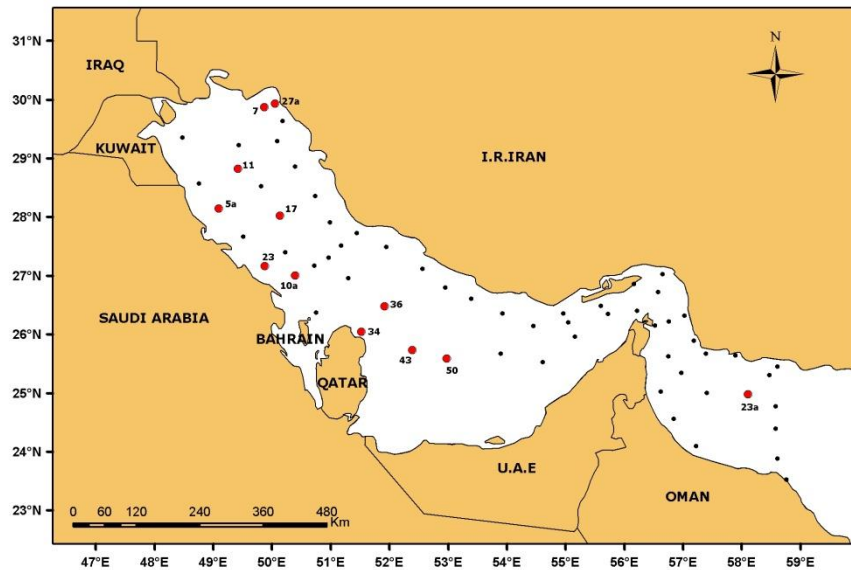
Cells 21-25 μm long; 30-32 μm wide.

Distribution:

Karenia papilionacea has been originally described from New Zealand coastal waters (Haywood *et al.*, 2004).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was encountered in the RSA samples of few sites (refer sites map), and had low abundance (not more than 1.04×10^3 ; < 3% of the total phytoplankton abundance). Maximum abundance of this species ($> 10^3$ cells/l) was mainly associated with the central part of the inner RSA.



Sites of occurrence of *Karenia papilionacea* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Gymnodiniales Lemmermann, 1910

Family: Gymnodiniaceae Lankester, 1885

Genus: *Torodinium* Kofoid *et* Swezy, 1921

Unarmored. Distinctive small to medium-sized cell. Body cigar shaped. Epitheca exceeds hypotheca (>5x) and sulcus extends almost entire length of cell. Sulcus and cingulum join posteriorly to form antapical loop. Chloroplasts are present (Steidinger and Tangen, 1997).

In Winter 2006 Cruise, two species of *Torodinium* genus were commonly detected in the collected samples, and some have ubiquitous occurrence (*T. robustum*). When abundant, these species contributed up to 6% of the total phytoplankton abundance; the highest concentration reached up to 1.4×10^4 cells/l. High abundance of this genus ($> 10^4$ cells/l) was

mainly associated with the waters of the central part of the inner RSA, with localized peak in the Sea of Oman.

Scientific name: *Torodinium robustum* Kofoid *et* Swezy

Plate A79: a-d (Annex A)

Synonym:

Gymnodinium teredo Pouchet in Paulsen, 1908

References:

Lebour, 1925: p. 66, Pl. X: 1; Dodge, 1982: p. 109, Fig. 13 A; Throndsen *et al.*, 2007: p. 71.

Description:

Body elongated fusiform, around 3 times as long as broad. Epicone very long; four-fifths of total length, hypocone reduced to a conical structure. Girdle forming a left-handed spiral. Sulcus is commencing near cell apex with a loop nearly completely around the cell, then curves to meet the girdle. It has not been observed on the hypocone. The flagella arise from the junction of girdle and sulcus, and the longitudinal flagellum is very short. The nucleus is elongated and situated along the center of the cell. Also, there is an elongated pusule which extends anteriorly from the flagellar pores; this appears pink in live cells. The cell contains numerous refractile granules, and a number of elongated yellow bodies of unknown function with more aggregated into a stellate cluster at the anterior end. The cytoplasm has a greenish colouration. The cell is presumably bounded only by thecal membranes as it rounds up before final collapse; 36-75 μm long; 21-25 μm wide (Dodge, 1982).



Dimensions:

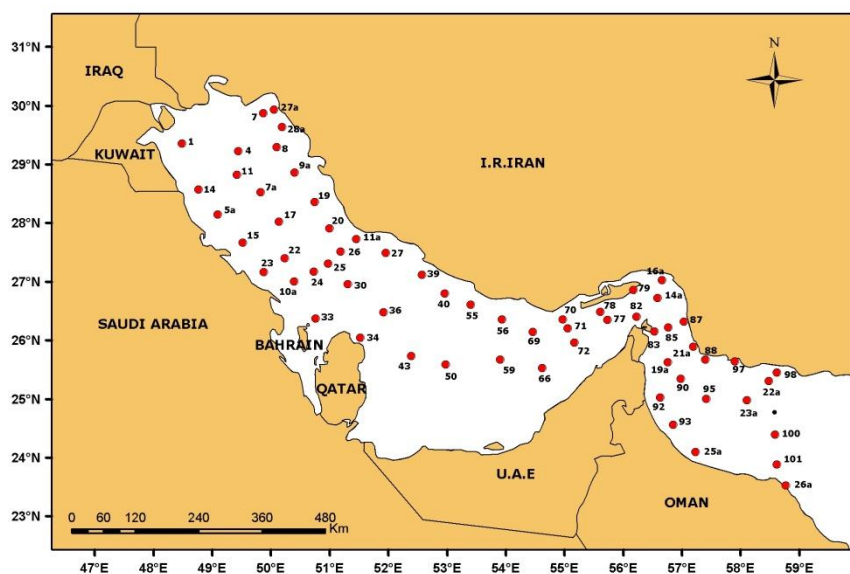
Cells 30-33 μm long; 14-16 μm wide.

Distribution:

Planktonic species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred ubiquitously over most of the area studied (refer sites map), encountered in 81.7 % of the samples, often in large numbers; maximum abundance (1.4×10^4 cells/l) was associated with the central part of the inner RSA (St. 36). It has been previously reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Torodinium robustum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Gymnodiniales Lemmermann, 1910

Family: Gymnodiniaceae Lankester, 1885

Genus: *Torodinium* Kofoid *et* Swezy, 1921

Species: *teredo*

Scientific name: *Torodinium teredo* (Pouchet) Kofoid *et* Swezy

Plate A79: e-h (Annex A)

Synonym:

Gymnodinium teredo Pouchet

References:

Lebour, 1925: p. 66, Fig. 16 b.

Description:

Cell length >3x width; cell with brown pigmentation. Slow swimmer. This species can be distinguished from *T. robustum* by the latter's size (<3x width); green pigmentation (Steidinger and Tangen, 1997).

Dimensions:

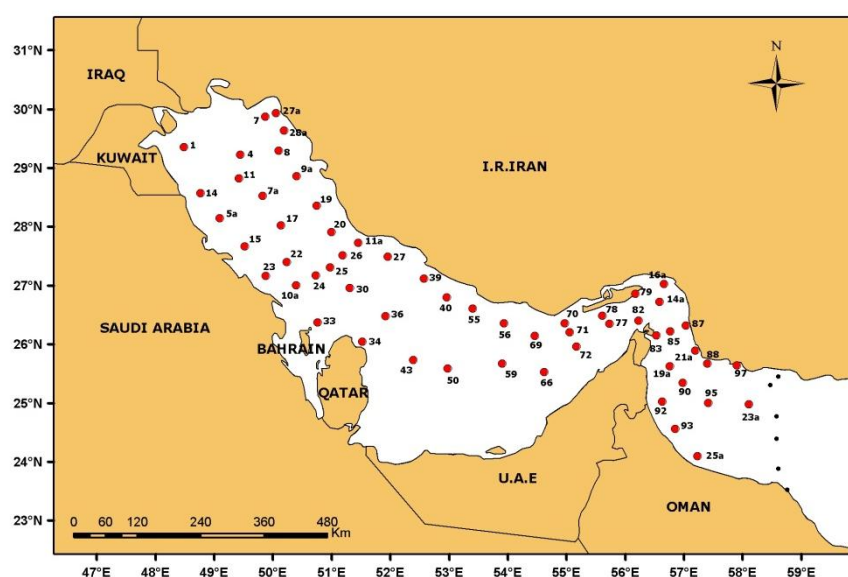
Cells 54-61 µm long; 14-21 µm wide.

Distribution:

Wide distribution in temperate to tropical waters.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was commonly observed at various sites (refer sites map), although never in large numbers; maximum abundance (4.5×10^2 cells/l) was associated with the central part of the inner RSA (St. 36).



Sites of occurrence of *Torodinium teredo* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Gymnodiniales Lemmermann, 1910

Family: Polykrikaceae Kofoed *et* Swezy, 1921

Genus: *Polykrikos* Bütschly, 1873

The specimens consist of zooids permanently integrated in pseudo-colonies with 2, 4, 8 or 16 zooids in a row, each with its cingulum and with a common sulcus, often reduced number of nuclei compared with the number of zooids (Thronsdén *et al.*, 2007).

Scientific name: *Polykrikos schwarzi* Bütschli

Plate A80: a-c (Annex A)

References:

Lebour, 1925: p. 67, Fig. 16 c; Pl. X: 2 a, b; Dodge, 1982: p. 120, Fig. 14 A, G; Thronsdén *et al.*, 2007: p. 70.

Description:

Colony is composed of 2-8 units with half the respective number of nuclei. Shape an elongated ovoid with flattened anterior end and slightly depressed posterior end. Girdles of the zooids, distinct and displaced by their own width; sulci appear to connect together to run the entire length of the colony. Lines of demarcation between zooids, not very conspicuous. Cell contents pinkish (no chloroplasts) containing nematocysts and refractile granules. Nutrition heterotrophic. Size: 100-150 µm long (Dodge, 1982).

**Harmful Effect:**

Non-toxic bloom-forming species; it may be regarded as potentially harmful (Fukuyo *et al.*, 2003).

Dimensions:

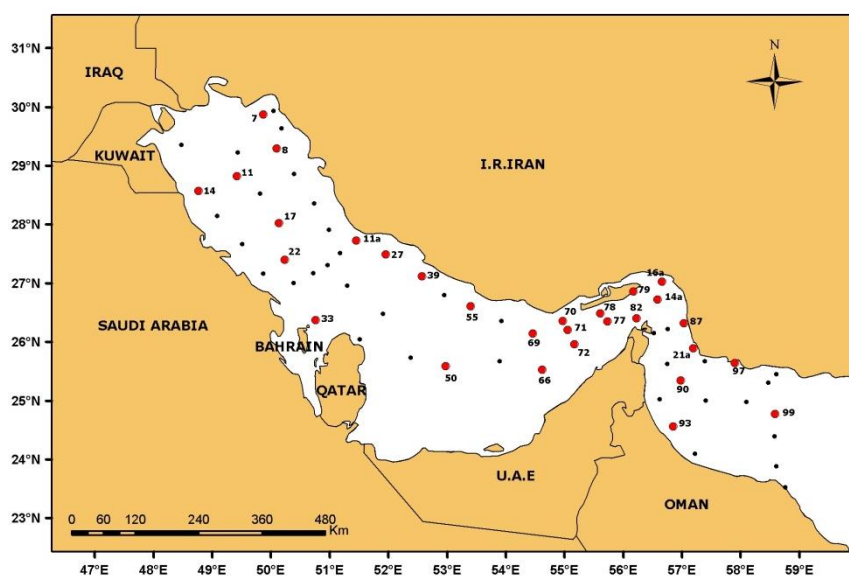
Cells 90-120 µm long; 38-44 µm wide.

Distribution:

Neritic species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at various sites (refer sites map), never in large numbers; maximum abundance (2.1×10^2 cells/l) was associated with the Sea of Oman (St. 97). It has been previously reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Polykrikos schwarzii* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Gymnodiniales Lemmermann, 1910

Family: Warnowiaceae Lindermann, 1928

Genus: *Warnowia* Lindermann, 1928 (= *Pouchetia* Schütt)

Unarmored. Small to large-sized gyrodinoid cell; cingulum with one or two turns; body may appear twisted. Some species with sulcal torsion, creating posterior loop. Apical groove present; ocellus and red or black pigment masses present, usually median or posterior. Nematocysts and chloroplasts are absent (Steidinger and Tangen, 1997).

Scientific name: *Warnowia violescens* (Kofoid *et* Swezy) Lindermann

Plate A75: g-i (Annex A)

References:

Wood, 1968: p. 129, Fig. 404.

Description:

Body ovoid; girdle spiral of one and four-fifths turns; sulcus with three turns and apical and antapical loops. Length 50-60 μm (Wood, 1968).

Dimensions:

Cells 41-47 μm long; 20-21 μm wide.

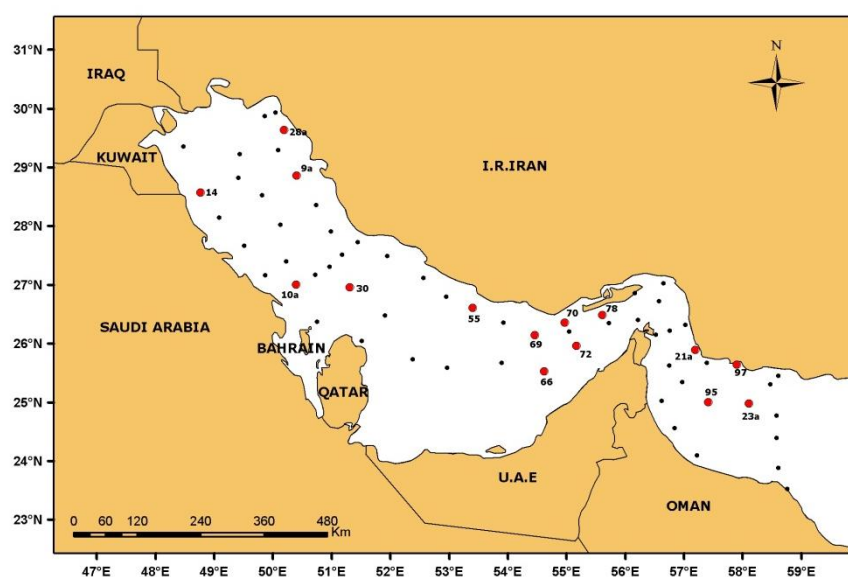


Distribution:

Warm Pacific waters.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at various sites (refer sites map), never in large numbers; maximum abundance (71 cells/l) was associated with the southern part of the inner RSA (St. 70).



Sites of occurrence of *Warnowia violescens* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Noctilucales Haeckel, 1894

Family: Kofoidiniaceae Taylor, 1976

Genus: *Kofoidinium* Pavillard, 1928

Heterotrophic dinoflagellates with their morphology changing as they grow in size from small *Gymnodinium*-like cells (sporocytes) to larger *Gymnodinium*- and *Amphidinium*-like morphotypes (trophonts) and finally develop into an asymmetrical and complex different cell type (sporont). The sporont is colorless and more or less laterally flattened, consisting of a reduced epicone and morphologically complex hypocone. The epicone is a nearly flat area in the cingulum plane, with the left part pointing ahead, such that the cingulum constitutes the apical limitation of the cell. The hypocone is composed of the cell body below the cingulum and a flat membrane-like, often circular keel (velum) as the posterior and lower part of the cell. The sporont has a circular and watch-glass-like shield loosely attached to hook-shaped protrusions on the ventral and dorsal side of the hypocone. The shield has a rotating movement and may be retracted close to the velum when irritated, and possibly has the function to trap nutrient particles. Heterotrophy, uptake of particles (phagotrophy) through a funnel-shaped opening in the ventral area. The species within genus are described on the basis of the sporont morphology. The cell is strongly vacuolized in all stages. It is likely that sporocytes and trophonts of *Kofoidinium* in many instances have been misidentified and described as separate species of *Gymnodinium* or *Amphidinium*. Species identification of sporocytes and trophonts is doubtful, and reliable identification is only possible in the sporont stage (Throndsen *et al.*, 2007).

Scientific name: *Kofoidinium velleloides* Pavillard

Plate A158: g (Annex A)

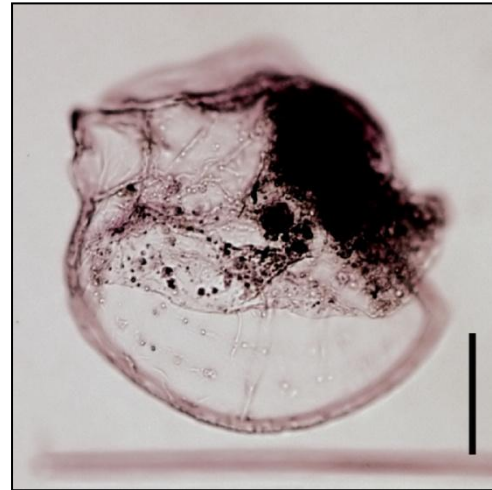
References:

Dodge, 1982: p. 134, Fig. 16 E, F; Balech, 1988: p. 225, L. 3: 1; Throndsen *et al.*, 2007: p. 72.

Description:

Relatively large, transparent species with a rounded body and distinctive keel-like velum. The epicone is reduced and consists of a narrow at girdle the left side of which is raised to become anterior to the rest of the epicone. The hypocone is rounded and contains the large nucleus

slightly anterior of the center. The distinctive keel-like velum is bordered by a narrow differentiated band and is rounded or irregular in preserved specimens. There is no tentacle, distinguishing it from *Noctiluca scintillans* and *Spatulodinium pseudonoclituca*. Development stages have *Gymnodinium* and *Amphidinium*-like forms and may be pigmented. 100-300 μm wide (Dodge, 1982).



Dimensions:

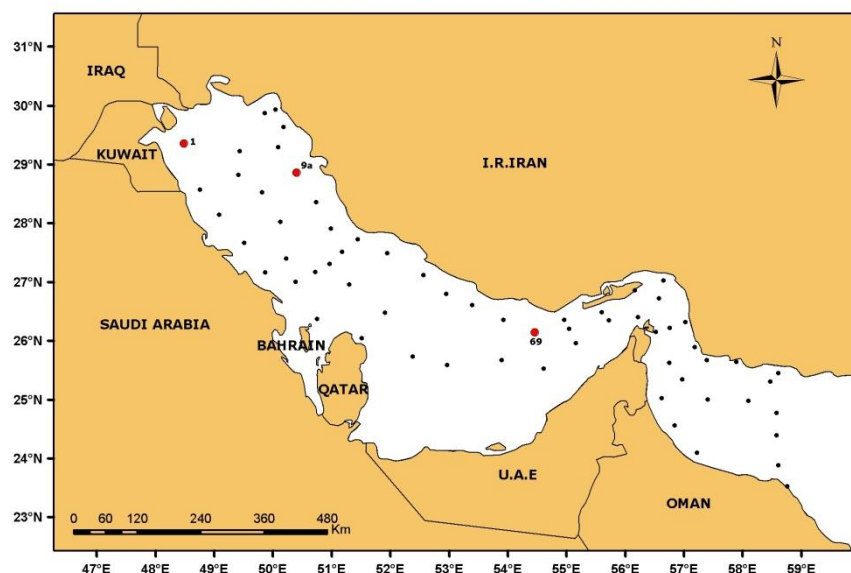
Cells 64-86 μm long; 67-90 μm wide.

Distribution:

Coastal and open temperate to tropical waters; cosmopolitan species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at three sites in the inner RSA (refer sites map) and in small numbers.



Sites of occurrence of *Kofoidinium velleioides* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Noctilucales Haeckel, 1894

Family: Noctilucaceae Kent, 1881

Genus: *Noctiluca* Suriray *ex* Lamarck, 1816

Large spherical cells without a firm theca, with a characteristic transversely striped tentacle. Strongly vacuolized, with large spherical nucleus surrounded by cytoplasm. Funnel-shaped depression at the basis of the tentacle (ingestion of nutrient particles), with rudimentary furrows and basis for the flagella. The cell content is often pink. Gymnodinioid, small swimmers (gametes) (Throndsen *et al.*, 2007).

Scientific name: *Noctiluca scintillans* (Macartney) Kofoed *et* Swezy

Plate A81: a-d (Annex A)

Synonyms:

Medusa scintillans Macartney; *Noctiluca miliaris* Suriray

References:

Lebour, 1925: p. 69, Fig. 17 a-d; Taylor, 1976: p. 186, Pl. 39: 478-479; Dodge, 1982: p. 135, Fig. 16 A-C; Balech, 1988: p. 223, L. 1: 11; Hallegraeff *et al.*, 1995: p. 291, Fig. 15.11; Hallegraeff, 2002: p. 69, Fig. 16 B; Faust and Gullede, 2002: p. 46, Pl. 30: 1-4; Throndsen *et al.*, 2007: p. 74.

**Description:**

Noctiluca scintillans is a distinctively shaped athecate species in which the cell is not divided into epitheca and hypotheca. Cells are very large, inflated (balloon-like) and subspherical. The ventral groove is deep and wide, and houses a flagellum, a tooth and a tentacle. Only one flagellum is present in this species, and is equivalent to the transverse flagellum in other dinoflagellates. The tooth is a specialized extension of the cell wall. The prominent tentacle is striated and extends posteriorly. Cells have a wide range in size: from 200-2000 µm in

diameter. *Noctiluca scintillans* is a nonphotosynthetic heterotrophic and phagotrophic dinoflagellate species; chloroplasts are absent, and the cytoplasm is mostly colorless. The presence of photosynthetic symbionts can cause the cytoplasm to appear pink or green in color. A number of food vacuoles are present within the cytoplasm. A large eukaryotic nucleus is located near the ventral groove with cytoplasmic strands extending from it to the edge of the cell (Faust and Gullledge, 2002).

Harmful Effect:

Toxic blooms of *N. scintillans* have been linked to massive mortality of fish and marine invertebrates. Although this species does not produce a toxin, it has been found to accumulate toxic levels of ammonia, which is then excreted into the surrounding waters possibly acting as the killing agent in blooms (Okaichi and Nishio, 1976; Fukuyo *et al.*, 1990). Extensive toxic blooms have been reported off the east and west coasts of India, where they have been implicated in the decline of fisheries (Aiyar, 1936; Bhimachar and George, 1950).

Dimensions:

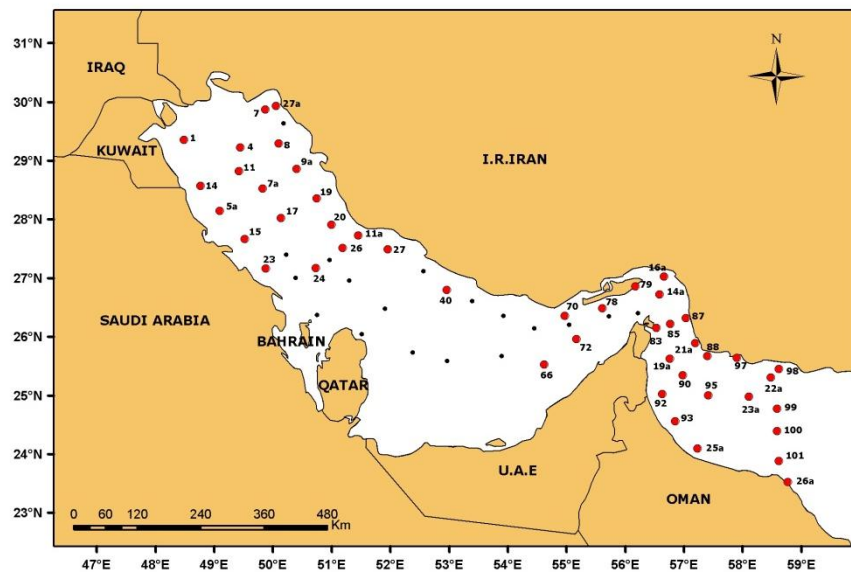
Cells diameter 580-720 μm .

Distribution:

Noctiluca scintillans is a cosmopolitan species distributed worldwide in cold and warm waters. Populations are commonly found in coastal areas and embayments of tropical and subtropical. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was frequently observed at various sites (refer sites map), although never in large numbers; maximum abundance (6.9×10^2 cells/l) was associated with the Sea of Oman (St. 90). Species has previously been reported from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Noctiluca scintillans* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Noctilucales Haeckel, 1894

Family: Protodiniferaceae Kofoed *et* Swezy, 1921

Genus: *Pronoctiluca* Fabre-Domergue, 1889

The cells are elongated-oval with apical tentacle and subapical flagella. Cingulum and sulcus poorly developed. Cell surface finely dotted (Throndsen *et al.*, 2007).

Scientific name: *Pronoctiluca pelagica* Fabre-Domergue

Plate A81: e (Annex A)

Synonyms:

Pelagorhynchus marina Pavillard; *Protodinifer tenticulatum* Kofoed *et* Swezy

References:

Lebour, 1925: p. 18, Fig. 6; Wood, 1968: p. 121, Fig. 370; Taylor, 1976: p. 187, Pl. 37: 426-428, 430, 431; Dodge, 1982: p. 112, Fig. 13 G; Throndsen *et al.*, 2007: p. 71.

Description:

Cell fusiform to pyriform; length about two and a half times diameter with a short, slender tentacle at apex. Two long flagella, one directed anteriorly, the other posteriorly, emerging near the anterior of the cell on the ventral surface. There is a short ventral anterior sulcus. Delicate cyst walls are produced exterior to the cell wall. The nucleus is large, and is in part responsible for this species inclusion in the *Dinoflagellata*. This has recently been questioned by Drebes and Elbrachter (1976) who feel the organism belongs to the Chrysophyta. A large accumulation body can sometimes be seen at the posterior end of the cell. Length 12-45 μm (Dodge, 1982).

**Dimensions:**

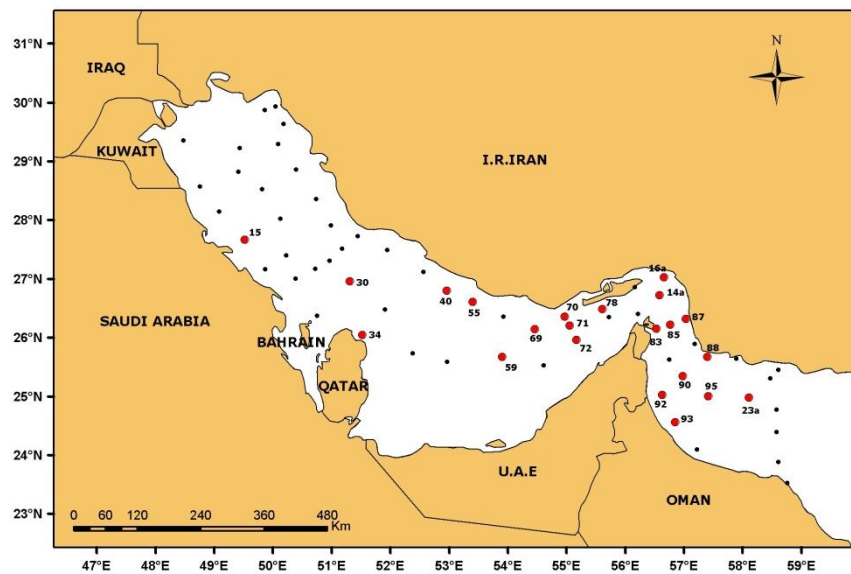
Cells 28-33 μm long; 15-17 μm wide.

Distribution:

Cosmopolitan in warm waters. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was occasionally observed at certain sites (refer sites map), usually in small numbers; however, it was quite abundant at some localities; maximum abundance (1.1×10^3 cells/l) was associated with the Sea of Oman (St. 95). Species has previously been reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Pronoctiluca pelagica* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Noctilucales Haeckel, 1894

Family: Protodiniferaceae Kofoed *et* Swezy, 1921

Genus: *Pronoctiluca* Fabre-Domergue, 1889

Species: *spinifera*

Scientific name: *Pronoctiluca spinifera* (Lohmann) Schiller

Plate A81: f-h (Annex A)

Synonym:

Rhynchomonas spinifer Lohmann

References:

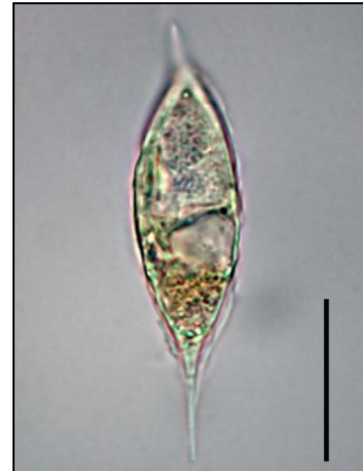
Wood, 1968: p. 121, Fig. 371; Taylor, 1976: p. 188, Pl. 37: 429.

Description:

Body narrow, elongate, slightly asymmetrical, broadest toward base; apex asymmetrical with almost straight, parallel walls, usually ending in a short, blunt process; girdle and sulcus anterior; tentacular process slender, cylindrical. Length 24-50 μm (Wood, 1968).

Dimensions:

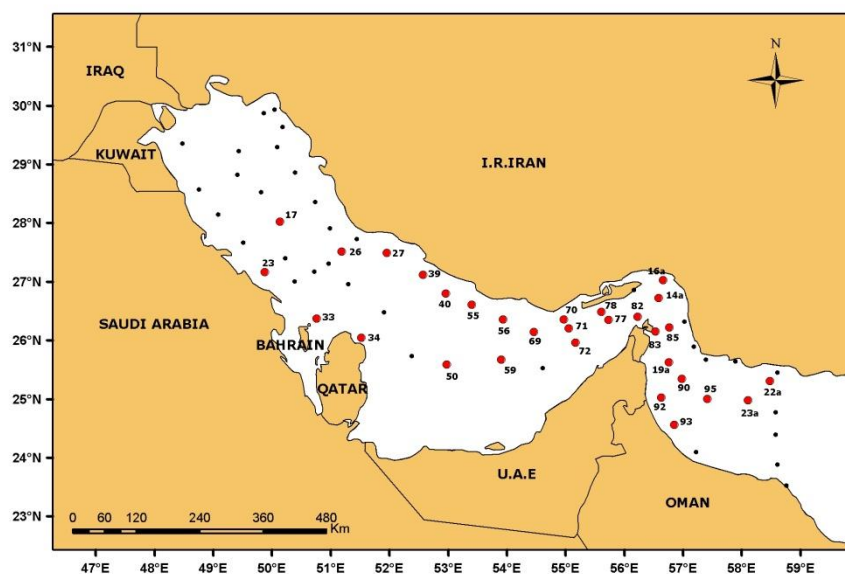
Cells 32-38 μm long; 16-18 μm wide.

**Distribution:**

Cosmopolitan in warm waters. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at different sites (refer sites map), usually in small numbers; maximum abundance (3×10^2 cells/l) was associated with the Iranian coast in the central part of the inner RSA (St. 27).



Sites of occurrence of *Pronoctiluca spinifera* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridiniales Haeckel, 1894

Family: Ceratiaceae Kofoed, 1907

Genus: *Ceratium* Schrank, 1793

Autotrophic dinoflagellates with well developed theca. The cell body is somewhat dorsoventrally compressed with a medium cingulum. Characteristics for the genus: pronounced extensions of epi- and hypotheca into conspicuous hollow anterior and posterior horns. The apical horn is pointing anteriorly, and slightly bent in some species, whereas some (tropical) species lack apical horn and have a flattened, wide leaf-shaped epitheca. With exception of the few species which have only one antapical horn, two antapical horns are developed pointing either posteriorly if they are bent forward. Plate formula: Po, cp, 4', 6", 5c, 2s(+), 6"', 2'''. The plates are usually visibly structured, with exception of three plates in the ventral area (6", 5c and 6'''). The species are usually distinguished by their external morphology. The end of apical horn is clean cut (open), the end of antapical horns are either pointed (closed) or open. Occasionally one antapical horn may be closed, whereas the other is open. When referring to the size of the cell body, the width means the width in the cingulum plane in ventral view (Thronsdén *et al.*, 2007).

In Winter 2006 Cruise, the *Ceratium* genus was very diverse, but not abundant within the sampled area; it includes large-sized, mainly heterotrophic dinoflagellates; some of them were frequently observed in samples (*C. furca*, *C. fusis*, *C. breve*, and *C. trichoceros*). Their contribution to total phytoplankton abundance was not more than 12%; the highest concentration reached was 2.9×10^3 cells/l. Maximum abundance of this genus ($> 10^3$ cells/l) occurred in the northernmost part of the northwestern waters of the inner RSA.

Scientific name: *Ceratium breve* (Ostenfeld *et* Schmidt) Schröder

Plate A82: f, g; 83: a (Annex A)

Synonym:

Ceratium tripos var. *brevis* Ostenfeld *et* Schmidt

References:

Sournia, 1967: p. 426, Fig. 47-50; Wood, 1968: p. 25, Fig. 42; Taylor, 1976: p. 80, Pl. 14: 141-146; Dowigar, 1983: p. 28, 29, Pl. II: 10; III: 2a.

Description:

Robust species; epitheca more than half as long as broad, left contour steep, right strongly and broadly convex; hypotheca as long, as or longer than epitheca, base contour even or swollen in middle; horns strong; antapicals evenly curved forward; theca porulate, ridged. Length 100-200 μm (Wood, 1968).

**Dimensions:**

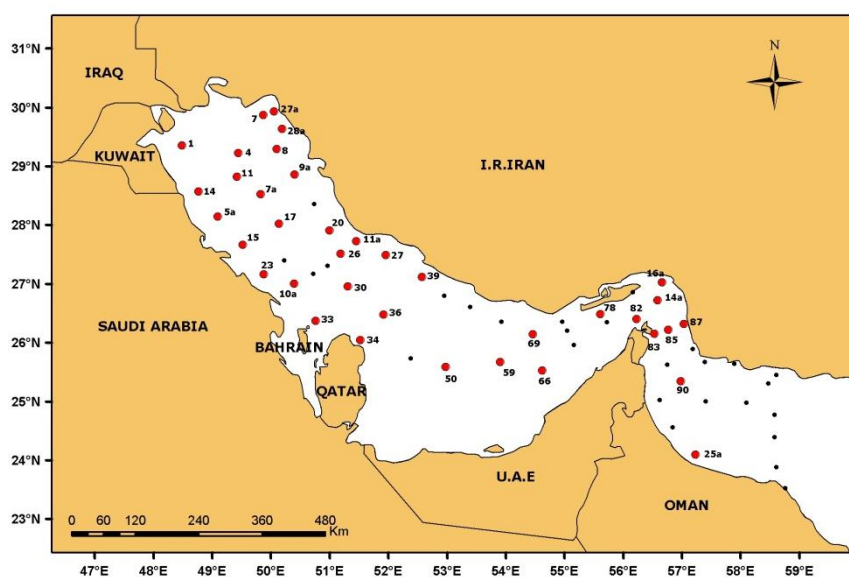
Total length 130-215 μm ; body 80 μm long; 68-70 μm wide.

Distribution:

Oceanic species; cosmopolitan in warm temperate to tropical waters; worldwide distribution. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was frequently observed at various sites (refer sites map), although never in large numbers; maximum abundance (72 cells/l) was associated with the northwestern part of the inner RSA (St. 28a). Species has previously been reported from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Ceratium breve* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Ceratiaceae Kofoid, 1907

Genus: *Ceratium* Schrank, 1793

Species: *candelabrum*

Scientific name: *Ceratium candelabrum* (Ehrenberg) Stein

Plate A84: a, b (Annex A)

Synonym:

Peridinium candelabrum Ehrenberg; *Ceratium candelabrum* var. (f.) *depressum* (Pouchet) Jørgensen

References:

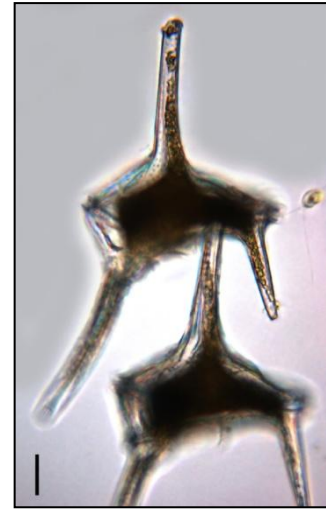
Lebour, 1925: p. 143, Fig. 45 b, c; Pl. XXX: 2; Sournia, 1967: p. 390, Fig. 14-17; Wood, 1968: p. 25, Fig. 44; Taylor, 1976: p. 59, Pl. 12: 124-126; Dowigar, 1983: p. 28, Pl. II: 2; Dodge, 1985: p. 94; Balech, 1988: p. 278, 279, L. 56: 17, 18; 57: 5.

Description:

Body broader than high; epitheca obliquely conical, tapering into a long apical horn which is straight or slightly bent; hypotheca very shallow, triangular; antapicals varying, usually thick and straight or slightly curved, widely separated laterally. Length 100-200 μm (Wood, 1968).

Dimensions:

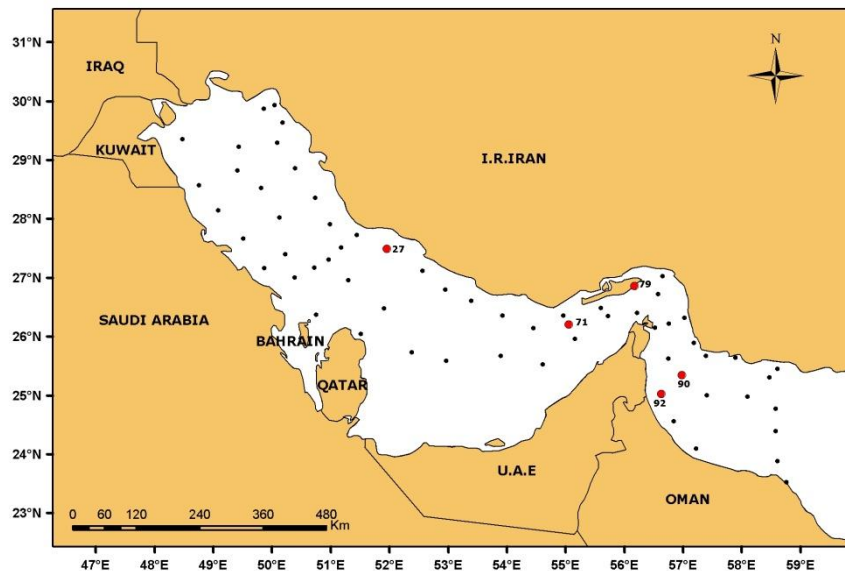
Total length 200-210 μm ; body 60 μm long; 98 μm wide.

**Distribution:**

Oceanic; warm temperate to tropical waters; worldwide distribution. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was present in small numbers at few stations (refer sites map).



Sites of occurrence of *Ceratium candelabrum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Ceratiaceae Kofoed, 1907

Genus: *Ceratium* Schrank, 1793

Species: *contortum*

Scientific name: *Ceratium contortum* (Gourret) Cleve

Plate A84: c, d (Annex A)

Synonym:

Ceratium gibberum var. *contortum* Gourret

References:

Sournia, 1967: p. 442, Fig. 67-72; Wood, 1968: p. 26, Fig. 48; Taylor, 1976: p. 81, Pl. 18: 179-181, 184.

Description:

Epitheca oblique on right, right; contour strongly convex; apical horn clearly bent to the left and twisted, almost S-shaped; base contour convex more or less swollen; antapicals more or less unequal, the right usually longer than the left, the latter like that of *C. karsteni*, the former twisted dorsally or ventrally and then forward. Length 200-500 µm (Wood, 1968).



Dimensions:

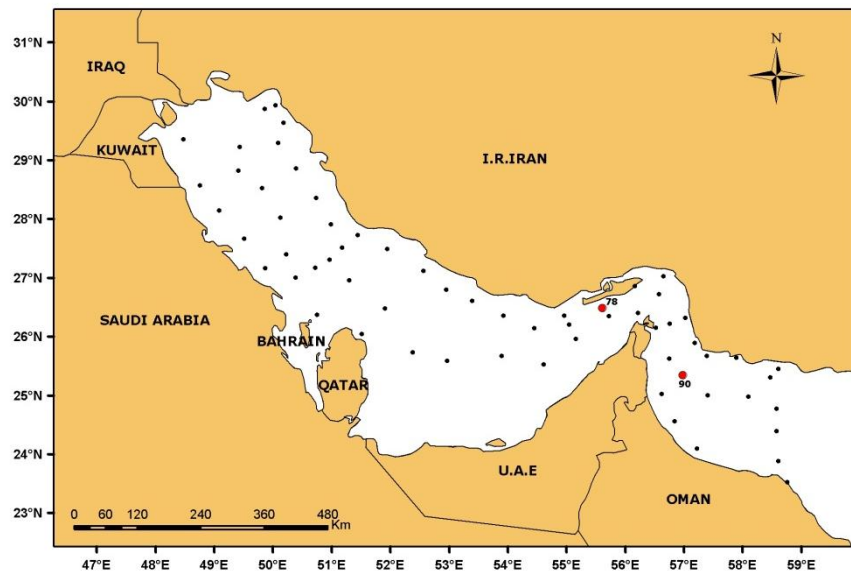
Total length 360 µm; body 109 µm long; 91 µm wide.

Distribution:

Oceanic and coastal species; cosmopolitan in warm temperate to tropical waters; worldwide distribution. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, a few specimens were found in samples from the Strait of Hormuz and the Sea of Oman (refer sites map).



Sites of occurrence of *Ceratium contortum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Ceratiaceae Kofoid, 1907

Genus: *Ceratium* Schrank, 1793

Species: *dens*

Scientific name: *Ceratium dens* Ostenfeld *et* Schmidt

Plate A85: a-d (Annex A)

References:

Sournia, 1967: p. 457, Fig. 80; Taylor, 1976: p. 68, Pl. 17: 172; Dowigar, 1983: p. 32, Pl. VI: 3; Balech, 1988: p. 291, L. 69: 3-5; Konovalova, 1998: p. 151, Fig. 29:11.

Description:

This is a large distinctive species, readily recognizable due to the very short, bluntly acute left antapical horn. The apical horn is straight and tilted to the left. The right antapical horn can exhibit autotomy in some species (Taylor, 1976).

Dimensions:

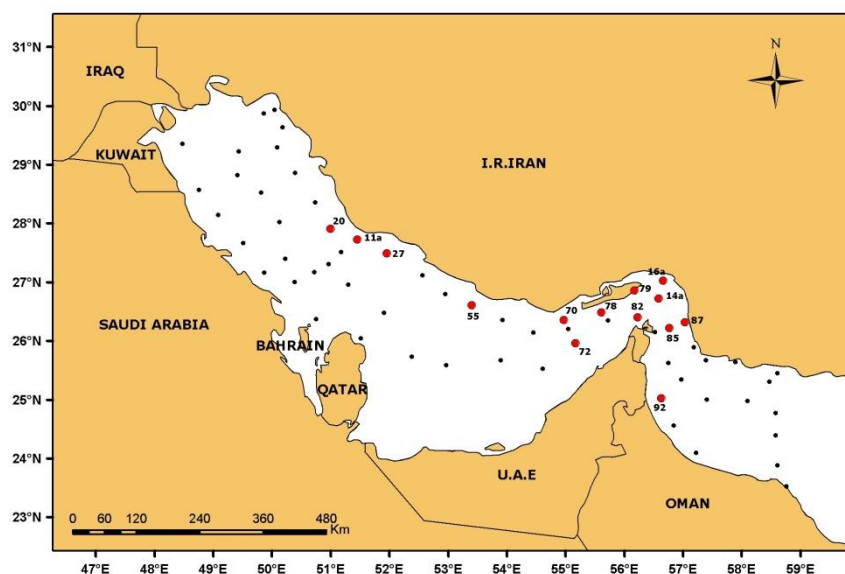
Total length 140-160 μm ; body 60-65 μm long; 65-71 μm wide.

Distribution:

Oceanic tropical species. Species has previously been reported from the Indian Ocean (Taylor, 1976).

**Sites of occurrence in RSA:**

In Winter 2006 Cruise, this species was observed at sporadic sites (refer sites map), and never in large numbers; maximum abundance (2.3×10^2 cells/l) was associated with the Strait of Hormuz (St. 79).



Sites of occurrence of *Ceratium dens* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Ceratiaceae Kofoed, 1907

Genus: *Ceratium* Schrank, 1793

Species: *extensum*

Scientific name: *Ceratium extensum* (Gourret) Cleve

Plate A86: a, b (Annex A)

Synonym:

Ceratium fusus var. *extensum* Gourret

References:

Sournia, 1967: p. 412; Wood, 1968: p. 28, Fig. 54.

Description:

A very long species similar in shape to *Ceratium fusus*; epitheca long and narrow, continuous with a long, straight, narrow apical horn; left antapical usually long, diverted slightly dorsally but straight; right antapical horn absent or needle-like, small; epitheca usually shorter than hypotheca. Length 500-1200 µm (Wood, 1968).

Dimensions:

Cells 1310 µm long; 30-32 µm wide.

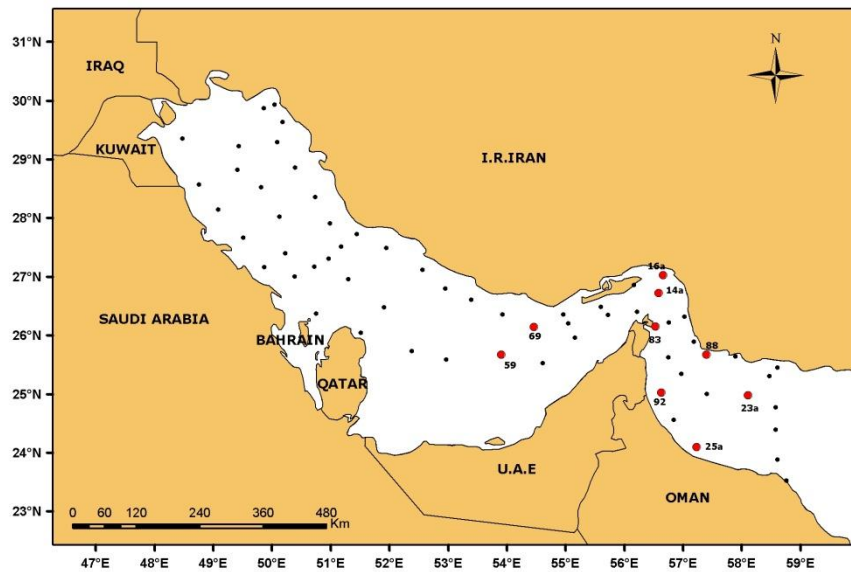
Distribution:

Tropical oceanic form, usually sparse; interoceanic.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at few sites (refer sites map), never in large numbers; maximum abundance (1.7×10^2 cells/l) was associated with the Sea of Oman (St. 92).





Sites of occurrence of *Ceratium extensum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridiniales Haeckel, 1894

Family: Ceratiaceae Kofoed, 1907

Genus: *Ceratium* Schrank, 1793

Species: *falcatum*

Scientific name: *Ceratium falcatum* (Kofoed) Jörgensen

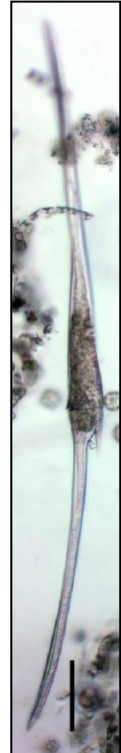
Plate A87: a-f (Annex A)

Synonym:

Ceratium pennatum f. *falcata* Kofoed

References:

Sournia, 1967: p. 413, Fig. 38; Wood, 1968: p. 29, Fig. 56; Taylor, 1976: p. 66, Pl. 13: 133; Dowigar, 1983: p. 27, Pl. I: 9; Balech, 1988: p. 277, L. 55: 13.



Description:

Body linear; apical and left antapical horns bent about two-thirds length; right antapical horn small, acicular. Length 200 μm (Wood, 1968).

Dimensions:

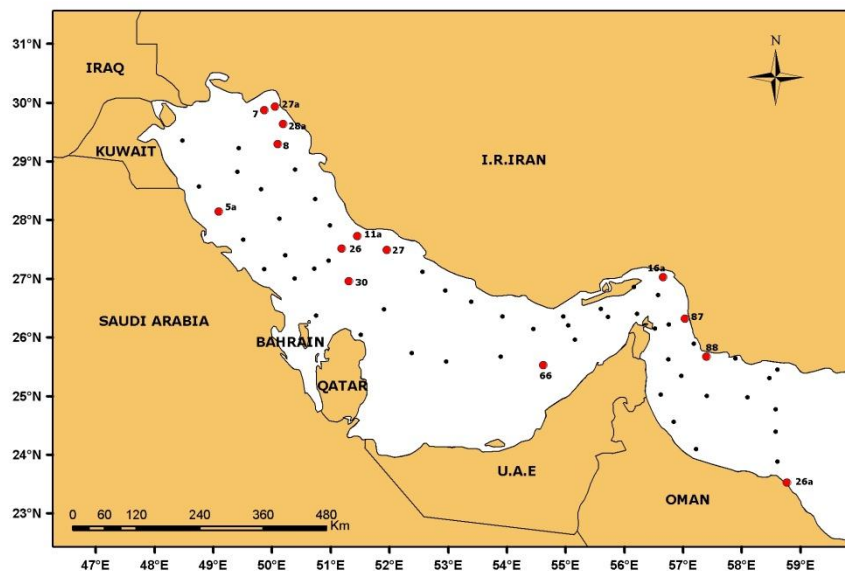
Cells 520-540 μm long; 25-27 μm wide.

Distribution:

Interoceanic warm-water species. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at few sites (refer sites map), never in large numbers; maximum abundances were associated with the northwestern part of the inner RSA (Stations 7, and 8).



Sites of occurrence of *Ceratium fulcatum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Ceratiaceae Kofoed, 1907

Genus: *Ceratium* Schrank, 1793

Species: *furca*

Scientific name: *Ceratium furca* (Ehrenberg) Claparede *et* Lachmann

Plate A86: e-j (Annex A)

Synonym:

Peridinium furca Ehrenberg

References:

Lebour, 1925: p. 145, Pl. XXX: 3; Sournia, 1967: p. 395, Fig. 18-20; Wood, 1968: p. 29, Fig. 57; Taylor, 1976: p. 60, Pl. 12: 107-109; Dowig, 1983: p. 28, Pl. II: 3; Dodge, 1982: p. 228, Fig. 28 C; Pl. VIII: e; Dodge, 1985: p. 96; Balech, 1988: p. 278, L. 56: 4-6; Throndsen *et al.*, 2007: p. 78.

Description:

Body straight, widest either side of the girdle. Epitheca tapering gradually into the anterior horn; hypotheca triangular and slightly tapering, extended into long left and short right antapical horns, which are usually straight in line with the cell and may be slightly toothed along the sides. Thecal plates moderately thick, ornamented with a regular reticulum of ridges with pores in the depressions. Central area on the ventral side is covered with very delicate plates. Size: 70-100 µm long; 30-50 µm wide (Dodge, 1982).

**Harmful Effect:**

This is a harmful algal bloom forming species. Harmful effects have been recorded in 1998 (China): the highest level of DSP (10 µg/g) was found in the blue mussel during a bloom of *Ceratium furca* and *Dinophysis fortii*, resulting in the reduction of fish mariculture operations

and economic loss (Zhao, 2000); blooms of this species were reported from Japan (Fukuyo *et al.*, 2003).

Dimensions:

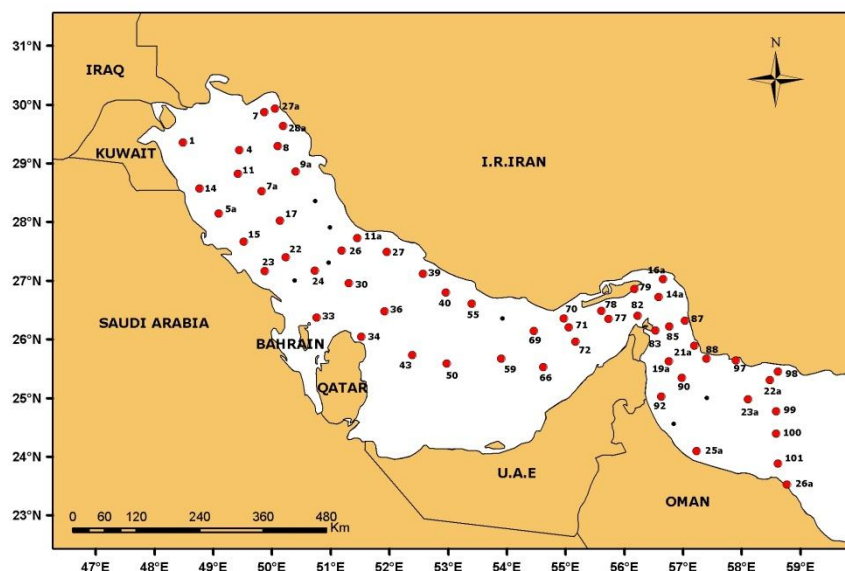
Cells 77-90 µm long; 13-15 µm wide.

Distribution:

Principally coastal, but found in estuarine and oceanic waters; cosmopolitan in cold temperate to tropical waters. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was frequently observed at various sites (refer sites map), often in large numbers; maximum abundance (2.06×10^3 cells/l) was associated with the northwestern part of the inner RSA (St. 7). Species has previously been reported from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Ceratium furca* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Ceratiaceae Kofoed, 1907

Genus: *Ceratium* Schrank, 1793

Species: *fuscus*

Scientific name: *Ceratium fuscus* (Ehrenberg) Dujardin

Plate A87: g-l (Annex A)

Synonym:

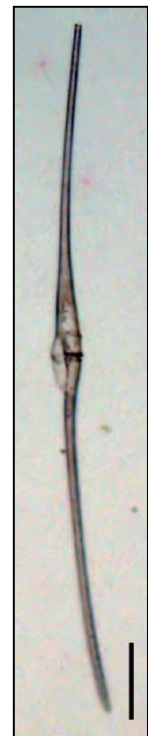
Peridinium fuscus Ehrenberg

References:

Lebour, 1925: p. 146, Pl. XXXI: 1; Sournia, 1967: p. 408, Fig. 32-34; Wood, 1968: p. 29, Fig. 58; Taylor, 1976: p. 66, Pl. 13: 129, 130; Dowidar, 1983: p. 27, Pl. I: 8; Hallegraeff *et al.*, 1995: p. 302, Fig. 15.22.

Description:

The cells are very elongated with two long, slightly and smoothly curved horns, the apical and left antapical horns. The right antapical horn well developed in many *Ceratium* species, is greatly reduced or completely absent. Length: 150-300 μm , transdiameter: 15-30 μm (Hallegraeff *et al.*, 1995).

**Harmful Effect:**

This species can cause harm to invertebrate larvae by an unknown mechanism (Hallegraeff *et al.*, 1995).

Dimensions:

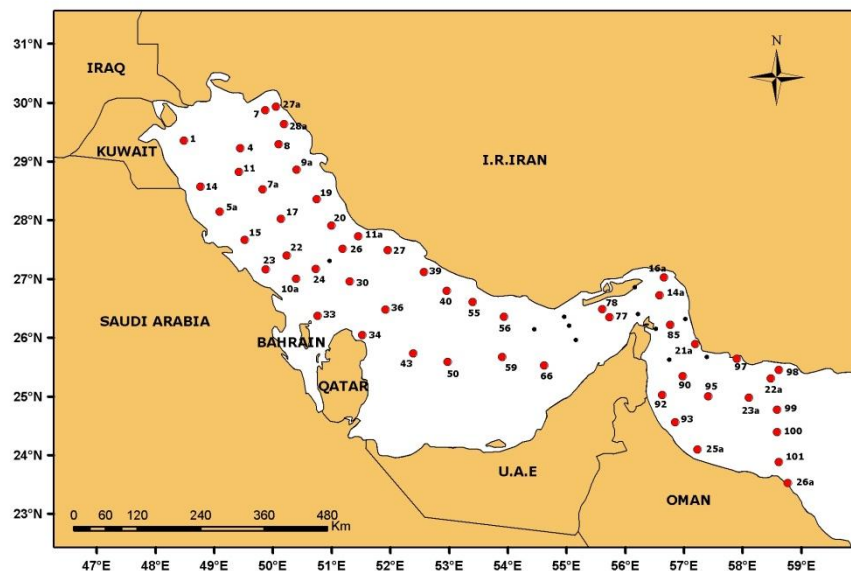
Cells 400-425 μm long; 19-21 μm wide.

Distribution:

Very widespread in coastal waters where it can tolerate a great range of salinities (5-70%), and found in oceanic to estuarine environments; cosmopolitan in cold temperate to tropical waters. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was commonly observed at various sites (refer sites map), although never in large numbers; maximum abundance (6.1×10^2 cells/l) was associated with the northwestern part of the inner RSA off Saudi Arabia (St. 5a). Species has previously been reported from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Ceratium fusus* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Ceratiaceae Kofoed, 1907

Genus: *Ceratium* Schrank, 1793

Species: *gibberum*

Scientific name: *Ceratium gibberum* Gourret

Plate A88: a-c (Annex A)

Synonyms:

Ceratium tripos var. *megaceras* Pouchet; *Ceratium gibberum* var. *megaceras* Jörgensen; *Ceratium gibberum* f. *sinistrum* Jörgensen; *Ceratium concilians* Jörgensen f. *dispar* (Pouchet) Böhm; *Ceratium gibberum* Gourret f. *dispar* (Pouchet) Jörgensen

References:

Lebour, 1925: p. 152, Fig. 49 a-c; Sournia, 1967: p. 446, Fig. 73; Wood, 1968: p. 30, Fig. 61; Taylor, 1976: p. 84, Pl. 19: 187; Dowigar, 1983: p. 29, Pl. III: 5; Dodge, 1985: p. 97; Balech, 1988: p. 285, L. 63: 3, 4.



Description:

Body thick, rather flattened; epitheca low, angled strongly on left, somewhat humped; hypotheca rounded to gibbous, longer than epitheca; left antapical strong, evenly bent, tip closed, directed anteriorly strong, evenly bent, tip closed, directed anteriorly; right antapical based close to girdle, transverse, then curved rapidly behind dorsal surface of epitheca, tip closed, directed transversely or slightly forward. Length 100-150 µm (Wood, 1968).

Dimensions:

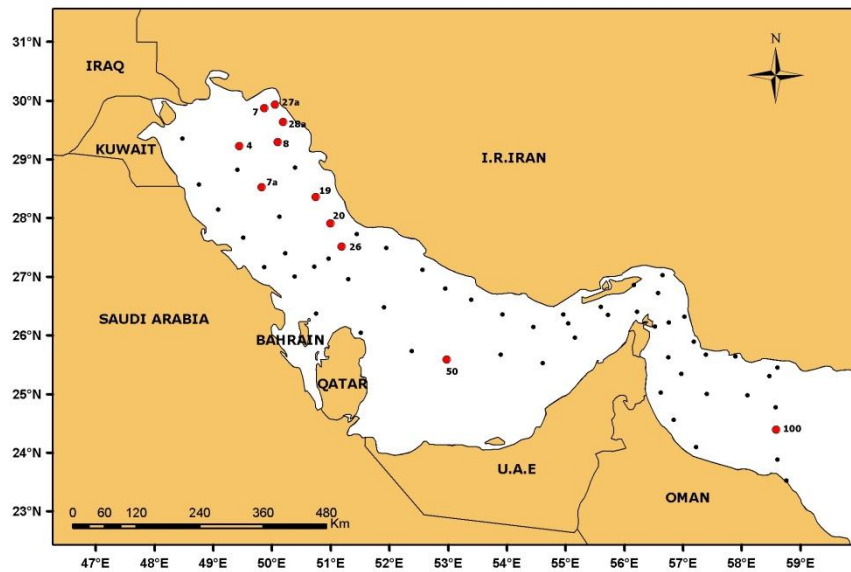
Total length 190-240 µm; body 97 µm long; 92 µm wide.

Distribution:

Oceanic and coastal; warm temperate to tropical waters; worldwide distribution. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at few sites (refer sites map), never in large numbers; maximum abundance (2.2×10^2 cells/l) was associated with the northwestern part of the inner RSA (St. 28a).



Sites of occurrence of *Ceratium gibberum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Ceratiaceae Kofoed, 1907

Genus: *Ceratium* Schrank, 1793

Species: *hexacanthum*

Scientific name: *Ceratium hexacanthum* Gourret

Plate A88: e-g (Annex A)

Synonyms:

Ceratium reticulatum (Pouchet) Cleve; *Ceratium hexacanthum* var. *contortum* Lemmermann;
Ceratium tripos var. *reticula* Pouchet.

References:

Sournia, 1967: p. 485, Fig. 98; Wood, 1968: p. 31, Fig. 63; Taylor, 1976: p. 70, Pl. 22: 214, 215, 219; Dowigar, 1983: p. 31, Pl. V: 6; Balech, 1988: p. 291, L. 69: 1, 2.

Description:

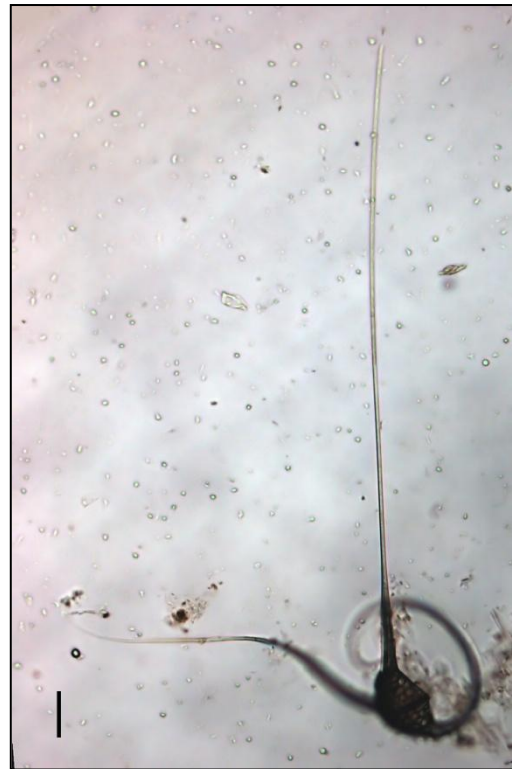
Body concave, very strongly marked with reticulations, bottom toothed; apical horn straight; antapicals curled spirally, right antapical whip-like. Size variable (Wood, 1968).

Dimensions:

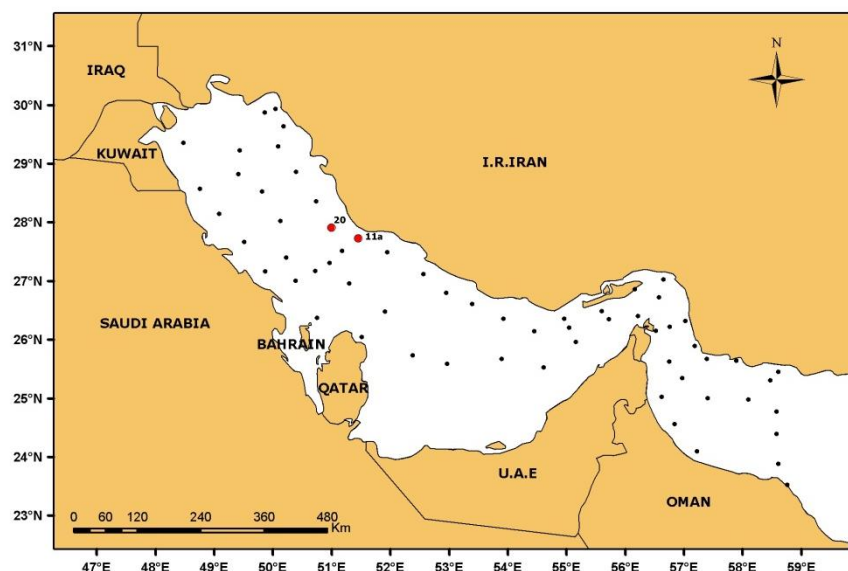
Total length 200-750 μm ; body 74 μm long; 62 μm wide.

Distribution:

Coastal and oceanic; cosmopolitan in cold temperate to tropical waters, but more common in warm waters. Species has previously been reported from the Indian Ocean (Taylor, 1976).

**Sites of occurrence in RSA:**

In Winter 2006 Cruise, a single specimen was found at each sample collected from two sites of the northwestern part of the inner RSA (refer sites map).



Sites of occurrence of *Ceratium hexacanthum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridiniales Haeckel, 1894

Family: Ceratiaceae Kofoed, 1907

Genus: *Ceratium* Schrank, 1793

Species: *horridum*

Scientific name: *Ceratium horridum* (Cleve) Gran

Plate A89: a-c (Annex A)

Synonyms:

Ceratium tripos var. *horridum* Cleve; *Ceratium intermedium* Jörgensen; *Ceratium tenue* (Ostenfeld *et* Schmidt) Jörgensen; *Ceratium buceros* Zacharias emend. Bohm *ex* Schiller; *Ceratium batavum* Paulsen

References:

Lebour, 1925: p. 155, Pl. XXXIV: 2; Sournia, 1967: p. 477, Figs. 91-94; Wood, 1968: p. 32, Fig. 65; Taylor, 1976: p. 71, Pl. 20: 202; Pl. 21: 203-208, 211, 212; Dodge, 1982: p. 240, Fig. 31 B, H; Dowigar, 1983: p. 32, 33; Pl. VI: 6; VII: 2; Balech, 1988: p. 287, L. 65: 3-9; Throndsen *et al.*, 2007: p. 79.



Description:

This is either a very variable species or, alternatively, one which has been much confused by earlier workers. It is a medium sized and fairly delicate organism with shortish open-ended horns. Body \pm pentangular; epitheca slightly asymmetric with the right side short and steep, and the left more rounded, leading with slight taper into the slender apical horn. Hypotheca flattened or depressed posteriorly with antapical horns emerging at an angle of 45° (left) or almost at right angles to the apical horn (right), they bend around to terminate at a slight angle to the apical and probably not more than its length. Body 40-50 μm long and wide (Dodge, 1982).

Dimensions:

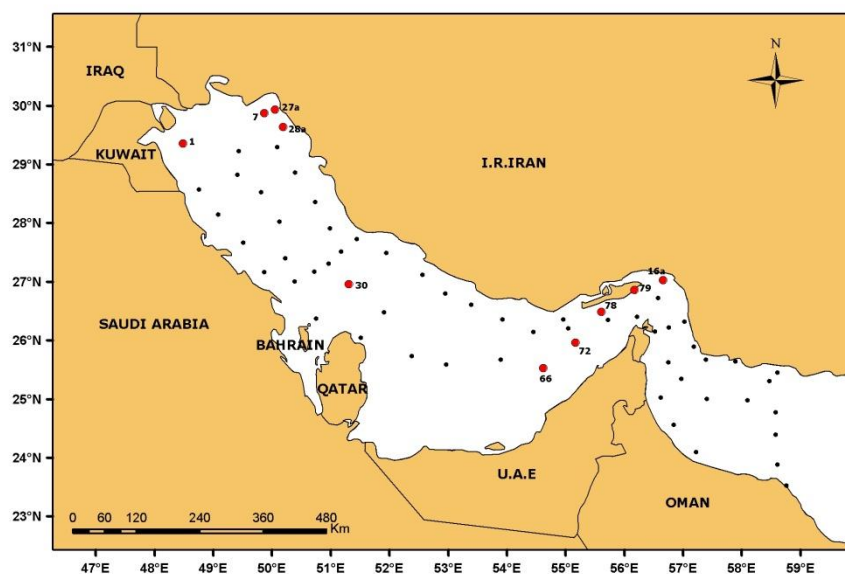
Total length 220-345 µm; body 50 µm long; 48 µm wide.

Distribution:

Coastal and oceanic; cold to warm temperate waters, but has been recorded in tropical waters; worldwide distribution. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at few sites (refer sites map), never in large numbers; maximum abundance (1.7×10^2 cells/l) was associated with the northwestern part of the inner RSA (St. 27a).



Sites of occurrence of *Ceratium horridum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Ceratiaceae Kofoid, 1907

Genus: *Ceratium* Schrank, 1793

Species: *karstenii*

Scientific name: *Ceratium karstenii* Pavillard

Plate A89: d-f (Annex A)

Synonym:

Ceratium arcuatum Cleve

References:

Wood, 1968: p. 33, Fig. 68; Dowigar, 1983: p. 30, Pl. IV: 6; Balech, 1988: p. 284, 285, L. 62: 3; 63: 1, 6.

Description:

A large robust species; theca almost triangular; apical horn curved slightly, long; base flat to convex; antapicals curving at base then straight, parallel to apical; right antapical bent toward apical near tip or twisted. Length 250-300 μm (Wood, 1968).



Dimensions:

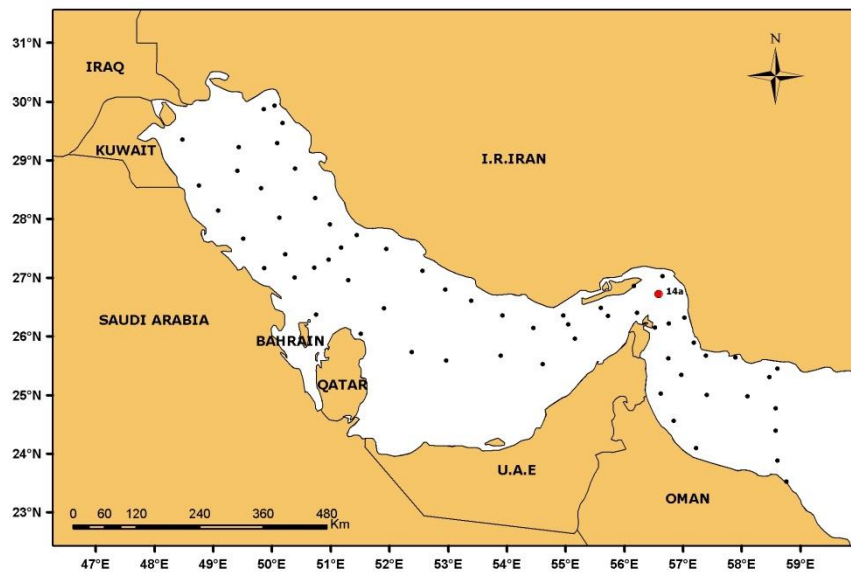
Total length 465 μm ; body 108 μm long; 104 μm wide.

Distribution:

Tropical to subtropical form, frequent but not abundant in oceanic waters.

Sites of occurrence in RSA:

In Winter 2006 Cruise, a single specimen was found in a sample from the Strait of Hormuz (St. 14a) (refer site map).



Site of occurrence of *Ceratium karstenii* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Ceratiaceae Kofoed, 1907

Genus: *Ceratium* Schrank, 1793

Species: *kofoedi*

Scientific name: *Ceratium kofoedi* Jörgensen

Plate A90: a-d (Annex A)

Reference:

Wood, 1968: p. 33, Fig. 69.

Description:

A small species; epitheca high, sides straight to convex; apical horn straight, tapering; hypotheca about equal to epitheca, base acutely angled; antapicals directed straight back, sharply pointed, left twice as long as right. Body length 40-50 μm (Wood, 1968).

Dimensions:

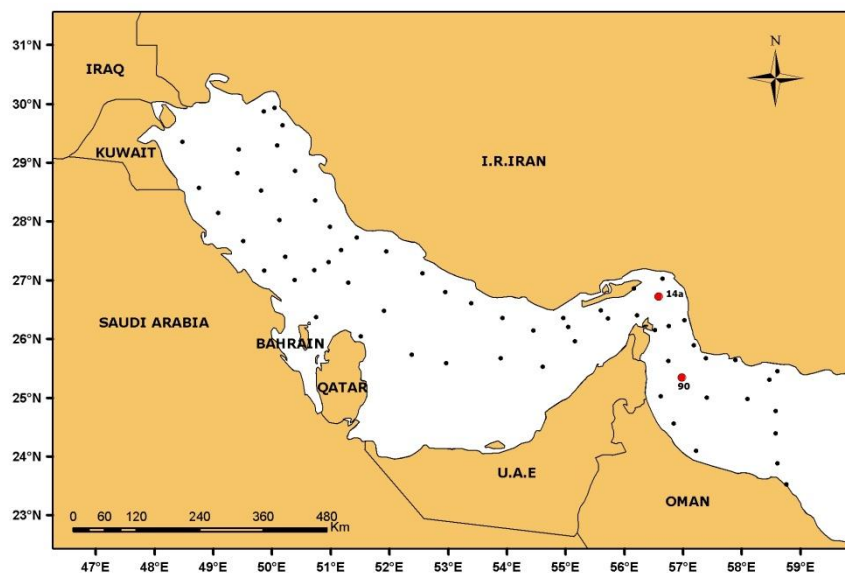
Total length 140 μm ; body 50 μm long; 30 μm wide.

Distribution:

Oceanic; warm temperate to tropical waters.

Sites of occurrence in RSA:

In Winter 2006 Cruise, a few specimens were found in samples from the Strait of Hormuz and Sea of Oman (refer sites map).



Sites of occurrence of *Ceratium kofoidi* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Ceratiaceae Kofoed, 1907

Genus: *Ceratium* Schrank, 1793

Species: *lineatum*

Scientific name: *Ceratium lineatum* (Ehrenberg) Cleve

Plate A82: a-e (Annex A)

Synonym:

Peridinium lineatum Ehrenberg

References:

Lebour, 1925: p. 145, Fig. 45 d, e; Sournia, 1967: p. 404, Fig. 25, 26; Wood, 1968: p. 34, Fig. 72; Taylor, 1976: p. 61, Pl. 12: 121; Dodge, 1982: p. 228, Fig. 28 D; Pl. VIII: f; Dowidar, 1983: p. 27, Pl. I: 6; Dodge, 1985: p. 100; Balech, 1988: p. 278, L. 56: 10-13; Throndsen *et al.*, 2007: p. 79.



Description:

A rather small and delicate member of the genus. Epitheca forming a more or less equilateral triangle with a sharp transition into a fairly long apical horn; hypotheca rather rectangular extended at the lower corners into two unequal antapical horns which are straight, but diverge slightly. Thecal plates rather thin and not strongly ornamented but usually have longitudinal ridges. Chloroplasts are lightly pigmented, yellowish-brown; 30-60 µm long, 25-45 µm wide (Dodge, 1982).

Taxonomical Remarks:

Population of *Ceratium lineatum* in the RSA was mainly composed of specimens with shorter apical horn than usual (Plate A82: b-e). Often short apical-horned cells were arranged in chains, composed of recently divided specimens with juvenile apical horns (Plate A82: a).

Dimensions:

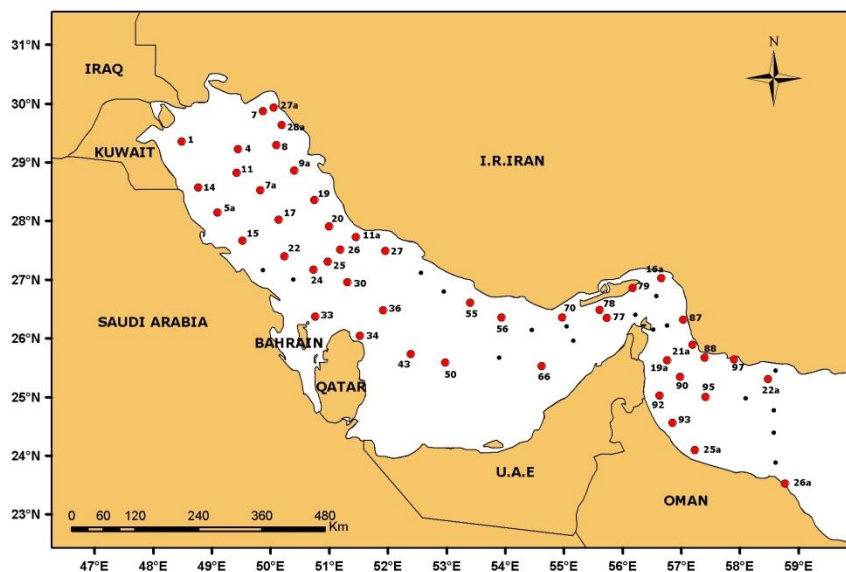
Total length 120-150 µm; body 90 µm long; 82 µm wide.

Distribution:

Neritic, oceanic; cold temperate to tropical waters, there may be distinct warm water forms. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was frequently observed at various sites (refer sites map), usually in small numbers; however, it was quite abundant at some localities; maximum abundance (1.5×10^3 cells/l) was associated with the northwestern part of the inner RSA off the Saudi Arabia (St. 5a). Species has previously been reported from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Ceratium lineatum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Ceratiaceae Kofoed, 1907

Genus: *Ceratium* Schrank, 1793

Species: *lunula*

Scientific name: *Ceratium lunula* Schimper

Plate A91: a-e (Annex A)

Synonyms:

Ceratium tripos lunula Schimper; *Ceratium lunula* Schimper f. *megaceros* (= f. *brachyceros*) Jörgensen

References:

Sournia, 1967: p. 450, Figs. 75, 76; Wood, 1968: p. 35, Fig. 76; Taylor, 1976: p. 85, Pl. 16: 171; Pl. 18: 183; Dowigar, 1983: p. 32, Pl. VI: 4; Balech, 1988: p. 284, L. 62: 1, 2.



Description:

Epitheca almost triangular, low; hypotheca shorter than epitheca with faintly convex base; apical horn may be long in first cell of chain or in single cells or very short and stumpy in subsequent chain of cells; antapicals very long, evenly rounded from base to tip, which is closed. Length 100-150 μm (Wood, 1968).

Dimensions:

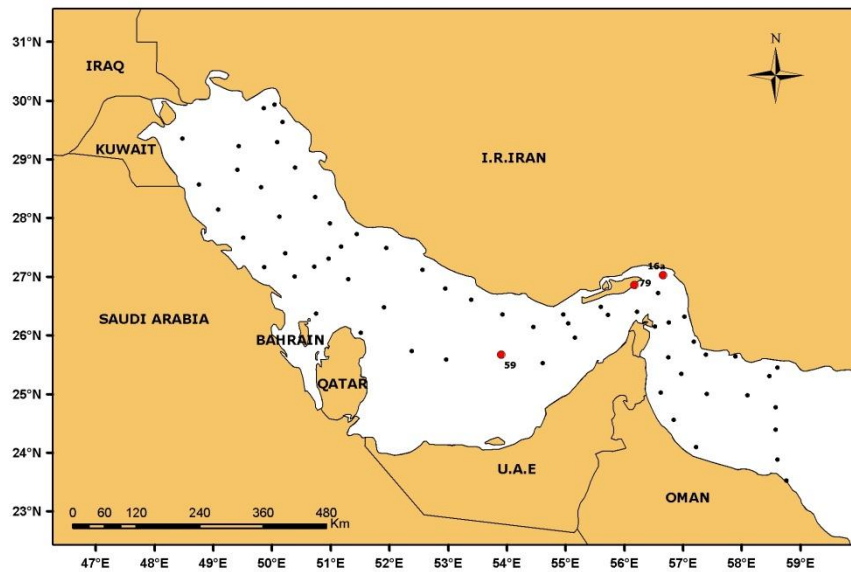
Total length 140 μm ; body 81 μm long; 88 μm wide.

Distribution:

Coastal and oceanic; warm temperate to tropical waters; worldwide distribution. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, a few specimens were found in samples from the southern part of the inner RSA and the Strait of Hormuz (refer sites map).



Sites of occurrence of *Ceratium lunula* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Ceratiaceae Kofoid, 1907

Genus: *Ceratium* Schrank, 1793

Species: *macroceros*

Scientific name: *Ceratium macroceros* (Ehrenberg) Vanhoffen

Plate A92: a-h (Annex A)

Synonym:

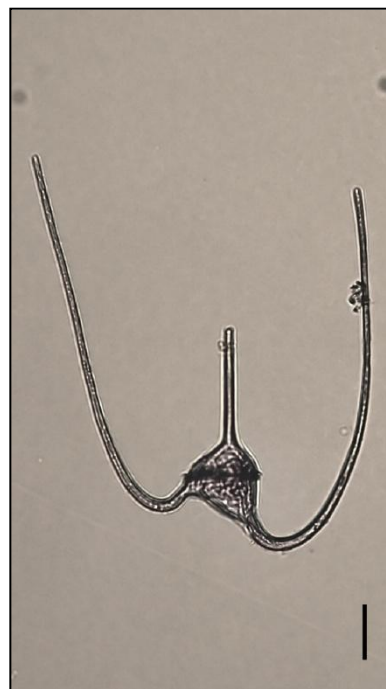
Peridinium macroceros Ehrenberg

References:

Lebour, 1925: p. 155, Pl. XXXV; Sournia, 1967: p. 462, Fig. 83; Wood, 1968: p. 36, Fig. 77; Taylor, 1976: p. 72, Pl. 20: 198, 199; Pl. 22: 218; Dodge, 1982: p. 235, Fig. 31 A; Throndsen *et al.*, 2007: p. 80.

Description:

A fairly large species and very delicate. Body small \pm pentangular; epitheca short with rounded top leading sharply into the long, slender, apical horn. Hypotheca slightly larger than the epitheca, bearing two long, open-tipped antapical horns which emerge in a posterior direction and then describe an almost perfect half-circle to end more or less parallel with, and almost as long as, the anterior horn. The left antapical horn emerges in line with the apical horn and the right at an angle of about 130° . Body 50-60 μm long; 45-55 μm wide; overall length 300-400 μm (Dodge, 1982).

**Taxonomic Remarks:**

This species is recognised in two main varieties:

Ceratium macroceros (Ehrenberg) Vanhoffen var. *macroceros*

Plate A92: a, b, e-h (Annex A)

Variety is a robust variety with a heavily developed theca of large size (girdle diameter exceeding 60 μm and occasionally 100 μm) and less abrupt antapical horn flexure (Taylor, 1976).

Ceratium macroceros (Ehrenberg) Vanhoffen var. *gallicum* (Kofoid) Sournia

Plate A92: c, d (Annex A)

Synonym:

Ceratium gallicum Kofoid

References:

Sournia, 1967: p. 463, Fig. 84, 85; Wood, 1968: p. 30, Fig. 59 (as *Ceratium gallicum*)



Variety is much more delicate with a smaller body size, slender horns abruptly curved, and often a somewhat angular left body profile. A posterior accessory list is often well developed in association with the base of the left antapical horn (Taylor, 1976).

Dimensions:

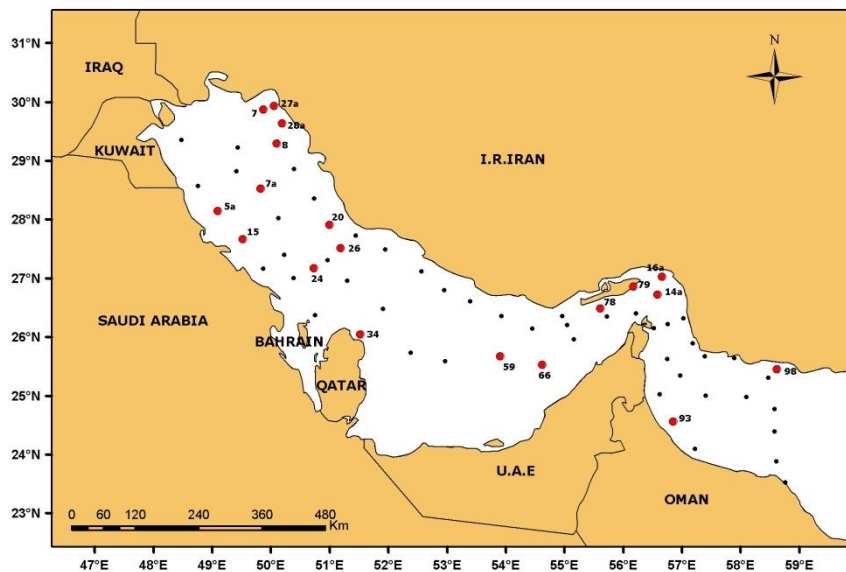
Total length 220-300 μm ; body 78 μm long; 67 μm wide.

Distribution:

Oceanic and coastal; cold temperate to tropical waters; worldwide distribution. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at certain sites (refer sites map), never in large numbers; maximum abundance (72 cells/l) was associated with the southern part of the inner RSA (St. 78).



Sites of occurrence of *Ceratium macroceros* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Ceratiaceae Kofoed, 1907

Genus: *Ceratium* Schrank, 1793

Species: *massiliense*

Scientific name: *Ceratium massiliense* (Gourret) Jörgensen

Plate A93: a-h (Annex A)

Synonym:

Ceratium tripos var. *massiliense* Gourret

References:

Sournia, 1967: p. 465; Wood, 1968: p. 36, Fig. 78; Taylor, 1976: p. 73, Pl. 20: 193-196; Dowigar, 1983: p. 28, 34, Pl. II: 11; VIII: 1; Balech, 1988: p. 286, L. 64: 2, 3, 5, 6.

Description:

Large cell with rounded epitheca and apical horn slightly directed to the right. Typical diagonal straight posterior body margin that makes proximal and of the left horn, wider than that of the right horn. Left horn curves and are almost immediately directed anteriorly. Right horn bends and is directed to the right. Hypothecal horns with open ends (Steidinger and Tangen, 1997).



Taxonomic Remarks:

This species is recognised in a few main varieties:

Ceratium massiliense (Gourret) Jörgensen var. *massiliense*

(Plate A93: a-e, h (Annex A)

Variety has relatively slender horns, and apart from the occasional presence of small fins near the base of the apical horn and small spines on the posterior proximal regions of the antapical horns, it is not strongly ornamented. The proximal region of the left antapical horn usually curves slightly to the posterior before bending anteriorly, but not always (Taylor, 1976).

Ceratium massiliense (Gourret) Jörgensen var. *armatum* (Karsten) Jörgensen

Plate A93: f, g (Annex A)

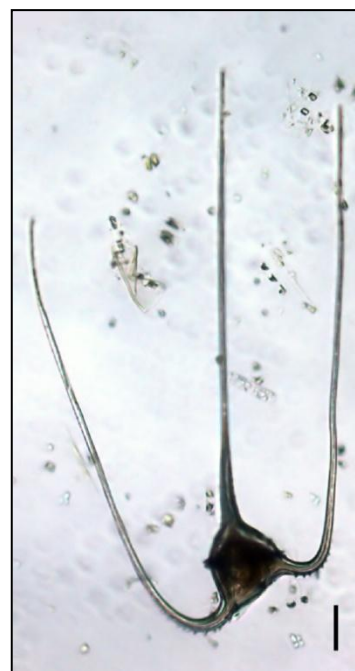
Synonyms:

Ceratium tripos protuberans Karsten; *Ceratium massiliense* var. *protuberans* (Karsten) Jörgensen

References:

Sournia, 1967: p. 468, Fig. 87, 88; Kononova, 1998: p. 156, Fig. 33: 2.

Variety has more robust horns and cell body. Fins are usually, but not invariably developed on the proximal contours of the apical horn and can also be present on the upper curves of the antapical horns. The antapical spinulae on the horns are somewhat stronger. The proximal region of the left antapical horn is only slightly bent to the posterior after leaving the cell body before curving anteriorly. The cell body is usually more convex than in the var. *massiliense* (Taylor, 1976).



Dimensions:

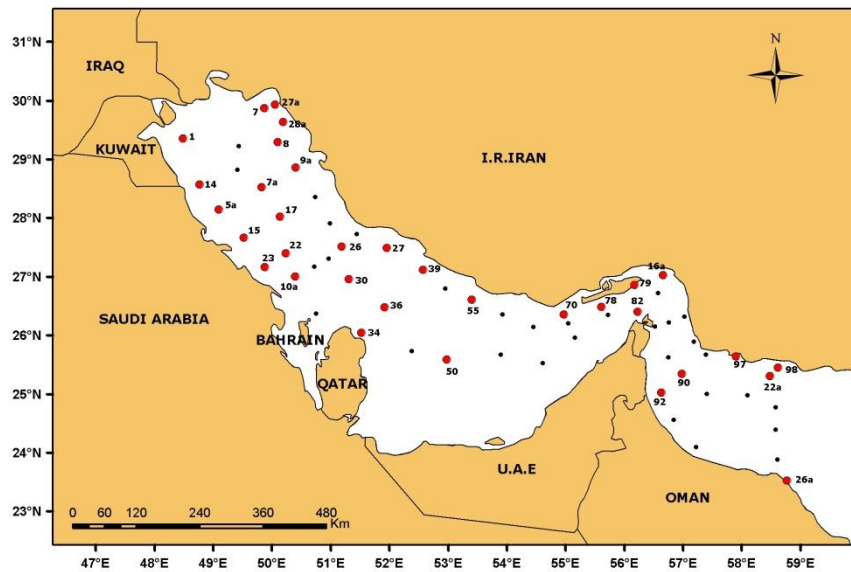
Total length 500-620 μm ; body 90 μm long; 80 μm wide.

Distribution:

Coastal and oceanic; cosmopolitan in warm temperate to tropical waters. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at certain sites (refer sites map), never in large numbers; maximum abundance (70 cells/l) was associated with the Strait of Hormuz area (St. 79). Species has previously been reported from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Ceratium massiliense* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Ceratiaceae Kofoid, 1907

Genus: *Ceratium* Schrank, 1793

Species: *minutum*

Scientific name: *Ceratium minutum* Jörgensen

Plate A90: h (Annex A)

References:

Lebour, 1925: p. 145, Pl. XXX: 4; Sournia, 1967: p. 405, Fig. 27; Wood, 1968: p. 36, Fig. 79; Taylor, 1976: p. 62, Pl. 12: 120; Dodge, 1982: p. 230, Fig. 28 E; Pl. VIII: c; Dowiglar, 1983: p. 27, Pl. I: 7.

Description: A very small species but much more sturdy than *C. lineatum*. Epitheca convexly rounded adjacent to the girdle then becoming concave as it sweeps gradually into

the rather short apical horn; hypotheca with straight tapering sides leading into two very short antapical horns. Thecal plates ornamented with longitudinal ridges and pores. Length up to 60 μm , width 25-30 μm (Dodge, 1982).

Dimensions:

Total length 70 μm ; body 45 μm long; 37 μm wide.

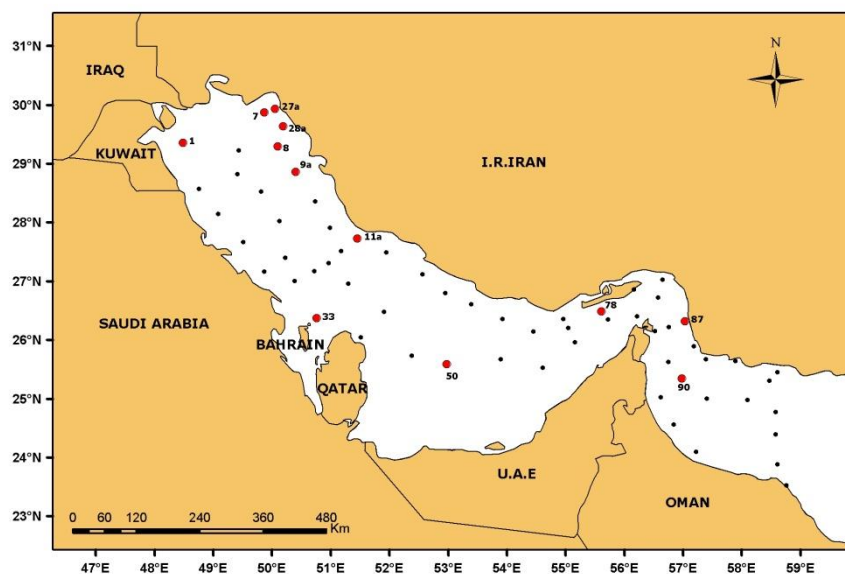
Distribution:

Species has previously been reported from the Indian Ocean (Taylor, 1976).



Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at few sites (refer sites map), never in large numbers.



Sites of occurrence of *Ceratium minutum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Ceratiaceae Kofoed, 1907

Genus: *Ceratium* Schrank, 1793

Species: *pentagonum*

Scientific name: *Ceratium pentagonum* Gourret

Plate A90: e-g (Annex A)

References:

Sournia, 1967: p. 402, Figs. 23, 24; Wood, 1968: p. 37, Fig. 82; Taylor, 1976: p. 62, Pl. 12: 111-113; Dodge, 1985: p. 96; Balech, 1988: p. 278, 279 L. 56: 14, 16; 57: 1-3.

Description:

Very variable; body pentagonal, usually with clear plate sutures and surface thickenings; apical horn long or short (reduced in certain strains); antapicals short, thick, tapering. Body length 50-150 μm (Wood, 1968).

Dimensions:

Total length 150-170 μm ; body 70 μm long; 60 μm wide.

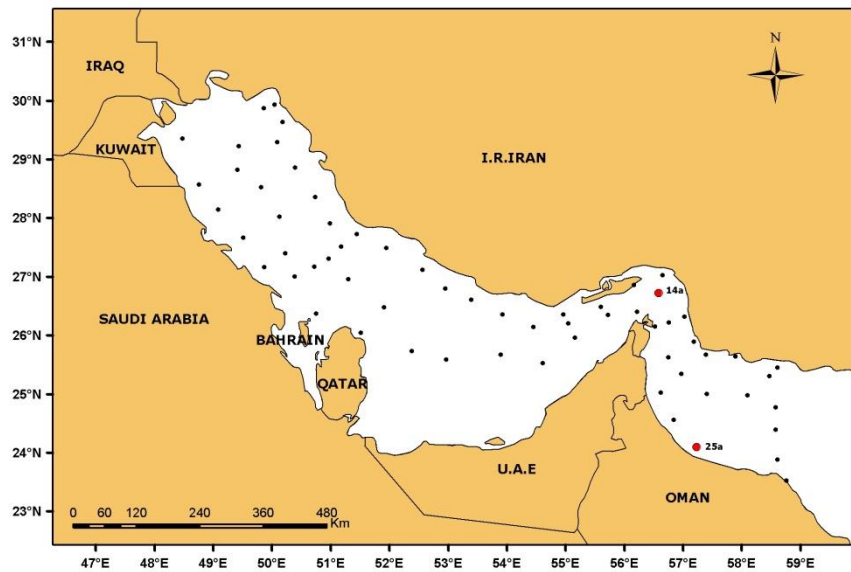


Distribution:

Oceanic; warm temperate to tropical waters; worldwide distribution. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, a few specimens were found in samples from the Strait of Hormuz and the Sea of Oman (refer sites map).



Sites of occurrence of *Ceratium pentagonum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Ceratiaceae Kofoed, 1907

Genus: *Ceratium* Schrank, 1793

Species: *praelongum*

Scientific name: *Ceratium praelongum* (Lemmermann) Kofoed

Plate A94: a-f (Annex A)

Synonym:

Ceratium gravidum var. *praelongum* Lemmermann

References:

Sournia, 1967: p. 386, Pl. I: 1; Wood, 1968: p. 38, Fig. 83; Taylor, 1976: p. 58, Pl. 11: 102, 103; Dowig, 1983: p. 27, Pl. I: 1; Balech, 1988: p. 276, L. 54: 3.

Description:

Epitheca much larger than hypotheca, widening toward apex, sides almost parallel, rounded toward apex; apical horn absent; apical pore in upper third of epitheca; hypotheca narrower than epitheca, almost square; antapical horns strong, normally diverging, sometimes converging, directed posteriorly. Length 200 μm (Wood, 1968).

Dimensions:

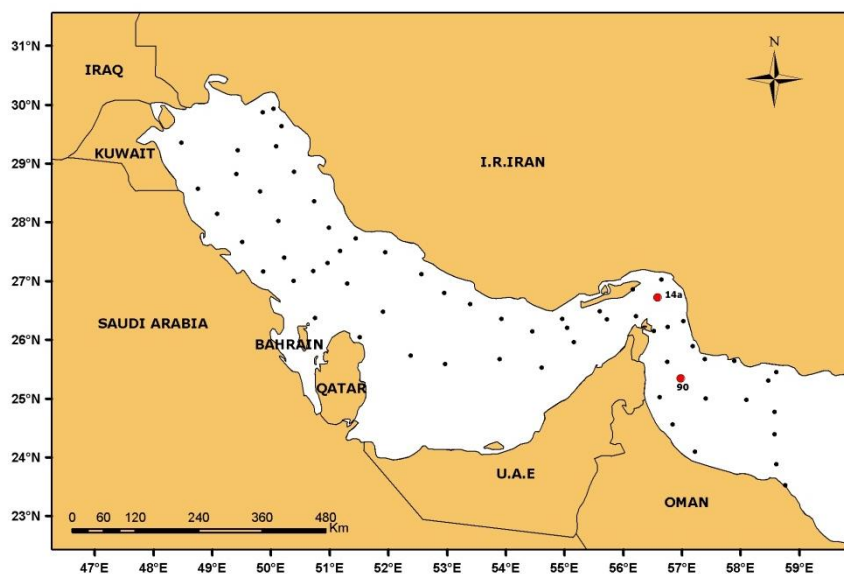
Total length 220-250 μm ; body 200 μm long; 75 μm wide.

Distribution:

Oceanic; tropical waters; worldwide distribution. Species has previously been reported from the Indian Ocean (Taylor, 1976).

**Sites of occurrence in RSA:**

In Winter 2006 Cruise, a few specimens were found in samples from the Strait of Hormuz and the Sea of Oman (refer sites map).



Sites of occurrence of *Ceratium praelongum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Ceratiaceae Kofoed, 1907

Genus: *Ceratium* Schrank, 1793

Species: *ranipes*

Scientific name: *Ceratium ranipes* Cleve

Plate A95: a-d (Annex A)

Synonym:

Ceratium palmatum Schröder var. *ranipes* (Cleve)
Jørgensen

References:

Sournia, 1967: p. 459, Fig. 81, 82; Wood, 1968: p. 38, Fig. 84; Taylor, 1976: p. 77, Pl. 19: 189-192; Dowidar, 1983: p. 31, Pl. V: 5; Balech, 1988: p. 282, 283, L. 60: 8, 9; 61: 1.

Description:

Small species with strong surface markings on theca; apical horn bent, winged; hypotheca triangular; right apical horn emerging at an angle of about 30° with apical horn, curving forward, approaching apical, with five to seven fingers at tip; left antapical also curved forward with fingers at tip. Body length 50-60 µm (Wood, 1968).



Dimensions:

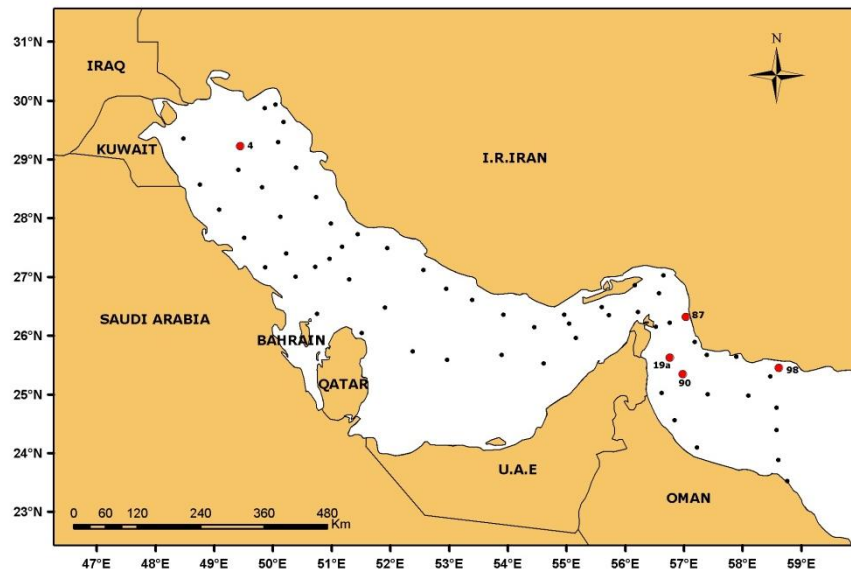
Total length 150-180 µm; body 57 µm long; 50 µm wide.

Distribution:

Oceanic; warm temperate to tropical waters; worldwide distribution. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, a few specimens were found in samples from the northernmost part of the inner RSA, and the Sea of Oman (refer sites map).



Sites of occurrence of *Ceratium ranipes* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridiniales Haeckel, 1894

Family: Ceratiaceae Kofoed, 1907

Genus: *Ceratium* Schrank, 1793

Species: *strictum*

Scientific name: *Ceratium strictum* (Okamura *et* Nishikawa) Kofoed

Plate A86: c, d (Annex A)

Synonym:

Ceratium extensum f. *strictum* Okamura *et* Nishikawa

References:

Balech, 1988: p. 133, Pl. 55: 3, 4; Konovalova, 1998: p. 140, Fig. 29: 2a-b.

Description:

A very long species similar in shape to *Ceratium extensum*; epitheca long and narrow, continuous with a long, straight, narrow apical horn; left antapical horn long, straight; right antapical horn small, but distinct; epitheca and hypotheca usually equal in length.

Dimensions:

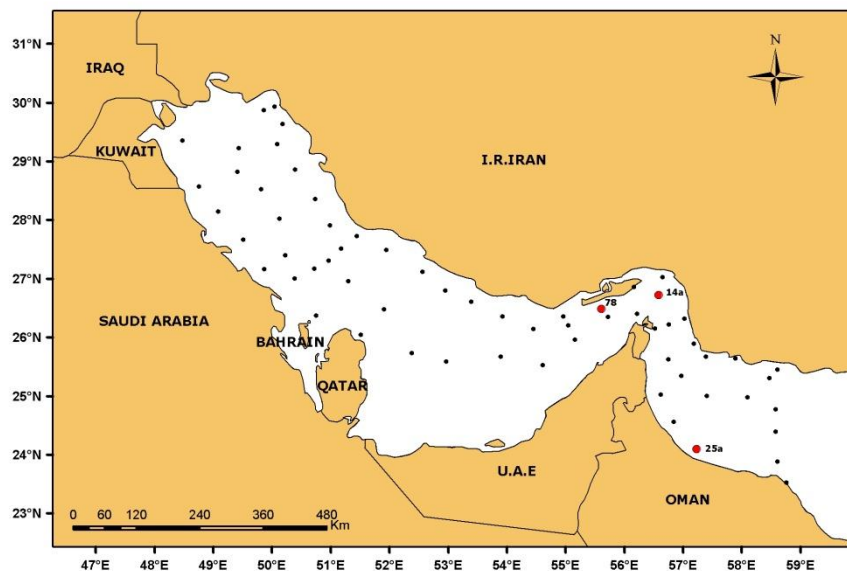
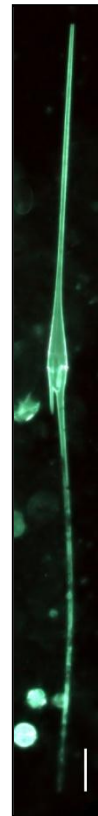
Cells 850 μm long; 25-27 μm wide.

Distribution:

Oceanic tropical species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, a few specimens were found in samples from the Strait of Hormuz and the Sea of Oman (refer sites map).



Sites of occurrence of *Ceratium strictum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Ceratiaceae Kofoed, 1907

Genus: *Ceratium* Schrank, 1793

Species: *tenue*

Variety: *buceros*

Scientific name: *Ceratium tenue* Ostenfeld *et* Schmidt var. *buceros* (Zacharias) Balech

Plate A96: a-d (Annex A)

Synonyms:

Ceratium buceros Zacharias; *Ceratium horridum* subsp. *buceros* Jörgensen; *Ceratium horridum* subsp. *buceros* var. *denticulatum* Jörgensen

References:

Wood, 1968: p. 24, Fig. 43 (as *Ceratium buceros*).

Description:

Body small, longer than broad, base markedly convex, sometimes sunken, all horns thin, may be spinulate or clavate. This species has many forms which often occur together. Length 50-100 μm (Wood, 1968).

Dimensions:

Total length 180-220 μm ; body 33 μm long; 36 μm wide.

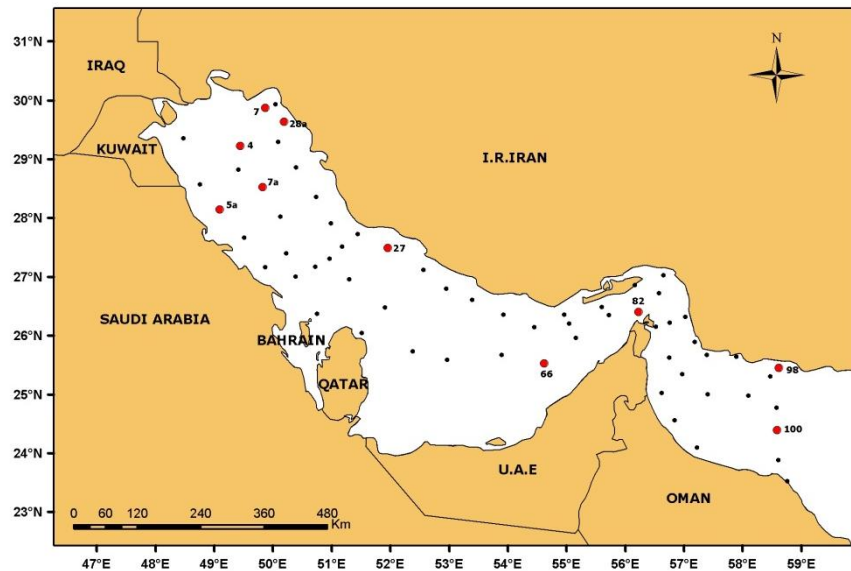
Distribution:

Estuarine-neritic, sometimes oceanic, cosmopolitan species.



Sites of occurrence in RSA:

In Winter 2006 cruise, this species was observed at few sites (refer sites map), never in large numbers.



Sites of occurrence of *Ceratium tenue* v. *buceros* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Ceratiaceae Kofoid, 1907

Genus: *Ceratium* Schrank, 1793

Species: *trichoceros*

Scientific name: *Ceratium trichoceros* (Ehrenberg) Kofoid

Plate A97: a-d (Annex A)

Synonym:

Peridinium trichoceros Ehrenberg

References:

Sournia, 1967: p. 472, Fig. 89, 90; Wood, 1968: p. 40, Fig. 91; Taylor, 1976: p. 75, Pl. 12: 117; Pl. 21: 210; Dowigar, 1983: p. 30, Pl. IV: 2; Balech, 1988: p. 288, L. 66: 4.

Description:

Body small; epitheca rounded; horns thin and long antapicals beginning almost parallel to girdle, then curved until they are parallel with apical horn and almost the same length forming a flat-bottomed U. Length 300-500 μm (Wood, 1968).

Harmful Effect:

Non-toxic bloom-forming species; it may be regarded as potentially harmful (Fukoyo *et al.*, 2003).

Dimensions:

Total length 350-370 μm ; body 50 μm long; 45 μm wide.

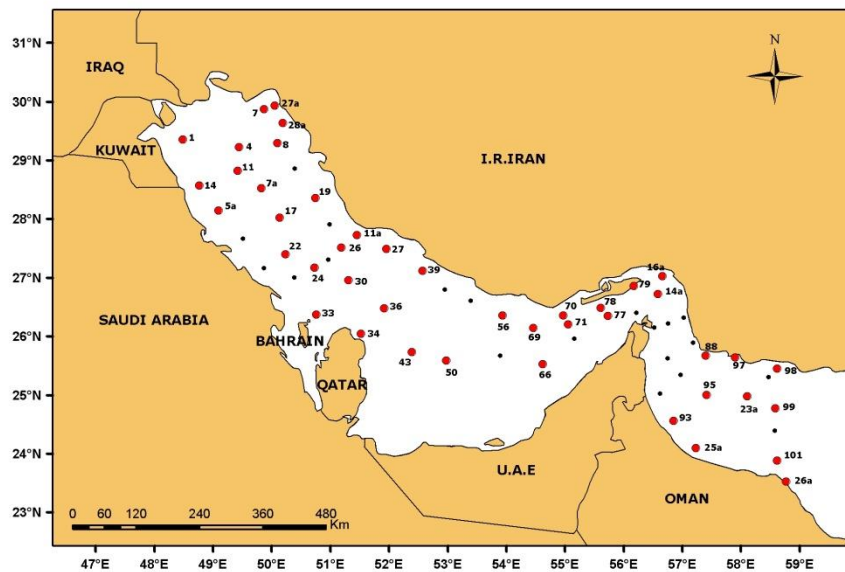
Distribution:

Coastal and oceanic; cosmopolitan in warm temperate to tropical waters; worldwide distribution. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was frequently observed at various sites (refer sites map), although never in large numbers; maximum abundance (74 cells/l) was associated with the northwestern part of the inner RSA (St. 7). This species has previously been reported from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).





Sites of occurrence of *Ceratium trichoceros* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Ceratiaceae Kofoed, 1907

Genus: *Ceratium* Schrank, 1793

Species: *tripos*

Scientific name: *Ceratium tripos* (O.F. Müller) Nitzsch

Plate A83: b-e (Annex A)

Synonym:

Cercaria tripos O.F. Müller

References:

Lebour, 1925: p. 148, Fig. 46 b-d; Pl. XXXII: a-c; XXXIII; Wood, 1968: p. 41, Fig. 92, 93; Taylor, 1976: p. 89, Pl. 14: 147-149, 151; Pl. 16: 168-170; Dodge, 1982: p. 234, Fig. 30 A-D; Balech, 1988: p. 280-281, L. 58-59; Throndsen *et al.*, 2007: p. 80.

Description:

Theca sturdy with almost straight apical horn and anteriorly curved, closed (pointed) antapical horns. Left antapical horn longer than the right. Cell body relatively large and extend below a tangential line between the posterior bend of the antapical horns. Size: cell body 50-80 μm wide, cell up to 300 μm long (Throndsen *et al.*, 2007).

**Dimensions:**

Total length 250-285 μm ; body 68 μm long; 53 μm wide.

Taxonomic Remarks:

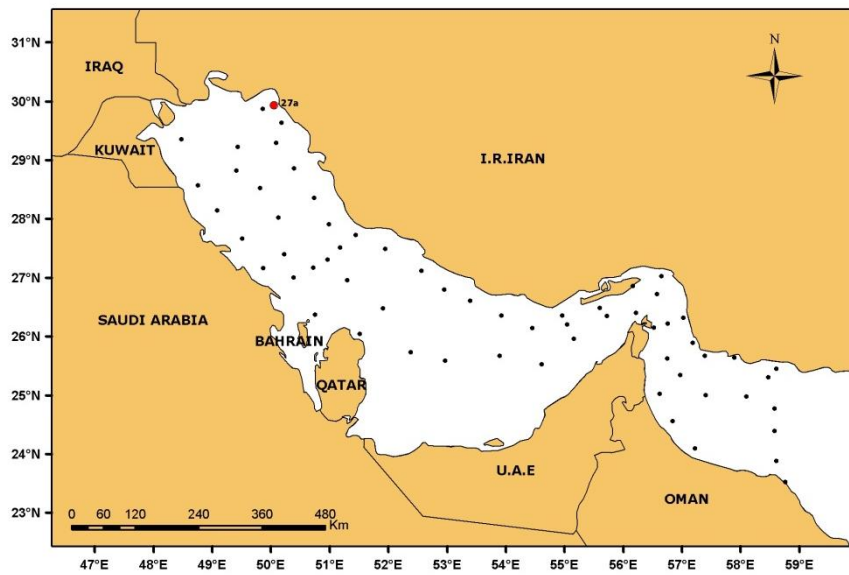
This species is very variable, several varieties have been described.

Distribution:

Coastal and oceanic; cosmopolitan in temperate to tropical waters; worldwide distribution. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at one site (refer site map), never in large numbers; maximum abundance (76 cells/l) was associated with the northwestern part of the inner RSA (St. 27a). Species has previously been reported from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Site of occurrence of *Ceratium tripos* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Ceratiaceae Kofoed, 1907

Genus: *Ceratium* Schrank, 1793

Species: *vultur*

Variety: *sumatranum*

Scientific name: *Ceratium vultur* Cleve var. *sumatranum* Karsten

Plate A97: e, f (Annex A)

Synonyms:

Ceratium sumatranum (Karsten)

Jørgensen; *Ceratium sumatranum* f. *angulatum* Jørgensen

References:

Sournia, 1967: p. 482; Wood, 1968: p. 41, Fig. 94; Taylor, 1976: p. 76, Pl. 22: 224; Balech, 1988: p. 289, L. 67: 1-3.



Description:

Robust species with low, wide epitheca and triangular hypotheca; apical horn bent, strongly winged; left antapical horn starts at right angles to apical, turning sharply forward, diverging from or parallel to apical; right antapical directed backward at base, abruptly elbowed and turning forward at an angle or parallel to apical. Size variable (Wood, 1968).

Dimensions:

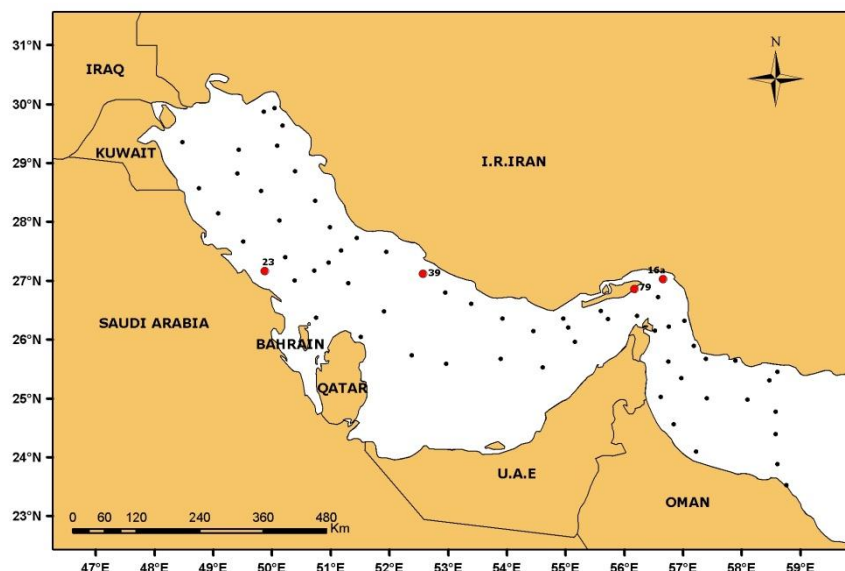
Total length 120-140 μm ; body 50 μm long; 80 μm wide.

Distribution:

Oceanic; warm temperate to tropical waters; worldwide distribution. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at few sites (refer sites map), never in large numbers; maximum abundance (83 cells/l) was associated with the Iranian coast in the central part of the inner RSA (St. 39).



Sites of occurrence of *Ceratium vultur v. sumatranus* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Ceratocorythaceae Lindermann, 1928

Genus: *Ceratocorys* Stein, 1883

Armored. Medium-sized cell of angular to round shape with characteristic short- or long-winged spines (two or eight) that can originate posteriorly from the antapical plate and ventrally or dorsally from postcingular plates; posterior spines associated with antapical plate; hypotheca exceeds epitheca and can be compressed laterally. Theca robust with prominent areolae. Cingulum premedian and displaced 0.5-2.5 \times . Cingular lists are supported by prominent spines; plate formula: Po, 3', 1a, 5'', 6c, 10s, 5''', 1'''''. Chloroplasts are present. Apical pore very distinct and not like *Goniadoma*. Po has linear slit in an elongate nontriangular plate (Steidinger and Tangen, 1997).

Scientific name: *Ceratocorys armata* (Schütt) Kofoed

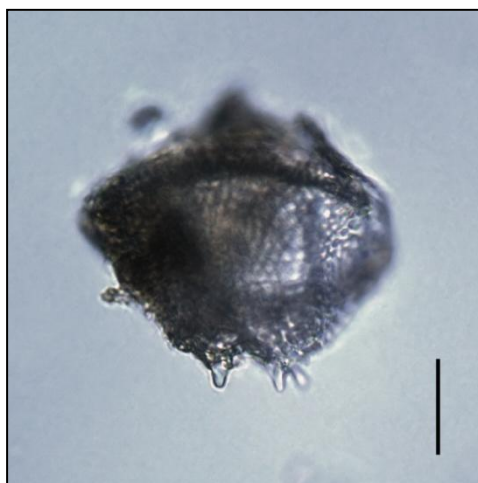
Plate A98: d (Annex A)

References:

Wood, 1968: p. 42, Fig. 95; Taylor, 1976: p. 90, Pl. 26: 269 a, b, 272, 273.

Description:

Epitheca angular or rounded, shallow; plates well marked; hypotheca trapezoidal, plates marked; three or four short horns arising from rims or edges of hypothecal plates; girdle list ribbed; surface of theca porulate. Length 100 μm (Wood, 1968).

**Dimensions:**

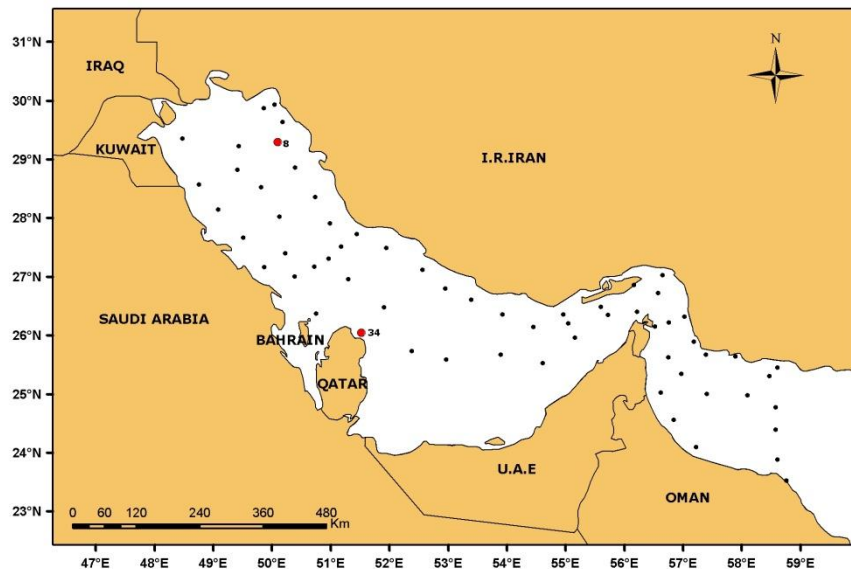
Cells 57-60 μm long; 61-65 μm wide.

Distribution:

Subtropical to tropical waters; worldwide distribution. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at two sites in the inner RSA (refer sites map) and in small numbers; single specimens were observed at two localities in the inner RSA (St. 8 and 34).



Sites of occurrence of *Ceratocorys armata* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Ceratocorythaceae Lindermann, 1928

Genus: *Ceratocorys* Stein, 1883

Species: *horrida*

Scientific name: *Ceratocorys horrida* Stein

Plate A98: a-c (Annex A)

References:

Wood, 1968: p. 42, Fig. 97; Taylor, 1976: p. 91, Pl. 26: 265-268; Pl. 46: 529.

Description:

Variable species; body angular; epitheca low; ribs marked; hypotheca angular to rounded, deep; girdle lists strongly ribbed; strong toothed spines extending from corners of antapical plates, sometimes winged. Body length 80-100 μm (Wood, 1968).

**Dimensions:**

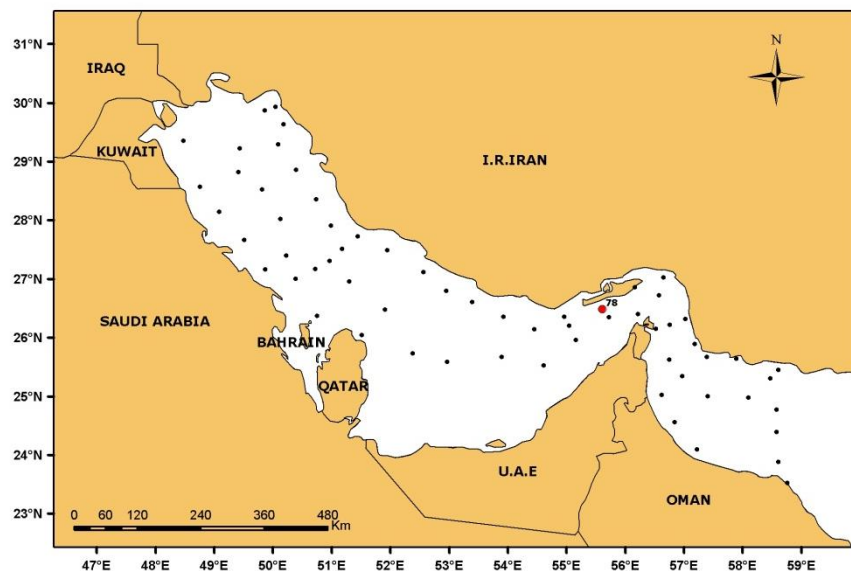
Total length 120-140 μm ; body 67 μm long; 78 μm wide.

Distribution:

Oceanic, neritic; warm temperate to tropical waters; worldwide distribution. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, a single specimen was observed at one locality in the southern part of the inner RSA (St. 78) (refer site map).



Site of occurrence of *Ceratocorys horrida* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: GoniDOMATAceae Lindermann, 1928

Genus: *Goniodoma* Stein, 1883 (= *Triadinium* (Dodge, 1981)

= *Heteraulacus* Diesing, 1850 *partim*.)

Armored. Cell similar to *Alexandrium*, but different in size, thickness of theca, surface markings, size and shape of plates, position of plates and the presence of strong cingular lists. Plate formula: Po, cp, 4', 6'', 6c, 6s, 6''', 2'''''. The 1' is a characteristic shape and is displaced. The connection between the Po and 1' in *Alexandrium* is either direct or in a straight line. In *Goniodoma*, the connection is not straight and appears as two lines at almost right angles. Also, in *Goniodoma* the Po is facing horizontally to the left side of the cell. Large ventral pore in 1' toward the anterior right margin. Chloroplasts are present (Steidinger and Tangen, 1997).

Scientific name: *Goniodoma polyedricum* (Pouchet) Jörgensen

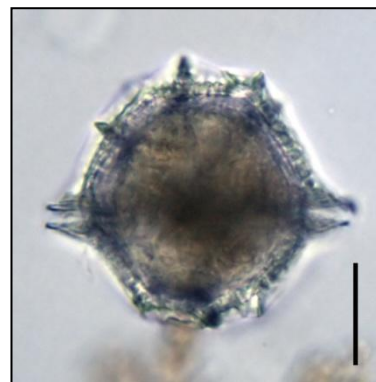
Plate A99: a-i (Annex A)

Synonyms:

Peridinium polyedricum Pouchet; *Goniodoma acuminatum* (Ehrenberg) Stein; *Triadinium polyedricum* (Pouchet) Dodge

References:

Lebour, 1925: p. 90, Fig. 26; Wood, 1968: p. 62, Fig. 163; Dodge, 1985: p. 90; Balech, 1988: p. 294, L. 72: 3-7.

**Description:**

Cell polyhedral, heptagonal; epitheca with three corners, hypotheca with two; apical pore elongate, directed to one side; transverse section nearly circular; girdle equatorial, left-handed, ribbed girdle lists; theca strongly pored; sutures well marked. Length 30-60 µm (Wood, 1968).

Dimensions:

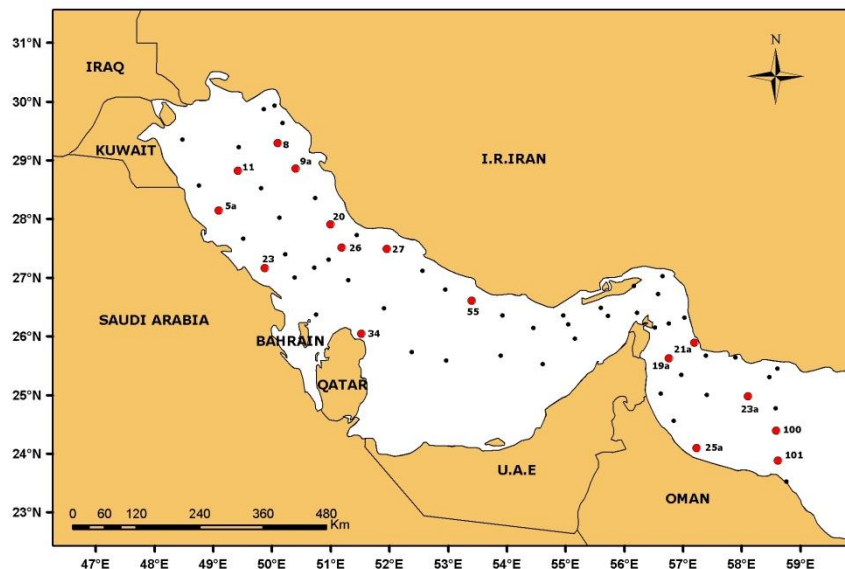
Cells 50 µm long; 43 µm wide.

Distribution:

Oceanic; cosmopolitan in tropical and subtropical waters; worldwide distribution.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was present in small numbers at scattered stations (refer sites map). This species has been previously reported from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Goniodoma polyedricum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Goniodomataceae Lindermann, 1928

Genus: *Pyrodinium* Plate, 1906

Thecate dinoflagellate with smooth to faintly structured theca and nearly globular cells with the cingulum located equatorially. Plate formula: Po, 4', 0a, 6'', 6c, 9(10)s, 5''', 2'''. Cingulum descending, displaced 1-1.5, cingulum width. The nucleus horseshoe shaped, located within the cingulum. Brown chloroplasts are irregular reticular or occasionally radially arranged. Salient features at species level: plates on the ventral side in the line from apex (Po, apical pore plate), shape of 1' (first apical plate) and if it touches Po or not (with eventual ventral pore at the right upper suture toward 4') shape of 6'' (six precingular plate), shape of sa (anterior sulcal plate). Outline of the cell and of these plates and construction of the furrows, e.g. if the sulcus is exavated, is usually sufficient for identification of the species. Toxin producing (neurotoxins or organotoxins), may form bloom. Have been subject to a number of taxonomic changes, and species from this genus have been referred to several other genera such as *Gonyaulax*, *Pyrodinium*, *Protogonyaulax* (Thronsdon *et al.*, 2007).

Taxonomic Remarks:

Pyrodinium bahamense (Plate A100, Annex A). *Pyrodinium bahamense* was first described from the Bahamas in the Atlantic Ocean. A different, more compressed form was described from the inner RSA, and Steidinger *et al.* (1980) gave the two forms formal taxonomic status, var. *bahamense* and var. *compressum*. The var. *bahamense* does not form chains and has a long apical spine. The two varieties also differ in distribution and toxicity.

Scientific name: *Pyrodinium bahamense* Plate var. *bahamense*

Plate A100: a-e, g, h (Annex A)

Reference:

Steidinger and Tangen, 1997: Pl. 40.

Description:

Variety with prominent apical protuberance or horn and an apical spine with a list (Steidinger and Tangen, 1997).

Harmful Effect:

This variety is nontoxic (Steidinger and Tangen, 1997).



Dimensions:

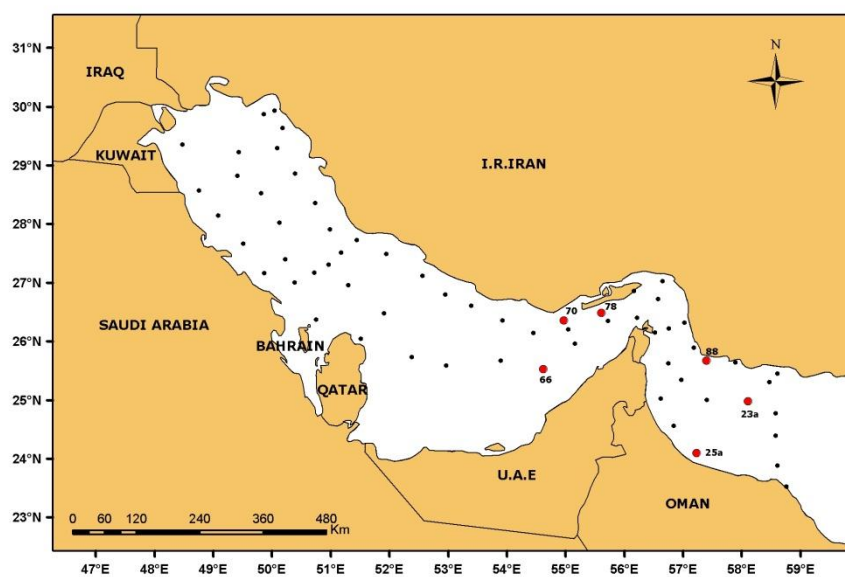
Total length 70 µm; body 42-45 µm long; 44 µm wide.

Distribution:

Subtropical and tropical waters, Atlantic Ocean.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at few sites (refer sites map) in small numbers.



Site of occurrence of *Pyrodinium bahamense* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Goniodomataceae Lindermann, 1928

Genus: *Pyrodinium* Plate, 1906

Species: *bahamense*

Variety: *compressum*

Scientific name: *Pyrodinium bahamense* Plate var. *compressum* (Bohm) Steidinger, Tester and Taylor

Plate A100: f, I (Annex A)

Synonyms:

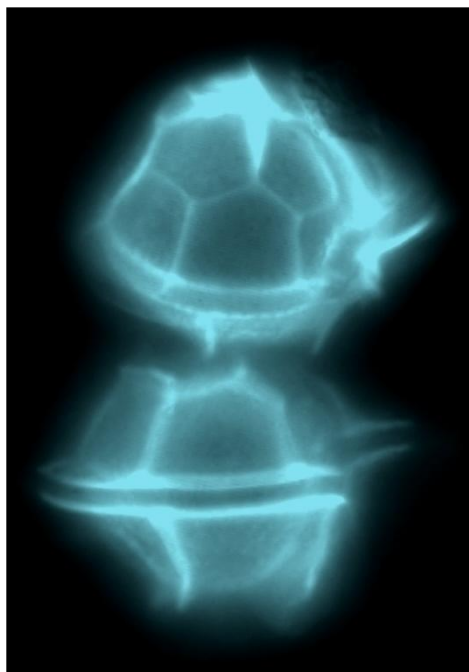
Pyrodinium buhamense f. *compressa* Bohm;
Gonyaulax schilleri Matzenauer; *Hemicystodinium*
zohuryi Rossignol (cyst); *Polysphaeridium zohuryi*
(Rossignol) Bujak *et al.*

References:

Dodge, 1985: p. 88; Hallegraeff *et al.*, 1995: p. 299-300, Fig. 15.18, 15.38a.

Description:

Cells single or, more commonly, in chains. Single cells rounded, those in chains showing distinct apico-antapical flattening. Thecal surface covered with dense fine spinulae (only clearly visible with SEM) and large, prominent pores. Strong low flanges mark the edges of most sutures, some more developed than others. The first apical plate homologue does not reach the APC (metasert). A distinct ventral pore is present near the upper right junction with the fourth apical plate. The apex is a low horn. The APC is large, triangular, with a very distinct separation of the inner and outer pore plates (spinules only on the inner). An anterior attachment pore lies close to the right margin of the inner plate. The girdle has well developed lists. The sulcal lists are large and contact each other anteriorly. Single individuals have prominent anterior and posterior spines. In intact chains, only the anterior individual has an apical spine, and only the most posterior cell has an antapical spine. The posterior sulcal plate is narrow, median, with a slit-like posterior attachment pore. Length of the cell body 33-47 µm, transdiameter 37-52 µm. Cyst spiny (Hallegraeff *et al.*, 1995).



Harmful Effect:

This species is a producer of paralytic shellfish poisoning (PSP) toxins (IOC list, 2002) which in severe cases is fatal to humans. Various aspects of the ecology and effects of blooms of this species are found in Usup and Azanza (1998) and Azanza and Taylor (2001). Toxic

strains of it have not been found so far. The sketch of the sutural relations of the first apical homologue and the APC by Steidinger (1990) erroneously shows an exsert condition (the genus is metasert) (Hallegraeff *et al.*, 1995).

Dimensions:

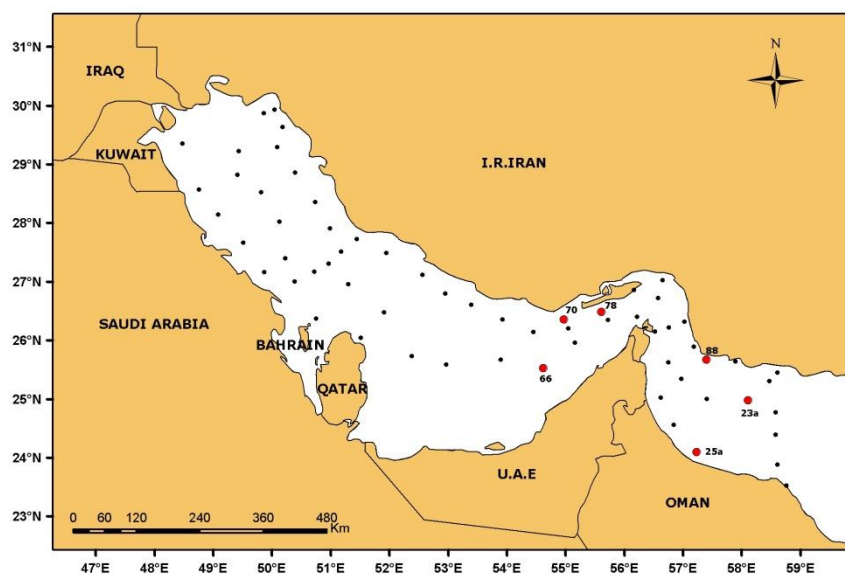
Cells 40-42 μm long; 44-46 μm wide.

Distribution:

Principally in South East Asian waters from the Philippines to New Guinea, including Palau, Solomon Islands, Halmahera, Sabah, Brunei, and also northern Indian Ocean, Red Sea, and possibly the Pacific coast of central America.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred in small numbers within the southern part of the inner RSA, the Strait of Hormuz and the Sea of Oman areas (refer sites map); maximum abundance (105 cells/l) was associated with the southern part of the inner RSA (St. 66). It has been previously reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Pyrodinium bahamense* var. *compressum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Gonyaulacaceae Lindermann, 1928

Genus: *Alexandrium* Halim, *emend.* Balech, 1989

(= *Protogonyaulax* Taylor, 1976)

Thecate dinoflagellates with smooth to faintly structured theca and nearly globular cells with the cingulum located equatorially. Plate formula: Po, 4', 0a, 6'', 6c, 9(10)s, 5''', 2'''. Cingulum descending, displaced 1-1.5 cingulum widths. The nucleus horseshoe shaped is located within the cingulum. Brown chloroplasts are irregular reticular or occasionally radially arranged. Salient features at species level: plates on the ventral side in the line from apex (Po, apical pore plate), shape of 1' (first apical plate) and if it touches Po or not (with eventual ventral pore at the right upper suture toward 4'), shape of 6'' (six precingular plate), shape of sa (anterior sulcal plate). outline of the cell and these plates and construction of the furrows, e.g., if the sulcus is excavated, it is usually sufficient for identification of the species. Toxin producing (neurotoxins or organotoxins), may form bloom (Thronksen *et al.*, 2007).

Scientific name: *Alexandrium tamiyavanichii* Balech

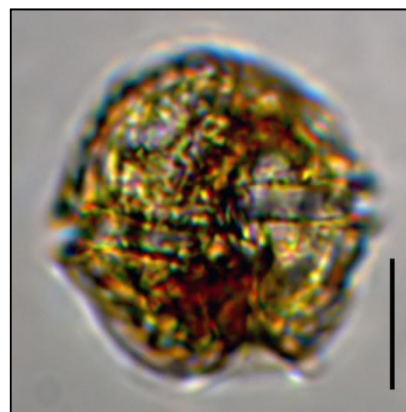
Plate A101: a-k (Annex A)

Synonym:

Protogonyaulax cohorticula (Balech) Taylor

References:

Hansen *et al.*, 2001: p. 52, Pl. 8: A-I; Larsen and Nguyen, 2004: p. 106, Pl. 15: 1-5.

**Description:**

The cells are more or less isodiametric, 32-38 µm in diameter, chain-forming. The epitheca is convex in shape, with a little shoulder, and shorter than hypotheca. The cingulum is descending, displaced about one girdle width. The 1' plate connects directly to the APC, and it has a ventral pore on the right margin. The APC has a large attachment pore on the right side of the pore plate, and some marginal pores. The s.a. plate has a pre-cingular part; the s.p.

plate is pentagonal with an attachment pore located near the center, and a channel connecting this pore with the right margin of the s.p. plate. Sulcal lists are well developed (Larsen and Nguyen, 2004).

Harmful Effect:

This species is a producer of paralytic shellfish poisoning toxins (IOC list, 2002). Kodama *et al.* (1988, as for *Protogonyaulax cohorticula*) found PSP toxins in this species.

Dimensions:

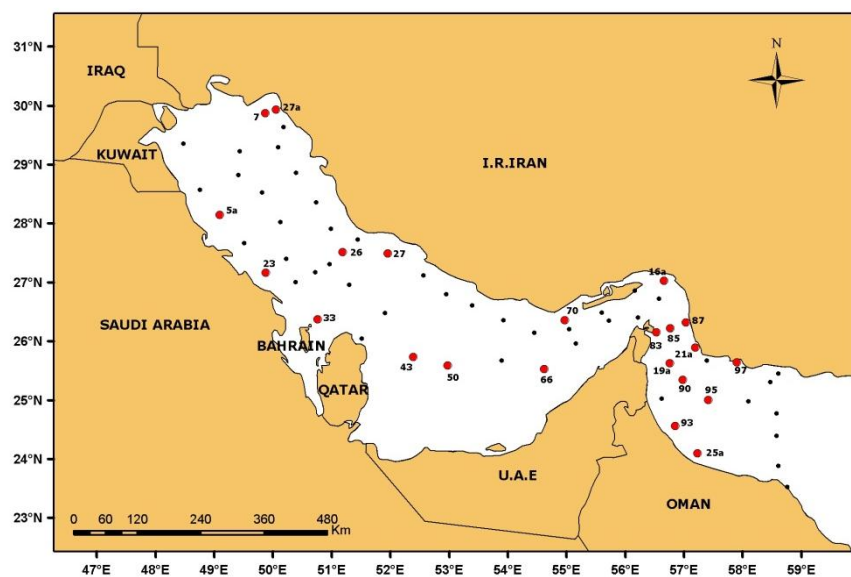
Cells 50 µm long; 46 µm wide.

Distribution:

Species has been reported from the Gulf of Thailand and Philippines (Balech, 1995), from Vietnamese waters (Larsen and Nguyen, 2004) and from the Indian Ocean waters near Madagascar (Hansen *et al.*, 2001).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was detected at certain sites (refer sites map). Highest abundance reached 2.0×10^3 cells/l (less than 2% of total phytoplankton abundance). Maximum abundance of this species ($> 10^3$ cells/l) was strongly associated with the waters of the Sea of Oman.



Sites of occurrence of *Alexandrium tamiyavanichii* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Gonyaulacaceae Lindermann, 1928

Genus: *Gonyaulax* Diesing, 186)

(= *Amylax* (Meunier, 1910 *partim.*)

The cells vary in shape from biconical, spherical to polyhedral with descending cingulum displaced one to many cingulum widths on the ventral side. The sulcus with or without overhang. Ornamented theca. With chloroplasts, benthic resting spores. Plate formula: Po, 3', 2a, 6'', 6c, 7s, 6''', 2'''' (Thronsdon *et al.*, 2007).

Sites of occurrence in RSA:

Some of the species from *Gonyaulax* genus were frequently observed in samples in quite low abundance. Maximum abundance (less than 4% of total phytoplankton abundance; 1.6×10^3 cells/l) was associated with the waters of the central part of the inner RSA and with the waters of the Sea of Oman.

Scientific name: *Gonyaulax birostris* Stein

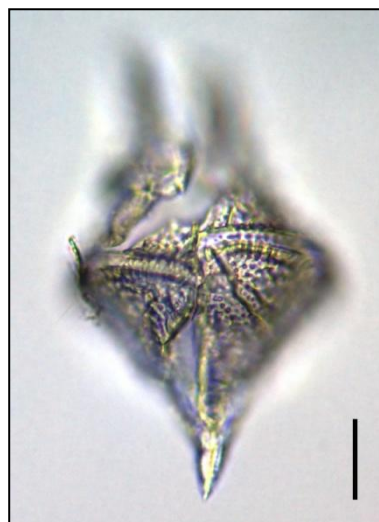
Plate A102: a-c (Annex A)

References:

Schiller, 1937: p. 300, Fig. 308; Wood, 1968: p. 57, Fig. 143; Balech, 1988: p. 299, L. 77: 6-8.

Description:

Body spindle-shaped, epitheca and hypotheca rounded, equal, both extended into processes about equal to the length of the body; girdle depressed, offset about one and one-half width; length 100-150 μm (Wood, 1968).



Dimensions:

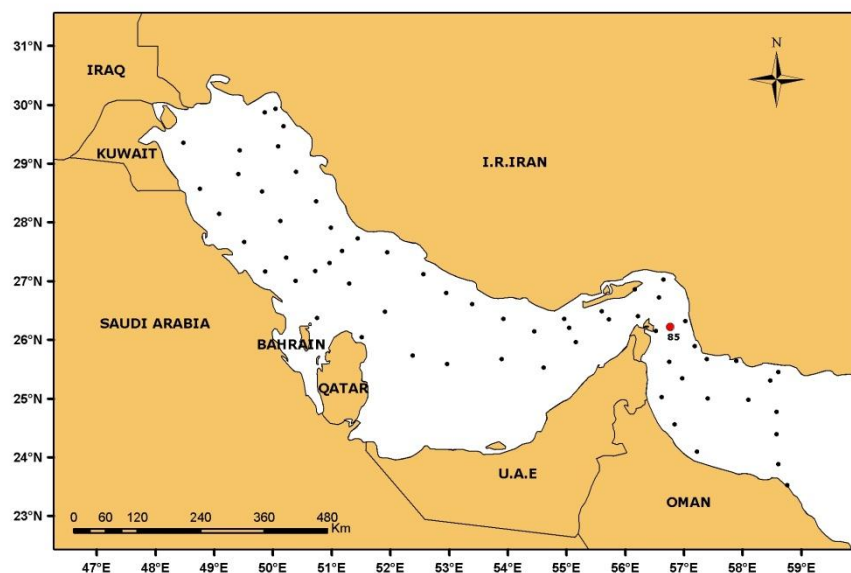
Cells 117-120 μm long; 60-63 μm wide.

Distribution:

Warm-water marine species. It has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, a single specimen was recorded at one locality (refer site map) in the Strait of Hormuz area (St. 85).



Site of occurrence of *Gonyaulax birostris* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridiniales Haeckel, 1894

Family: Gonyaulacaceae Lindermann, 1928

Genus: *Gonyaulax* Diesing, 186)

(= *Amylax* (Meunier, 1910 *partim.*)

Species: *digitale*

Scientific name: *Gonyaulax digitale* (Pouchet) Kofoid

Plate A103: a-f (Annex A)

Synonym:

Protoperidinium digitale Pouchet

References:

Lebour, 1925: p. 92, Fig. 28 a; Wood, 1968: p. 58, Fig. 149; Dodge, 1982: p. 208, Fig. 26 A; Pl. VI: c, d; Dodge, 1985: p. 72; Balech, 1988: p. 296, L. 74: 7-9; Throndsen *et al.*, 2007: p. 87.

Description:

Top-shaped to rhomboidal; a largish sturdy cell. Epitheca straight-sided or slightly concave, tapering to apical horn; hypotheca rounded or square-sided with two stout antapical spines. Girdle offset 2-2½ widths with only slight overhang, fairly deeply impressed but no lists; sulcus extending from apex to antapex, deeply impressed with narrow lists. Thecal plates thick with pattern of rounded thickenings or reticulations around pores. Plate formula: 3', 0a, 6'', c, s, 6''', 1p, 1'''. Size: length 50-75 µm, width 35-50 µm (Dodge, 1982).



Dimensions:

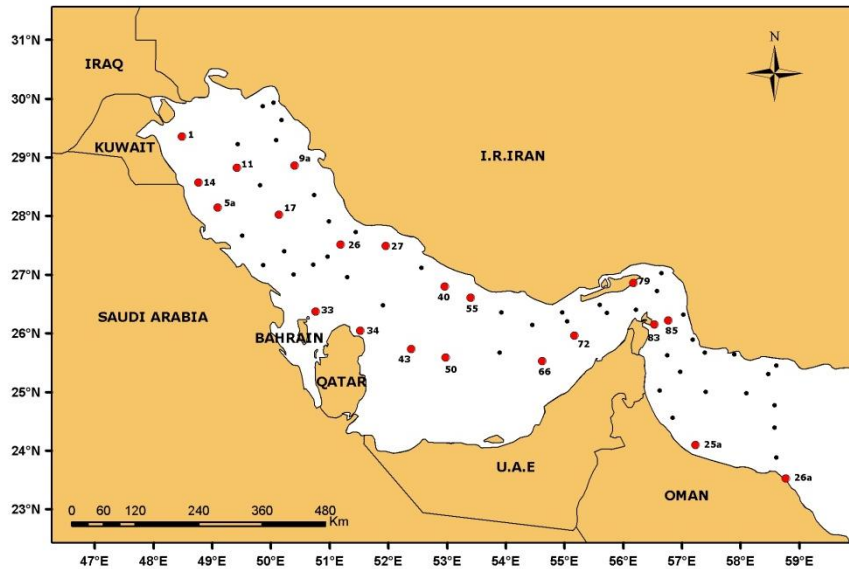
Cells 69-73 µm long; 50-53 µm wide.

Distribution:

Oceanic species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at scattered sites (refer sites map), never in large numbers; maximum abundance (70 cells/l) was associated with the central part of the inner RSA off Bahrain (St. 33).



Sites of occurrence of *Gonyaulax digitale* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Gonyaulacaceae Lindermann, 1928

Genus: *Gonyaulax* Diesing, 186)

(= *Amylax* (Meunier, 1910 *partim.*)

Species: *fragilis*

Scientific name: *Gonyaulax fragilis* (Schütt) Kofoid

Plate A104: a-i (Annex A)

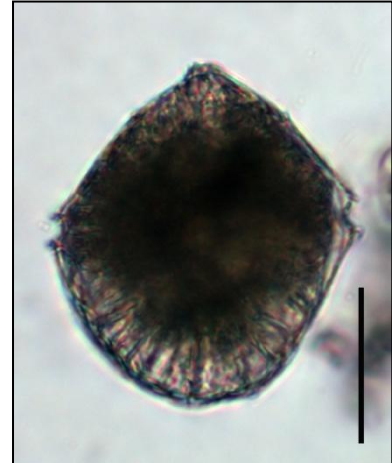
References:

Wood, 1968: p. 58, Fig. 150; Taylor, 1976: p. 101, Pl. 36: 420.

Description:

Body rotund, somewhat elongated, ventrally flattened; epitheca and hypotheca subequal; no apical horn; hypotheca abruptly rounded, asymmetrical; girdle slightly pre-median, displaced three widths, without overhang, shallow; lists absent; sulcus widening posteriorly. Length 80-100 μ m (Wood, 1968). The first apical plate is very narrow and lies in a midventral groove. Apicals two and three are situated rather symmetrically to the left and right of the elongate,

well developed apical closing platelet which extends well into the dorsal surface. The surface markings with strongly developed reticulation bearing short spines at the reticular junctions on most plates. On the apical plates, this is apparently reduced to short, disjunct ridges arranged in semiparallel or radiating rows. The latter structure may, however, be an immature developmental state (Taylor, 1976).



Dimensions:

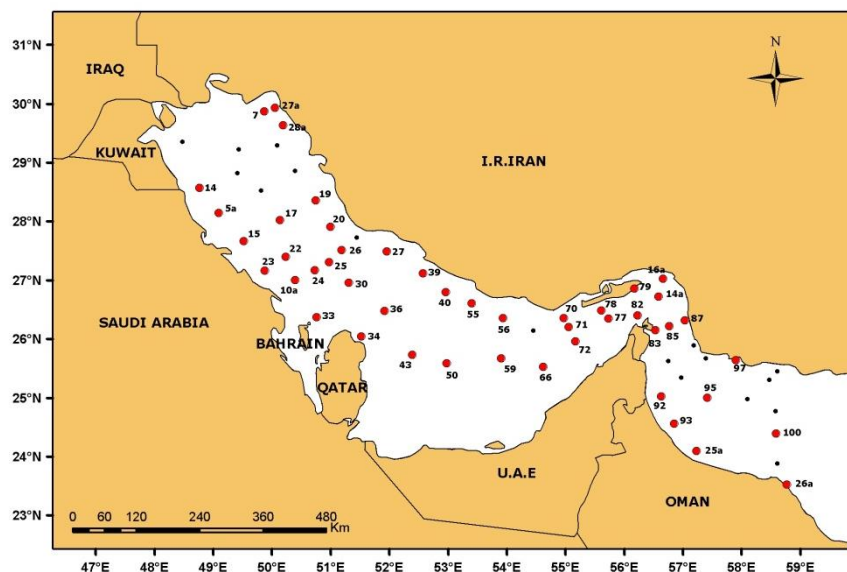
Cells 70-85 μm long; 60-68 μm wide.

Distribution:

Oceanic and coastal; warm temperate and tropical waters. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was frequently observed at various sites (refer sites map), usually in small numbers, however, it was quite abundant at some localities; maximum abundance (1.6×10^3 cells/l) was associated with the Iranian coast in the southern part of the inner RSA (St. 56).



Sites of occurrence of *Gonyaulax fragilis* + *G. hyalina* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridiniales Haeckel, 1894

Family: Gonyaulacaceae Lindermann, 1928

Genus: *Gonyaulax* Diesing, 186)

(= *Amylax* (Meunier, 1910 *partim.*)

Species: *hyalina*

Scientific name: *Gonyaulax hyalina* Ostenfeld *et* Schmidt

Plate A105: a-i (Annex A)

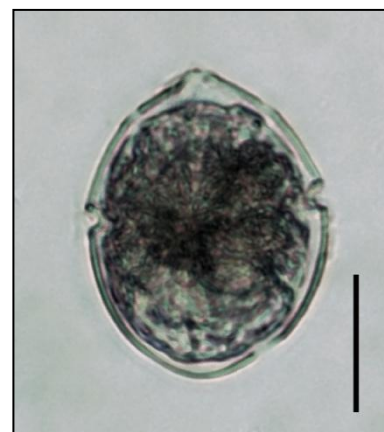
References:

Taylor, 1976: p. 103, Pl. 36: 415, 416, 418, 419.

Description:

Species is similar in morphology to *Gonyaulax fragilis*, but is more robust in shape and very delicate; has a greater cingulum displacement (Steidinger and Tangen, 1997).

This species is similar to *Gonyaulax fragilis* and *G. inflata*. It is readily distinguishable from them by its less narrow first apical plate, the presence of a slender fourth apical plate on the right ventral surface, and the strong, parallel longitudinal ridges passing over an otherwise delicately marked theca (secondary markings consist of delicate side ridges projecting at right angles to the primary ridges and pores). It usually has a broader shape. An apical view of a dissociated, delicately developed epitheca is seen. The fourth apical plate can be seen as a narrow rectangle, lacking markings other than peripheral ridges. Secondary spines projecting out from the margins of the postcingular plates can be observed. A further distinctive feature appears to be the lack of strong ridges on the large posterior intercalary plate as well as the sulcal plates, although this may vary developmentally (Taylor, 1976).

**Dimensions:**

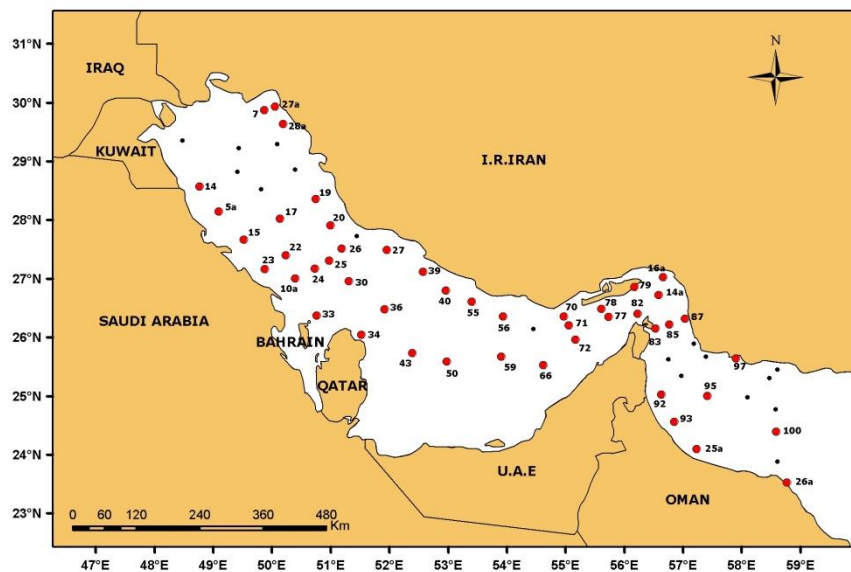
Cells 40-43 μm long; 31-33 μm wide.

Distribution:

Warm temperate and tropical waters. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at various sites (refer sites map) in small numbers.



Sites of occurrence of *Gonyaulax fragilis* + *G. hyalina* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridiniales Haeckel, 1894

Family: Gonyaulacaceae Lindermann, 1928

Genus: *Gonyaulax* Diesing, 186)

(= *Amylax* (Meunier, 1910 *partim.*))

Species: *polygramma*

Scientific name: *Gonyaulax polygramma* Stein

Plate A106: a-i (Annex A)

Synonyms:

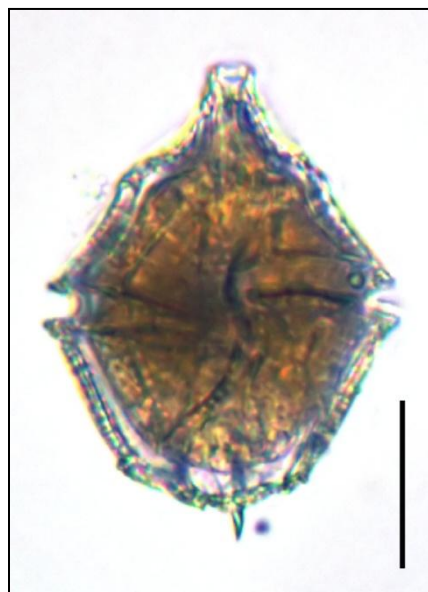
Gonyaulax schuetti Lemmermann; *Protoperidinium pyrophyrum* Pouchet

References:

Lebour, 1925: p. 94, Pl. XIII: 4 a-c; Wood, 1968: p. 60, Fig. 157; Taylor, 1976: p. 107, Pl. 35: 398; Dodge, 1985: p. 76; Balech, 1988: p. 296, L. 74: 11-15; Faust and Gulledge, 2002: p. 37, Pl. 21: 1-6; Hallegraeff, 2002: p. 45, 10 E; Throndsen *et al.*, 2007: p. 87.

Description:

Cells are medium-sized, elongate and pentagonal. The tapered epitheca bears a prominent apical horn, and exceeds the symmetrical hypotheca. Longitudinal ridges ornament the thecal surface; reticulations are present between the ridges. On mature cells, longitudinal ridges may be thick and spinulose. Cells range in size from 29-66 μm in length and 26-56 μm in dorso-ventral depth. The plate formula is: Po, 3', 2a, 6'', 6c, 4-8s, 6''', 1'''. *G. polygramma* is a photosynthetic species with chloroplasts. The large oval nucleus is located posteriorly (Faust and Gulledge, 2002).

**Harmful Effect:**

It is a non-toxin producing species, but is a bloom-forming species. It has been associated with massive fish and invertebrate kills due to anoxia and high sulfide and ammonia levels resulting from cell decomposition (Hallegraeff, 1991; Koizumi *et al.*, 1996).

Dimensions:

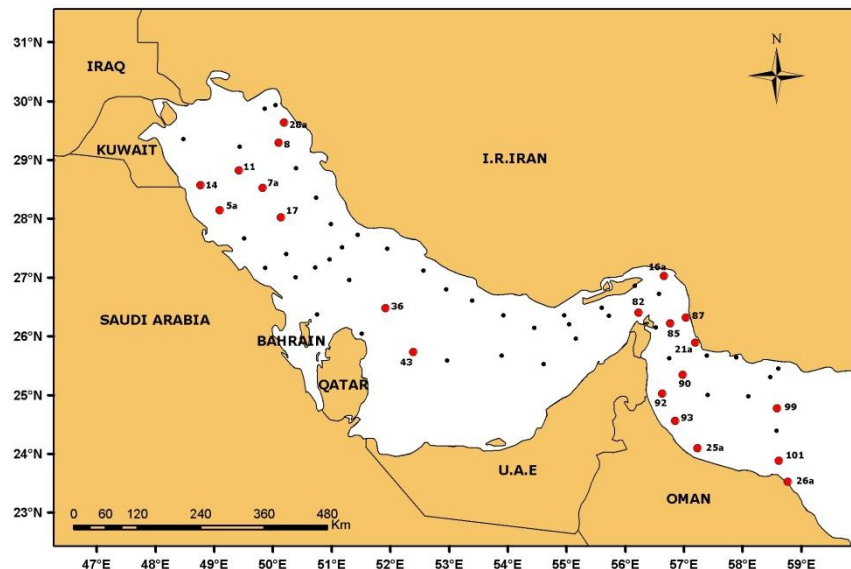
Cells 52-55 μm long; 34-36 μm wide.

Distribution:

G. polygramma is a cosmopolitan species common in cold temperate to tropical waters worldwide. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at various sites (refer sites map) occasionally, never in large numbers; maximum abundance (75 cells/l) was associated with the northwestern part of the inner RSA (St. 5a). Species has previously been reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Gonyaulax polygramma* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Gonyaulacaceae Lindermann, 1928

Genus: *Gonyaulax* Diesing, 186)

(= *Amylax* (Meunier, 1910 *partim.*)

Species: *scrippsae*

Scientific name: *Gonyaulax scrippsae* Kofoid

Plate A103: g-i (Annex A)

References:

Wood, 1968: p. 60, Fig. 158; Throndsen *et al.*, 2007: p. 87.

Description:

Body spheroidal; girdle median, displaced two to three widths, indented and ridged; apical horn short with oblique apex; sulcus deep, sigmoid, rather narrow, end rounded; antapicals absent; theca with fine subparallel lines and may be punctuate or reticulate. Length 30-50 μm (Wood, 1968).

**Dimensions:**

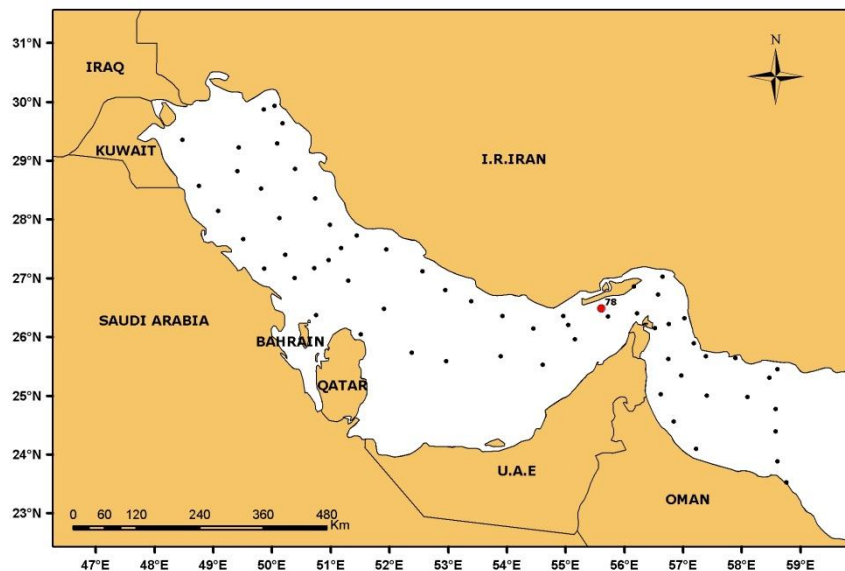
Cells 40-43 μm long; 33-35 μm wide.

Distribution:

Neritic, oceanic (rare); worldwide distribution.

Sites of occurrence in RSA:

In Winter 2006 Cruise, a single specimen was recorded at one locality (refer site map) in the southern part of the inner RSA (St. 78).



Site of occurrence of *Gonyaulax scrippsae* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Gonyaulacaceae Lindermann, 1928

Genus: *Gonyaulax* Diesing, 186)

(= *Amylax* (Meunier, 1910 *partim.*)

Species: *spinifera*

Scientific name: *Gonyaulax spinifera* (Claparede and Lachmann) Diesing

Plate A102: d-i (Annex A)

Synonym:

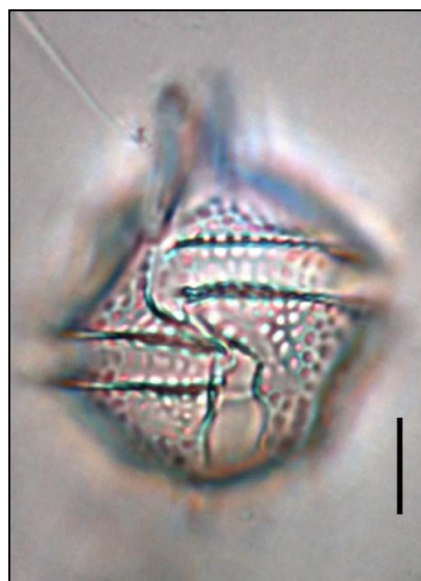
Peridinium spiniferum Claparede *et* Lachmann

References:

Lebour, 1925: p. 92, Pl. XIII: 1 a, b; Wood, 1968: p. 61, Fig. 160; Dodge, 1982: p. 214, Fig. 26 C-F; Pl. VI: f; Dodge, 1985: p. 78; Balech, 1988: p. 296, L. 74: 1-4; Throndsen *et al.*, 2007: p. 88.

Description:

Cell delicate, top shaped, slightly longer than broad. Epitheca with convex sides leading into an apical horn; hypotheca rounded or with straight sides and two or more small antapical spines. Girdle displaced 2 or more widths with a large overhang, deeply excavated but without lists; sulcus sinuous extending from apex to antapex. Surface of theca variable, may be poroid or delicately reticulate. Plate formula: 3', 0a, 6'', c, s, 6''', 1p, 1'''. Yellow-brown chloroplasts are present. Size: length 24-50 µm, width 30-40 µm (Dodge, 1982).

**Harmful Effect:**

Non-toxic bloom-forming species; it may be regarded as potentially harmful (Fukuyo *et al.*, 2003).

Dimensions:

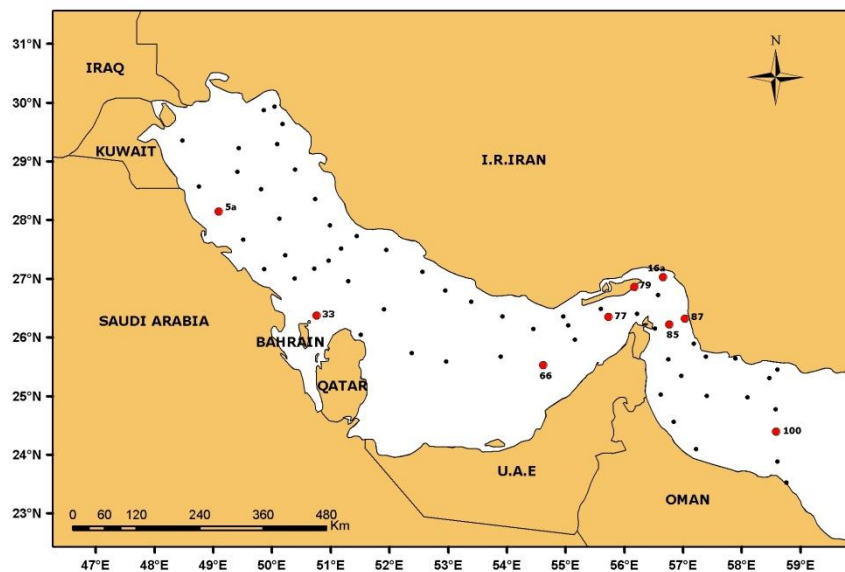
Cells 40-42 µm long; 28-33 µm wide.

Distribution:

Neritic, estuarine and oceanic; cosmopolitan species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at few sites (refer sites map) and in small numbers; maximum abundance (102 cells/l) was associated with the central part of the inner RSA off Bahrain (St. 33).



Sites of occurrence of *Gonyaulax spinifera* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Gonyaulacaceae Lindermann, 1928

Genus: *Gonyaulax* Diesing, 186)

(= *Amylax* (Meunier, 1910 *partim.*))

Species: *turbinei*

Scientific name: *Gonyaulax turbinei* Murray *et* Whitting

Plate A107: a-i (Annex A)

References:

Wood, 1968: p. 61, Fig. 161; Taylor, 1976: p. 108, Pl. 35: 399.

Description:

Theca small, oval; epitheca subrotund with tapering apex and slight, tapering apical horn; girdle depressed, displaced about two widths; hypotheca rotund; sulcus depressed, widened and rounded near base; plates sculptured; sutures marked. Length about 40 μm (Wood, 1968).



Dimensions:

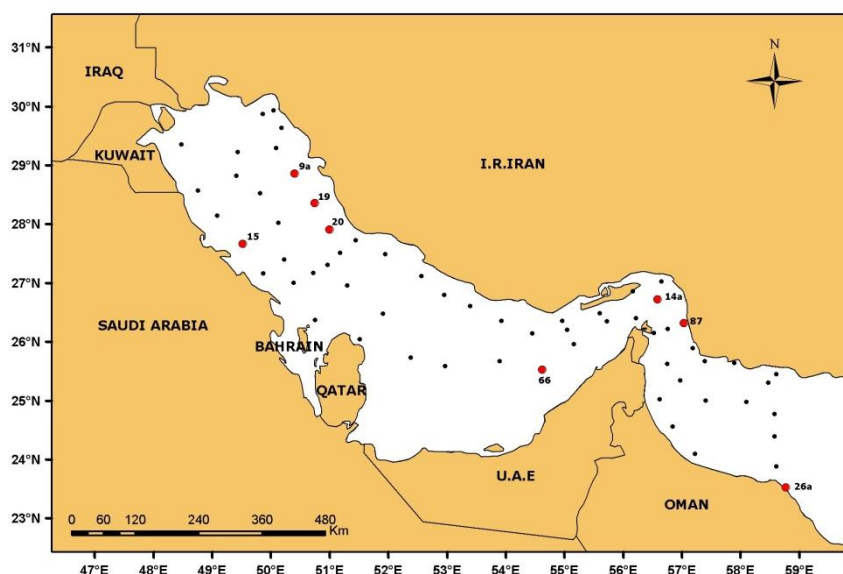
Cells 35-37 μm long; 36-38 μm wide.

Distribution:

Oceanic tropical species; it has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at few sites (refer sites map) and in small numbers; maximum abundance (3.5×10^2 cells/l) was associated with the Strait of Hormuz (St. 14a).



Sites of occurrence of *Gonyaulax turbinei* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Gonyaulacaceae Lindermann, 1928

Genus: *Gonyaulax* Diesing, 186)

(= *Amylax* (Meunier, 1910 *partim.*)

Species: *verior*

Scientific name: *Gonyaulax verior* Sournia

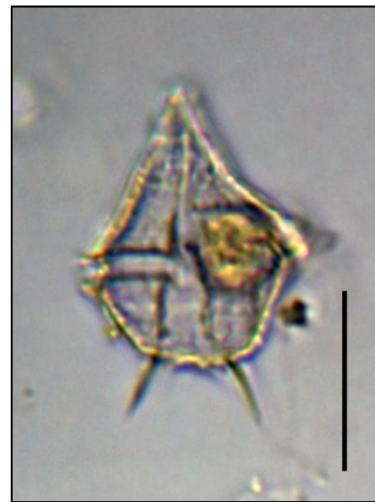
Plate A108: a-f (Annex A)

Synonyms:

Gonyaulax diacantha Meunier; *Amylax diacantha*
(Meunier) Schiller; *Gonyaulax longispina* Lebour

References:

Dodge, 1982: p. 217, Fig. 25 L; Throndsen *et al.*, 2007: p. 88.



Description:

Cell elongated, inverted top-shaped; epitheca longer than hypotheca, convex sides tapering into an apical horn; hypotheca hemispherical with two conspicuous spines which may be curved with wings, or smaller and almost straight; left spine is longer than the right. Girdle situated below mid-point of cell, offset by 1-2 girdle widths, with narrow lists; sulcus, shallow. Thecal plates lightly reticulate; plate forming 4', 2a, 6'', c, s, 6''', 1p, 1'''. Cell contents yellow, presumably containing chloroplasts. Size: length 40-56 µm; width c. 24 µm (Dodge, 1982).

Dimensions:

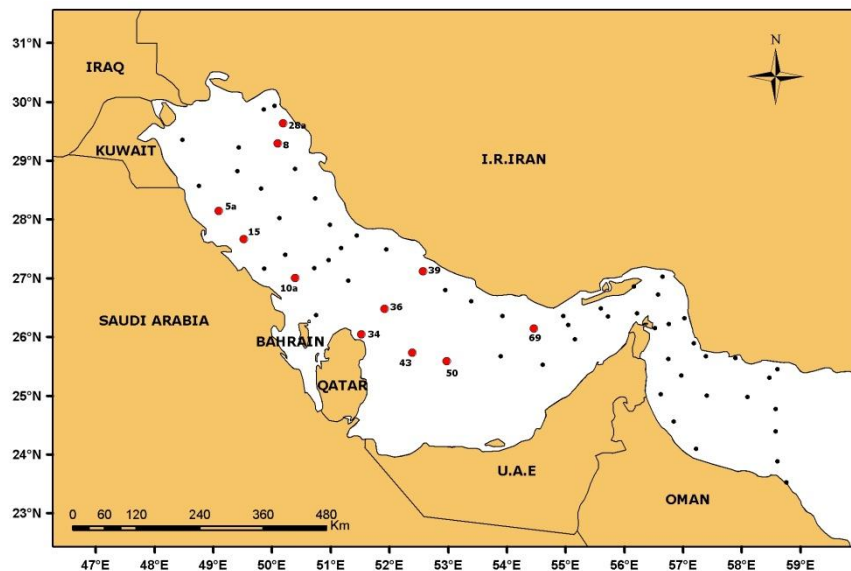
Cells 30-35 µm long; 21-24 µm wide.

Distribution:

Temperate to tropical waters; cosmopolitan.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at few sites (refer sites map) and in small numbers; maximum abundance (3.9×10^2 cells/l) was associated with the central part of the inner RSA off Qatar (St. 43).



Sites of occurrence of *Gonyaulax verior* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Gonyaulacaceae Lindermann, 1928

Genus: *Gonyaulax* Diesing, 186)

(= *Amylax* (Meunier, 1910 *partim.*)

Scientific name: *Gonyaulax* sp. 1

Plate A108: g-i (Annex A)

Description:

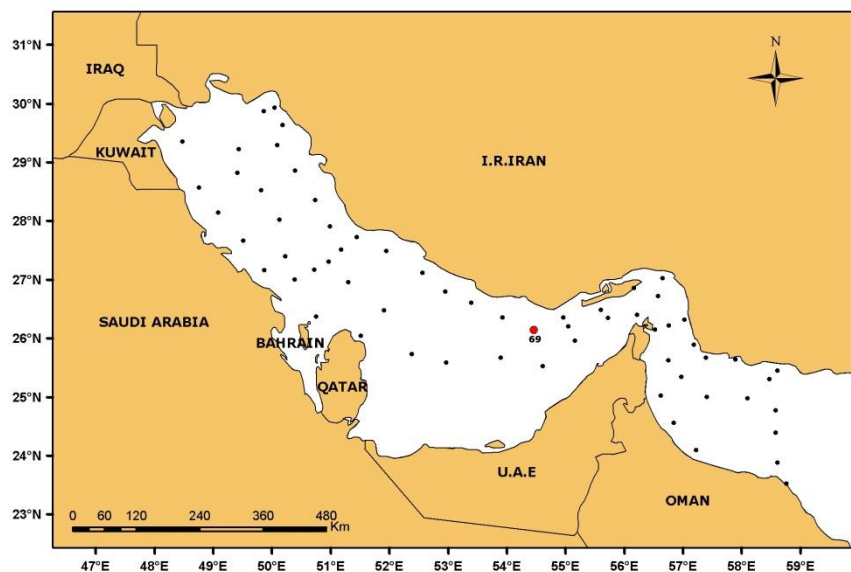
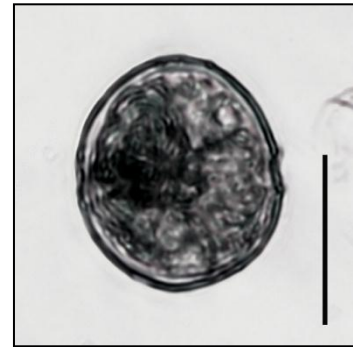
Cell small, oval. Epitheca hemispherical; hypotheca rotund. Girdle depressed, displaced about two widths.

Dimensions:

Cells 38 μm long, 31 μm wide.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at one site (refer site map) and in small numbers.



Site of occurrence of *Gonyaulax* sp.1 in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridiniales Haeckel, 1894

Family: Gonyaulacaceae Lindermann, 1928

Genus: *Gonyaulax* Diesing, 186)

(= *Amylax* (Meunier, 1910 *partim.*))

Scientific name: *Gonyaulax* sp. 2

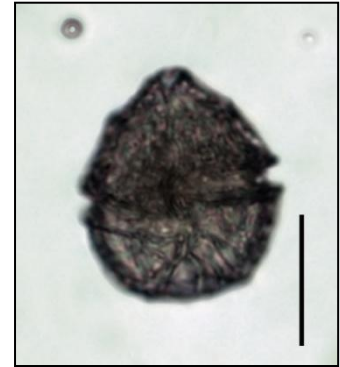
Plate A109: a-f (Annex A)

Description:

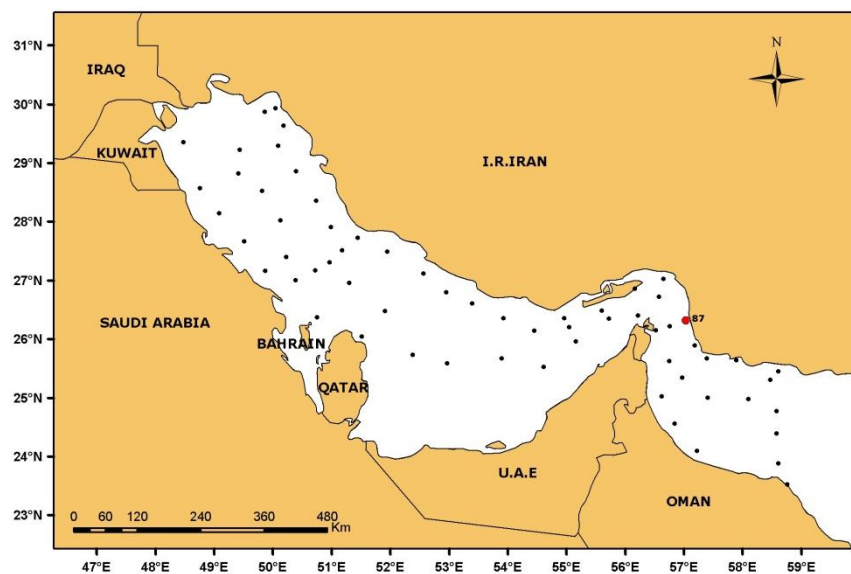
Cell small, oval. Epitheca subrotund with tapering apex and slight, tapering apical horn; girdle depressed, displaced about two widths. Hypotheca rotund; sulcus depressed, widened and rounded near base, plates sculptured.

Dimensions:

Cells 36 μm long, 27 μm wide.

**Sites of occurrence in RSA:**

In Winter 2006 Cruise, this species occurred at one site (refer site map) and in small numbers.



Site of occurrence of *Gonyaulax* sp.2 in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Gonyaulacaceae Lindermann, 1928

Genus: *Gonyaulax* Diesing, 186)

(= *Amylax* (Meunier, 1910 *partim.*))

Scientific name: *Gonyaulax* sp. 3

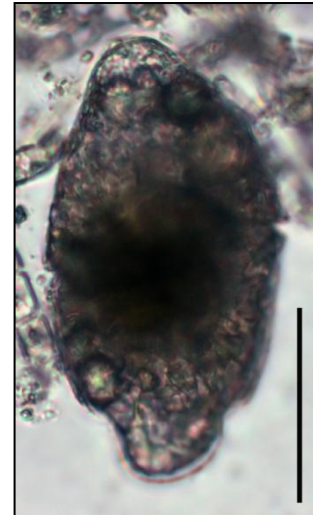
Plate 110: a-i (Annex A)

Description:

Large species with elongated body and delicate theca. Epitheca and hypotheca almost equal; no apical horn and antapical spines. Girdle depressed, slightly overhand, displaced about three widths. Surface coarsely porulate, longitudinally striate.

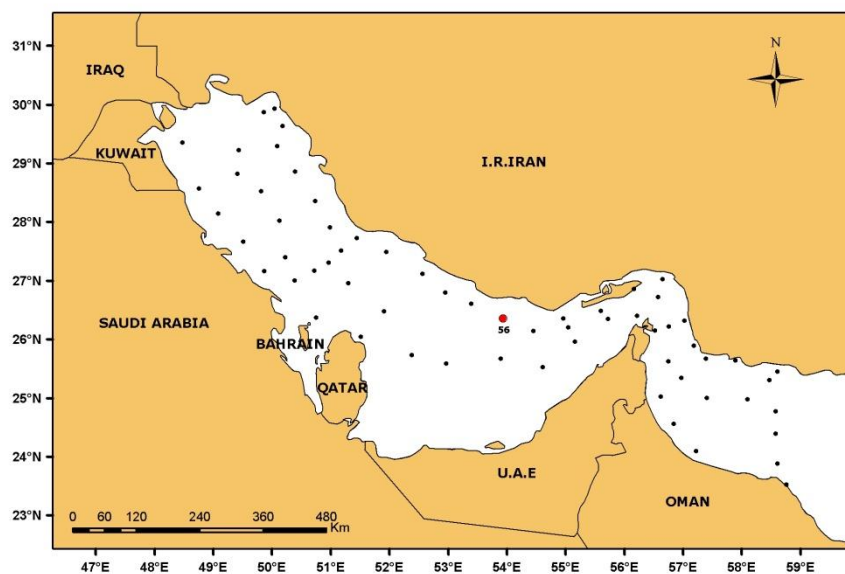
Dimensions:

Cells 113 μm long, 56 μm wide.



Sites of occurrence in RSA:

In Winter 2006 Cruise, a single specimen was recorded at one locality (refer site map) in the Strait of Hormuz area (St. 79).



Site of occurrence of *Gonyaulax* sp.3 in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridiniales Haeckel, 1894

Family: Gonyaulacaceae Lindermann, 1928

Genus: *Lingulodinium* Wall *emend.* Dodge, 1989

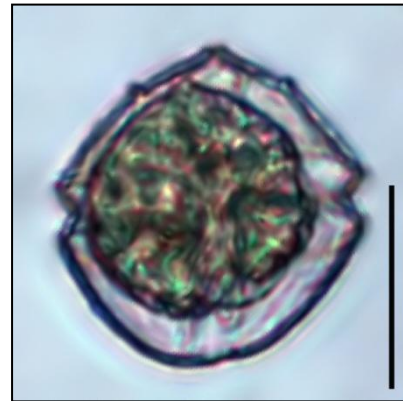
Polyhedral cells. Epi- and hypotheca with large flattened plates. Plate formula: Po, 3', 3a, 6'', 6c, 7s, 6''', 2'''' (Throndsen *et al.*, 2007).

Scientific name: *Lingulodinium polyedrum* (Stein) Dodge

Plate A109: g-l (Annex A)

Synonyms:

Gonyaulax polyedra Stein; *Lingulodinium machaerophorum* (Deflandre *et* Cookson) Wall (cyst); *Hystriosphæridium machaerophorum* Deflandre *et* Cookson (cyst)

**References:**

Balech, 1988: p. 297, L. 75: 17-24 (as *Gonyaulax polyedra*); Hallegraeff, 2002: p. 44, 10 B; Faust and Gualledge, 2002: p. 45, Pl. 29: 1-6; Throndsen *et al.*, 2007: p. 88.

Description:

Cells are angular, roughly pentagonal and polyhedral-shaped. Cells range in size from 40-54 µm in length and 37-53 µm in transdiameter width. No apical horn or antapical spines are present. Thecal plates are thick, well defined, and coarsely areolate. Distinct ridges are present along the plate sutures. Numerous large trichocyst pores are present within areolae. The plate formula is: Po, 3', 3a, 6'', 6c, 7s, G''', 2'''''. Photosynthetic species with dark orange-brown chloroplasts. The unusual carotenoid, peridinin, is present in the chloroplasts. Also present a pusule, a C-shaped nucleus, and scintillons (light-emitting organelles) (Faust and Gualledge, 2002).

Harmful Effect:

It is a toxic bloom-forming species. Bruno *et al.* (1990) reported the presence of a PSP toxin, saxitoxin, in water samples taken during a bloom of *L. polyedrum*.

Dimensions:

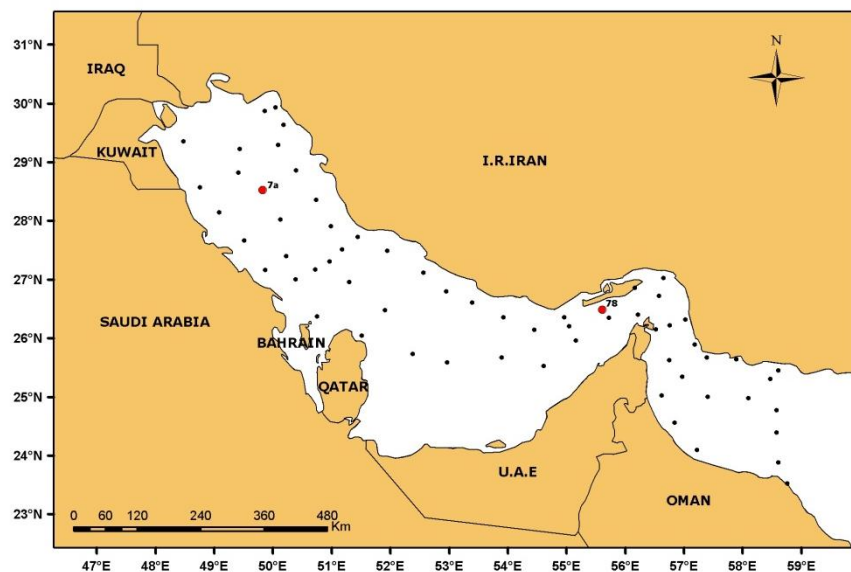
Cells 38-40 µm long; 37-39 µm wide.

Distribution:

Widely distributed species found in warm temperate and subtropical waters of the coastal areas.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was present in small numbers at two stations (refer sites map). This species has been previously reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Lingulodinium polyedrum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Gonyaulacaceae Lindermann, 1928

Genus: *Protoceratium* Bergh, 1881

(= *Gonyaulax* Diesing, 1866 *partim*.)

Round to polyhedral cells with cingulum equatorial or closer to apex. Characteristic reticulation of the theca. Plate formula: Po, 3', 0a, 6'', 6c, 6s, 6''', 2'''' (Throndsen *et al.*, 2007).

Scientific name: *Protoceratium reticulatum* (Claparede *et* Lachmann) Bütschli

Plate A111: a-i (Annex A)

Synonyms:

Peridinium reticulatum Claparede *et* Lachmann;
Protoceratium aceros Bergh; *Gonyaulax grindleyi*
Reinecke

References:

Wood, 1968: p. 125, Fig. 389; Dodge, 1985: p. 86;
Hallegraeff, 2002: p. 46, 10F; Throndsen *et al.*, 2007: p.
89.



Description:

Body rotund; epitheca and hypotheca subequal, round or angular; girdle left-handed, displaced about one width; lists narrow, supported by spines; ventral area not reaching antapex; theca slightly reticulate, often with apicules; plates very difficult to see on account of reticulation. Length 30-50 µm (Wood, 1968).

Harmful Effect:

This species is a producer of yessotoxin, which may accumulate in bivalves, and is toxic to mice. Effect on humans is unknown (Satake *et al.*, 1997, 1999; IOC list, 2002).

Dimensions:

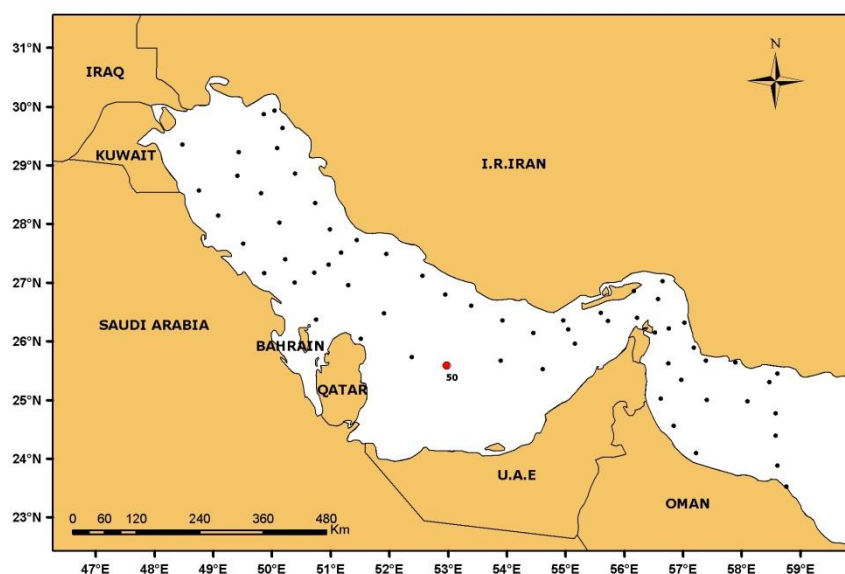
Cells 37-41 µm long; 30-32 µm wide.

Distribution:

Estuarine-neritic species; cold temperate to subtropical waters.

Sites of occurrence in RSA:

In Winter 2006 Cruise, a single specimen was recorded at one locality (refer site map) in the central part of the inner RSA off the United Arab Emirates (St. 50). This species has been previously reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Site of occurrence of *Protoceratium reticulatum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Oxytoxaceae Lindermann, 1928

Genus: *Corythodinium* Loeblich *et* Loeblich III, 1966

(= *Oxytoxum* Stein, 1883 *partim.*)

Armored. Small to large biconical to elongate cell with sculptured theca; cingulum anterior to median and descending about 1-1.5×; cingulum prominently excavated and with narrow lists.

Although the epitheca is shorter than the hypotheca, and the cell can be biconical or tapered, the anterior cingular list is almost the same diameter as the posterior cingular list. The s.a. (sulcus) plate is obovate or angled and prominently invades the epitheca. Plate formula is tentative: Po, 3', 2a, 6'', 5c, 4(?)s, 5''', 1'''(or 1p). Chloroplasts present (Steidinger and Tangen, 1997).

Scientific name: *Corythodinium constrictum* (Stein) Taylor

Plate A112: a-d (Annex A)

Synonym:

Oxytoxum constrictum (Stein) Bütschli

References:

Wood, 1968: p. 88, Fig. 249 (as *Oxytoxum constrictum*); Dodge, 1985: p. 107 (as *Oxytoxum constrictum*); Balech, 1988: p. 304, L. 82: 6, 24.

Description:

Epitheca bluntly conical, apex rounded, sides concave; hypotheca conical with convex margins, constricted near the upper third and with a short, sharp spine. Length 75 µm (Wood, 1968).



Dimensions:

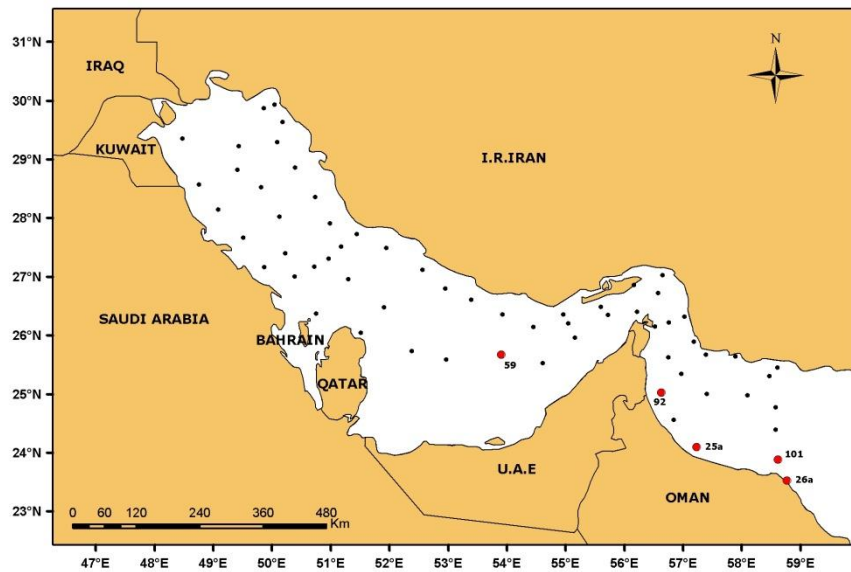
Cells 44-57 µm long; 24-28 µm wide.

Distribution:

Open water species; warm temperate to tropical waters; worldwide distribution.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was found at few sites (refer sites map), and in small numbers mainly in the Sea of Oman.



Sites of occurrence of *Corythodinium constrictum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Oxytoxaceae Lindermann, 1928

Genus: *Corythodinium* Loeblich *et* Loeblich III, 1966

(= *Oxytoxum* Stein, 1883 *partim.*)

Species: *diploconus*

Scientific name: *Corythodinium diploconus* (Stein) Taylor

Plate A112: g, h (Annex A)

Synonym:

Oxytoxum diploconus Stein

References:

Lebour, 1925: p. 141, Fig. 44 d; Dodge, 1982: p. 244, Fig. 32 D.

Description:

A medium-sized species with a bi-conical profile. Epitheca about one third cell length pointed with slightly concave sides. Hypotheca tapering from girdle to pointed posterior; with longitudinal ribs. Girdle slightly displaced on the right side. Length 64-95 μm (Dodge, 1982).

Dimensions:

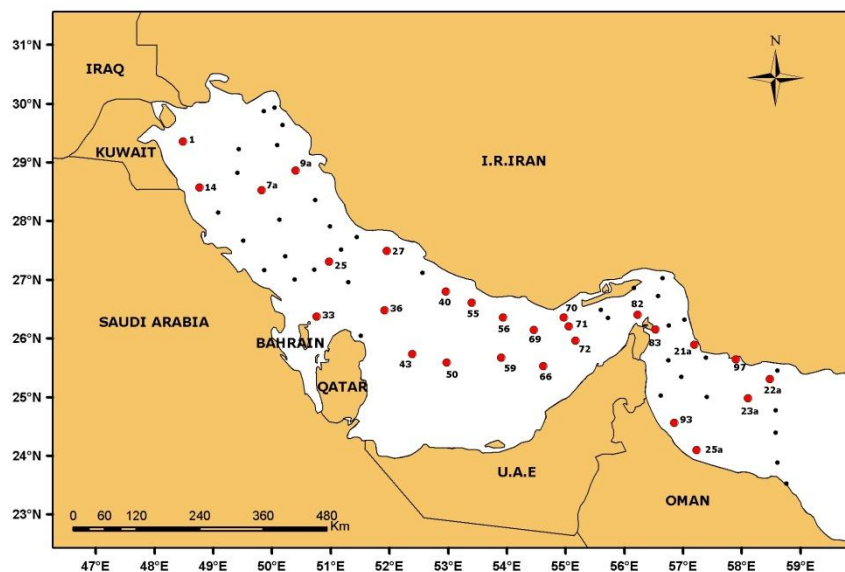
Cells, 58-63 μm long; 23-25 μm wide.

Distribution:

Oceanic warm water species.

**Sites of occurrence in RSA:**

In Winter 2006 Cruise, this species was observed at few sites (refer sites map), usually in small numbers, however, it was quite abundant at some localities; maximum abundance (3.6×10^3 cells/l) was associated with Kuwaiti waters in the northwestern part of the inner RSA (St. 1).



Sites of occurrence of *Corythodinium dipoconus* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridiniales Haeckel, 1894

Family: Oxytoxaceae Lindermann, 1928

Genus: *Corythodinium* Loeblich *et* Loeblich III, 1966

(= *Oxytoxum* Stein, 1883 *partim.*)

Species: *tesselatum*

Scientific name: *Corythodinium tessellatum* Loeblich *et* Loeblich III

Plate A112: e, f (Annex A)

Synonym:

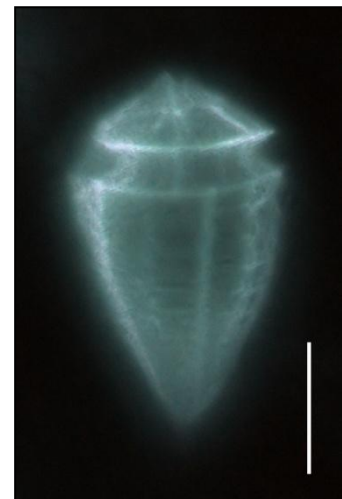
Oxytoxum tessellatum (Stein) Schütt

References:

Wood, 1968: p. 94, Fig. 273 (as *Oxytoxum tessellatum*);
Dodge, 1985: p. 113 (as *Oxytoxum tessellatum*); Balech, 1988:
p. 303, L. 81: 2.

Description:

Epitheca conical, low; hypotheca top-shaped, ending in an antapical spinule; girdle deep, moderately wide; hypotheca surface with rectangular meshes. Length 60 µm (Wood, 1968).

**Dimensions:**

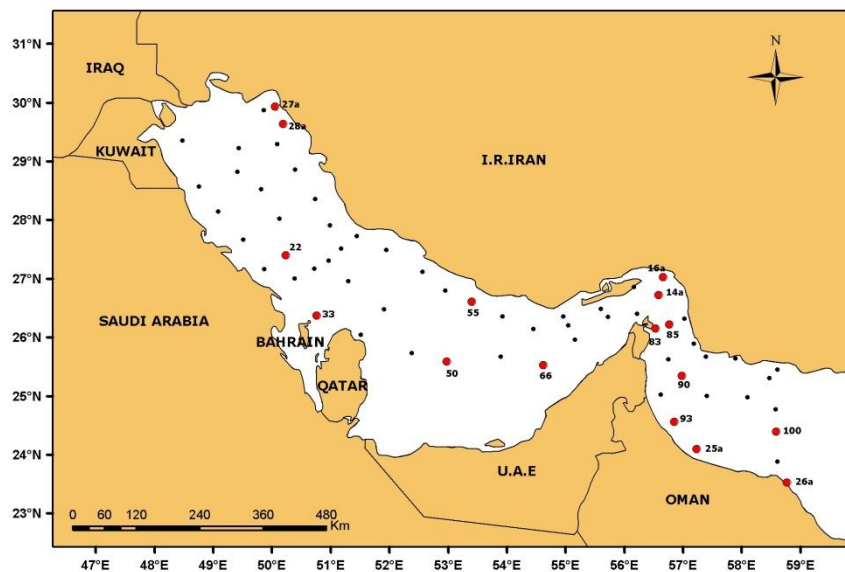
Cells 52-55 µm long; 31-33 µm wide.

Distribution:

Warm temperate to tropical waters; most records from the Atlantic Ocean.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at certain sporadic sites (refer sites map), usually in small numbers, however, it was quite abundant at some localities; maximum abundance (1.9×10^3 cells/l) was associated with the northwestern part of the inner RSA (St. 28a). Species has been previously reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Corythodinium tessellatum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridiniales Haeckel, 1894

Family: Oxytoxaceae Lindermann, 1928

Genus: *Corythodinium* Loeblich *et* Loeblich III, 1966 (= *Oxytoxum* Stein, 1883 *partim.*)

Scientific name: *Corythodinium* sp.

Plate A113: a-h (Annex A)

Description:

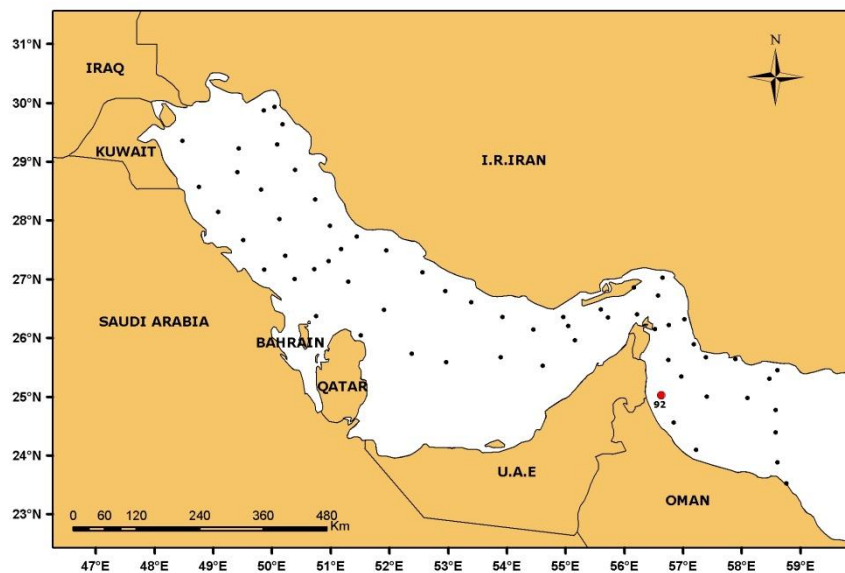
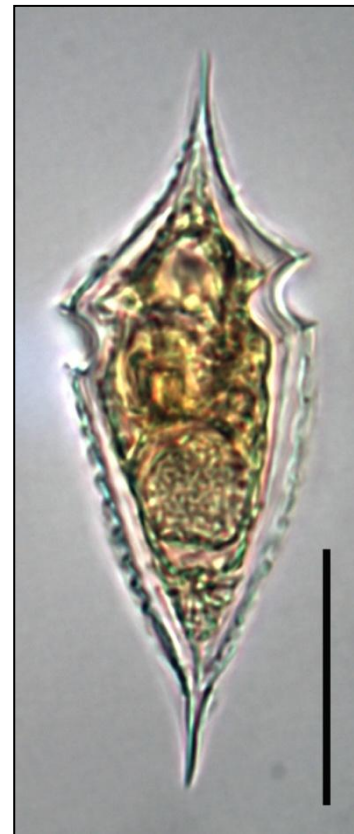
Epitheca low and broad; with a long, cylindrical process, truncated at apex. Hypotheca tapering with convex sides to a fine antapical spine. Girdle and sulcus deeply indented. Surface of hypotheca with rectangular meshes.

Dimensions:

Cells 62 μm long; 27 μm wide.

Sites of occurrence in RSA:

In Winter 2006 Cruise, a single specimen was recorded at one locality (refer site map) in the Sea of Oman (St. 92).



Site of occurrence of *Corythodinium* sp. in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Oxytoxaceae Lindermann, 1928

Genus: *Oxytoxum* Stein, 1883

Armored. Small to large, needle-shaped to top-shaped cell with a decidedly anterior epitheca that is drastically narrower and shallower than the hypotheca. Cingulum is anterior with little displacement (0-0.5×) and the suture plate barely invades the epitheca. Plate formula is thought to be same as that for *Corythodinium*, except that some authors consider the two anterior intercalaries to be apicals. Certain species less than 15 µm in length, probably less than 10 µm. Chloroplasts are present (Steidinger and Tangen, 1997).

The *Oxytoxum* genus includes seven small- and medium-sized species. In Winter 2006 Cruise, some of them were frequently observed in the RSA samples or have ubiquitous occurrence (*O. variabile*). When abundant, these species contributed up to 22 % of the total phytoplankton abundance; the highest concentration reached 2.0×10^4 cells/l, mainly due to the occurrence of the small-sized species. High abundance of this genus ($> 10^4$ cells/l) was associated with the central part of the inner RSA, and with the Sea of Oman waters.

Scientific name: *Oxytoxum curvatum* (Kofoid) Kofoid

Plate A114: a-c (Annex A)

Synonym:

Prorocentrum curvatum Kofoid

Reference:

Wood, 1968: p. 89, Fig. 253.

Description:

Epitheca shortly cylindrical; hypotheca with blunt apical region, parallel sides curving to the tapering antapex. Length 60-100 µm (Wood, 1968).

Dimensions:

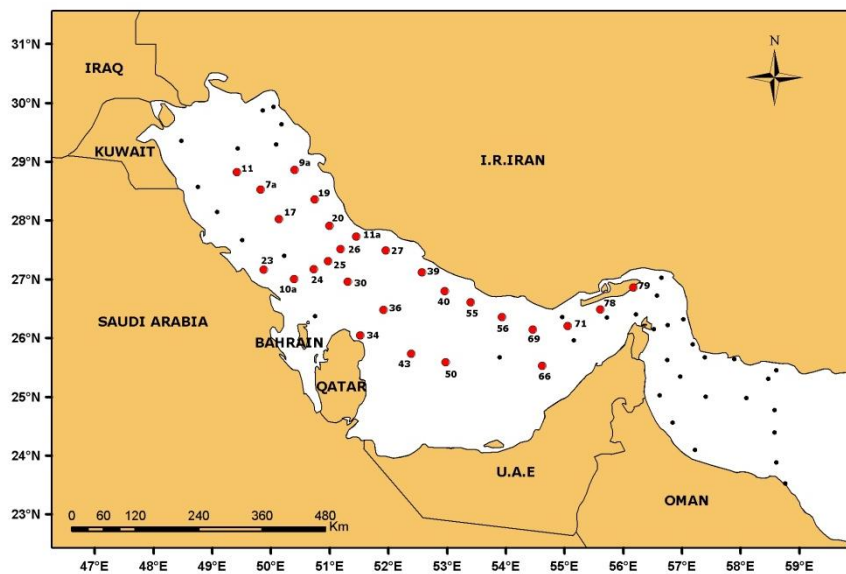
Cells 70-85 µm long; 17-20 µm wide.

Distribution:

Atlantic, Pacific and Indian Oceans.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at various sites of inner RSA (refer sites map), never in large numbers; maximum abundance (68 cells/l) was associated with the central part of the inner RSA (St. 36).



Sites of occurrence of *Oxytoxum curvatum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Oxytoxaceae Lindermann, 1928

Genus: *Oxytoxum* Stein, 1883

Species: *scolopax*

Scientific name: *Oxytoxum scolopax* Stein

Plate A112: i (Annex A)

References:

Lebour, 1925: p. 141, Fig. 44 c; Wood, 1968: p. 93, Fig. 270; Taylor, 1976: p. 127, Pl. 24: 252, 253: Pl. 43: 512; Dodge, 1982: p. 246, Fig. 32 H; Dodge, 1985: p. 108; Balech, 1988: p. 304, L. 82: 16; Throndsen *et al.*, 2007: p. 106.

Description:

Cell spindle-shaped with acutely pointed ends. Hypotheca about three times the length of the epitheca with an occasional small swelling at the base of the antapical point. Epitheca bulbous at the base and tapering to the apex. Length 70-120 μm (Dodge, 1982).

**Dimensions:**

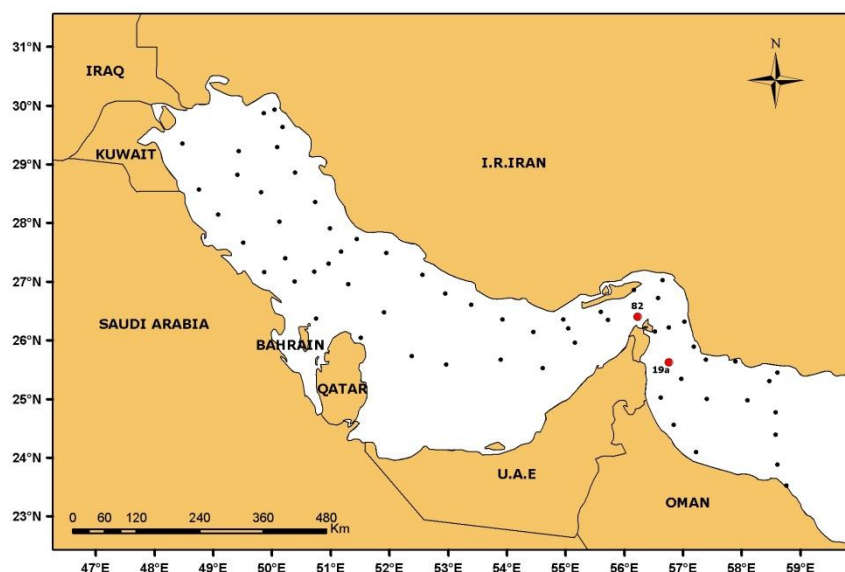
Cells 71-75 μm long; 10-13 μm wide.

Distribution:

Warm temperate to tropical waters; worldwide distribution, but more typical of the Atlantic Ocean. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at two sites (refer sites map) in small numbers; maximum abundance (80 cells/l) was associated with the Sea of Oman (St. 19a).



Sites of occurrence of *Oxytoxum scolopax* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Oxytoxaceae Lindermann, 1928

Genus: *Oxytoxum* Stein, 1883

Species: *variabile*

Scientific name: *Oxytoxum variabile* Schiller

Plate A114: e-g (Annex A)

References:

Schiller, 1937: p. 455, Fig. 505; Wood, 1968: p. 94, Fig. 275;
Taylor, 1976: p. 129, Pl. 24: 243, 244.

Description:

Epitheca hemispherical to broadly conical with a short fine spinule; hypotheca more or less cordate or top-shaped, ending in a fine spinule; girdle narrow; sulcus long, only on hypotheca. Length 20-25 µm (Dodge, 1982).

**Dimensions:**

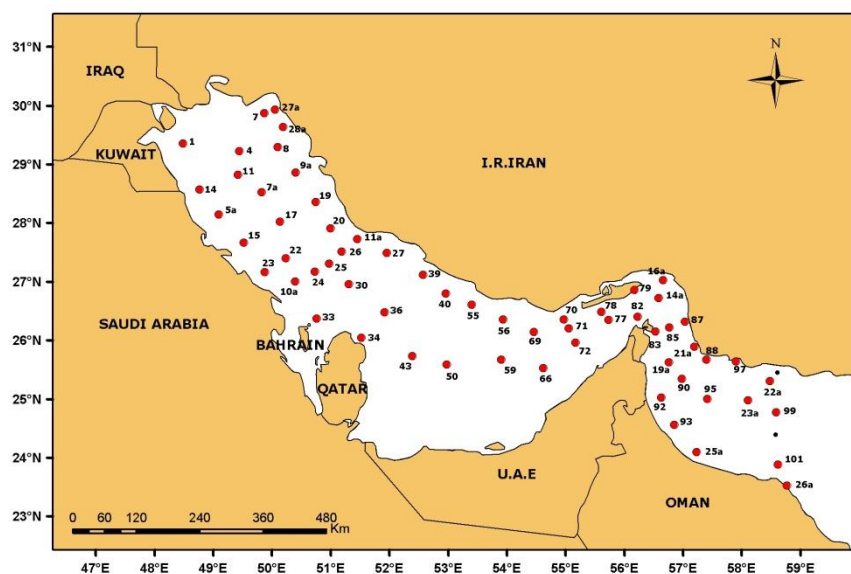
Cells 26-31 µm long; 12-14 µm wide.

Distribution:

Warm temperate to tropical waters; worldwide distribution. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred ubiquitously over most of the area studied (refer sites map), encountered in 83.8 % of the samples, often in large numbers; maximum abundance (1.5×10^4 cells/l) was associated with the central part of the inner RSA off Bahrain (St. 33).



Sites of occurrence of *Oxytoxum variabile* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Oxytoxaceae Lindermann, 1928

Genus: *Oxytoxum* Stein, 1883

Scientific name: *Oxytoxum* sp. 1

Plate A114: d (Annex A)

Description:

Small-sized species. Epitheca dome-shaped, apex rounded. Hypotheca horn-shaped, bent at antapex with small antapical spine.

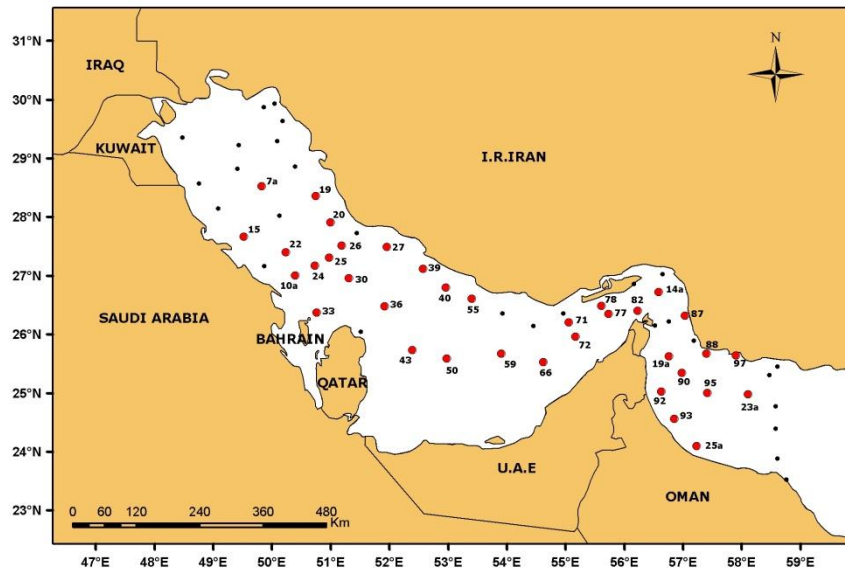
Dimensions:

Cells 17-20 μm long; 8-9 μm wide.



Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at various sites (refer sites map), usually in small numbers; however, it was quite abundant at some localities; maximum abundance (1.2×10^4 cells/l) was associated with central part of the inner RSA off the United Arab Emirates (St. 50).



Sites of occurrence of *Oxytoxum* sp. 1 in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Oxytoxaceae Lindermann, 1928

Genus: *Oxytoxum* Stein, 1883

Scientific name: *Oxytoxum* sp. 2

Plate A114: h, i.

Description:

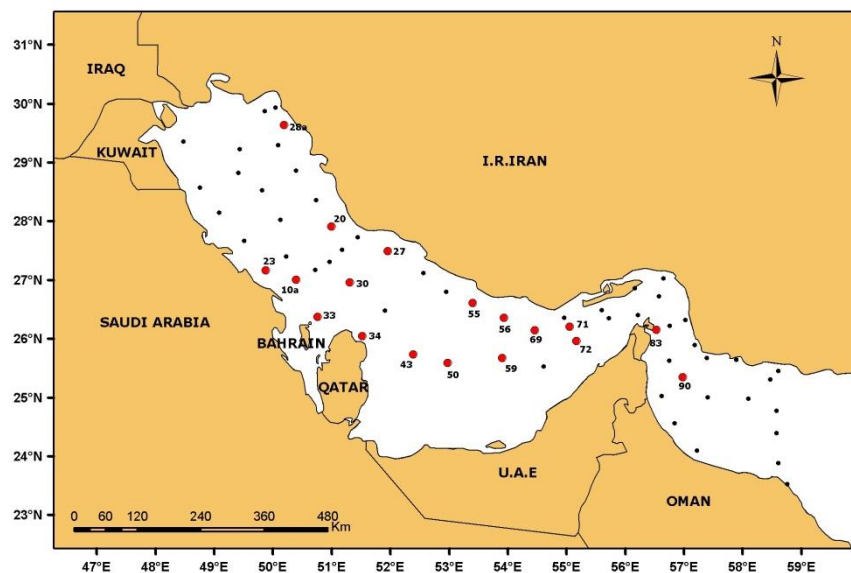
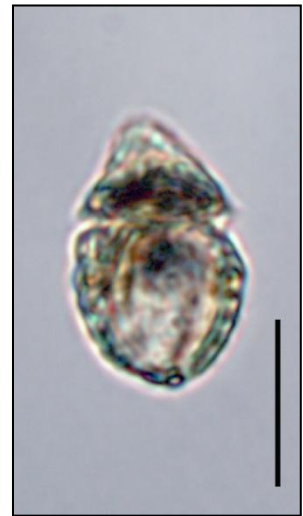
Small-sized species. Epitheca bluntly conical, apex rounded. Hypotheca much larger, almost spherical, without antapical spine.

Dimensions:

Cells 17-21 µm long; 10-11 µm wide.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at various sites (refer sites map), usually in small numbers; however, it was quite abundant at some localities; maximum abundance (3.8×10^3 cells/l) was associated with the southern part of the inner RSA (St. 69).



Sites of occurrence of *Oxytoxum* sp. 2 in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridiniales Haeckel, 1894

Family: Oxytoxaceae Lindermann, 1928

Genus: *Oxytoxum* Stein, 1883

Scientific name: *Oxytoxum* sp. 3

Plate A114: j-l (Annex A)

Description:

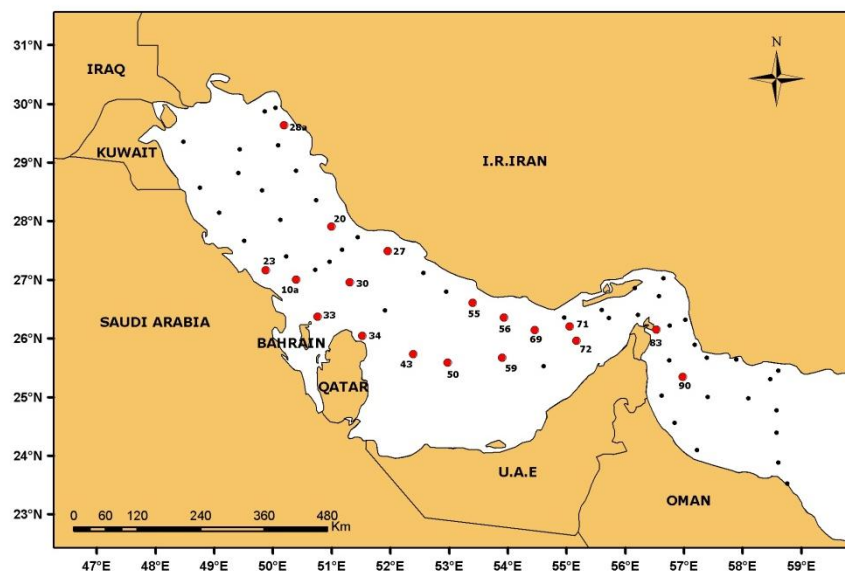
Small-sized species. Epitheca much less than hypotheca, apex rounded. Hypotheca conical, bent at antapex with small antapical spine; surface with longitudinal ribs.

Dimensions:

Cells 21-24 μm long; 10-11 μm wide.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was present in small numbers at scattered stations (refer sites map).



Sites of occurrence of *Oxytoxum* sp. 3 in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Diplopelta* Stein *ex* Jörgensen, 1912

(= *Dissodium* Abé, 1941 *partim.*)

Heterotrophic dinoflagellates with theca, the cells spherical to lens-shaped with conspicuous furrow lists as in the rest of the *Diplopsalis* group. First apical plate 1' ortho, two unequal intercalary plates. Very similar to *Preperidinium*, but has 6 precingular plates and 2 antapical plates (Throndsen *et al.*, 2007).

Scientific name: *Diplopelta bomba* Stein *ex* Jörgensen

Plate A115: a-i (Annex A)

Synonyms:

Diplopelta asymmetrica (Mangin) Lebour; *Peridiniopsis asymmetrica* Mangin; *Glenodinium lenticula* f. *asymmetrica* (Mangin) Schiller; *Dissodinium asymmetricum* (Mangin) Loeblich; *Diplopsalopsis asymmetrica* (Mangin) Abé

References:

Taylor, 1976: p. 132, Pl. 28: 296 a, b; pl. 45: 520 a-c (as *Peridiniopsis asymmetrica*); Throndsen *et al.*, 2007: p. 83.



Description:

Cell lens-shaped, circular outline in apical view. First apical plate 1' ortho, relatively broad. First intercalary plate 1a small, rhomboid/quadratic, second intercalary plate 2a large, almost reaching to apex. Sulcus short with sulcal list which is orientated obliquely to the sulcus, and is not projecting far from the cell surface. Cytoplasm is usually pink to red. Length 35-70 µm, width/diameter 60-95 µm (Throndsen *et al.*, 2007).

Dimensions:

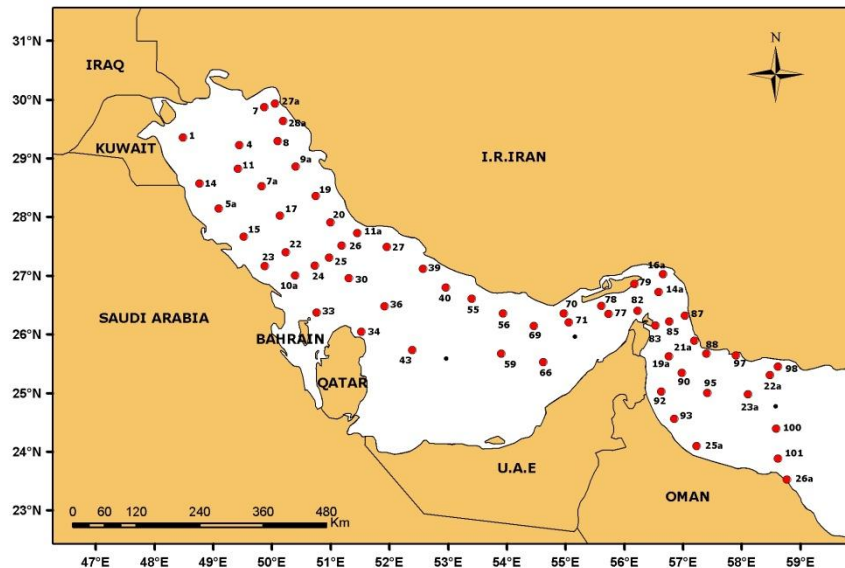
Cells 50-58 µm long; 70-75 µm in diameter.

Distribution:

Widely distributed species. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was commonly observed at various sites (refer sites map), although never in large numbers; maximum abundance (3.2×10^2 cells/l) was associated with the Sea of Oman (St. 93).



Sites of occurrence of *Diplopelta bomba* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Diplopelta* Stein *ex* Jörgensen, 1912

(= *Dissodium* Abé, 1941 *partim*.)

Species: *steinii*

Scientific name: *Diplopelta steinii* (Abé) Balech

Plate A117: f-h (Annex A)

Reference:

Balech, 1988: L. 19: 14-17.

Description:

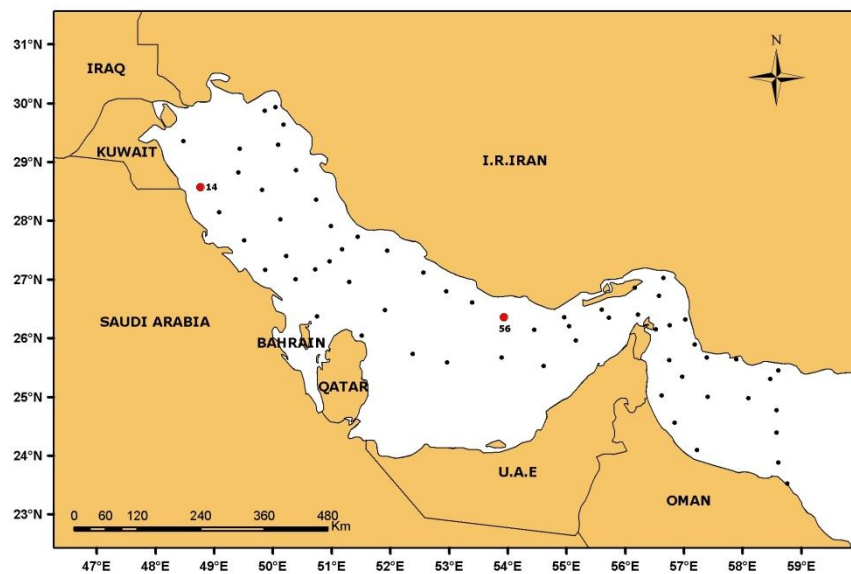
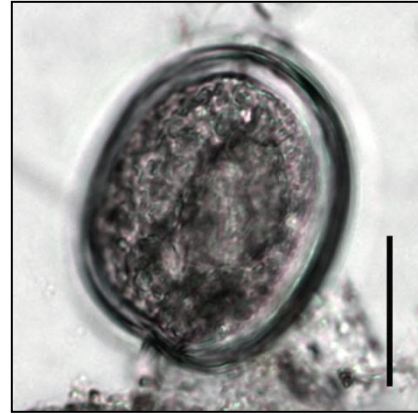
Species is distinguished from *Diplopelta bomba* by size and shape the first intercalary plate 1a; it is larger than in *D. bomba* and has pentagonal shape.

Dimensions:

Cells 40-45 μm in diameter.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at few sites (refer sites map) and in small numbers.



Sites of occurrence of *Diplopelta steinii* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Diplopsalis* Bergh, 1881

(= *Dissodium* (Abé, 1941) *partim.*)

Heterotrophic dinoflagellates with theca, the cells lens-shaped with well developed cingulum and sulcus lists, left sulcus list wide and curved. Epitheca with an almost symmetrical plate pattern. First apical plate 1' ortho, intercalary plate broad and dorsal. Hypotheca with symmetrical plate pattern and one large antapical plate (Throndsen *et al.*, 2007).

Scientific name: *Diplopsalis lenticula* Bergh

Plate A117: a-e (Annex A)

Synonyms:

Glenodinium lenticula (Bergh) Schiller; *Glenodinium lenticula* Pouchet; *Dissodium lenticulum* (Bergh) Loeblich

References:

Taylor, 1976: p. 130, Pl. 28: 298, 299; Dodge, 1982: p. 154, Fig. 18 I-K, Pl. III: b, c; Throndsen *et al.*, 2007: p. 84.



Description:

Cell lens-shaped with small apical projection and large, prominent sulcal list. The epitheca and hypotheca are almost equal. There are three large apical plates, a long, narrow dorsal intercalary plate and six narrow precingulars. The girdle is equatorial, not displaced but bordered lists supported by spines. There are five postcingular plates and a single, large antapical plate. The sulcus almost reaches the center of the hypotheca and is bordered on the left side by a wide wing which is curved to the right. The theca is finely punctate and the plasma is pink. Plate formula: 3', 1a, 6'', 3c, 6s, 5''', 1'''''. Cells 23-48 µm long, 32-68 µm diameter (Dodge, 1982).

Dimensions:

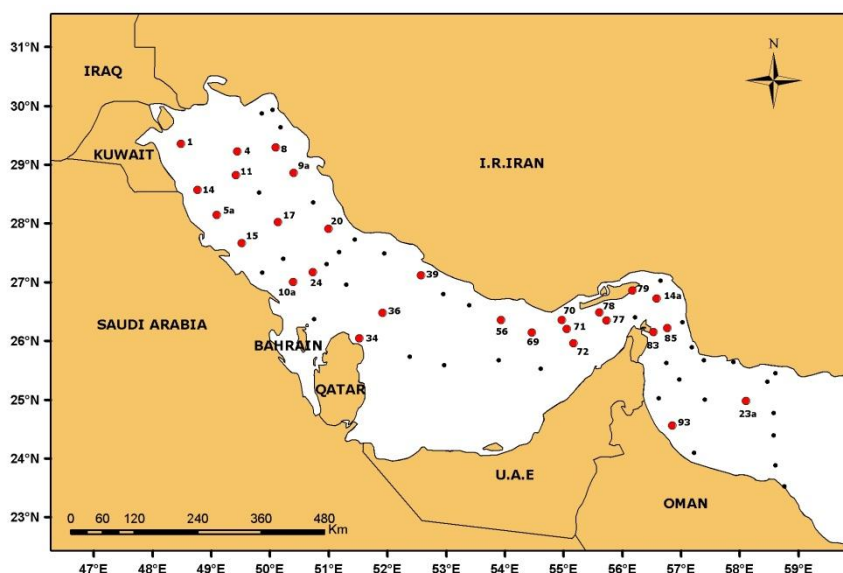
Cells 33-36 µm long; 39-45 µm in diameter.

Distribution:

Estuarine to oceanic; cosmopolitan in cold temperate to tropical waters. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at certain sites (refer sites map), never in large numbers; maximum abundance (1.5×10^2 cells/l) was associated with the southern part of the inner RSA (St. 78). Species has previously been reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Diplopsalis lenticula* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Peridinium* Ehrenberg, 1831

Armored. Small to medium-sized cell of varied shape from spherical to ovoid to lenticular. Type species without APC. Surface markings varied. Plate formula: 4', 3a, 7'', 5c, 5s, 5''', 2'''' (Steidinger and Tangen, 1997).

Scientific name: *Peridinium quinquecorne* Abè

Plate A117: i-k (Annex A)

Synonym:

Protoperidinium quinquecorne (Abè) Balech

References:

Abè, 1981: Fig. 264-272; Horiguchi and Pienaar, 1991: Fig. 1-24; Faust *et al.*, 2005: p. 122, Fig. 7-10; Mohammad-Noor *et al.*, 2007: p. 677, Fig. 34a-c.

**Description:**

Epitheca is conical with a pointed apex. Hypotheca is angular; 4 antapical spines variable in length. Intercalary plates 1a pentagonal and 2a heptagonal. Apical plate is a round chamber with a Po plate and X canal plate. Cell shape is rhomboid. Red eyespot present (Faust *et al.*, 2005).

Harmful Effect:

This species can cause anoxia and fish kills during blooms with very high cell numbers (Fukuyo *et al.*, 1990).

Dimensions:

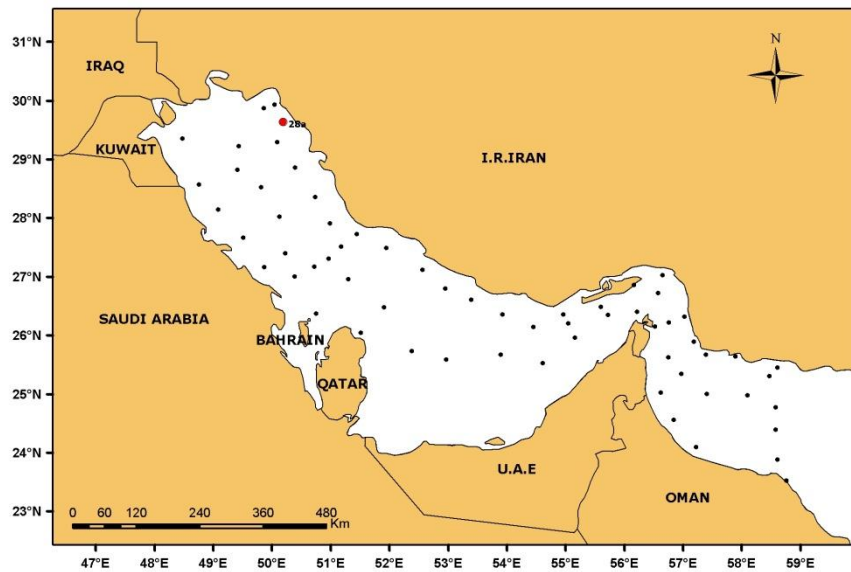
Cells 21-24 µm long, 17-20 µm wide.

Distribution:

Peridinium quinquecorne has been reported from the different habitats in the tropics including floating detritus, macroalgae, seagrass, tide pools, benthic and planktonic shallow waters in Japan, South Africa, Philippines, Australia, Belize and Malaysia (Horiguchi and Pienaar, 1991; Faust *et al.*, 2005; Mohammad-Noor *et al.*, 2007).

Sites of occurrence in RSA:

In Winter 2006 Cruise, a single specimen was recorded at one locality (refer site map) in the northwestern part of the inner RSA (St. 28a).



Site of occurrence of *Peridinium quinquecorne* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: Preperidinium Margin 1913

(= *Diplopeltopsis* Pavillard 1913;

= *Zygabikodinium* Loeblich *et* Loeblich 1970)

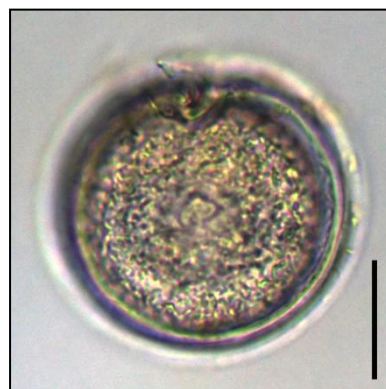
Heterotrophic dinoflagellates with smooth theca. The cell shape oval in ventral view, circular in apical view. First apical plate 1' ortho, narrow. First intercalary plate 1a small, nearly quadratic, dorsally on the left side of the cell. Second intercalary plate 2a is large and almost reaching apex. With seven precingular plates and one antapical plate (Thronsdén *et al.*, 2007).

Scientific name: *Preperidinium meunieri* (Pavillard) Elbrächter

Plate A116: a-i (Annex A)

Synonyms:

Zygabikodinium lenticulatum Loeblich *et* Loeblich;
Peridinium paulsenii Mangin; *Peridinium lenticulatum*
Mangin; *Diplopeltopsis minor* (Paulsen) Pavillard;
Diplopsalis lenticulata f. *minor* Paulsen; *Diplopsalis*
minor (Paulsen) Lindermann

**References:**

Dodge, 1982: p. 160, fig. 18 C, D (as *Zygabikodinium lenticulatum*); Throndsen *et al.*, 2007: p. 82

Description:

Cells globular to lens-shaped in ventral view, almost circular in apical view, 28-56 µm in diameter, usually over 40 µm. First apical plate 1' a narrow 'ortho' type, but with anterior triangle longer than posterior triangle. There are three apicals and one small square intercalary plate on the left side and a large intercalary plate in a dorsal position almost reaching the apical pore. There are seven precingular plates. The girdle is equatorial, not incised, but bordered by lists supported by spines. The hypotheca has convex sides, composed of five postcingular plates and only one antapical plate. The sulcus almost reaches the center of the hypotheca and is bordered by a narrow list on the left. Cell contents pink. Theca delicately punctate (Dodge, 1982).

Dimensions:

Cells 35-41 µm long; 45-49 µm in diameter.

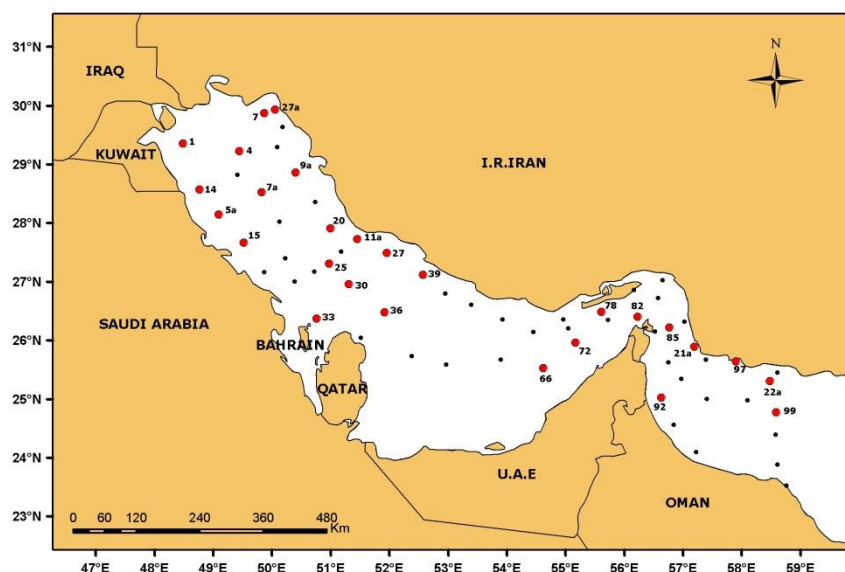
Distribution:

Marine cosmopolitan species (Throndsen *et al.*, 2007).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at few sites (refer sites map), never in large numbers; maximum abundance (1.2×10^2 cells/L) was associated with the north-western part

of the inner RSA off Kuwait (St. 14). It has been reported previously from Kuwaiti coastal waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Preperidinium meunieri* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Protoperidinium* Berg *emend.* Balech, 1974

(= *Peridinium* Ehrenberg, 1831 *partim.*,

= *Minuscula* Lebour 1925)

Thecate dinoflagellates with distinct, almost median cingulum, circular or somewhat displaced. Large variation in cell shape, especially hypotheca which varies from smoothly rounded to extruded into two horns or with protrusions from the plates antapically and along the sulcus. The plates are with varying degree of ornamentation. Lacks chloroplasts and has heterotrophic nutrition, but the cytoplasm may be colored, yellow-green to pink; oil droplets (reddish) and large vacuoles, common. Cysts (resting spores) are described from many species. Plate formula: Po, x, 4', 2-3a, 7'', 4(3+t)c, 5''', 2'''. The genus may be divided into

groups of species based on the shape of two plates on epitheca: first apical plate (1') and median intercalary plate (2a). 1' is surrounded by four (ortho), five (meta) or six (para) other plates, whereas similarly the 2a is called quadra, penta, hexa, respectively. Within many species, there is a relatively great variation in cell shape with apparent overlapping between species from different groups of the genus. It is therefore often necessary to reveal the plate pattern, at least for the two plates (1' and 2a), to ensure the most reliable species identification. Toxin production is indicated for some species (Thronsdon *et al.*, 2007).

Among the dinoflagellates, the *Protoperidinium* genus was the most diverse and rather abundant. When abundant, *Protoperidinium* spp. contributed up to 16 % of the total phytoplankton abundance; In Winter 2006 Cruise, the highest concentration reached up to 1.2×10^4 cells/l. Spatial distribution was quite localized with high abundance of this genus ($> 10^4$ cells/l) mainly associated with the northwestern and the central parts of the inner RSA.

Scientific name: *Protoperidinium abei* (Paulsen) Balech

Plate A118: a-j (Annex A)

Synonym:

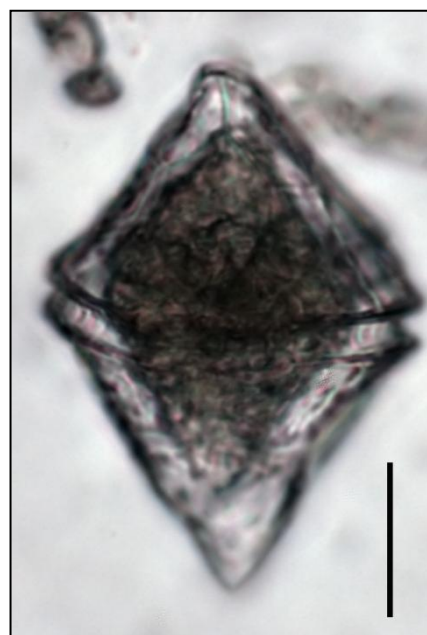
Peridinium abei Paulsen

References:

Schiller, 1937: p. 138, Fig. 136 a-h (as *Peridinium abei*); Wood, 1968: p. 97, Fig. 283 (as *Peridinium abei*); Taylor, 1976: p. 136, Pl. 33: 363, 366 (as *Peridinium abei*).

Description:

Cell biconical, longer than broad; epitheca approximately equal to hypotheca, left-handed; girdle indented with narrow lists; sulcus deep, curving to left, ending on left margin of hypotheca; surface often porulate; ortho; two intercalary plates. Length 70-100 μm (Wood, 1968).



Dimensions:

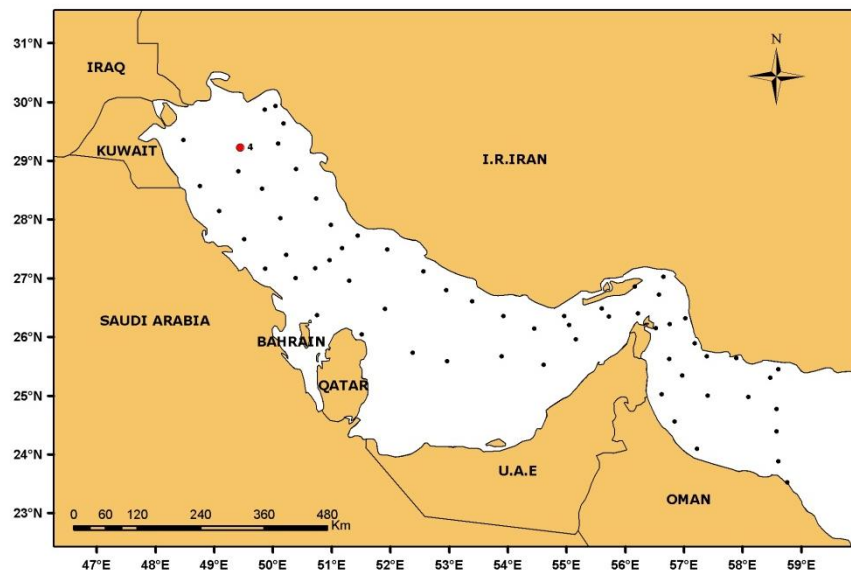
Cells 70-77 μm long; 49-53 μm wide.

Distribution:

Estuarine species, Indian and Pacific oceans. Species has previously been reported from the Indian Ocean by Taylor (1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, a single specimen was recorded at one locality (refer site map) in the Strait of Hormuz area (St. 79).



Site of occurrence of *Protoperidinium abei* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Protoperidinium* Berg *emend.* Balech, 1974

(= *Peridinium* Ehrenberg, 1831 *partim.*,

= *Minuscula* Lebour 1925)

Species: cf. *achromaticum*

Scientific name: *Protoperidinium* cf. *achromaticum* (Levander) Balech

Plate A119: a-i (Annex A)

Synonym:

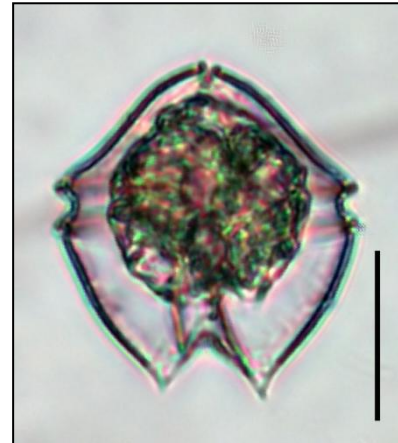
Peridinium achromaticum Levander

References:

Taylor, 1976: p. 138, Pl. 33: 371 a, b (as *Peridinium achromaticum*); Dodge, 1982: 183, Fig. 21 B.

Description:

Cell rhombic in ventral view with straight or slightly convex sides. The first apical plate is ortho and usually symmetrical. The second anterior intercalary plate is six-sided, symmetrical and touches precingulars 3", 4" and 5".



The hypotheca is divided from the epitheca by a median girdle which is not offset. The sulcus broadens slightly posteriorly, and is bordered by narrow lists which protrude posteriorly and is bordered by narrow lists which protrude posteriorly giving the appearance of small spines. The girdle is slightly excavated, bordered by narrow lists. Plate formula: 4', 3a, 7'', 3c, 5''', 2'''. Size: length 27-40 μm ; breadth 23-40 μm (Dodge, 1982).

Dimensions:

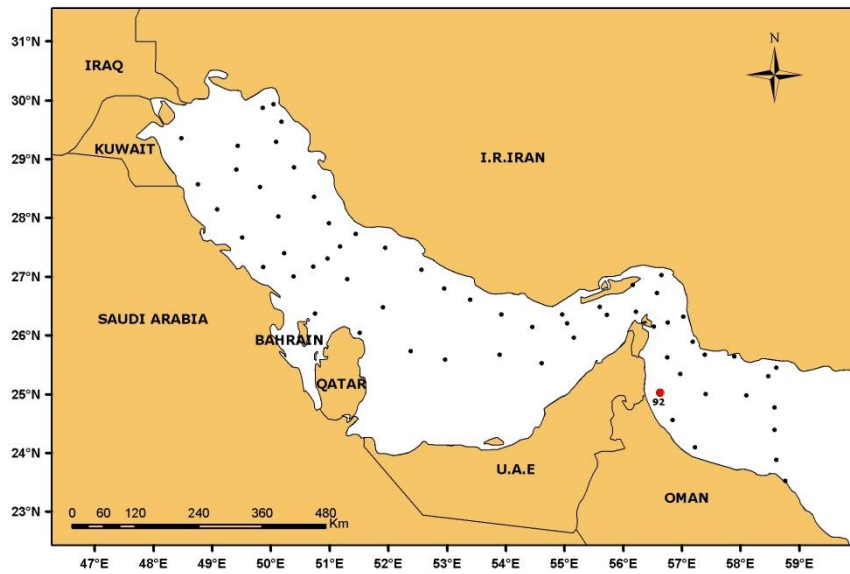
Cells 38-42 μm long; 32-34 μm wide.

Distribution:

Neritic, brackish and marine species. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, a single specimen was recorded at one locality (refer site map) in the Sea of Oman (St. 92).



Site of occurrence of *Protoperidinium* cf. *achromaticum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridiniales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Protoperidinium* Berg *emend.* Balech, 1974

(= *Peridinium* Ehrenberg, 1831 *partim.*,

= *Minuscula* Lebour 1925)

Species: *biconicum*

Scientific name: *Protoperidinium biconicum* (Dangeard) Balech

Plate A120: g-k (Annex A)

Synonym:

Peridinium biconicum Dangeard

References:

Schiller, 1937: p. 230, Fig. 227 a-c (as *Peridinium biconicum*); Wood, 1968: p. 97, Fig. 285 (as *Peridinium biconicum*); Taylor, 1976: p. 139, Pl. 33: 365 (as *Peridinium biconicum*).

Description:

Theca biconical, apex and antapex acute, no apical horn or spines; ortho-hexa; girdle depressed, not displaced; sulcus broad, not reach antapex. Length 80-100 μm (Wood, 1968).

Dimensions:

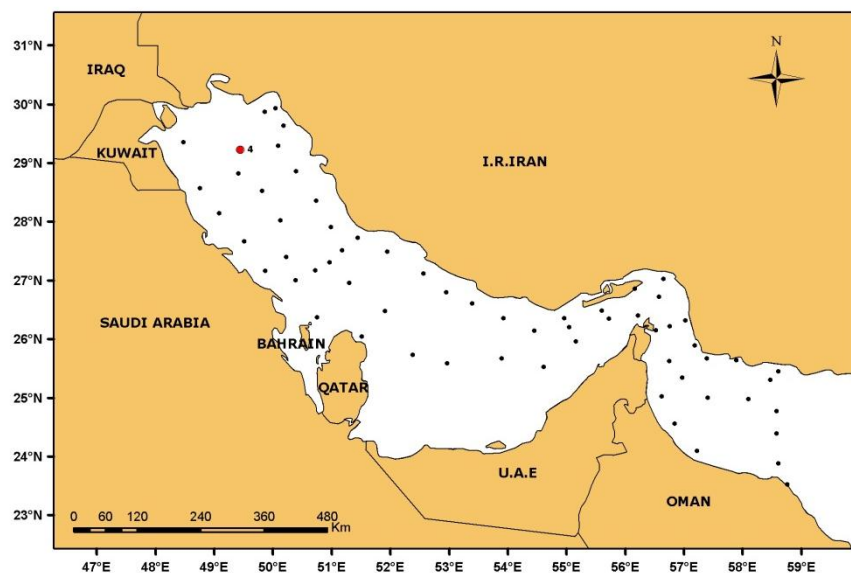
Cells 90 μm long; 105 μm wide.

Distribution:

Widely distributed species; it has been recorded previously from the Indian Ocean (Taylor, 1976).

**Sites of occurrence in RSA:**

In Winter 2006 Cruise, a single specimen was recorded at one locality (refer site map) in the northwestern part of the inner RSA (St. 4). It has been recorded previously from the the inner RSA (Wood, 1968) and from Kuwaiti waters (Al-Kandari *et al.*, 2009).



Site of occurrence of *Protoperidinium biconicum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Protoperidinium* Berg *emend.* Balech, 1974

(= *Peridinium* Ehrenberg, 1831 *partim.*,

= *Minuscula* Lebour 1925)

Species: *claudicans*

Scientific name: *Protoperidinium claudicans* (Paulsen) Balech

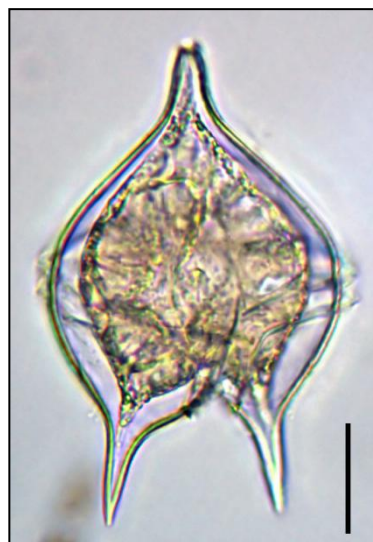
Plate A121: a-j (Annex A)

Synonym:

Peridinium claudicans Paulsen

References:

Lebour, 1925: p. 123, Pl. XXV: 1 a-d (as *Peridinium claudicans*); Wood, 1968: p. 99, Fig. 290 (as *Peridinium claudicans*); Dodge, 1982: p. 182, Fig. 20 G, H; Dodge, 1985: p. 45; Balech, 1988: p. 246, L. 24: 5-9; Throndsen *et al.*, 2007: p. 96.



Description:

Cell dorsoventrally compressed. Epitheca drawn out into apical horn. Plates ortho and penta or quadra. Hypotheca bears two unequal hollow antapical horns (the right side longer than the left). The girdle is left-handed, excavated and bordered by lists supported by ribs. Theca finely reticulated; said to be luminescent. Cell contents pale yellow. Size: 50-105 μm long, 48-76 μm wide (Dodge, 1982).

Dimensions:

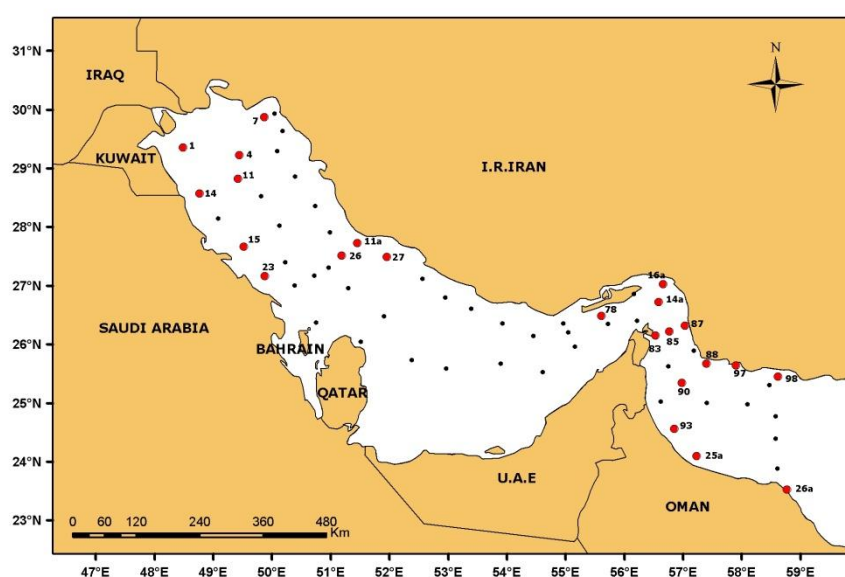
Cells 75-88 μm long; 48-52 μm wide.

Distribution:

Principally coastal and open water, but found in estuarine environments; temperate to tropical waters; cosmopolitan species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at sporadic sites (refer sites map), never in large numbers; maximum abundance (1.4×10^2 cells/l) was associated with Kuwaiti waters in the northwestern part of the inner RSA (St. 1). It has been previously reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Protoperdinium claudicans* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Protoperdinium* Berg *emend.* Balech, 1974

(= *Peridinium* Ehrenberg, 1831 *partim.*,

= *Minuscula* Lebour 1925)

Species: *conicoides*

Scientific name: *Protoperidinium conicoides* (Paulsen) Balech

Plate A122: a-j (Annex A)

Synonym:

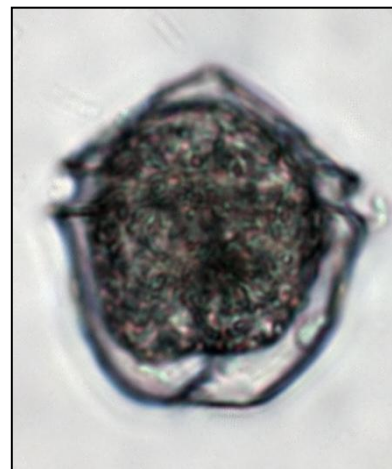
Peridinium conicoides Paulsen

References:

Dodge, 1982: p. 184, Fig. 21 A; Throndsen *et al.*, 2007: p. 97.

Description:

Cell rhombic in dorsoventral view; nearly circular in apical view. The conical epitheca may have slightly convex ending at the apex with a small projection. Ortho-hexa plate arrangement. Hypotheca also with convex sides ending with two hollow spines at the antapex. Girdle excavated with fine list which may be also absent. Sulcus deeply excavated, broadening posteriorly, with a characteristic twist on the left just below the girdle. Thecal sculpting is delicate with random pores; intercalary striae may occur. Cell content pale yellow. Size: 45-71 μm long; 45-60 μm wide (Dodge, 1982).



Dimensions:

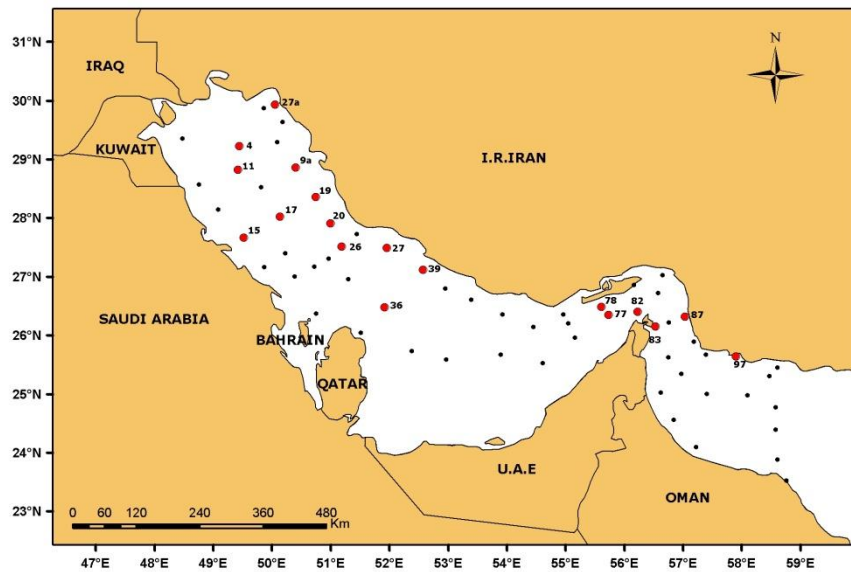
Cells 36-40 μm long; 29-33 μm wide.

Distribution:

Neritic, cosmopolitan in temperate waters.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at certain sporadic sites (refer sites map) in small numbers; maximum abundance (78 cells/l) was associated with the northwestern part of the inner RSA (St. 9a).



Sites of occurrence of *Protoperidinium conicoides* group in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Protoperidinium* Berg *emend.* Balech, 1974

(= *Peridinium* Ehrenberg, 1831 *partim.*,

= *Minuscula* Lebour 1925)

Species: *conicum*

Scientific name: *Protoperidinium conicum* (Gran) Balech

Plate A123: a-h; 124: a-f (Annex A)

Synonyms:

Peridinium conicum Gran; *Peridinium divergens* var. *conica* Gran; *Protoperidinium leonis* (Pavillard) Balech.

References:

Lebour, 1925: p. 111, Pl. XIX: 1 a-d (as *Peridinium conicum*); Wood, 1968: p. 99, Fig. 292 (as *Peridinium conicum*); Taylor, 1976: p. 139, Pl. 33: 361, 362 (as *Peridinium conicum*); Dodge, 1982: p. 186, Fig. 21 G, H; Dodge, 1985: p. 47; Balech, 1988: p. 248, L. 26: 1-4; Konovalova, 1998: p. 217, Fig. 49: 2a, 2b, 3a, 3b, 4; Throndsen *et al.*, 2007: p. 97.

Description:

Cell nearly symmetrical and square when seen in dorsal view; flattened dorsoventrally. Epitheca triangular in dorsal view with ortho-hexa plate arrangement. The sutures between the apical plates and precingulars 1-2, 2-3, 5-6 and 6-7 are characteristically raised and radial. This is in contrast to the zigzag arrangement in *P. leonis*. The deep sulcus divides the posterior end of the hypotheca into two hollow horns. Girdle excavated, bordered by narrow lists supported by spines. Theca finely reticulated and intercalary striae, when present, may be wide. Cell contents pink. Size: length 70-85 μm , breadth c. 60 μm (Dodge, 1982).

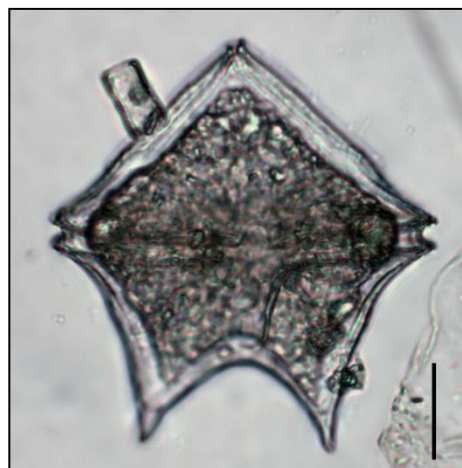
Taxonomic Remarks:

Protoperidinium conicum is variable in shape and size. Some authors divide this species into a few varieties (Konovalova, 1998).

Protoperidinium conicum (Gran) Balech var. *conicum*

Plate A123: a-h (Annex A)

Characterized by symmetrical cell shape in ventral view. Epitheca is conical, with straight sides. Hypotheca with straight or slightly concave sides, ending with two equal spines at the antapex. 1' is large, wide and symmetrical, square or wide-rhombic.



Protoperidinium conicum (Gran) Balech var. *concavum*

Plate A124: b, c, e, f (Annex A)

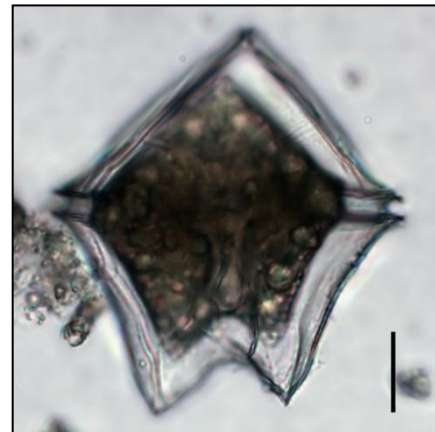
Matzenauer has epitheca with concave sides; hypotheca with strong concave sides and deep notched antapex



Protoperidinium conicum (Gran) Balech var. *quardafuianum*

Plate A124: a, d (Annex A)

Matzenauer has oblong cell shape, epitheca with straight or convex/concave sides; hypotheca with concave sides, ending with two unequal horns, right horn is larger and longer than left horn



Dimensions:

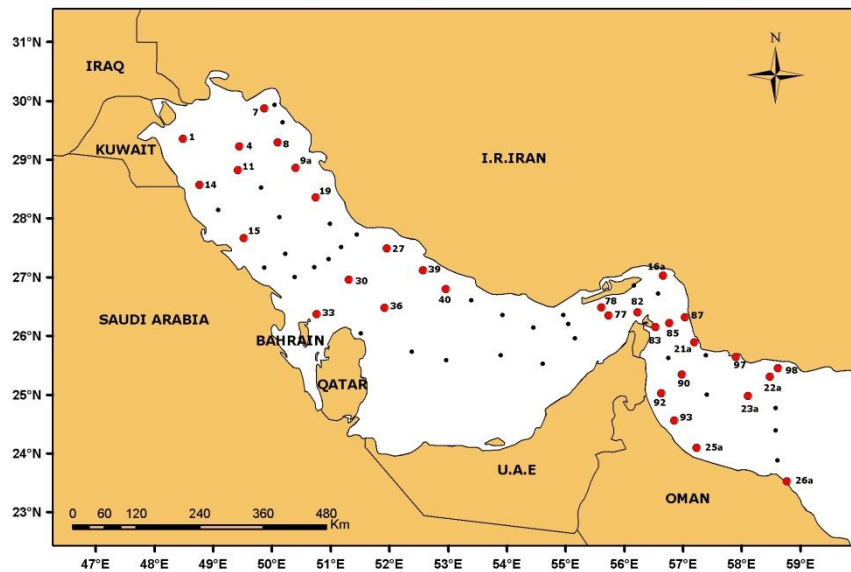
Cells 69-102 μm long; 64-84 μm wide.

Distribution:

Coastal and oceanic; cosmopolitan in temperate to tropical waters. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at certain sporadic sites (refer sites map) , never in large numbers; maximum abundance (2.4×10^2 cells/l) was associated with the Sea of Oman (St. 90). Species has previously been reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Protoperedinium conicum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Protoperedinium* Berg *emend.* Balech, 1974

(= *Peridinium* Ehrenberg, 1831 *partim.*,

= *Minuscula* Lebour 1925)

Species: *curtipes*

Scientific name: *Protoperedinium curtipes* (Jørgensen) Balech

Plate A125: a-l (Annex A)

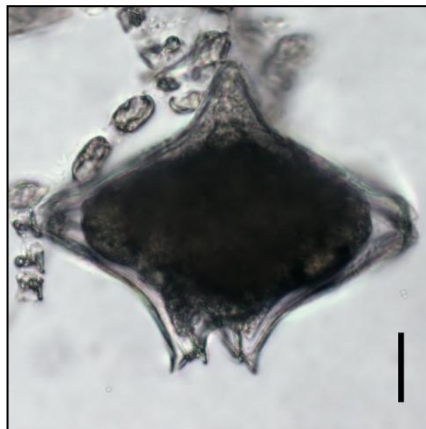
Synonym: *Peridinium curtipes* Jørgensen

References:

Taylor, 1976: p. 148, Fig. 4 E; Pl. 31: 322, 323 (as *Peridinium curtipes*); Dodge, 1982: p. 192, Figs. 22 E-G; Pl. IV: a; Throndsen *et al.*, 2007: p. 103.

Description:

Cell of slightly greater breadth than length, not dorsoventrally flattened. Walls of epitheca and hypotheca, markedly concave. Thecal plates metaquadra and strongly reticulated with spines at the junction of the reticulations. Broad intercalary striae frequent; hypotheca ending in two hollow horns which characteristically bears projections inside, which are continuations of sulcal lists and end in spines. Girdle not displaced, deeply excavated and bordered by lists supported by spines. Cell contents yellow, not pink as in *P. crassipes*. Size: length 80-100 μm ; breadth 67-100 μm (Dodge, 1982).

**Harmful Effect:**

It is a probable toxin producer (azaspiracid, which gives DSP-like symptoms in humans) (Thronsdon *et al.*, 2007).

Dimensions:

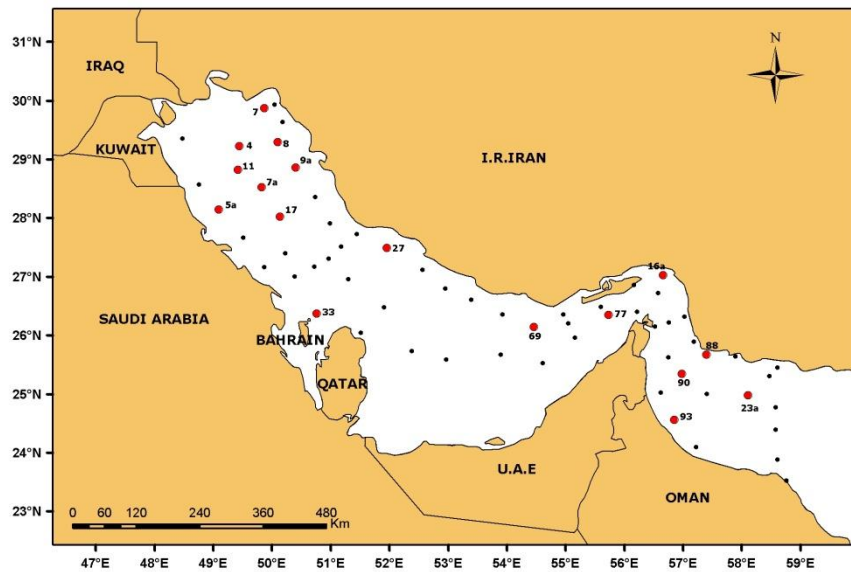
Cells 85-93 μm long; 97-111 μm wide.

Distribution:

Oceanic species. It has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at certain sporadic sites (refer sites map), never in large numbers; maximum abundance (48 cells/l) was associated with the northwestern part of the inner RSA (St. 8). Species has previously been reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Protoperidinium curtipes* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Protoperidinium* Berg *emend.* Balech, 1974

(= *Peridinium* Ehrenberg, 1831 *partim.*,

= *Minuscula* Lebour 1925)

Species: *curvipes*

Scientific name: *Protoperidinium curvipes* (Ostenfeld) Balech

Plate A126: a-i (Annex A)

Synonym:

Peridinium curvipes Ostenfeld

References:

Dodge, 1982: p. 199, Fig. 22 L, M.

Description:

Cell roundish-oval with short apical horn and one spine plus a curved wing at antapex. Epitheca conical with a para-quadra plate arrangement which may be variable. The sulcus does not widen markedly toward the antapex and the margins end in a spine. The left spine is larger with a well-developed, characteristically curved wing. Girdle slightly right-handed; unexcavated; with lists supported by spines. Cell contents pale yellow. Theca finely reticulated. Plate formula typical for genus. Size: 44-55 µm long (Dodge, 1982).

**Dimensions:**

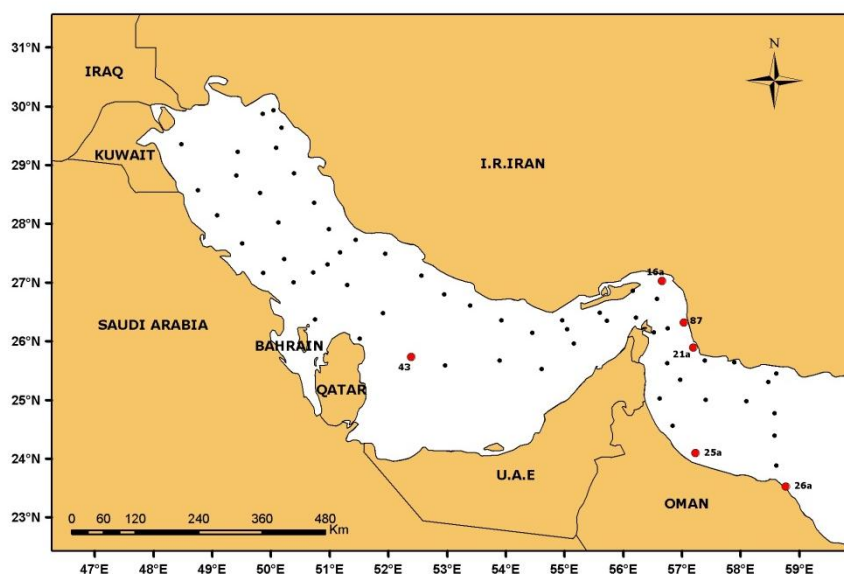
Cells 40-42 µm long; 40-42 µm wide.

Distribution:

Cosmopolitan in temperate to tropical waters.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at few sites (refer sites map) and never in large numbers; maximum abundance (3.1×10^2 cells/l) was associated with the Sea of Oman (St. 25a).



Sites of occurrence of *Protoperidinium curvipes* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Protoperidinium* Berg *emend.* Balech, 1974

(= *Peridinium* Ehrenberg, 1831 *partim.*,

= *Minuscula* Lebour 1925)

Species: *denticulatum*

Scientific name: *Protoperidinium denticulatum* (Gran *et* Braarud) Balech

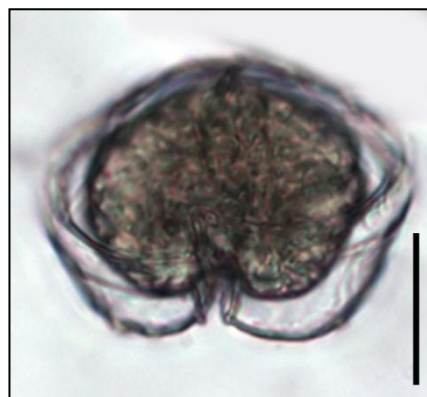
Plate A127: a-i (Annex A)

Synonyms:

Peridinium denticulatum Gran *et* Braarud; *Peridinium clavis* Abé.

References:

Dodge, 1982: p. 173, Fig. 19 A, B; Throndsen *et al.*, 2007: p. 105.

**Description:**

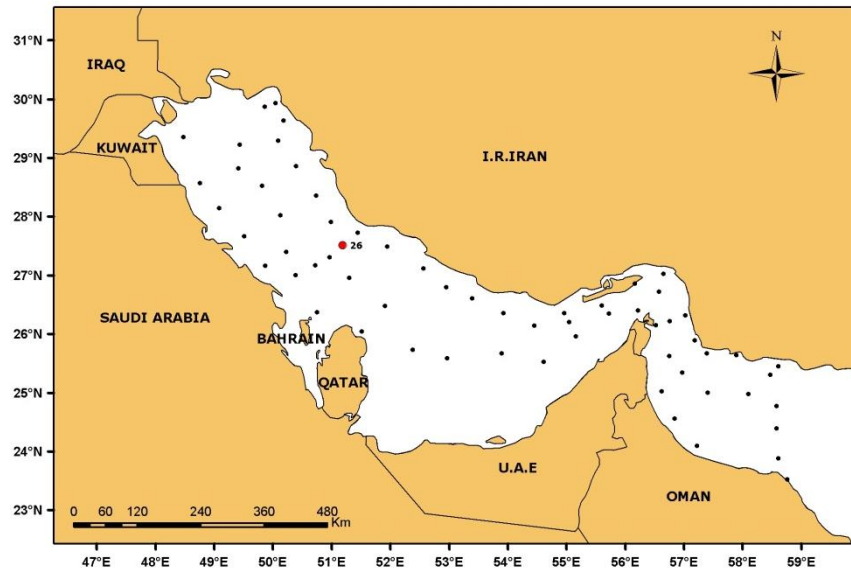
This species has a characteristic shape. The epitheca is conical with a wide base and almost straight sides. There is a distinctive slit-like groove at the apex with the apical pore at the ventral end. The species belongs to Jorgensen's *Archaeoperidinium* group having only two anterior intercalary of this flat area. The girdle is excavated with narrow lists supported by conspicuous ribs. It is left-handed, displaced about one girdle width. The sulcus is deep. Cells can be seen in pairs attached by their hypothecae. Plate formula: 4', 2a, 7'', 5''', 2'''. Size: length 32-43 μm ; breadth 43-76 μm (Dodge, 1982).

Dimensions:

Cells 35-39 μm long; 50-52 μm wide.

Sites of occurrence in RSA:

In Winter 2006 Cruise, a single specimen was found in samples from the northwestern part of the inner RSA (St. 26) (refer site map).



Site of occurrence of *Protoperidinium denticulatum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Protoperidinium* Berg *emend.* Balech, 1974

(= *Peridinium* Ehrenberg, 1831 *partim.*,

= *Minuscula* Lebour 1925)

Species: *depressum*

Scientific name: *Protoperidinium depressum* (Bailey) Balech

Plate A128: a-h (Annex A)

Synonyms:

Peridinium depressum Bailey; *Peridinium claudicanoides* Graham

References:

Lebour, 1925: p. 119, Pl. XXIII: a-f (as *Peridinium depressum*); Wood, 1968: p. 100, Fig. 295 a, b (as *Peridinium depressum*); Taylor, 1976: p. 160, Pl. 34: 383; Pl. 45: 526 (as *Peridinium depressum*); Dodge, 1982: p. 177, Fig. 20 A; Pl. V: e; Dodge, 1985: p. 50; Balech, 1988: p. 247, L. 25: 4-8; Throndsen *et al.*, 2007: p. 96.

Description:

Cell flattened obliquely in a dorsoventral plane. Prominent apical horn and two long, hollow antapical horns, present. Ortho- quadra plate arrangement. Theca reticulated. The antapical horns each has an internal projection which is a continuation of the sulcal list. The sulcus is deeply excavated. Girdle left-handed, unexcavated, bordered by wide lists supported by spines. Intercalary striae when present may be broad. Sides of the theca concave toward apex and antapex and convex near the girdle. Cell contents pink. A luminescent species. Size: 116-200 μm long, 116-144 μm wide (Dodge, 1982).

**Dimensions:**

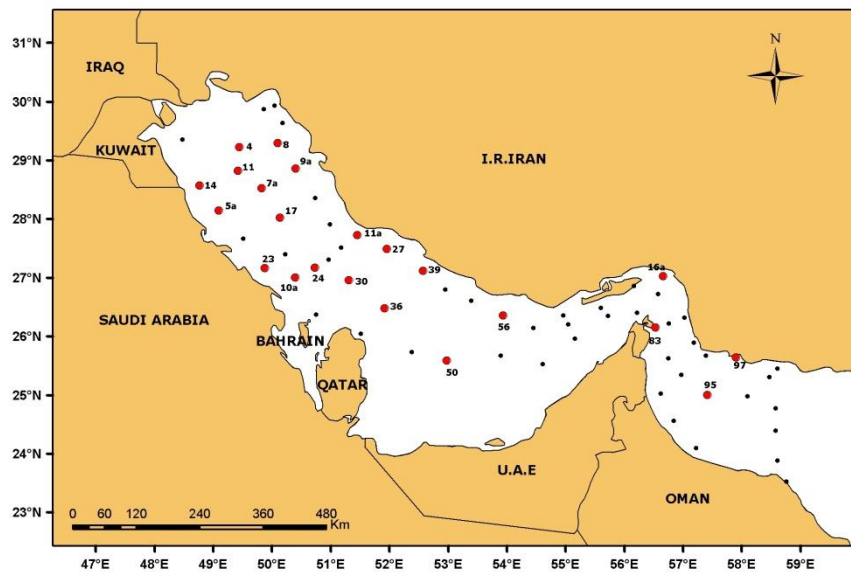
Cells 150-163 μm long; 145-152 μm wide.

Distribution:

Coastal and oceanic; even forms blooms in warm water estuaries; temperate to tropical waters; cosmopolitan species. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at certain sporadic sites (refer sites map), never in large numbers; maximum abundance (79 cells/l) was associated with the northwestern part of the inner RSA off the Kuwaiti (St. 14). Species has previously been reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Protoperidinium depressum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Protoperidinium* Berg *emend.* Balech, 1974

(= *Peridinium* Ehrenberg, 1831 *partim.*,

= *Minuscula* Lebour 1925)

Species: *divergens*

Scientific name: *Protoperidinium divergens* (Ehrenberg) Balech

Plate A129: a-j (Annex A)

Synonym:

Peridinium divergens Ehrenberg

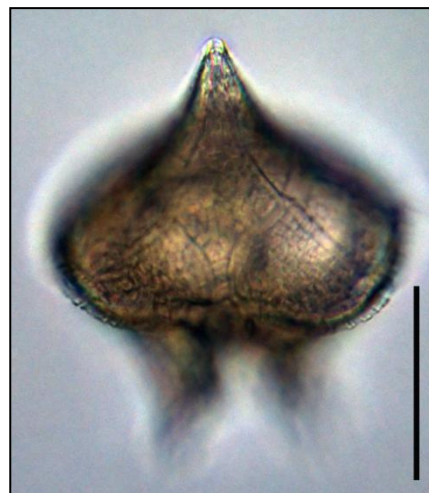
References:

Lebour, 1925: p. 127, Pl. XXVI: 2 a-e (as *Peridinium divergens*); Wood, 1968: p. 101, Fig. 298 (as *Peridinium divergens*); Taylor, 1976: p. 148, Fig. 4 a, b; Pl. 31: 319, 320, 324; Pl. 46:

530 (as *Peridinium divergens*); Dodge, 1982: p. 193, Fig. 22 D; Dodge, 1985: p. 52; Balech, 1988: p. 263, L. 41: 11-13; 42: 1.

Description:

Cell longer than broad with concave sides to both epitheca and hypotheca. Prominent apical horn and two diverging hollow antapical horns. Meta-quadra plate arrangement. Sulcus widening slightly, posteriorly, bordered by lists which project antapically appearing as spines on the inside of the antapical horns. Girdle excavated with lists supported by spines, not offset. Theca strongly reticulated with spines at the junctions of the reticulations. Intercalary striae broad. Cell contents pink.



Cells emitted bright luminescence when stimulated. Size: length 80-84 μm , breadth 56 μm (Dodge, 1982).

Harmful Effect:

It is a probable toxin producer (azaspiracid, which gives DSP-like symptoms in humans) (Thronsdon *et al.*, 2007).

Dimensions:

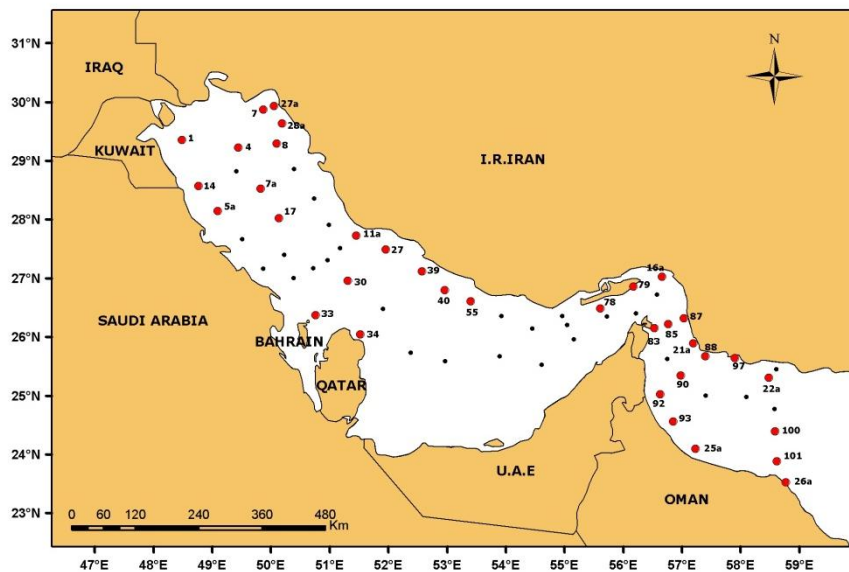
Cells 76-88 μm long; 62-76 μm wide.

Distribution:

Principally coastal; temperate to tropical waters; cosmopolitan species. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was frequently observed at various sites (refer sites map), although never in large numbers; maximum abundance (1.3×10^2 cells/l) was associated with the central part of the inner RSA off Bahrain (St. 33). Species has previously been reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Protoperidinium divergens* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Protoperidinium* Berg *emend.* Balech, 1974

(= *Peridinium* Ehrenberg, 1831 *partim.*,

= *Minuscula* Lebour 1925)

Species: *globulus*

Scientific name: *Protoperidinium globulus* (Stein) Balech

Plate A130: a-i (Annex A)

Synonym:

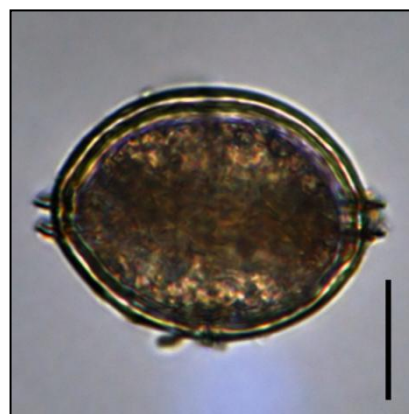
Peridinium globulus Stein

References:

Lebour, 1925: p. 129, Fig. 40 (as *Peridinium globulus*); Taylor, 1976: p. 155, Pl. 29: 301 a-d (as *Peridinium globulus*); Dodge, 1982: p. 194, Fig. 22 A.

Description:

Cell spherical or globular, compressed anterior-posteriorly; apical horn in the form of small knob; no other body projections except girdle lists. Meta-quadra or hexa plate arrangement with plates covered in pores. Intercalary striae broad. Girdle strongly right-handed, displaced approximately two girdle widths with slight overhand, not excavated but with lists supported by spines. Sulcus narrow, not reaching to center of hypotheca but extending onto epitheca. Theca finely reticulated. Size: length 50-79 μm (Dodge, 1982).

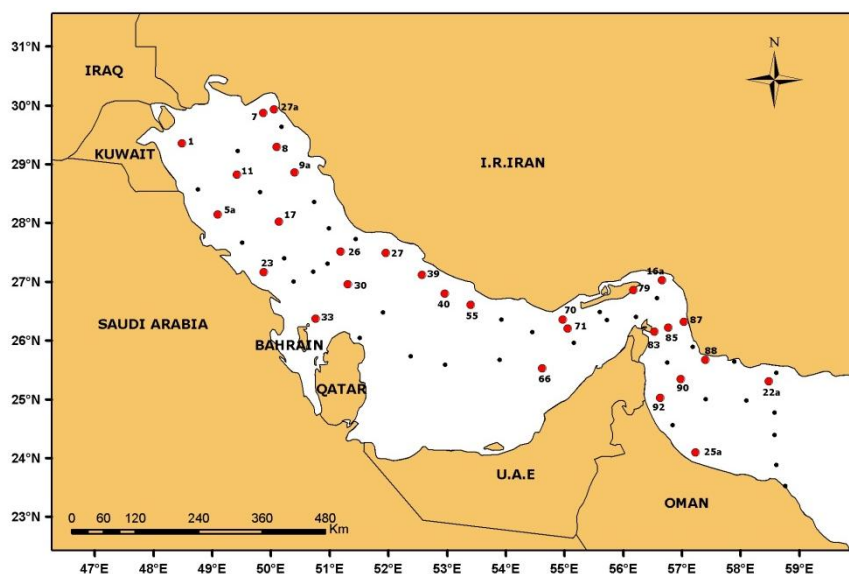
**Dimensions:**

Cells 45-52 μm long; 56-61 μm wide.

Distribution: Oceanic; warm temperate to tropical waters; worldwide distribution. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at various sites (refer sites map), never in large numbers; maximum abundance (1.7×10^2 cells/l) was associated with the Iranian coast in the central part of the inner RSA (St. 27).



Sites of occurrence of *Protoperidinium globulus* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Protoperidinium* Berg *emend.* Balech, 1974

(= *Peridinium* Ehrenberg, 1831 *partim.*,

= *Minuscula* Lebour 1925)

Species: *hamatum*

Scientific name: *Protoperidinium hamatum* Balech

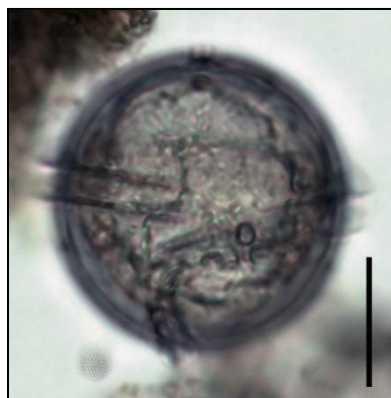
Plate A132: a-l (Annex A)

Reference:

Balech, 1988: L. 45: 9-13

Description:

Cell spherical or globular; apical horn in form of small knob; no other body projections except girdle lists. Meta-hexa plate arrangement with plates covered in pores. Girdle strongly right-handed, displaced approximately two girdle widths with overhand.

**Dimensions:**

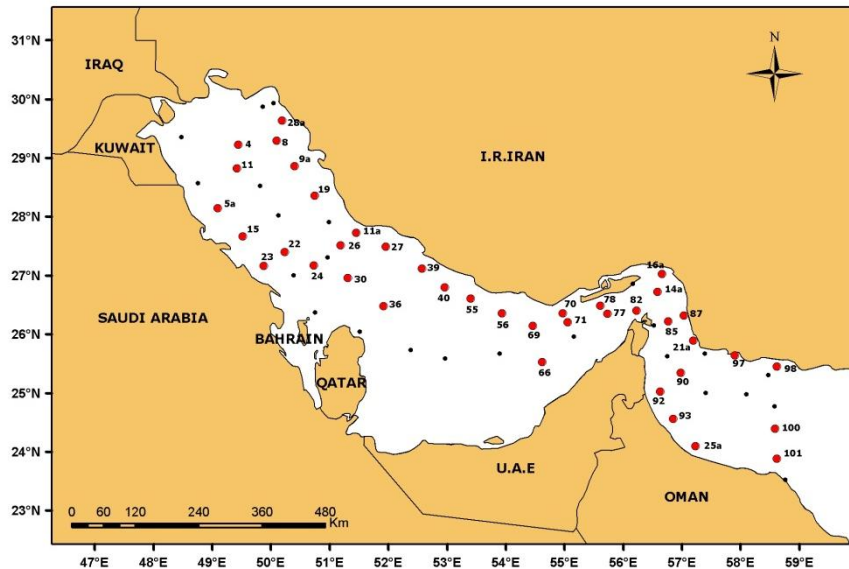
Cells 48-54 µm in diameter.

Distribution:

Species was described from South-West Atlantic area (Balech, 1988).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was present in small numbers at various scattered stations (refer sites map).



Sites of occurrence of *Protoperidinium hamatum*

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Protoperidinium* Berg *emend.* Balech, 1974

(= *Peridinium* Ehrenberg, 1831 *partim.*,

= *Minuscula* Lebour 1925)

Species: *latissimum*

Scientific name: *Protoperidinium latissimum*

Plate A133: e, f (Annex A)

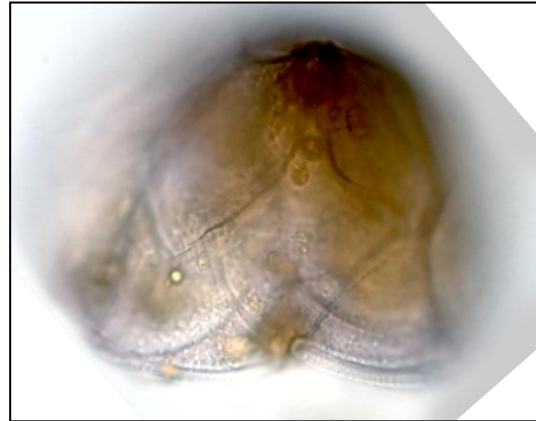
References:

Taylor, 1976: p. 140, Pl. 33: 360 (as *Peridinium latissimum*); Konovalova, 1998: p. 236, Figs. 53: 2a, b.

Description:

Cells dorsoventrally flattened; pentagonal in ventral view; 73-112 μm long; 82-95 μm wide. Epitheca wide-conical, with almost straight sides and slightly prominent apex. Hypotheca

with strongly concave sides, deeply notched, ending with two wide and short horns with sharp ends. Sulcus is wide, not reaching antapex. Plates 1' and 2a correspond to parahexa, but the sutures between these plates and precingular plates, too short due to 1' and 2a are seen often as ortho-quadra (Konovalova, 1998).



Dimensions:

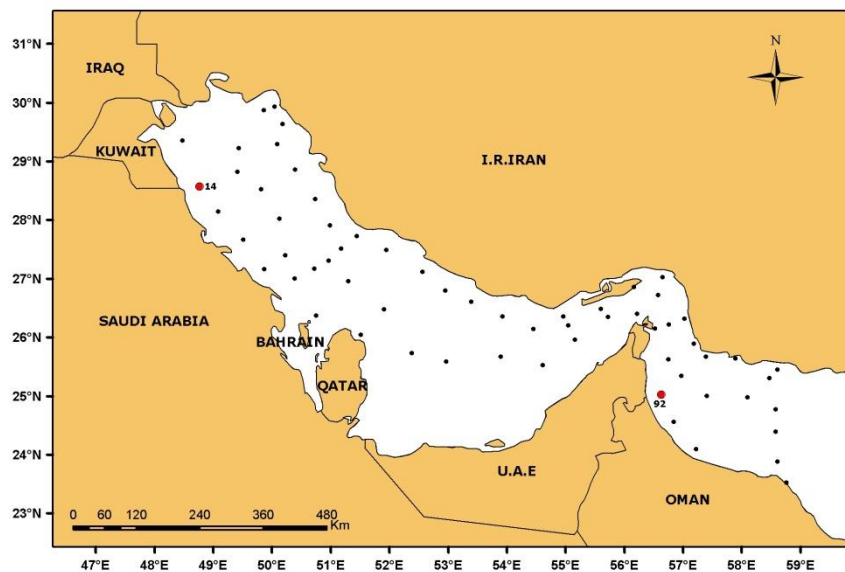
Cells 60-74 μm long; 80-88 μm wide.

Distribution:

Oceanic and neritic, Pacific and Atlantic oceans. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was present in small numbers at scattered stations (refer sites map).



Sites of occurrence of *Protoperidinium latissimum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Protoperidinium* Berg *emend.* Balech, 1974

(= *Peridinium* Ehrenberg, 1831 *partim.*,

= *Minuscula* Lebour 1925)

Species: *leonis*

Scientific name: *Protoperidinium leonis* (Pavillard) Balech

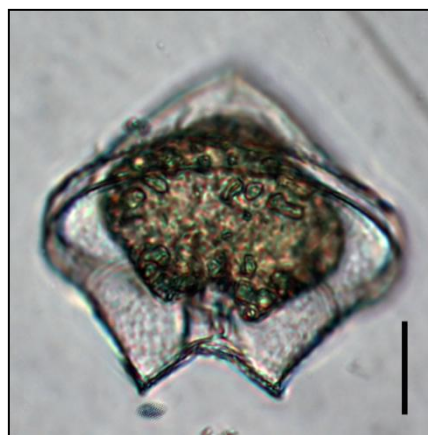
Plate A124: g-l (Annex A)

Synonym:

Peridinium leonis Pavillard

References:

Taylor, 1976: p. 141, Pl. 33: 369 (as *Peridinium leonis*); Dodge, 1982: p. 187, Fig. 21 D-F; Pl. V: d; Throndsen *et al.*, 2007: p. 98.



Description:

Cell slightly flattened dorsoventrally. Epitheca and hypotheca more or less straight-sided or slightly concave. Ortho-hexa plate arrangement, rarely a fourth intercalary plate may be present, but normally there are only three. Hypotheca ends in two hollow horns each, bearing a single solid spine. Sulcus deeply excavated, with small lists. Girdle excavated with lists supported by spines, circular or slightly left-handed. Theca with scattered pores, reticulated with fine spines at junctions of reticulations or may bear longitudinal ridges. Luminescence of this species has been observed. Size: length 53-95 μm ; breadth 53-95 μm (Dodge, 1982).

Dimensions:

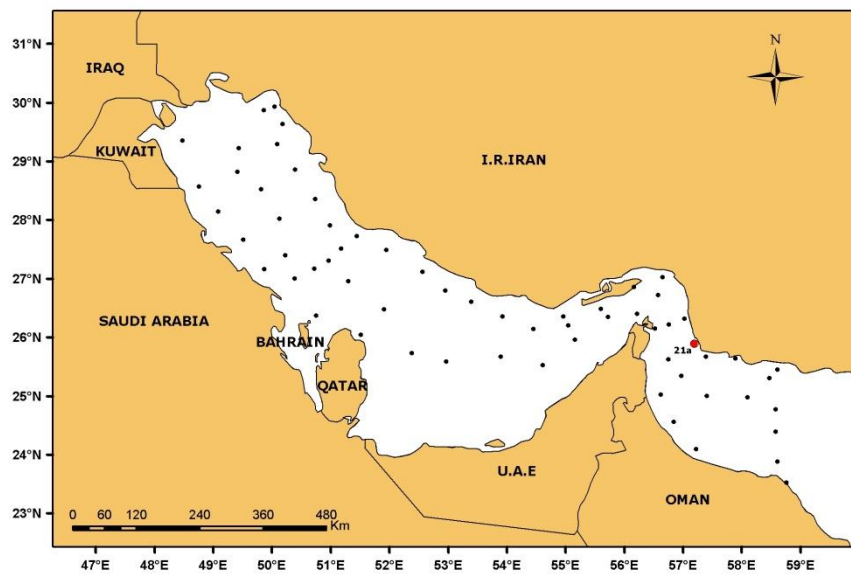
Cells 75 μm long; 80 μm wide.

Distribution:

Coastal and oceanic; temperate to tropical waters; worldwide distribution. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, a single specimen was found in a sample from the Sea of Oman (St. 21a) (refer site map). This species has previously been reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Site of occurrence of *Protoperidinium leonis* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Protoperidinium* Berg *emend.* Balech, 1974

(= *Peridinium* Ehrenberg, 1831 *partim.*,

= *Minuscula* Lebour 1925)

Species: *marielebourae*

Scientific name: *Protoperidinium mariebourae* (Paulsen) Balech

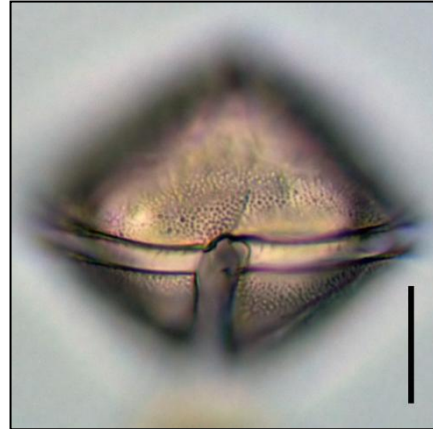
Plate A134: g-l (Annex A)

Synonyms:

Peridinium mariebouriae Paulsen; *Peridinium obtusum* (Karsten) Lebour; non *Peridinium obtusum* Karsten; non *Peridinium divergens obtusum* Karsten.

References:

Dodge, 1982: p. 178, Fig. 20 H-J; Throndsen *et al.*, 2007: p. 98.



Description:

Cell rhombic with two hollow horns at antapex. The cell is flattened dorsoventrally. The epitheca has straight to weakly-convex sides. It has a regular ortho first apical plate and quadra 2a. On the dorsal surface, the intercalary bands between the plates and the girdle are in a straight line; 2a, which is trapezoid, therefore it touches 1a, 4" and 3a. At the end of the hollow horns, there are small spines. The girdle is excavated and bordered by lists supported by ribs. The sulcus does not widen posteriorly. The cell surface is covered with small spines, although rarely, these are not present, and fine reticulation or punctation occurs. Size: length 48-75 μm , breadth 45-70 μm (Dodge, 1982).

Dimensions:

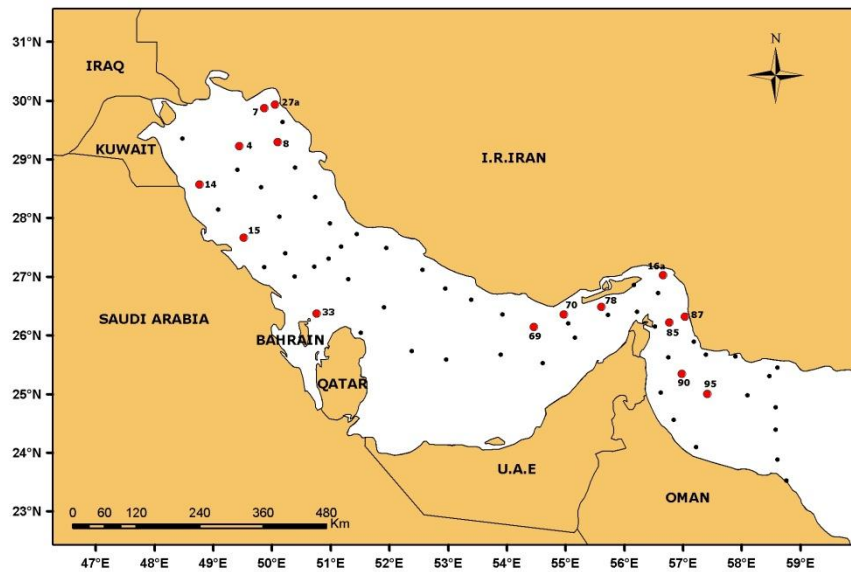
Cells 50-57 μm long; 64-67 μm wide.

Distribution:

Oceanic; temperate to tropical waters.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was present in small numbers at scattered stations (refer sites map). This species has been previously reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Protoperidinium marielebourae* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Protoperidinium* Berg *emend.* Balech, 1974

(= *Peridinium* Ehrenberg, 1831 *partim.*,

= *Minuscula* Lebour 1925)

Species: *mite*

Scientific name: *Protoperidinium mite* (Pavillard) Balech

Plate A135: a-l (Annex A)

Synonyms:

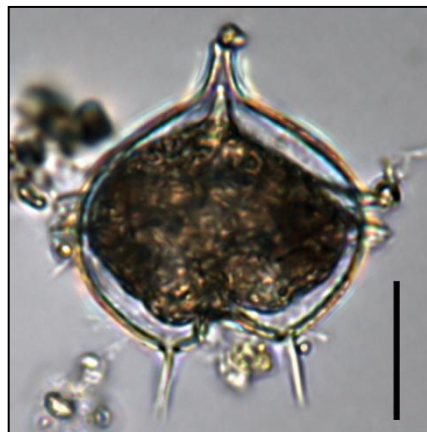
Peridinium mite Pavillard; *Peridinium granii* f. *mite* (Pavillard) Schiller

References:

Dodge, 1982: p. 198, Fig. 23 B.

Description:

Cell with rounded sides drawn out into an apical horn on the epitheca. Meta-penta plate arrangement; intercalary striae, narrow. Hypotheca broad posteriorly bearing two long, slender, diverging antapical spines situated at the edge of the base of the antapex where it meets the sides when seen in ventral view. The girdle is slightly right-handed, not excavated, with narrow lists supported by spines. Theca is covered with fine reticulations or scattered pores. Size: length 39-60 μm ; breadth 34-50 μm (Dodge, 1982).

**Dimensions:**

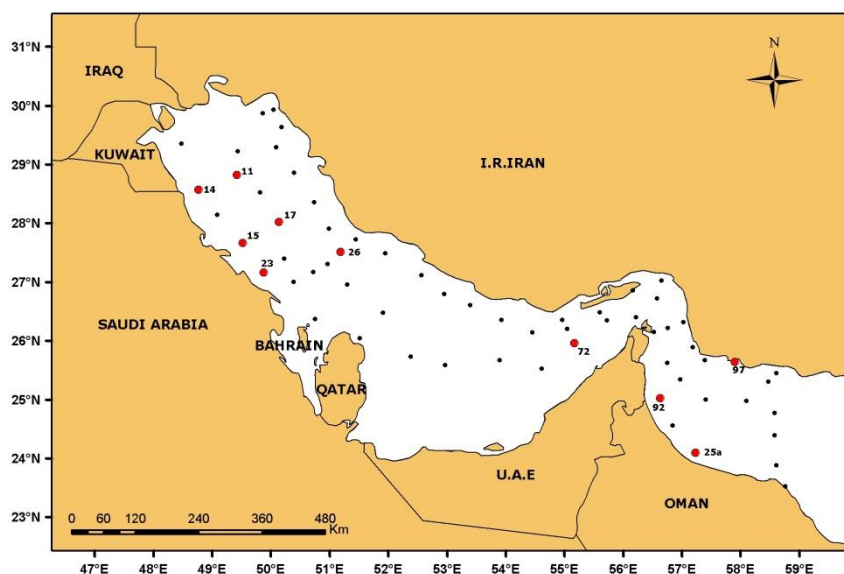
Cells 56 μm long; 41 μm wide.

Distribution:

Coastal and oceanic; temperate to tropical waters.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at scattered sites (refer sites map), never in large numbers; maximum abundance (3×10^2 cells/l) was associated with the Sea of Oman (St. 25a).



Sites of occurrence of *Protoperidinium mite* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Protoperidinium* Berg *emend.* Balech, 1974

(= *Peridinium* Ehrenberg, 1831 *partim.*,

= *Minuscula* Lebour 1925)

Species: *murrayi*

Scientific name: *Protoperidinium murrayi* (Kofoid) Hernandez-Becerril

Plate A136: a-f (Annex A)

Synonym:

Peridinium murrayi Kofoid

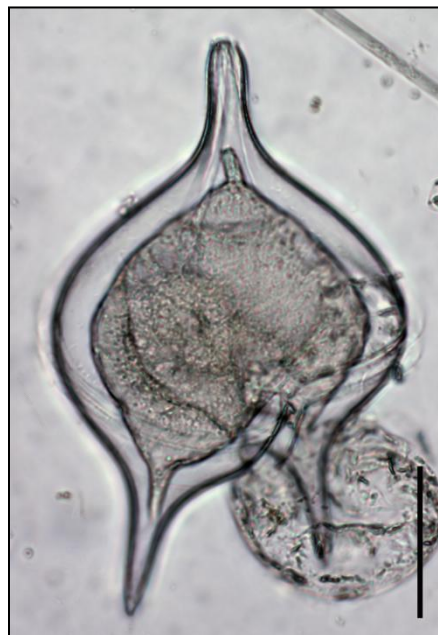
References:

Wood, 1968: p. 105, p. 312 (as *Peridinium murrayi*);

Taylor, 1976: p. 161, Pl. 34: 379, 380; Pl. 45: 522 a, b, 523 (as *Peridinium murrayi*).

Description:

Body small, rhomboidal; apical and antapical horns, long; the latter strongly diverging, with a deep hollow between. Length 150-200 μm (Wood, 1968). In lateral view, the cell is asymmetrical with the longitudinal axis and the antapical horns bent to the ventral direction. The cingulum is strongly inclined to the equatorial plane of the cell. The thecal plates are smooth; the 1'-plate is ortho, and the 2a-plate is quadra. The latter is difficult to observe due to the asymmetrical shape of the cell (Al-Kandari *et al.*, 2009).



Taxonomic Remarks:

P. murrayi is similar to *P. oceanicum* in size, but may be distinguished by the more slender apical and antapical horns. Taylor (1976) added that the girdle is the widest point of cells of *P. murrayi*, whereas in *P. oceanicum* the epitheca is as wide or wider. The angle of the girdle

and the antapical horns bent to the ventral direction may be used to distinguish *P. murrayi* from *P. oceanicum*.

P. murrayi and *P. oceanicum* have most probably been confused in the earlier literature, and Graham (1942) regarded the two species as synonymous. The diverging angle of the antapical horns which is sometimes larger in *P. murrayi* than of the *P. oceanicum* should not be used to differentiate the species, as this is a variable feature (Taylor, 1976; Al-Kandari *et al.*, 2009).

Dimensions:

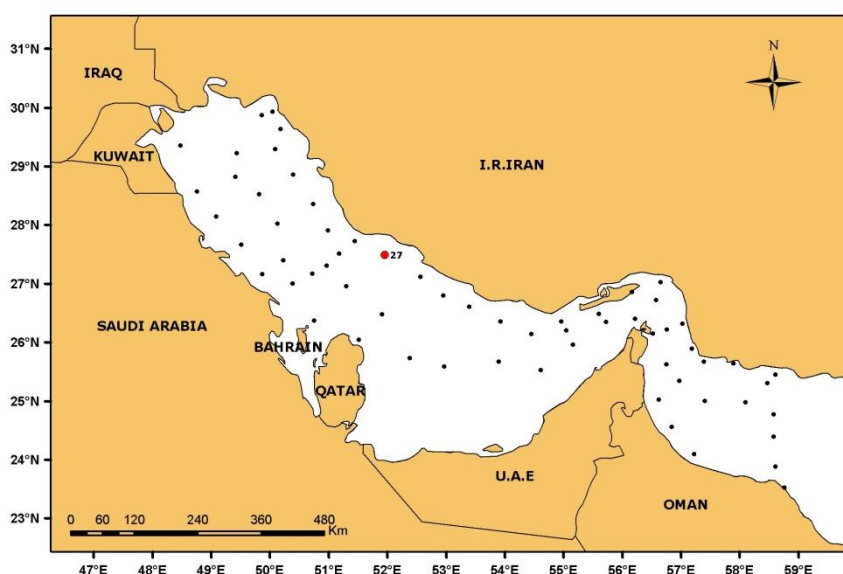
Cells 160-174 µm long; 85-88 µm wide.

Distribution:

Tropical interoceanic species. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was present in small numbers at one station (refer site map). This species has previously been reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Site of occurrence of *Protoperidinium murrayi* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Protoperidinium* Berg *emend.* Balech, 1974

(= *Peridinium* Ehrenberg, 1831 *partim.*,

= *Minuscula* Lebour 1925)

Species: *oblongum*

Scientific name: *Protoperidinium oblongum* (Aurivillius) Parke *et* Dodge

Plate A137: a-f (Annex A)

Synonyms:

Peridinium divergens Ehrenberg var. *oblongum*

Aurivillius; *Peridinium oceanicum* Vanhöffen var.

oblongum Aurivillius; *Peridinium oblongum* Lebour.

References:

Lebour, 1925: p. 121, Pl. XXIV: 1 a-c (as *Peridinium oblongum*); Dodge, 1982: p. 180, Fig. 20 B-D; Dodge, 1985: p. 58; Throndsen *et al.*, 2007: p. 96.



Description:

Cell compressed dorsoventrally, longer than broad in dorsoventral view with long apical horn and two long, subequal antapical horns. Ortho-quadra or hexa plate arrangement. Theca finely reticulated with pores. Sulcus deep and bordered by lists. Girdle not excavated, but bordered by narrow lists supported by spines. Intercalary striae when present may be very wide. Size: length 75-160 µm, breadth 60-65 µm (Dodge, 1982).

Dimensions:

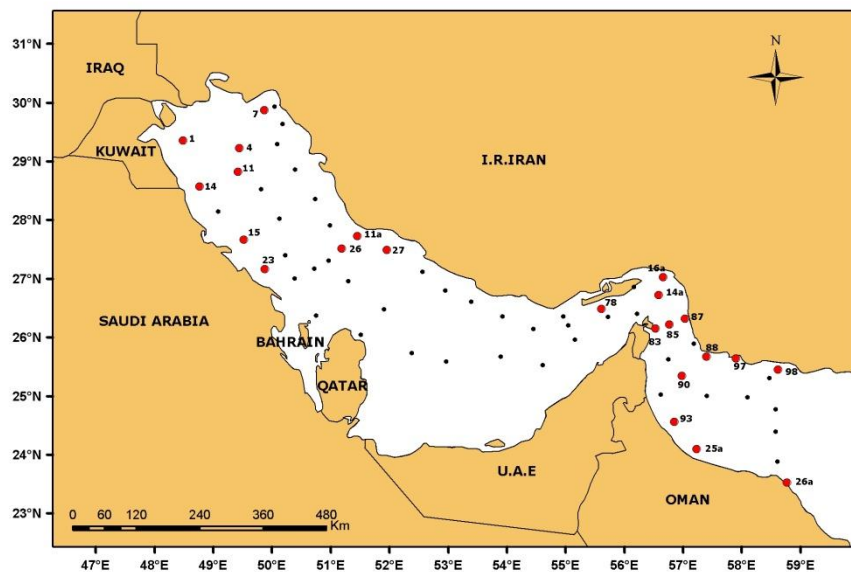
Cells 89-94 µm long; 56-59 µm wide.

Distribution:

Neritic, oceanic; cosmopolitan in cold temperate to tropical waters.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred at scattered sites (refer sites map) in small numbers.



Sites of occurrence of *Protoperidinium oblongum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Protoperidinium* Berg *emend.* Balech, 1974

(= *Peridinium* Ehrenberg, 1831 *partim.*,

= *Minuscula* Lebour 1925)

Species: *obtusum*

Scientific name: *Protoperidinium obtusum* (Karsten) Parke *et* Dodge

Plate A138: a-l (Annex A)

Synonyms:

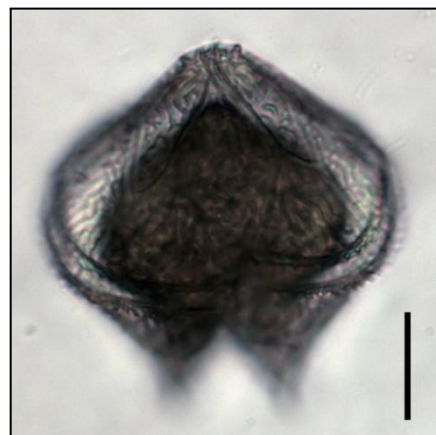
Peridinium obtusum Schiller; *P. divergens obtusum* Karsten

Reference:

Dodge, 1982: p. 187, Fig. 21 C.

Description:

This species has a blunt apex, a rounded dorsal surface and is dorsoventrally flattened. The first apical is ortho, but the upper (apical) triangle is much shorter than the lower (antapical), and the right is larger than the left one. The hexagonal second intercalary plate touches 3", 4", 5" as well as 1a and 3a. The hypotheca has two hollow antapical horns. The girdle is inclined, and the sulcus is straight-sided. An unusual thecal sculpturing has been noted for this species: the epitheca is covered by longitudinal striations, whereas the hypotheca is reticulated. The plasma is pinkish. Size: length 62 μm ; breadth 53 μm (Dodge, 1982).



Dimensions:

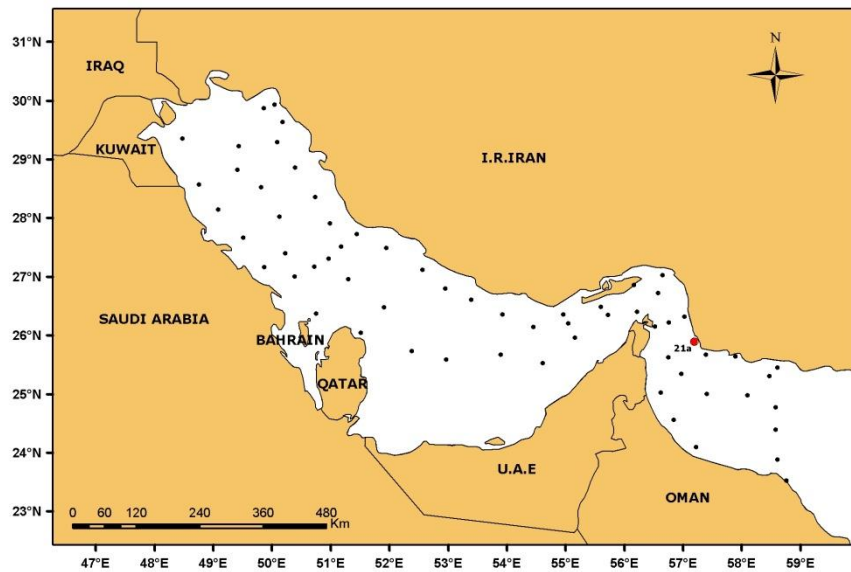
Cells 67 μm long; 64 μm wide.

Distribution:

Coastal and oceanic; cosmopolitan in temperate to tropical waters.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was present in small numbers at one station (refer site map).



Site of occurrence of *Protoperidinium obtusum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Protoperidinium* Berg *emend.* Balech, 1974

(= *Peridinium* Ehrenberg, 1831 *partim.*,

= *Minuscula* Lebour 1925)

Species: *oceanicum*

Scientific name: *Protoperidinium oceanicum* (Vanhöffen) Balech

Plate A137: g-i (Annex A)

Synonyms:

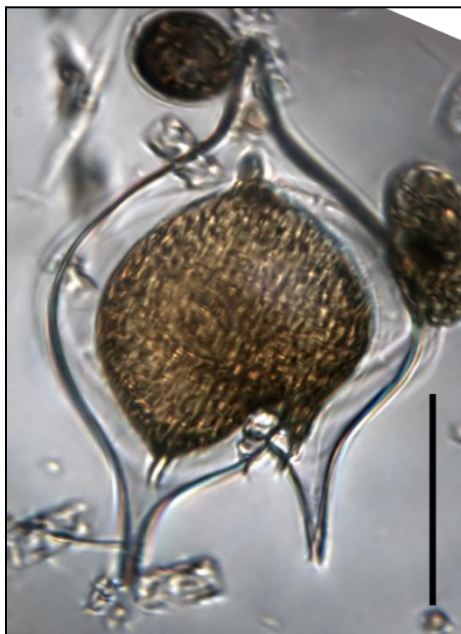
Peridinium divergens var. *oceanicum* Ostenfeld; *Peridinium oceanicum* Vanhöffen

References:

Lebour, 1925: p. 120, Fig. 36 b (as *Peridinium oceanicum*); Wood, 1968: p. 105, Fig. 313 (as *Peridinium oceanicum*); Taylor, 1976: p. 162, Pl. 34: 381, 382 (as *Peridinium oceanicum*); Dodge, 1982: p. 180, Fig. 20 E; Dodge, 1985: p. 60; Balech, 1988: p. 245, L. 23: 7-10; Throndsen *et al.*, 2007: p. 97.

Description:

Cell very long with long, narrow apical and antapical horns. Ortho quadra plate arrangement for 1' and 2a respectively. Theca punctate or reticulate. Girdle oblique, left-handed, not excavated, with lists supported by spines. Sulcus straight-sided and narrow. Size: 220-300 µm long, 150 µm wide (Dodge, 1982).

**Dimensions:**

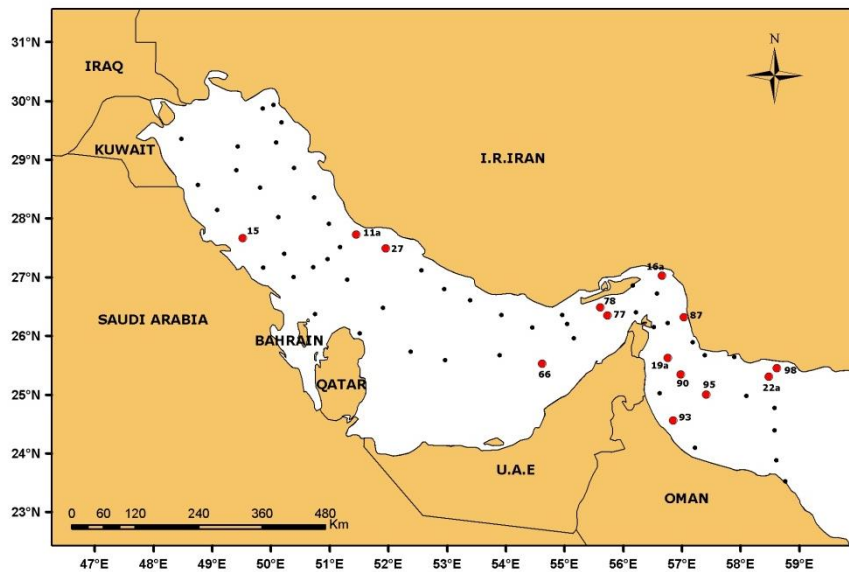
Cells 127-160 µm long; 87-95 µm wide.

Distribution:

Coastal and oceanic; cosmopolitan in temperate to tropical waters; uncommon in cold temperate waters. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at sporadic sites (refer sites map), never in large numbers; maximum abundance (52 cells/l) was associated with the Iranian coast in the northwestern part of the inner RSA (St. 11a).



Sites of occurrence of *Protoperidinium oceanicum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Protoperidinium* Berg *emend.* Balech, 1974

(= *Peridinium* Ehrenberg, 1831 *partim.*,

= *Minuscula* Lebour 1925)

Species: *ovatum*

Scientific name: *Protoperidinium ovatum* Pouchet

Plate 139: a-f (Annex A)

Synonyms:

Peridinium ovatum (Pouchet) Schütt; *Peridinium globulus* var. *ovatum* Schiller

References:

Dodge, 1982: p. 195, Fig. 2 H-J; Pl. IV: f; V: b; Throndsen *et al.*, 2007: p. 100.

Description:

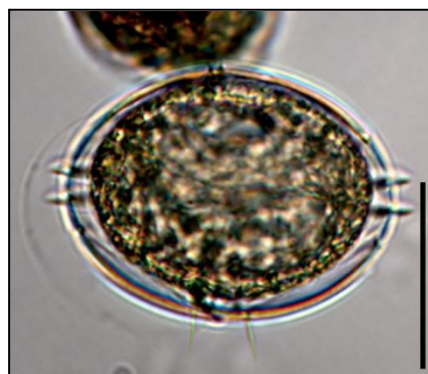
Cell lenticular, slightly flattened anterior-posteriorly; hypotheca ending with two solid spines. Meta-quadra (or sometimes penta) plates on the epitheca. There is a small apical horn. The girdle is offset; may or may not be excavated, with lists supported by spines. The hypotheca is rounded antapically, and bears two slightly diverging spines on either side of the sulcus, each with two wings. The sulcus is shallow. The thecal plates (and some of the sulcal plates) are sculptured with poroids or areolae and reticulations. Cell contents pink. Intercalary striae may be broad. Size: length 54-68 μm ; breadth 57-88 μm (Dodge, 1982).

Dimensions:

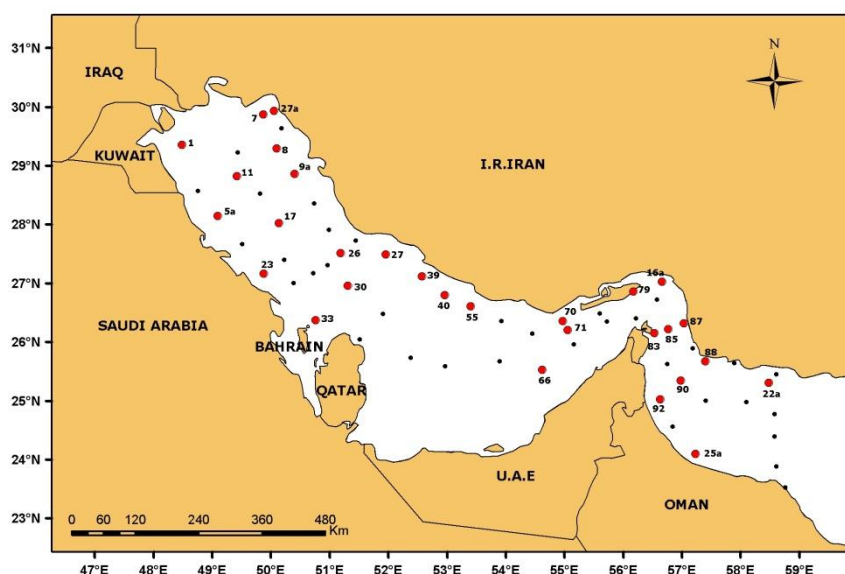
Cells 28-41 μm long; 38-46 μm wide.

Distribution:

Coastal and oceanic species.

**Sites of occurrence in RSA:**

In Winter 2006 Cruise, this species was present in small numbers at scattered stations (refer sites map). The species has been previously reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Protoperidinium ovatum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Protoperidinium* Berg *emend.* Balech, 1974

(= *Peridinium* Ehrenberg, 1831 *partim.*,

= *Minuscula* Lebour 1925)

Species: *ovum*

Scientific name: *Protoperidinium ovum* (Schiller) Balech

Plate A139: g-l; 140: a-i (Annex A)

Synonym:

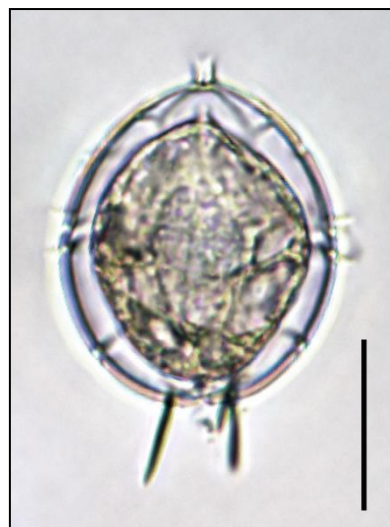
Peridinium ovum Schiller

References:

Wood, 1968: p. 106, Fig. 317 (as *Peridinium ovum*); Taylor, 1976: p. 165, Pl. 32: 350 (as *Peridinium ovum*); Balech, 1988: p. 273, L. 51: 9-12.

Description:

Cell oval, almost spherical with a short, affixed apical horn and two long winged or short unwinged antapical spines; girdle not depressed, lists supported by fine spines; sulcus, wide with lists, left list wide and attached to antapical spine; tabulation para-hexa. Length 40-50 μm (Wood, 1968).



Dimensions:

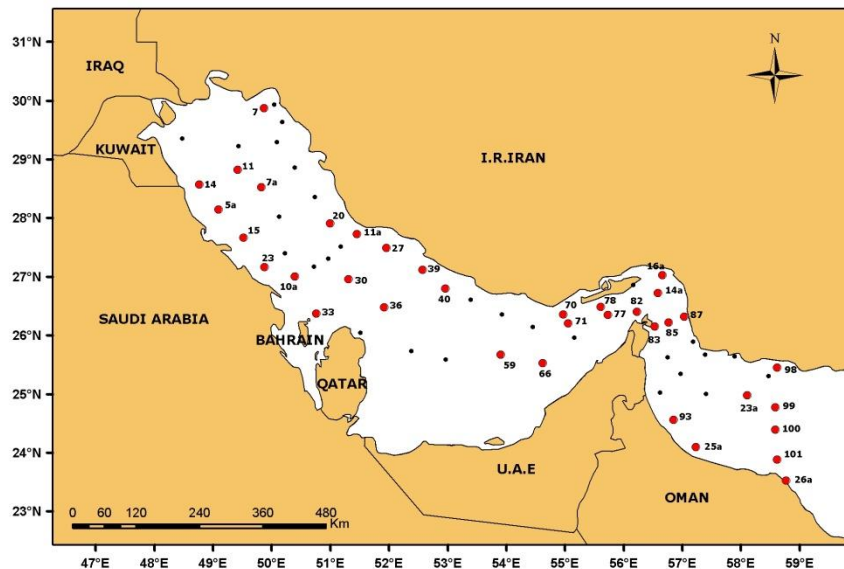
Total length 48-50 μm ; body 36-40 μm long; 31-33 μm wide.

Distribution:

Interoceanic species; tropical and subtropical waters. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at various sites (refer sites map), never in large numbers; maximum abundance (7.9×10^2 cells/l) was associated with the Iranian coast in the central part of the inner RSA (St. 27).



Sites of occurrence of *Protoperidinium ovum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Protoperidinium* Berg *emend.* Balech, 1974

(= *Peridinium* Ehrenberg, 1831 *partim.*,

= *Minuscula* Lebour 1925)

Species: *pellucidum*

Scientific name: *Protoperidinium pellucidum* (Schütt) Balech

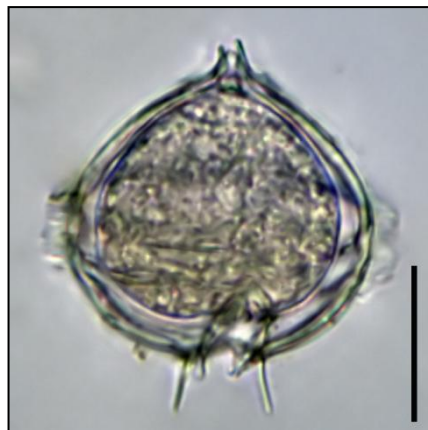
Plate A141: a-l (Annex A)

Synonym:

Peridinium pellucidum Schütt

References:

Lebour, 1925: p. 134, Pl. XXVIII: 2 a-d (as *Peridinium pellucidum*); Wood, 1968: p. 107, Fig. 320 (as *Peridinium pellucidum*); Dodge, 1982: p. 202, Fig. 23 J, K; Pl. V: c; Dodge, 1985: p. 62; Throndsen *et al.*, 2007: p. 103.

**Description:**

Cell slightly flattened dorsoventrally with rounded sides in ventral view. Para-hexa plate arrangement on epitheca. Short apical horn present. Hypotheca bears two antapical spines which may or may not have lists. When present, they are small. The left side of the sulcus bears an oblique list giving the appearance of a third spine. The girdle is slightly right-handed, excavated and bordered by lists supported by spines. Intercalary striae when present may be broad, and the surface is finely reticulated. The sulcus widens slightly, posteriorly. A large pusule is usually seen; chromatophores are absent, but the cell contents are pinkish, yellowish or colorless. Size: length 40-68 μm , breadth 36-70 μm (Dodge, 1982).

Dimensions:

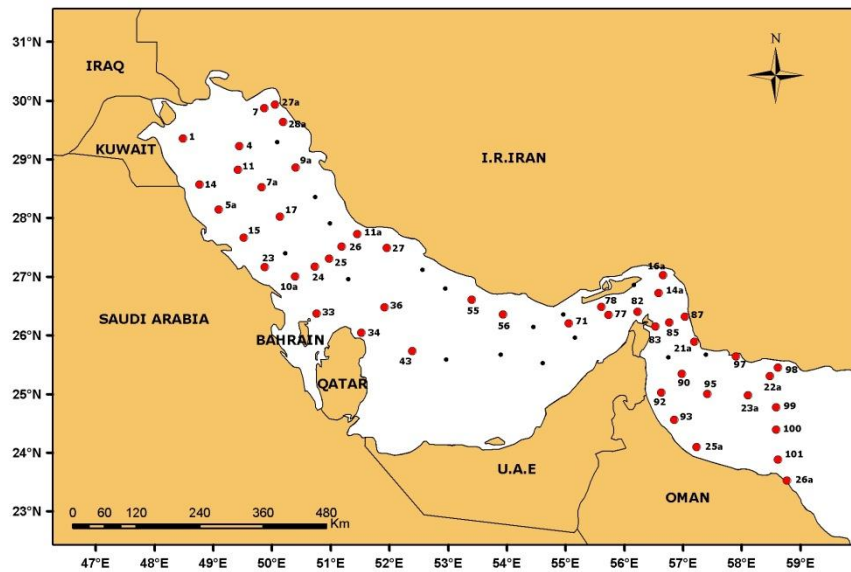
Total length 56-60 μm ; body 38-44 μm long; 40-45 μm wide.

Distribution:

Mainly coastal waters; cosmopolitan in temperate to tropical waters.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was frequently observed at various sites (refer sites map), although never in large numbers; maximum abundance (5.4×10^2 cells/l) was associated with the northwestern part of the inner RSA (St. 7). It has been previously reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Protoperidinium pellucidum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Protoperidinium* Berg *emend.* Balech, 1974

(= *Peridinium* Ehrenberg, 1831 *partim.*,

= *Minuscula* Lebour 1925)

Species: *pentagonum*

Scientific name: *Protoperidinium pentagonum* (Gran) Balech

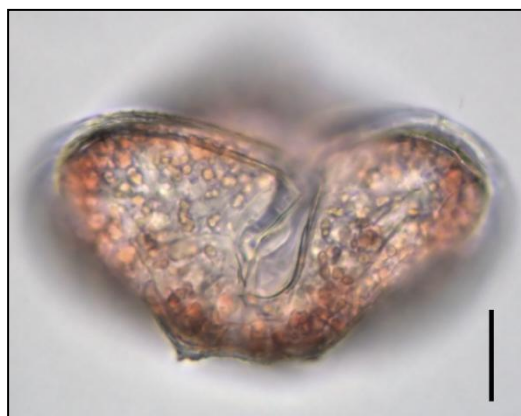
Plate A133: a-d (Annex A)

Synonyms:

Peridinium pentagonum Gran; *Peridinium sinuosum* Lemmermann; *Peridinium divergens pentagonum* Karsten; *Peridinium divergens* var. *sinuosum* Lemmermann.

References:

Lebour, 1925: p. 112, Pl. XX: 1 a-e (as *Peridinium pentagonum*); Wood, 1968: p. 107, Fig. 321 (as *Peridinium pentagonum*); Dodge, 1982: p. 188, Fig. 21 L-N; Dodge, 1985: p. 63; Balech, 1988: p. 249, L. 27: 1-6; Throndsen *et al.*, 2007: p. 98.

**Description:**

Cell pentagonal in dorsoventral view and concave ventrally. This species is characterized by the flattened antapex, the slightly displaced girdle, the short sulcus and the distinct ridges situated between the apex and the girdle, bordering plates 1', 2', 4', and 1'', 2'', 6'' and 7'' (the latter is a feature shared with *P. conicum*). The first apical plate is of ortho type; the second anterior intercalary plate is hexa, touching 3'', 4'' and 5''. There are two solid spines antapically. Usually, the girdle diameter is greater than the length of the cell. The girdle is excavated, bordered by lists and is left-handed. The nucleus is central and in the living cell the contents are pink. Plate formula: 4', 3a, 7'', 3c, 5''', 2'''. Size: length 75-110 μm , breadth 75-100 μm (Dodge, 1982).

Dimensions:

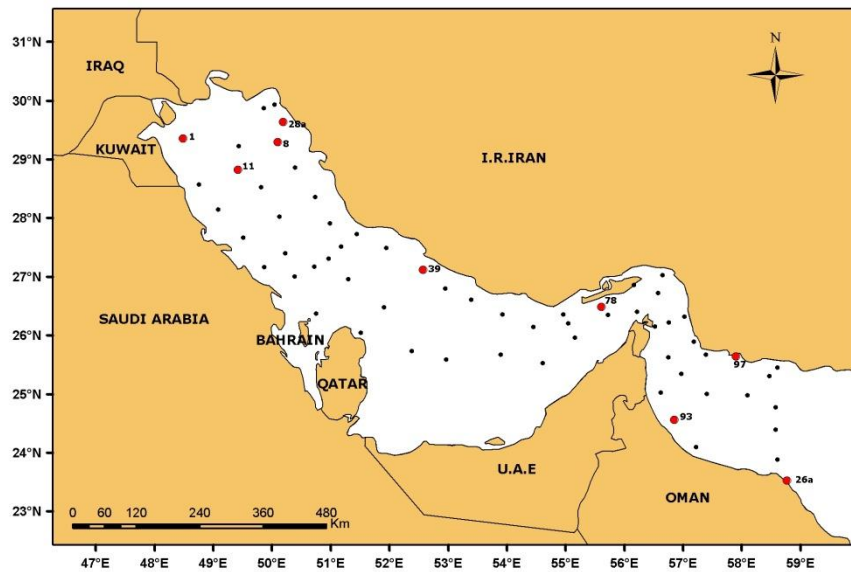
Cells 69-78 μm long; 100 μm wide.

Distribution:

Principally coastal, but found in estuarine environments; cosmopolitan in temperate to tropical waters.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was present in small numbers at scattered stations (refer sites map). This species has been previously reported from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Protoperidinium pentagonum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Protoperidinium* Berg *emend.* Balech, 1974

(= *Peridinium* Ehrenberg, 1831 *partim.*,

= *Minuscula* Lebour 1925)

Species: *punctulatum*

Scientific name: *Protoperidinium punctulatum* (Paulsen) Balech

Plate A142: a-l (Annex A)

Synonyms:

Peridinium punctulatum Paulsen; *Peridinium subinerme* Paulsen var. *punctulatum* (Paulsen) Schiller.

References:

Lebour, 1925: p. 123, Fig. 37 (as *Peridinium punctulatum*); Dodge, 1982: p. 183, Fig. 20 L, M; Dodge, 1985: p. 64; Balech, 1988: p. 252, L. 30: 1-5.

Description:

Shape of cell similar to *P. subinerme*, but the surface is punctate or spiny without reticulations, and there are no antapical spines at the sides of the sulcus. The cell has a straight or slightly convex-sided epitheca, when seen in dorsoventral view, forming a cone. The hypotheca has concave or straight sides with a flattened antapex. The girdle is equatorial, excavated, and has lists supported by spines. The sulcus is narrow (usually narrower than in *P. subinerme*) and reaches the center of the hypotheca. The first apical is ortho, and the species was thought by Lebour (1925) to belong to the section tabulata (i.e., 2a touches 4" and 5" or 3" and 4"). Plate formula: 4', 3a, 7", 3c, 5"', 2'''. Size: length 40-72 μm (Dodge, 1982).

**Dimensions:**

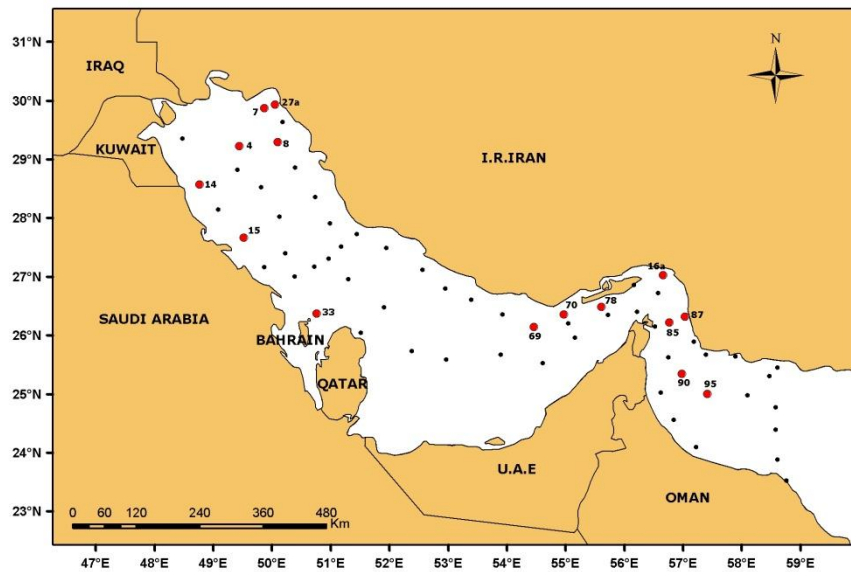
Cells 38-44 μm long; 40-45 μm wide.

Distribution:

Oceanic and neritic species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at scattered sites (refer sites map), never in large numbers; maximum abundance (70 cells/l) was associated with the southern part of the inner RSA (St. 69). It has been previously reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Protoperidinium punctulatum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Protoperidinium* Berg *emend.* Balech, 1974

(= *Peridinium* Ehrenberg, 1831 *partim.*,

= *Minuscula* Lebour 1925)

Species: *quarnerense*

Scientific name: *Protoperidinium quarnerense* (Schröder) Balech

Plate A143: a-i (Annex A)

Synonym:

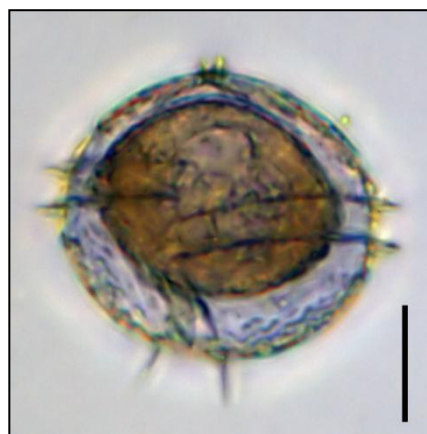
Peridinium quarnerense Schröder

References:

Balech, 1988: p. 112, L. 45: 6-8; Throndsen *et al.*, 2007: p. 101.

Description:

Cell almost spherical with bud-shaped apex and two slender antapical spines. Cingulum is displaced more than one cingulum width, slightly overhanging. Sulcus widens toward antapex, delimited antapically by the spines. Theca smooth to feebly reticulated; plates 1'-2a: meta-quadra. Cytoplasm pink. Length (diameter of cell body) 40-80 μm (Thronksen *et al.*, 2007).

**Dimensions:**

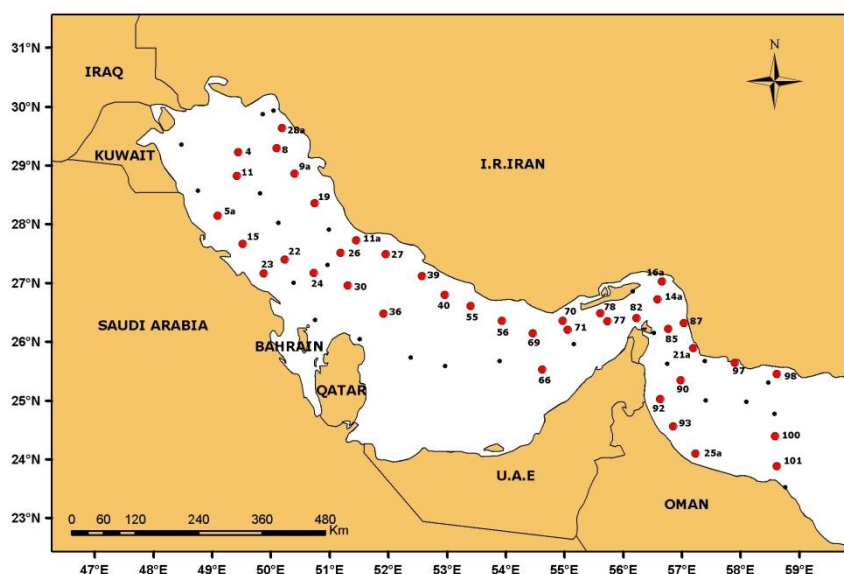
Cells 51-55 μm long; 55-57 μm wide.

Distribution:

Principally oceanic; cosmopolitan in warm temperate to tropical waters.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred frequently at various sites (refer sites map), usually in small numbers; however, it was quite abundant at some localities; maximum abundance (2.7×10^3 cells/l) was encountered off the Iranian coast in the northwestern part of the inner RSA (St. 11a). It has been previously reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Protoperidinium quarnerense*

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Protoperidinium* Berg *emend.* Balech, 1974

(= *Peridinium* Ehrenberg, 1831 *partim.*,

= *Minuscula* Lebour 1925)

Species: *steinii*

Scientific name: *Protoperidinium steinii* (Jørgensen) Balech

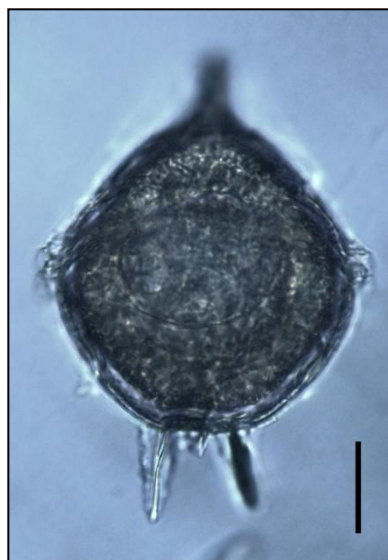
Plate A144: a-i (Annex A)

Synonyms:

Peridinium steinii Jørgensen; *Peridinium michaelis* Stein

References:

Lebour, 1925: p. 125, Pl. XXV: 4 a-d (as *Peridinium steinii*); Wood, 1968: p. 109, Fig. 329 (as *Peridinium steinii*); Taylor, 1976: p. 159, Pl. 32: 349 a, b (as *Peridinium steinii*); Dodge, 1982: p. 199, Fig. 23 C; Dodge, 1985: p. 65; Throndsen *et al.*, 2007: p. 101.

**Description:**

Cell pyriform with elongated apical horn and rounded hypotheca bearing two long three-winged spines; round in polar view. Epitheca with meta-penta plate arrangement. Girdle right-handed, not excavated, with prominent lists supported by spines. Chromatophores are absent; cell contents, colorless or pale pink or yellow. Intercalary striae usually broad. Species has been reported to be luminescent. Size: length including spines 39-60 µm; breadth 22-44 µm; length of spines 9-14 µm (Dodge, 1982).

Dimensions:

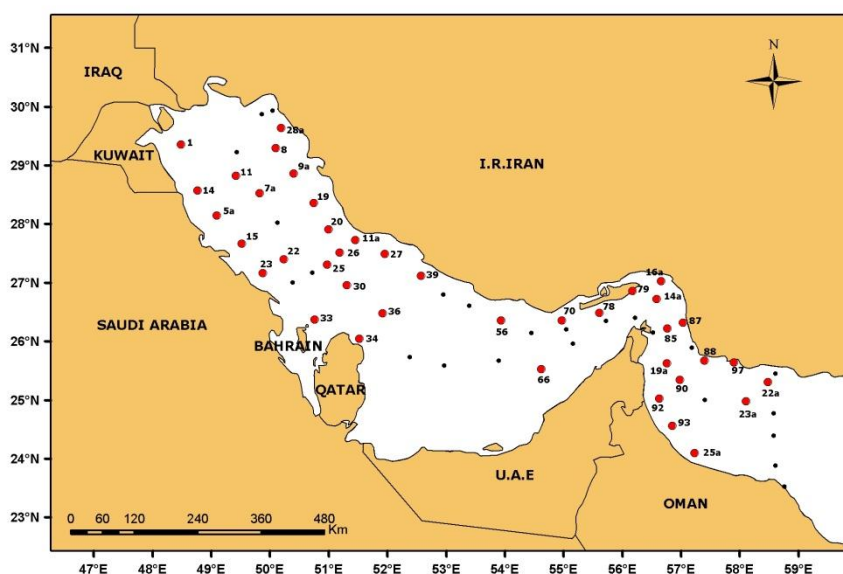
Total length 100-105 µm; body 66-71 µm long; 55-59 µm wide.

Distribution:

Coastal and open water; cosmopolitan in temperate to tropical waters. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at various sites (refer sites map), although never in large numbers; maximum abundance (1.8×10^2 cells/l) was associated with the waters off the Iranian coast in the northwestern part of the inner RSA (St. 11a). Species has previously been reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Protoperidinium steinii* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Protoperidinium* Berg *emend.* Balech, 1974

(= *Peridinium* Ehrenberg, 1831 *partim.*,

= *Minuscula* Lebour 1925)

Species: *subinermis*

Scientific name: *Protoperidinium subinerme* (Paulsen) Loeblich III

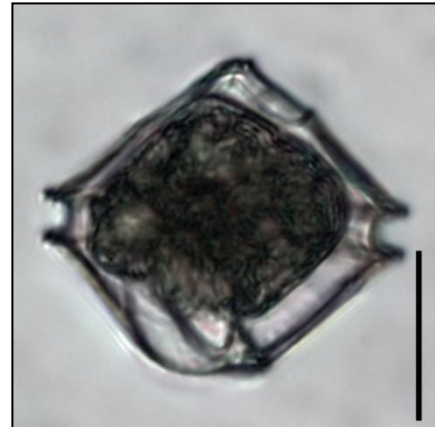
Plate A134: a-f (Annex A)

Synonyms:

Peridinium subinermis Paulsen; *Peridinium subinerme* Paulsen

References:

Lebour, 1925: p. 114, Pl. XXII: 2 a-f (as *Peridinium subinerme*); Wood, 1968: p. 109, Fig. 330 (as *Peridinium subinerme*); Taylor, 1976: p. 142, Pl. 33: 364, 367 a, b (as *Peridinium subinerme*); Dodge, 1982: p. 189, Fig. 21 I-K; Pl. V: f; Dodge, 1985: p. 66; Throndsen *et al.*, 2007: p. 99.



Description:

Dorsal view of cell approximately square with flat base to hypotheca; epitheca with slightly convex sides and hypotheca straight-sided in this view. Ortho, quadra-hexa plate arrangement. The girdle is equatorial or slightly right-handed, excavated and surrounded by lists supported by spines. The sulcus is deep, widening antapically and having small spines at its posterior margins. These spines may be missing. The theca is usually reticulated; intercalary striae when present may be broad. Bioluminescence has been reported. Size: length 50-75 μm , breadth 50-60 μm (Dodge, 1982).

Dimensions:

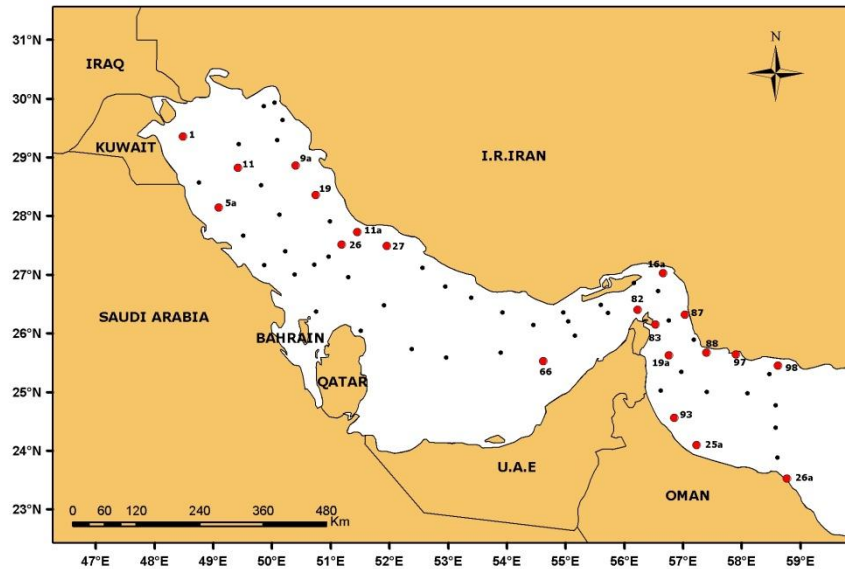
Cells 38-42 μm long; 37-40 μm wide.

Distribution:

Coastal and open water; cosmopolitan in temperate to tropical waters. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at scattered sites (refer sites map), never in large numbers; maximum abundance (2.8×10^2 cells/l) was associated with the Sea of Oman (St. 88). This species has previously been reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Protoperidinium subinerme* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Protoperidinium* Berg *emend.* Balech, 1974

(= *Peridinium* Ehrenberg, 1831 *partim.*,

= *Minuscula* Lebour 1925)

Species: *thorianum*

Scientific name: *Protoperidinium thorianum* (Paulsen) Balech

Plate A145: a-l (Annex A)

Synonym:

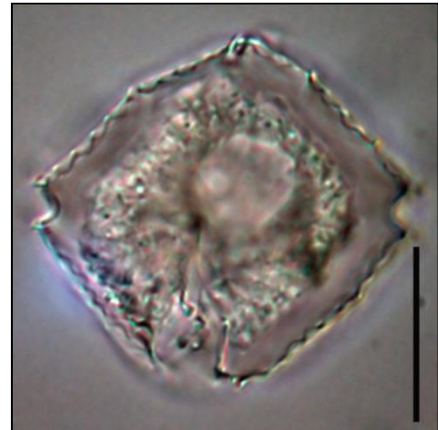
Peridinium thorianum Paulsen

References:

Dodge, 1982: p.176, Fig. 19 E; Throndsen *et al.*, 2007: p. 105.

Description:

Rounded cell is characterized by strong papillate or wavy thecal surface and presence of only two epithelial intercalary plates. In ventral view, the sides are rounded. The first apical plate is ortho with apical pore plate long, extending onto third apical plate. Sulcus is straight, narrow and not usually reaching to center of hypotheca; there may be short delicate spines at the bottom of the sulcus. Girdle is left-handed, striated, excavated and bordered by small lists not supported by spines. Cell contents yellow. Size: 56-85 μm long, 56-85 μm wide (Dodge, 1982).

**Dimensions:**

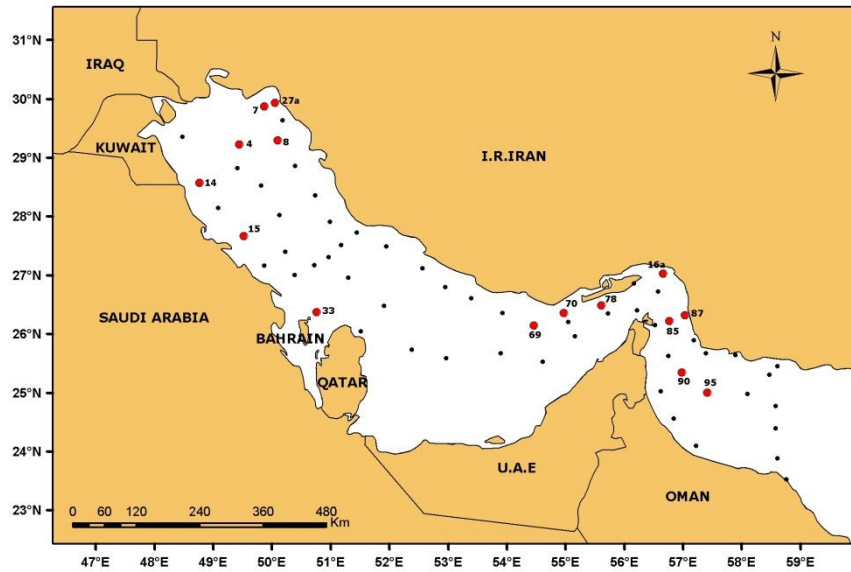
Cells 40-51 μm long; 40-49 μm wide.

Distribution:

Coastal and open water; cosmopolitan in cold temperate to tropical waters.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was present in small numbers at scattered stations (refer sites map). This species has been previously reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Protoperidinium thorianum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Protoperidinium* Berg *emend.* Balech, 1974

(= *Peridinium* Ehrenberg, 1831 *partim.*,

= *Minuscula* Lebour 1925)

Species: *venustum*

Scientific name: *Protoperidinium venustum* (Matzenauer) Balech

Plate A131: a-i (Annex A)

Synonym:

Peridinium venustum Matzenauer 1933

References:

Schiller, 1937: fig. 260; Balech, 1988: p. 86, Pl. 24: 1-4; Pl. 84: 13-16

Description:

Cell longer than broad with concave sides to both epitheca and hypotheca, flattened obliquely in a dorsoventral plane. Prominent apical horn and two long, hollow antapical horns present. Ortho-quadra plate arrangement. Theca reticulated. The antapical horns each have an internal projection which is a continuation of the sulcal list. The sulcus is deeply excavated. Girdle bordered by wide lists supported by spines. Cell contents pink.

**Dimensions:**

Cells 115-122 μm long; 74-77 μm wide.

Taxonomical Remarks:

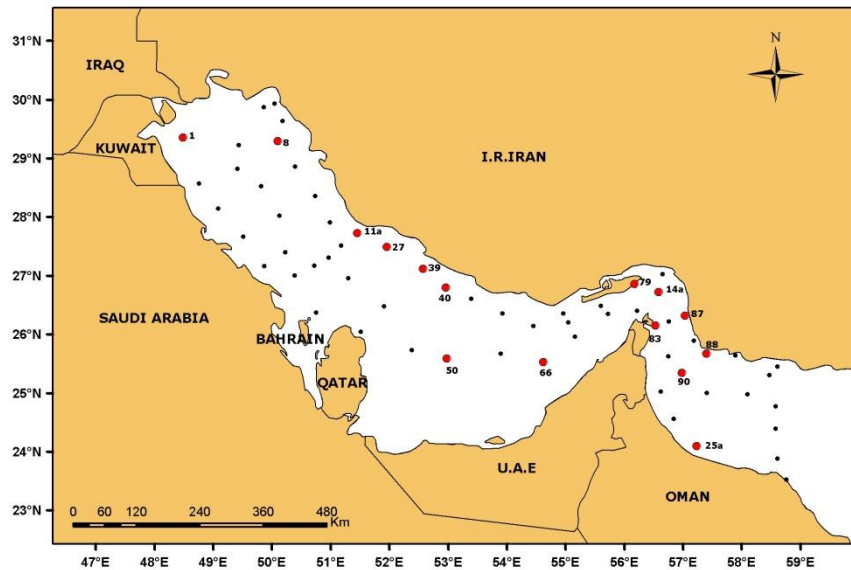
Specimens illustrated somewhat resemble *Protoperidinium grange* (Kofoid) Balech, but differ in four-sided the first apical plate 1' against five-sided 1' of *Protoperidinium grande* (Balech, 1988: Pl. 42: 2-9; Steidinger & Tangen, 1997: Pl. 54).

Distribution:

Marine widespread species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at few sites (refer sites map), never in large numbers; maximum abundance (1.5×10^2 cells/L) was associated with the north-western part of the inner RSA off Kuwait (St. 1).



Sites of occurrence of *Protoperidinium venustum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Protoperidinium* Berg *emend.* Balech, 1974

(= *Peridinium* Ehrenberg, 1831 *partim.*,

= *Minuscula* Lebour 1925)

Scientific name: *Protoperidinium* sp. 1

Plate A120: a-f (Annex A)

Description:

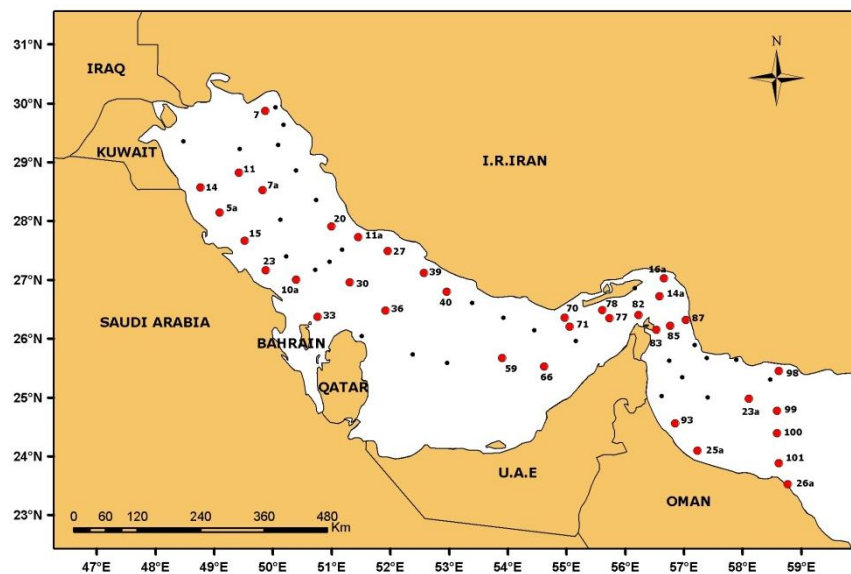
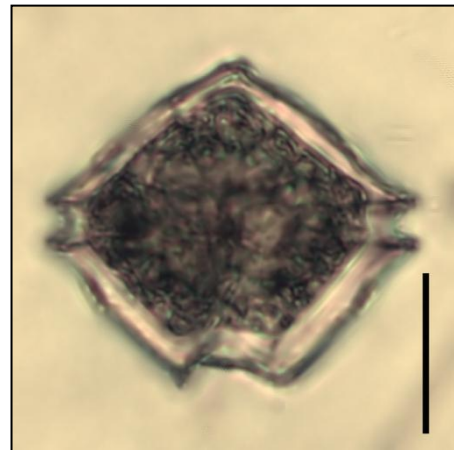
Epitheca almost domed, tapering into slight apical horn; hypotheca equal to epitheca with two small, hollow antapicals; girdle median, wide; sulcus broadening posteriorly. Ortho-hexa plate arrangement.

Dimensions:

Cells 42 µm long; 43 µm wide.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred in small numbers at scattered stations (refer sites map).



Sites of occurrence of *Protoperidinium* sp. 1 in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Protoperidinium* Berg *emend.* Balech, 1974

(= *Peridinium* Ehrenberg, 1831 *partim.*,

= *Minuscula* Lebour 1925)

Scientific name: *Protoperidinium* sp. 2

Plate A146: a-c (Annex A)

Description:

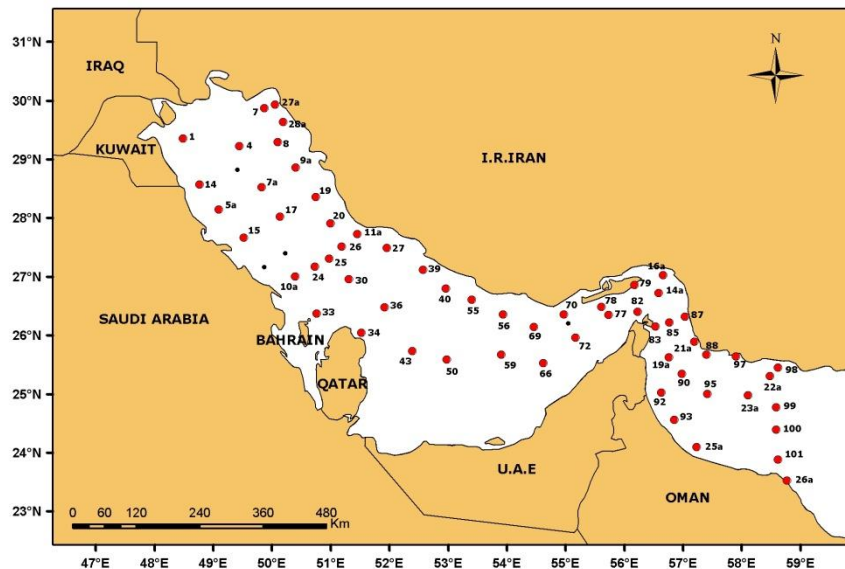
Medium-sized hyaline forms with slightly ovate body, long apical horn and two long winged antapical spines equal in length to $\frac{3}{4}$ diameter of a cell.

Dimensions:

Total length 65-68 μm ; body 39-40 μm long; 35 μm wide.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was commonly observed at many sites (refer sites map), often in large numbers; maximum abundance (1.9×10^3 cells/l) was associated with the waters off the Iranian coast in the central part of the inner RSA (St. 27).



Sites of occurrence of *Protoperidinium* sp. 2 in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Protoperidinium* Berg *emend.* Balech, 1974

(= *Peridinium* Ehrenberg, 1831 *partim.*,

= *Minuscula* Lebour 1925)

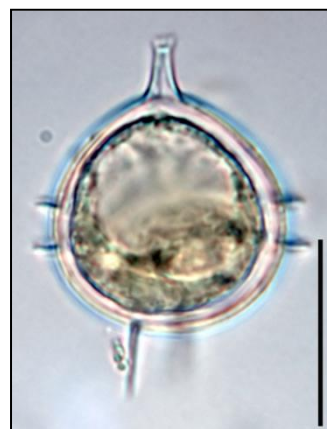
Scientific name: *Protoperidinium* sp. 3

Plate A146: d-i (Annex A)

Description: Small-sized hyaline forms with rounded body, long apical horn and two long antapical spines equal in length to ½ diameter of a cell.

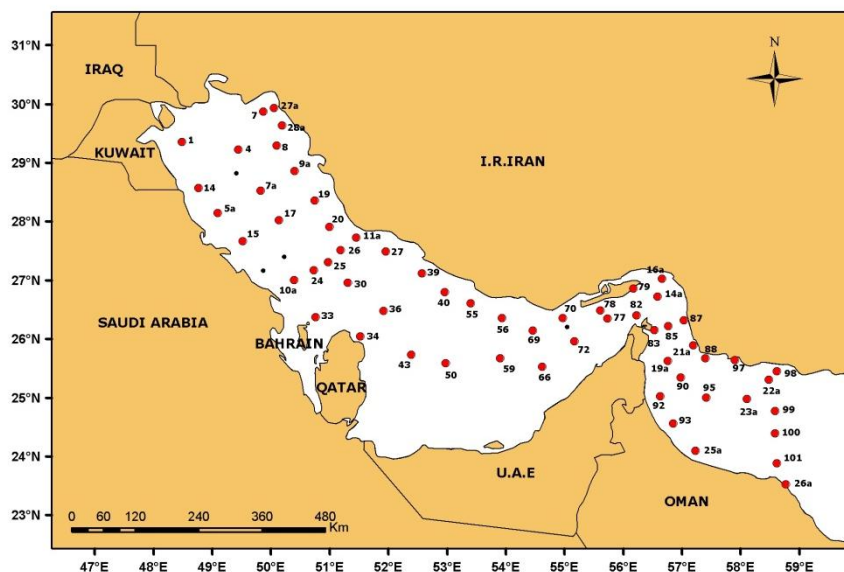
Dimensions:

Total length 40-43 µm; body 28 µm in diameter.



Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was encountered in small numbers at many stations (refer sites map).



Sites of occurrence of *Protoperidinium* sp. 3 in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Protoperidinium* Berg *emend.* Balech, 1974

(= *Peridinium* Ehrenberg, 1831 *partim.*,

= *Minuscula* Lebour 1925)

Scientific name: *Protoperidinium* sp. 4

Plate A147: a-f; 149: a-f (Annex A)

Description:

Similar to *P. steinii*, but smaller and delicate. Cell pear-shaped; epitheca and hypotheca, rounded, with tapering, elongated apical horn; antapex with two broadly winged spines. Meta-penta plate arrangement.

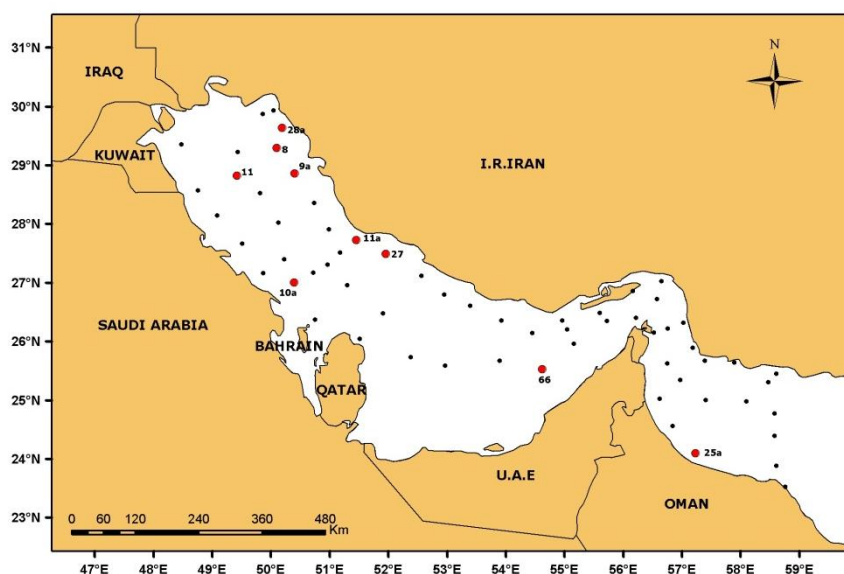
Dimensions:

Total length 65-71 μm ; body 48-50 μm long; 35-36 μm wide.



Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was encountered in small numbers at scattered stations (refer sites map).



Sites of occurrence of *Protoperidinium* sp. 4 in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Scrippsiella* Balech *ex* Loeblich III, 1965

Thecate dinoflagellates. Plate formula: Po, x, 4', 3a, 7'', 6c, 5(4)s, 5''', 2'''. Cell pear-shaped or ovoid, theca smooth or with some structure (poroids, reticulation, stripes). The cingulum is depressed, slightly descending. Apex may be extruded to an apical horn, or apex is rounded with slightly elevated Po plate suture. Antapex rounded, evenly cut or slightly excavated. Sp plate is large and reaches the cingulum. Yellow-brown to olive-green chloroplasts (Throndsen *et al.*, 2007).

Scientific name: *Scrippsiella trochoidea* (Stein) Balech *ex* Loeblich III

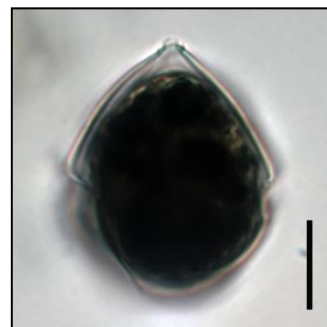
Plate A151: e-g (Annex A)

Synonyms:

Glenodinium trochoideum Stein; *Peridinium trochoideum* (Stein) Lemmermann; *Scrippsiella faeroense* Paulsen

References:

Lebour, 1925: p. 113, Pl. XIX: 3 a-d (as *Peridinium trochoideum*); Dodge, 1982: p. 163, Fig. 18 Q-S; Pl. III: d; Balech, 1988: p. 293, L. 71: 9-11; Hallegraeff, 2002: p. 66, Fig. 16 A; Throndsen *et al.*, 2007: p. 93.

**Description:**

Small pyriforme cell with conical epitheca. The girdle is wide, excavated, composed of six plates and surrounded by narrow lists. The epitheca has orthohexa tabulation. There are no antapical projections, and the wide excavated sulcus does not indent the antapex. The theca has scattered poroids. Several yellow-brown chromatophores are present, and the nucleus is

central. Plate formula: 4', 3a, 7'', 6c, 5''', 2'''. Cells 16-36 µm long, 20-23 µm broad (Dodge, 1982).

Harmful Effect:

It is a nontoxic species, but it can cause fish kills in sheltered bays through the generation of anoxic conditions (Hallegraeff, 2002).

Dimensions:

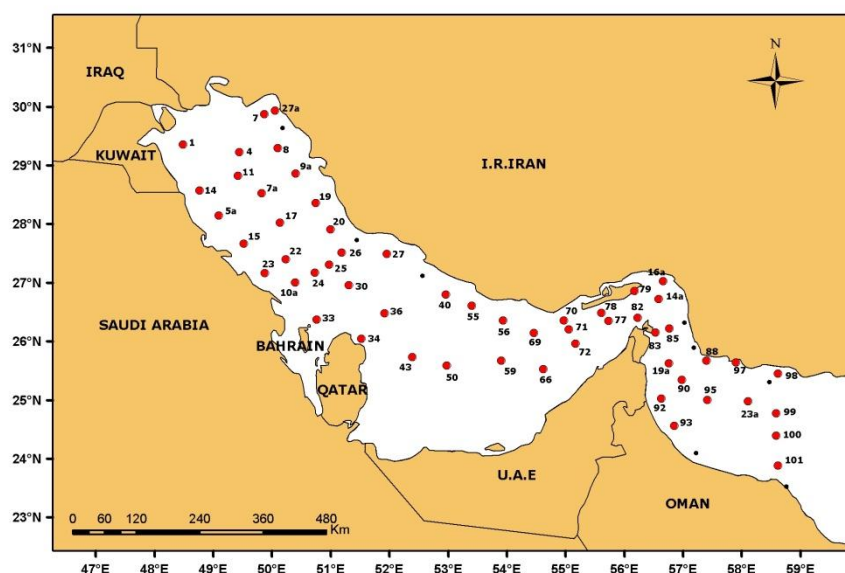
Cells 28-32 µm long; 21-22 µm wide.

Distribution:

Cosmopolitan neritic and estuarine species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was commonly observed at many sites (refer sites map), often in large numbers; maximum abundance (7.5×10^3 cells/l) was associated with the central part of the inner RSA (St. 36). It has been previously reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Scrippsiella trochoidea* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Scrippsiella* Balech *ex* Loeblich III, 1965

Scientific name: *Scrippsiella* sp. 1

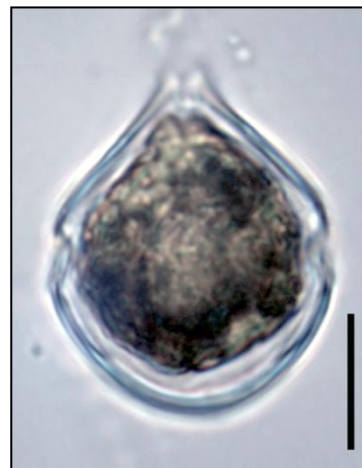
Plate A151: h-j (Annex A)

Description:

Cell pear-shaped, theca smooth. The cingulum depressed, slightly descending. Apex is extruded to an apical horn, antapex, rounded. Chloroplasts present.

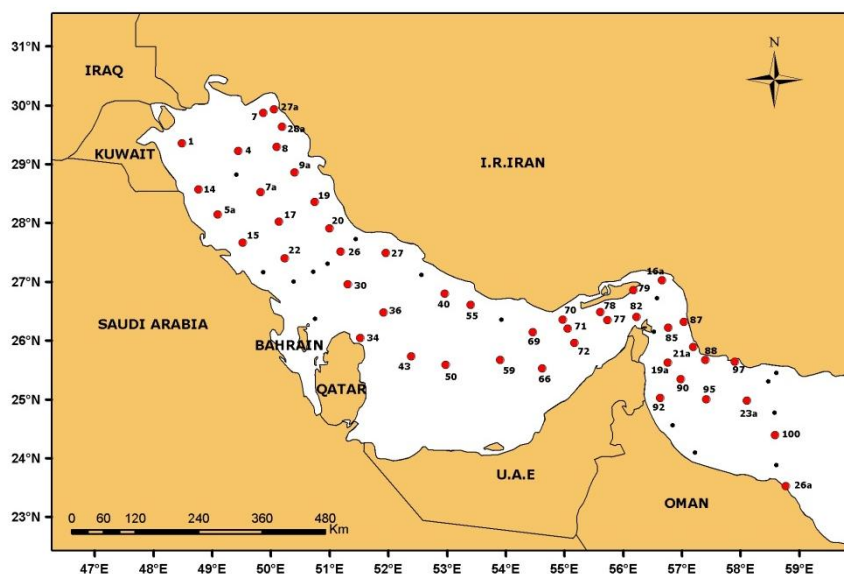
Dimensions:

Cells 26-28 µm long; 19-20 µm wide.



Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was frequently observed at many sites (refer sites map), often in large numbers; maximum abundance (1.1×10^4 cells/l) was associated with the northwestern part of the inner RSA (St. 7).



Sites of occurrence of *Scrippsiella* sp. in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Peridiniaceae Ehrenberg, 1828

Genus: *Scrippsiella* Balech *ex* Loeblich III, 1965

Scientific name: *Scrippsiella* sp. 2

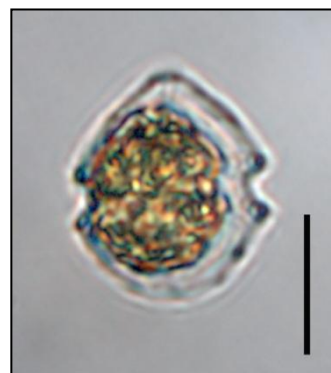
Plate A151: k, l (Annex A)

Description:

Cell ovoid, theca smooth. The cingulum median, wide. Apex rounded with slightly elevated Po plate suture. Antapex rounded. Chloroplasts present.

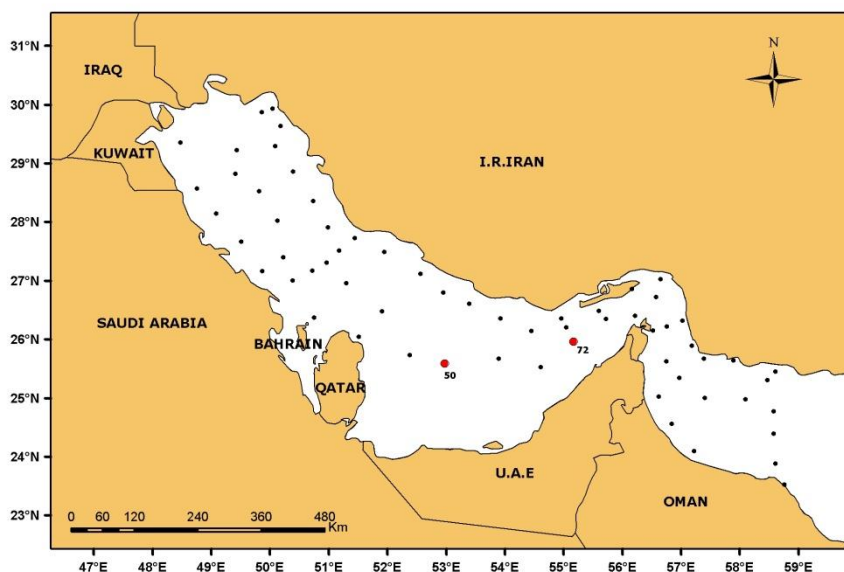
Dimensions:

Cells 17-20 μm long; 14-15 μm wide.



Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was found in small numbers at two stations (refer sites map).



Sites of occurrence of *Scrippsiella* sp. 2 in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Podolampadaceae Lindermann, 1928

Genus: *Podalampas* Stein, 1883

Pear- to drop-shaped species with a distinct apical horn which ends in an apical pore, antapically rounded with two (1-3) marked antapical spines parallel to the length axis. Somewhat dorsoventrally flattened. Cingulum apparently lacking. Plate pattern evident. Pale chloroplasts (Throndsen *et al.*, 2007).

Scientific name: *Podalampas bipes* Stein

Plate A149: a-d (Annex A)

Synonyms:

Parrocelia ovalis Gourret; *Podalampas reticulata* Kofoid;
Podalampas bipes f. *reticulata* (Kofoid) Schiller.

References:

Lebour, 1925: p. 160, Fig. 52 b; Wood, 1968: p. 119, Fig. 362; Taylor, 1976: p. 171, Pl. 27: 287, 288: Pl. 45: 524; Dodge, 1985: p. 117; Balech, 1988: p. 275, L. 53: 1, 2; Throndsen *et al.*, 2007: p. 107.

Description:

Cell broadly pear-shaped, narrowing to apical horn; girdle not apparent, probably fused with adjacent precingular plates; flagellar pore in ventral area; two strong, equal, antapical spines supporting transverse wings, the left being a continuation of the ventral area; theca porulate; wings more or less reticulate; plate formula 2', 1a, 6'', 3'', 4'''. Length 80-100 µm (Wood, 1968).



Dimensions:

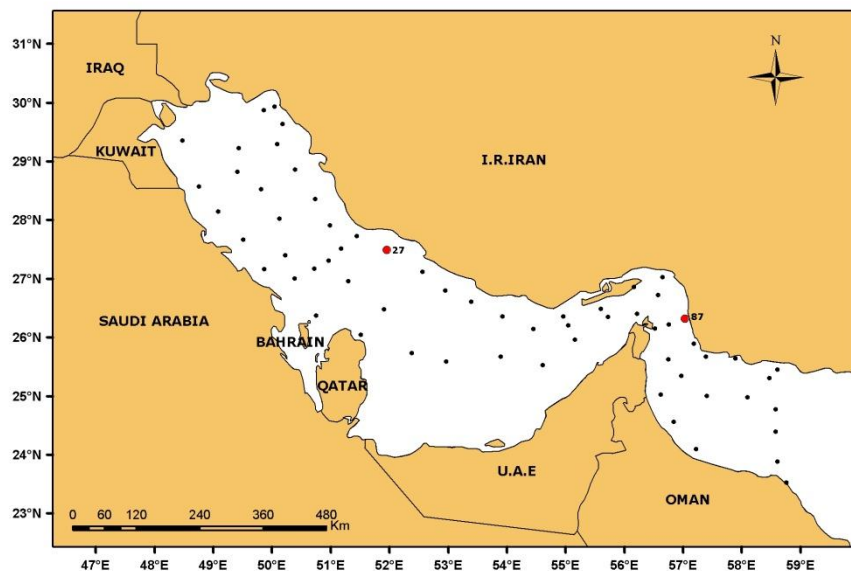
Total length 105-112 μm ; body 88-90 μm long; 72-75 μm wide.

Distribution:

Oceanic; warm temperate to tropical waters; worldwide distribution. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred in small numbers at two stations (refer sites map). This species has previously been reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Podalampas bipes* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Podolampadaceae Lindermann, 1928

Genus: *Podalampas* Stein, 1883

Species: *palmipes*

Scientific name: *Podalampas palmipes* Stein

Plate A149: e-g (Annex A)

References:

Lebour, 1925: p. 159, Fig. 52 a; Wood, 1968: p. 119, Fig. 365; Taylor, 1976: p. 171, Pl. 27: 278, 279; Dodge, 1982: p. 254, Fig. 33 I; Dodge, 1985: p. 118; Balech, 1988: p. 275, L. 53: 3, 4; Throndsen *et al.*, 2007: p. 107.

Description:

Cell pyriform, narrow, ending in two unequal antapical spines. The epitheca is drawn out into a long, slender neck. The intercalary plate is more or less pentagonal. The precingular plates bear elongated pores roughly arranged in a transverse row. There are three cingular plates described by Balech. C₁ and C₃ are long and narrow; C₂ constituting most of the cingular area. The cingulars are notably wide, being nearly half the length of the body. The hypotheca is greatly reduced in depth, being less than one tenth of body length. The post cingular plates have on them two transverse rows of pores. The first antapical plate (1'') has a large spine which is slightly sinuous and bordered by wings. The plate itself is small, and has a few pores. 2'' is small, has pores at the top; 3'' has a short spine bordered by wings. The right-hand spine is therefore much shorter than the left antapical spine. The nucleus is elongated and situated in the right half of the cell in the cingulum region. A yellow-orange pigmentation has been recorded by Balech in the epitheca at the base of the neck; 71-106 µm length of body; 20-37 µm wide; length of left spine 24-28 µm, length of the right spine 14-23 µm (Dodge, 1982).



Dimensions:

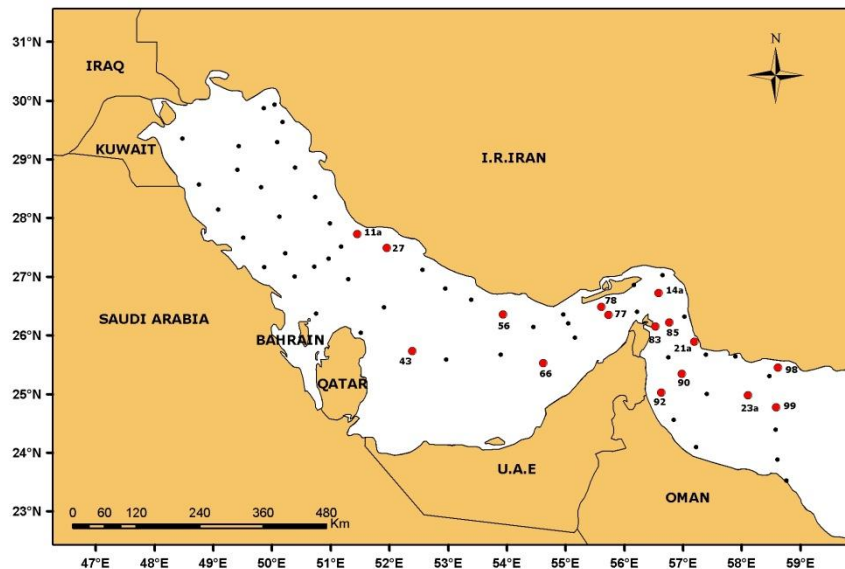
Total length 75-82 µm; body 62-66 µm long; 20-21 µm wide.

Distribution:

Oceanic; warm temperate to tropical waters; worldwide distribution. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred in small numbers at scattered stations (refer sites map). This species has previously been reported from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Podalampus palmipes* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: Pyrophacaceae Lindermann, 1928

Genus: *Pyrophacus* Stein, 1883

Apical-antapically flattened, lens-shaped or biconical cells. Brown chloroplasts. Plate formula: Po, cp?, 5-9', 0-8a, 7-15'', 9-16c, 8s, 8-17''', 0-15p and 3'''' (Thronsdén *et al.*, 2007).

Scientific name: *Pyrophacus horologicum* Stein *emend.* Wall *et* Dale

Plate A150: g-i (Annex A)

References:

Wood, 1968: p. 128, Fig. 398; Taylor, 1976: p. 182, Pl. 34: 387, 388, 390; Dodge, 1982: p. 144, Fig. 17 A, B; Throndsen *et al.*, 2007: p. 91.

Description:

Cell discoidal, almost circular in anterior view but biconvex lens-shaped in lateral, dorsal or ventral views. Theca weakly sculptured with a large and variable number of plates giving a plate formula within the range: 5-6', 0-1a, 7-10", 9c, 8-10"', 0-1p, 3-5'''. Intercalary bands are narrow to very broad. Cytoplasm with a strong tendency to round up, containing numerous chloroplasts. Reproduction by formation of 2-4 spores (? cysts); cysts are oblate reniform with a smooth transparent wall surrounded by gelatinous material, and contain brownish protoplasm with a reddish area. Width 35-136 μm , height 32-125 μm (Dodge, 1982).

**Dimensions:**

Cells 70-76 μm in diameter.

Taxonomic Remarks:

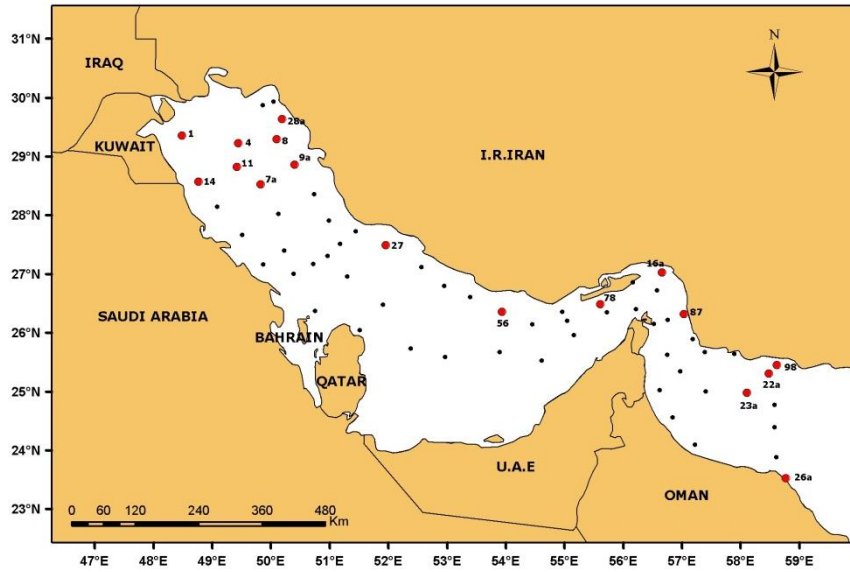
The observed material had 5 apical plates (1'-5') and 9 pre-cingular plates (1''-9'') (Plate A150: h).

Distribution:

Oceanic, neritic, estuarine; cosmopolitan in cold temperate to tropical waters. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at scattered sites (refer sites map), never in large numbers; maximum abundance (53 cells/l) was associated with the northwestern part of the inner RSA (St. 7a). This species has previously been reported from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Pyrophacus horologicum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridiniales Haeckel, 1894

Family: Pyrophacaceae Lindermann, 1928

Genus: *Pyrophacus* Stein, 1883

Species: *steinii*

Scientific name: *Pyrophacus steinii* (Schiller) Wall *et* Dale

Plate A150: a-f (Annex A)

Synonym:

Pyrophacus horologium var. *steinii* Schiller

References:

Taylor, 1976: p. 183, Pl. 34: 384-386, 389; Pl. 44: 518; Balech, 1988: p. 310, L. 88: 6-14.



Description:

Flattened, lenticular cell with attenuated epitheca. Typically, the epitheca has 7', 0a and 12" (Steidinger and Tangen, 1997).

Harmful Effect:

Non-toxic bloom-forming species; it may be regarded as potentially harmful (Fukuyo *et al.*, 2003).

Dimensions:

Cells 130-145 µm long; 140-148 µm wide.

Taxonomic Remarks:

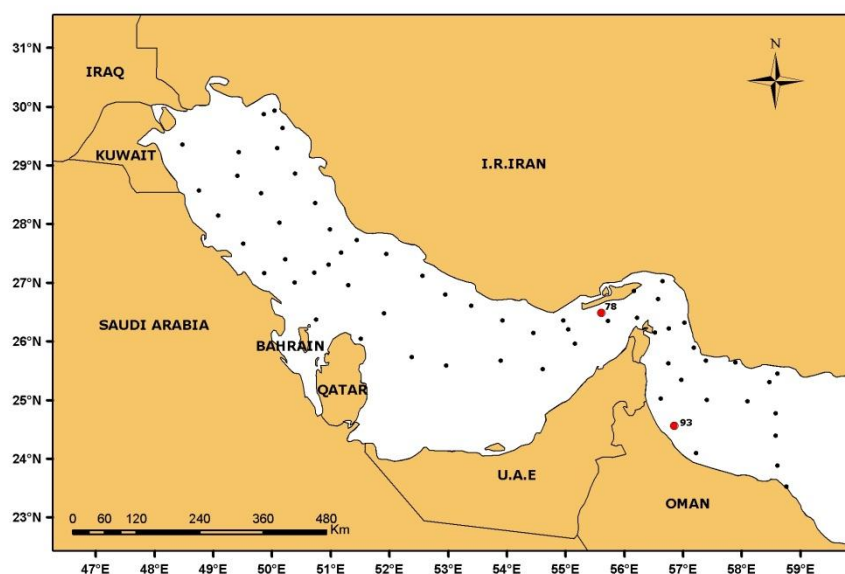
The observed material had 7 apical plates (1'-7') and 12 pre-cingular plates (1"-12") (Plate A150: c-e).

Distribution:

Restricted to warm temperate waters to tropical waters of all oceans. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was encountered in small numbers at two stations (refer sites map). This species has previously been reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Pyrophacus steinii* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: *insertae sedis*

Genus: *Heterocapsa* Stein, 1883

(= *Cachonina* Loeblich III, 1968)

Armored dinoflagellates. Small (< 20 µm) peridinoid that appears unarmored at the light microscope level resolution. Epitheca rounded to conical; hypotheca rounded to attenuated. Cingulum is slightly displaced and descending. Thinly thecate with characteristic body scales. Chloroplasts are present. Most typical plate formula: Po, cp, X, 6', 3a, 7", 6c, 5s, 5"', 0(1)p, 2'''. The 1' is displaced from the Po and lies above the sa. The Sa plate is small. The X plate is the anterior left margin of the 6' and in contact with the Po. Species can be bloom formers. This genus has been confused with *Gymnodinium*, *Glenodinium* and *Katodinium*, because plates were not initially detected. The plate formula can differ based on different authors' interpretation of plates. Some authors also demonstrated extreme variation in plate tabulation of cultured specimens (Steidinger and Tangen, 1997).

Species of the genus *Heterocapsa* were frequently encountered in the RSA samples. When abundant, they contributed up to 14 % of the total phytoplankton abundance. In Winter 2006 Cruise, the highest concentration reached 3.2×10^4 cells/l. High abundance of this genus ($> 10^4$ cells/l) was associated with waters of the southern part of the inner RSA, the Strait of Hormuz and the Sea of Oman.

Scientific name: *Heterocapsa triquetra* (Ehrenberg) Stein

Plate A151: a, b (Annex A)

Synonyms:

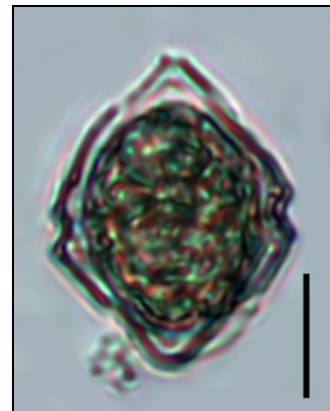
Glenodinium triquetrum Ehrenberg; *Properidinium heterocapsa* Meunier; *Peridinium triquetra* Lebour; *Peridinium triquetrum* Schiller.

References:

Dodge, 1982: p. 150, Fig. 17 C, D; Pl. III: a; Throndsen *et al.*, 2007: p. 94.

Description:

Cell irregularly spindle-shaped. Epicone with straight sides and rounded or squared apex; hypocone variably shaped, often with displaced antapex. Girdle slightly excavated, median, fractionally depressed on the right side; sulcus inconspicuous, not reaching the antapex. No spines or ornamentation; thecal plates, smooth with trichocyst pores; typical plate formula: 5', 3a, 7'', 6c, 7s, 5''', 1p, 2'''. Cell contents dense with a brown peripheral chloroplast, a large pyrenoid situated in a median position and nucleus in the epicone. Tiny scales over the surface of the cell present. Size: length 16-30 μm ; width 9-18 μm (Dodge, 1982).

**Dimensions:**

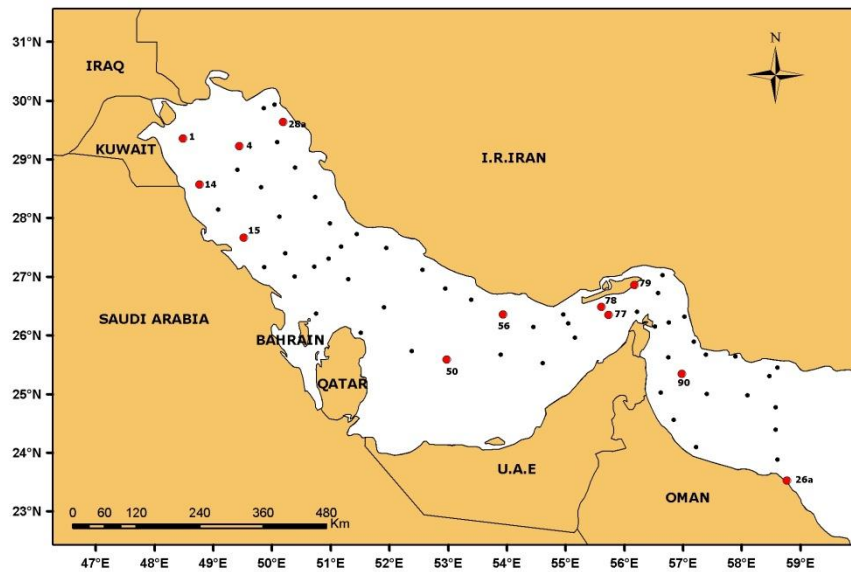
Cells 23-26 μm long; 18-20 μm wide.

Distribution:

Neritic, estuarine, brackish water, marine and in some low-salinity waters; worldwide distribution.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at few scattered sites (refer sites map), never in large numbers; maximum abundance (6.6×10^2 cells/l) was associated with the northwestern part of the inner RSA (St. 4).



Sites of occurrence of *Heterocapsa triquetra* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: *insertae sedis*

Genus: *Heterocapsa* Stein, 1883

(= *Cachonina* Loeblich III, 1968)

Scientific name: *Heterocapsa* sp.

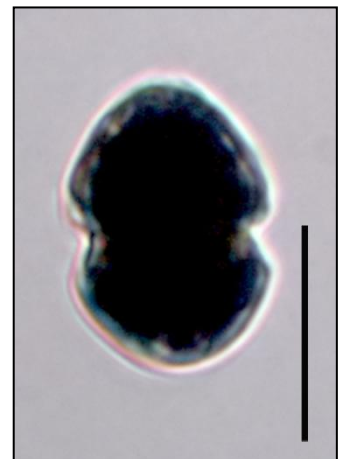
Plate A151: c, d (Annex A)

Description:

Small-sized species. Epitheca conical with rounded apex; hypotheca rounded. Cingulum median, wide; chloroplasts present.

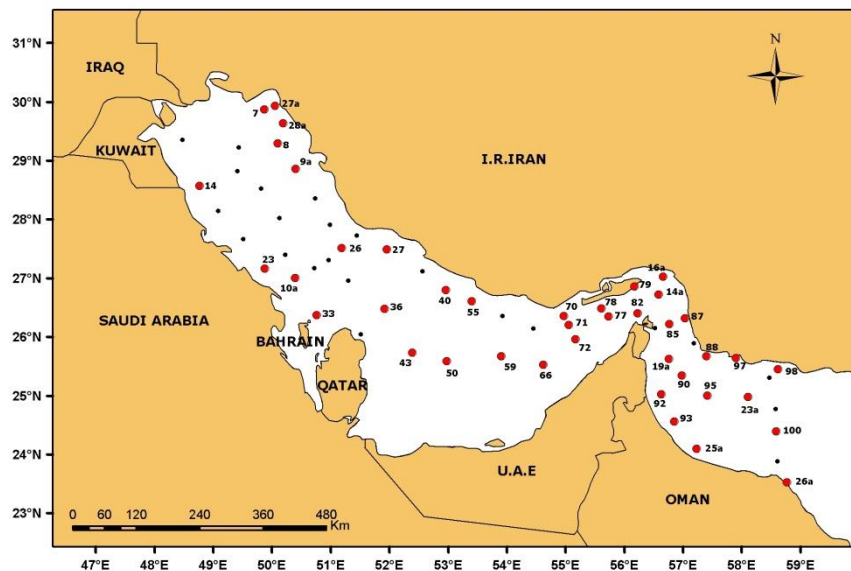
Dimensions:

Cells 13-15 μm long; 10-11 μm wide.



Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at many sites (refer sites map), often in large numbers; maximum abundance (3.2×10^4 cells/l) was associated with the Strait of Hormuz waters (St. 82).



Sites of occurrence of *Heterocapsa* sp. in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: *insertae sedis*

Genus: *Spiraulax* Kofoid

Differs from *Gonyaulax* in that, sulcus does not invade epitheca. Theca is biconical with single antapical process. Often united with *Gonyaulax* (Wood, 1968).

Scientific name: *Spiraulax jolliffei* (Murray *et* Whitting) Kofoid

Plate A152: a-d (Annex A)

Synonym:

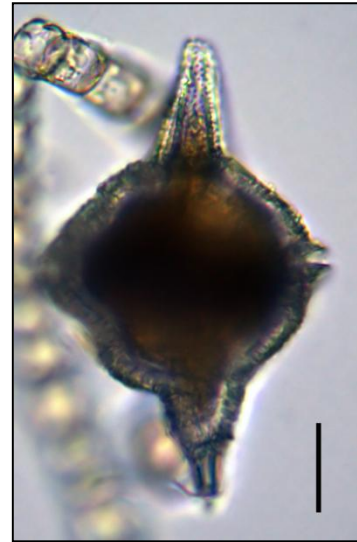
Gonyaulax jolliffei Murray *et* Whitting

References:

Wood, 1968: p. 128, Fig. 399; Taylor, 1976: p. 112, Pl. 36: 424; Balech, 1988: p. 299, L. 77: 9-12.

Description:

A stout species; body broadly and irregularly fusiform; epitheca and hypotheca subequal; subconical apex truncate, margins concave; girdle displaced, lists low; surface coarsely pitted; sulcus not invading epitheca; single strong antapical horn. Plate formula: 4, 1a, 6", 6"', 1p, 1'''. Length 200-400 μm (Wood, 1968).



Dimensions:

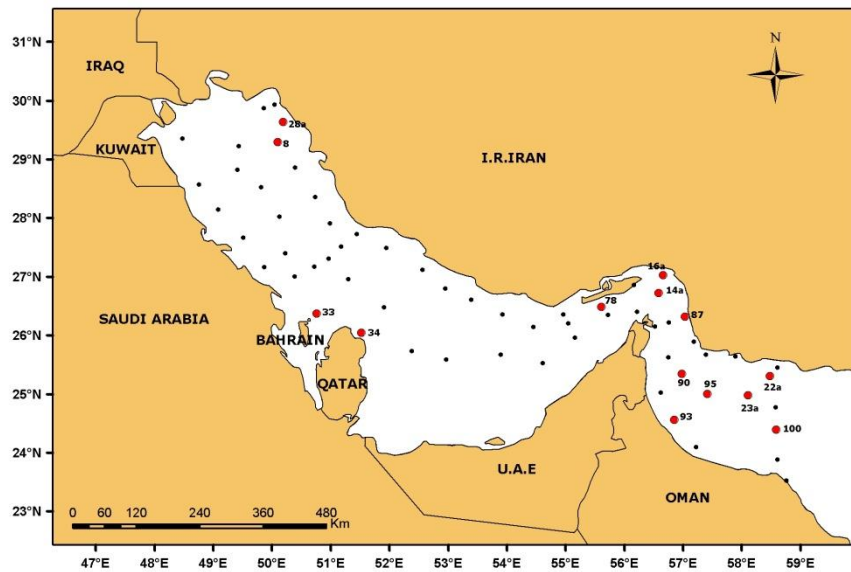
Cells 107-130 μm long; 66-75 μm wide.

Distribution:

Warm-water marine species. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was found in small numbers at scattered stations (refer sites map).



Sites of occurrence of *Spiraulax jolliffei* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Peridinales Haeckel, 1894

Family: *insertae sedis*

Genus: *Spiraulax* Kofoid

Scientific name: *Spiraulax* sp.

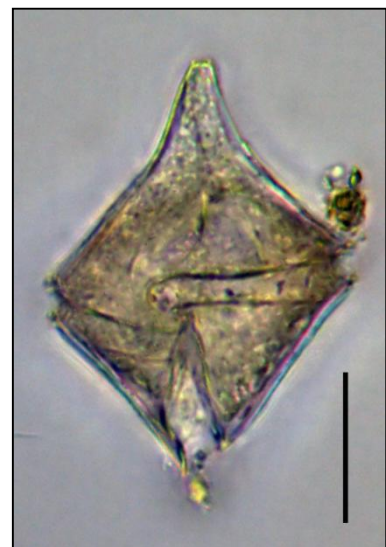
Plate A152: e-g (Annex A)

Description:

Theca biconical. Epitheca conical tapering into a rather long apical horn. Hypotheca with single antapical process. Cingulum median, depressed, displaced.

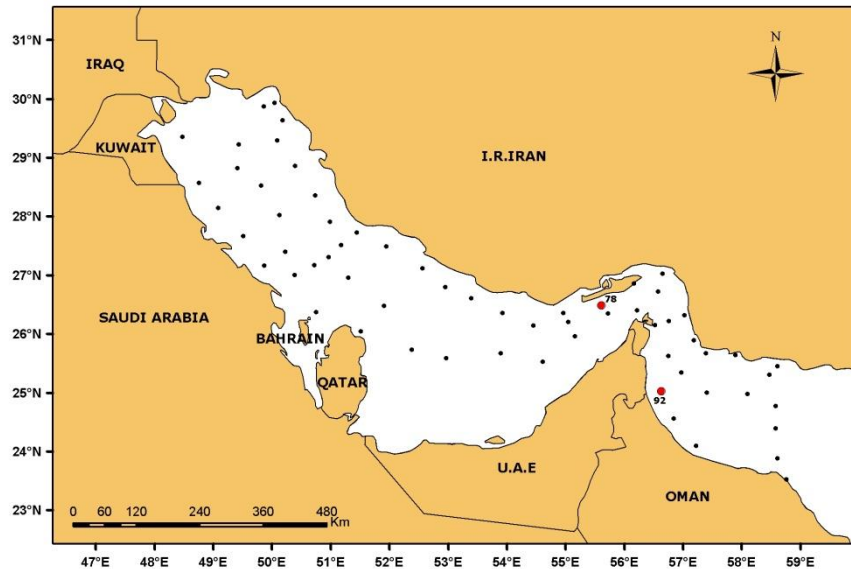
Dimensions:

Cells 59 μm long, 39 μm wide.



Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was encountered in small numbers at two stations (refer sites map).



Sites of occurrence of *Spiraulax* sp. in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Prorocentrales Lemmermann, 1910

Family: Prorocentraceae Stein, 1883

Genus: *Mesoporos* Lillick, 193)

(= *Porella* Schiller, 1928)

Cell ovoid; round or heart-shaped; with funnel-shaped depression centrally on the main plates mimicking pores. Weakly developed spines near the flagella pores. Yellow-brown chloroplasts. Distinguished from *Prorocentrum* by the funnel-shaped “pores” (Thronsdén *et al.*, 2007).

Scientific name: *Mesoporos perforatus* (Gran) Lillick

Plate 153: a-e (Annex A)

Synonyms:

Exuviaella perforata Gran; *Porella perforata* Schiller

References:

Dodge, 1982: p. 24, Fig. 2 A, B; Pl. I: a, b; Dodge, 1985: p. 14;
Thronsdon *et al.*, 2007: p. 52.

Description:

Cell oval, round or chordate in valve view. Row of small pores around periphery of each valve in addition to central pore. Chloroplasts two; one situated under each valve, sometimes having a lobed outline. Nucleus is situated in the posterior end of the cell; 14-27 µm long; 18-21 µm wide (Dodge, 1982).



Dimensions:

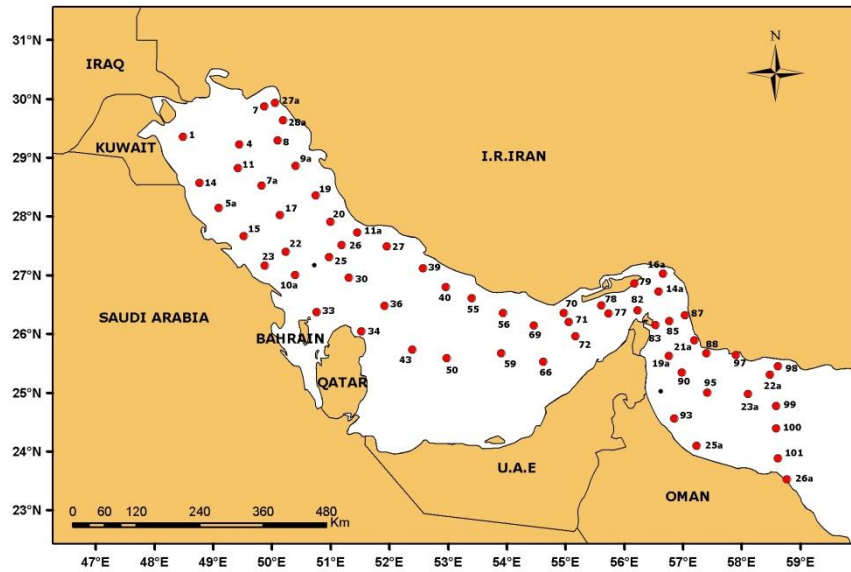
Cells 14-16 µm long; 13-14 µm wide.

Distribution:

Neritic to oceanic; cold to tropical waters.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was commonly observed at many sites (refer sites map), often in large numbers; maximum abundance (1.5×10^4 cells/l) was associated with the northwestern part of the inner RSA (St. 7).



Sites of occurrence of *Mesoporos perforatus* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Prorocentrales Lemmermann, 1910

Family: Prorocentraceae Stein, 1883

Genus: *Prorocentrum* Ehrenberg, 1834

(= *Exuviaella* Cienkowski, 1881)

Most of the species are more or less flattened with the suture as contour. The cell shape is elliptical, heart-shaped, round, ovoid, almond-shaped or elongated. Autotrophs with yellow-brown, brown, red-brown chloroplasts. Marine and brackish water forms. Without or with protruding, often spine-shaped structures near the flagellar pores. Mainly planktonic, some benthic (Thronsdén *et al.*, 2007).

Scientific name: *Prorocentrum balticum* (Lohmann) Loeblich III

Plate A153: i-k (Annex A)

Synonyms:

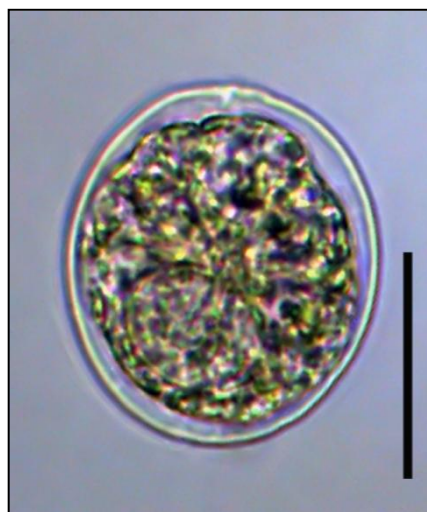
Exuviaella baltica Lohmann; *Prorocentrum pomoideum* Bursa; *Exuviaella aequatorialis* Hasle

References:

Dodge, 1982: p. 35, Fig. 2 M, N; Pl. I: e; Throndsen *et al.*, 2007: p. 50.

Description:

Cell round to slightly ovate in valve view; round and scarcely compressed in side view, with minute apical projections beside flagellar pores; thecal plates covered with minute spines; nucleus subspherical and posterior in position; 9-10 µm long; 7-20 µm wide (Dodge, 1982).

**Harmful Effect:**

Toxicology for this species is unknown, but it is regarded as potentially toxic (Steidinger and Tangen, 1997; Faust *et al.*, 1999).

Dimensions:

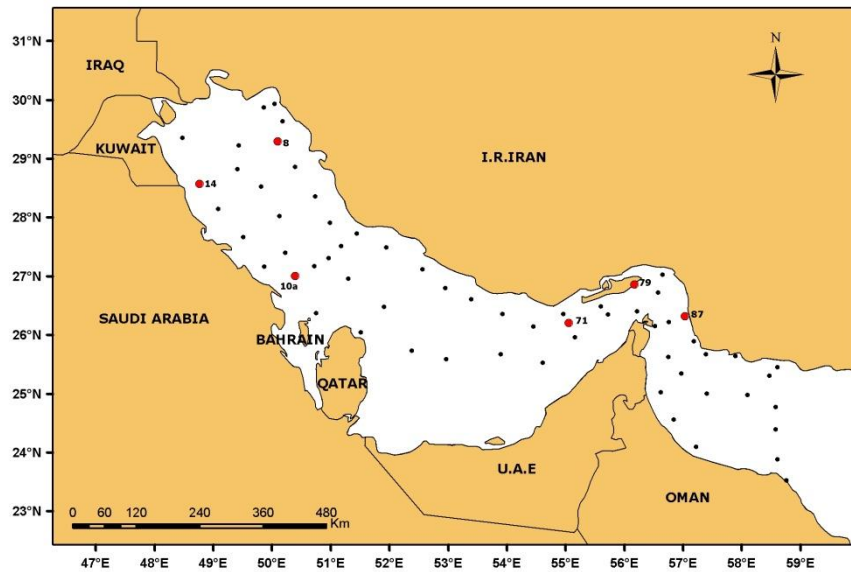
Cells 14-16 µm long; 11-14 µm wide.

Distribution:

Planktonic; neritic; worldwide distribution.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was recorded in lower abundances at few scattered stations (refer sites map). This species has been previously reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Prorocentrum balticum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Prorocentrales Lemmermann, 1910

Family: Prorocentraceae Stein, 1883

Genus: *Prorocentrum* Ehrenberg, 1834

(= *Exuviaella* Cienkowski, 1881)

Species: *compressum*

Scientific name: *Prorocentrum compressum* (Bailey) Abé *ex* Dodge

Plate A154: a-f (Annex A)

Synonyms:

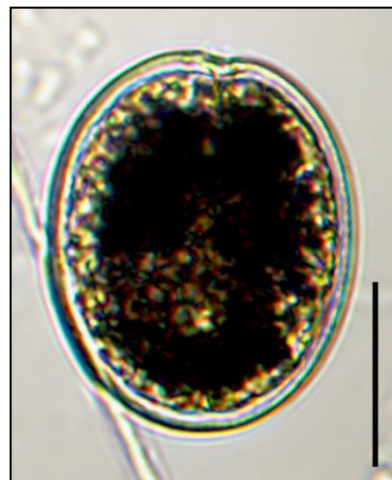
Pyxidicula compressa Bailey; *Exuviaella compressa* (Bailey) Ostefeld; *Prorocentrum bidens* Schiller; *Prorocentrum lebourae* Schiller.

References:

Lebour, 1925: p. 13, Pl. 1: 2 (as *Exuviella compressa*);
Dodge, 1975: p. 110, Fig. 2 F, 4 H, I; Pl. 4: E, F; Taylor,
1976: p. 21, Pl. 1: 8, 9; Dodge, 1982: p. 31, Fig. 2 I;
Dodge, 1985: p. 13; Balech, 1988: p. 226, L. 4: 3, 4;
Thronksen *et al.*, 2007: p. 51.

Description:

Cell ovate to rotundate in valve view, rounded and not much compressed in side view; anterior end, usually with very slight depression and two projections, equal, unequal, or bearing fine wings; thecal plates covered with small depressions; chloroplasts two, plate-like; 30-50 µm long; c. 25 µm wide (Dodge, 1982).

**Harmful Effect:**

It is a bloom-forming species, regarded as potentially toxic. Blooms of this species produce harmless water discolorations (Fukuyo *et al.*, 2003).

Dimensions:

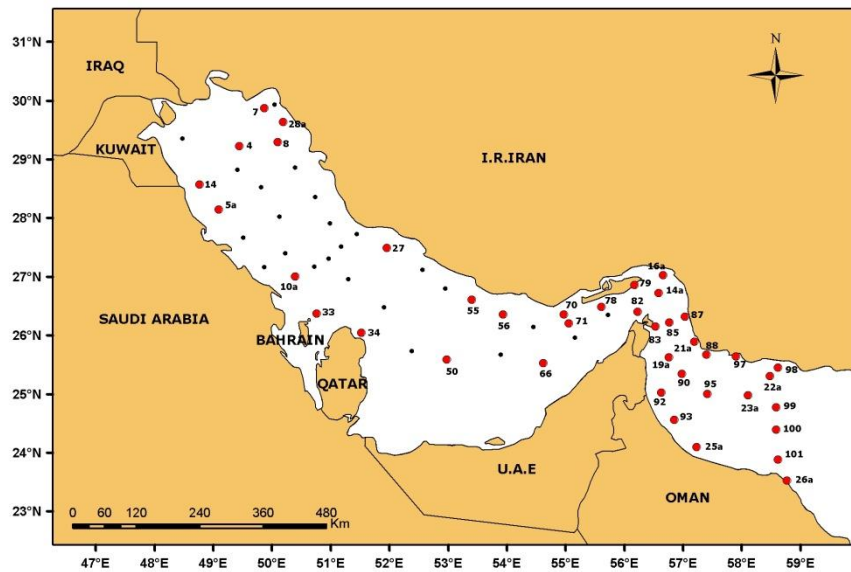
Cells 40-42 µm long; 32-36 µm wide.

Distribution:

Mostly planktonic; neritic, oceanic; cosmopolitan in cold temperate to tropical waters. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was frequently observed at various stations (refer sites map), although never in large numbers; maximum abundance (1.6×10^2 cells/l) was associated with Kuwaiti waters in the northwestern part of the inner RSA (St. 14). This species has previously been reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Prorocentrum compressum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Prorocentrales Lemmermann, 1910

Family: Prorocentraceae Stein, 1883

Genus: *Prorocentrum* Ehrenberg, 1834

(= *Exuviaella* Cienkowski, 1881)

Species: *dentatum*

Scientific name: *Prorocentrum dentatum* Stein

Plate A155: h-k (Annex A)

Synonyms:

Prorocentrum obtusidens Schiller; *Prorocentrum veloi* Tafall; *Prorocentrum monacense* Kufferath.

References:

Wood, 1968: p. 121, Fig. 374; Dodge, 1982: p. 34, Fig. 2 R.

Description:

Cell elongated, heart-shaped to lanceolate with an anterior extension at one side which may be pointed or blunt; anterior end sometimes with small depression; posterior end acute; plates with surface, covered with small spines. Size: 36-60 μm long; 15-20 μm wide (Dodge, 1982).

**Dimensions:**

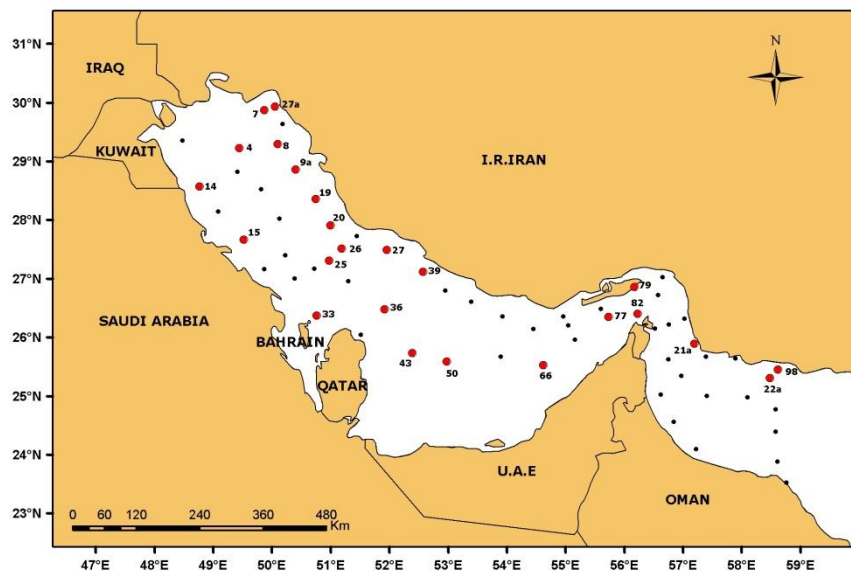
Cells 19-21 μm long; 9-10 μm wide.

Distribution:

Oceanic species.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at scattered sites (refer sites map), usually in small numbers; however, it was quite abundant at some localities; maximum abundance (4.2×10^3 cells/l) was associated with the central part of the inner RSA (St. 50).



Sites of occurrence of *Prorocentrum dentatum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Prorocentrales Lemmermann, 1910

Family: Prorocentraceae Stein, 1883

Genus: *Prorocentrum* Ehrenberg, 1834

(= *Exuviaella* Cienkowski, 1881)

Species: *gracile*

Scientific name: *Prorocentrum gracile* Schütt

Plate A154: k; A155: a-d; A156: g-j (Annex A)

Synonyms:

Prorocentrum macrurus Athanassopoulos; *Prorocentrum hentschelii* Schiller; *Prorocentrum diamantinae* Wood

References:

Wood, 1968: p. 122, Fig. 376; Taylor, 1976: p. 22, Pl. 1: 2; Dodge, 1982: p. 33, Fig. 2 L; Balech, 1988: p. 226, L. 4: 2.

**Description:**

Cell elongated, lanceolate, with rounded anterior end and pointed posterior end; anterior spine long, sharp, narrow in plate view; broad-lanceolate in side view; thecal plates with surface perforated by trichocyst pores and patterned with surface depressions; 40-60 µm long. This species has certain similarities to *P. micans* and Steidinger and Williams (1970) showed photographs of the thecal plates in which the pattern of trichocyst pores appears identical with that of *P. micans*. It is distinguished by having a much longer anterior spine and by being at least twice as long as broad (Dodge, 1982).

Harmful Effect:

It is a bloom-forming species, regarded as potentially toxic. Blooms of this species produce harmless water discolorations (Fukuyo *et al.*, 2003).

Dimensions:

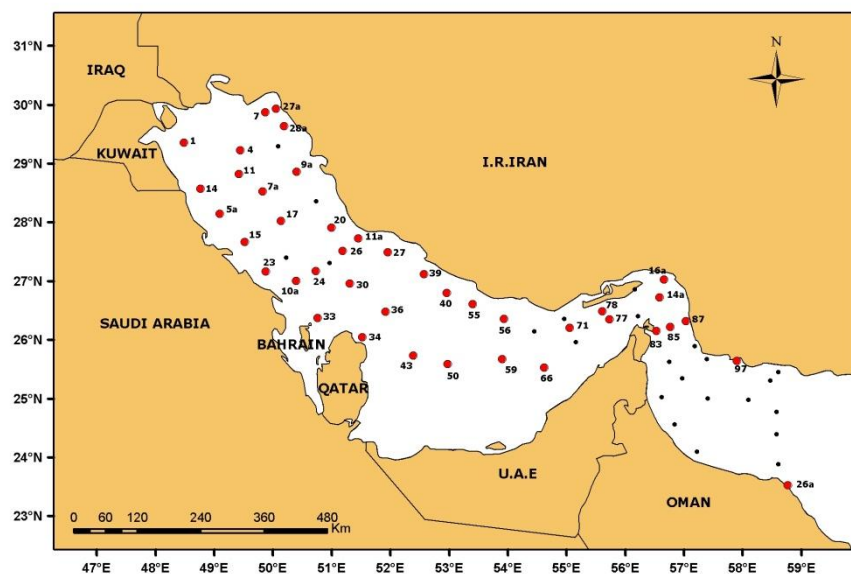
Cells 47-50 µm long; 21-23 µm wide.

Distribution:

Principally neritic and estuarine; cosmopolitan in cold temperate to tropical waters. This species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed frequently at various sites (refer sites map), usually in small numbers, however, it was quite abundant at some localities; maximum abundance (4×10^3 cells/l) was associated with the central part of the inner RSA (St. 36). Species has previously been reported from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Prorocentrum gracilis* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Prorocentrales Lemmermann, 1910

Family: Prorocentraceae Stein, 1883

Genus: *Prorocentrum* Ehrenberg, 1834

(= *Exuviaella* Cienkowski, 1881)

Species: *micans*

Scientific name: *Prorocentrum micans* Ehrenberg

Plate A156: a-f (Annex A)

Synonym:

Prorocentrum schilleri Bohrn

References:

Lebour, 1925: p. 16, Pl. 1: 5 a-c; Wood, 1968: p. 123, Fig. 380; Taylor, 1976: p. 23, Pl. 1: 1; Dodge, 1982: p. 32, Fig. 2 K, Pl. I: c, d; Dodge, 1985: p. 11; Balech, 1988: p. 226, L. 4: 1; Faust and Gullede, 2002: p. 63, Pl. 46: 1-6; Thronsen *et al.*, 2007: p. 51.



Description:

Cells of this species are highly variable in shape and size. Cells are tear-drop to heart shaped, rounded anteriorly, pointed posteriorly, and broadest around the middle. This species is strongly flattened with a well-developed winged apical spine (10 µm long) on the left valve. Cells are medium-sized (35-70 µm long, 20-50 µm wide) with a length:width ratio usually less than two. The cell surface is rugose, covered with shallow minute depressions. Numerous tubular trichocyst pores are also present in short rows arranged radially. Intercalary band is smooth and wide. The periflagellar area is a relatively small, shallow, broad triangular depression situated apically on the right valve off-center. Two periflagellar pores are present: one large flagellar pore and one smaller auxiliary pore. Adjacent to the flagellar pore is a small, slightly curved periflagellar plate. The large pointed apical spine lies adjacent to the periflagellar area, directly opposite the periflagellar plate. *P. micans* is a photosynthetic species with two golden-brown chloroplasts situated peripherally. A large kidney-shaped nucleus is situated posteriorly. Two anterior vacuoles are usually present (Faust and Gullede, 2002).

Harmful Effect:

Although *P. micans* is capable of forming extensive blooms, it is usually considered harmless (Taylor and Seliger, 1979; Anderson *et al.*, 1985; Graneli *et al.*, 1990). It may excrete substances that inhibit diatom growth, but apparently these substances do not enter the food chain or affect organisms at higher trophic levels (Uchida, 1977). There are only a few reports of *P. micans* that caused problems: shellfish kills in Portugal (Pinto and Silva, 1956) and South Africa (Horstman, 1981). Claims for toxicity of this species need confirmation. Early reports on *P. micans* being a paralytic shellfish poison (PSP) producer (Pinto and Silva, 1956) are unconfirmed, and recent incidents involving shellfish mortality have been attributed to oxygen depletion (Lassus and Berthome, 1988).

Dimensions:

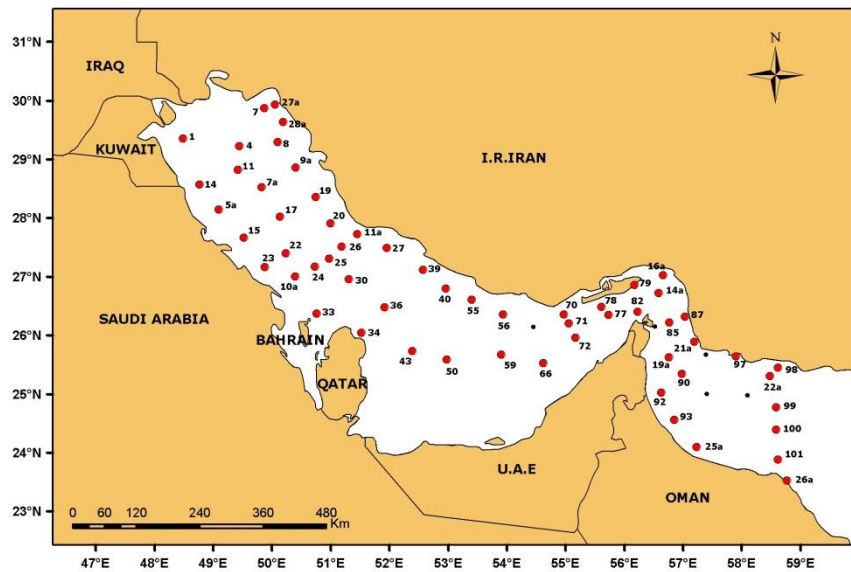
Cells 46-52 µm long; 30-33 µm wide.

Distribution:

Commonly found in marine waters all over the world. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed commonly at many sites (refer sites map), usually in small numbers, however, it was quite abundant at some localities; maximum abundance (3.3×10^3 cells/l) was associated with the central part of the inner RSA (St. 36). Species has previously been reported from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Prorocentrum micans* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Prorocentrales Lemmermann, 1910

Family: Prorocentraceae Stein, 1883

Genus: *Prorocentrum* Ehrenberg, 1834

(= *Exuviaella* Cienkowski, 1881)

Species: *minimum*

Scientific name: *Prorocentrum minimum* (Pavillard) Schiller

Plate A153: f-h (Annex A)

Synonyms:

Exuviaella minima Pavillard; *Prorocentrum triangulatum* Martin; *Exuviaella mariae-lebouriae* Parke *et* Ballantine; *Prorocentrum cordiformis* Bursa



References:

Taylor, 1976: p. 24, Pl. 1: 17; Dodge, 1982: p. 35, Fig. 20 P; Pl. I: f, g; Throndsen *et al.*, 2007: p. 52.

Description:

Cell ovate, triangular or heart-shaped in plate view, posterior end usually rounded and anterior end truncate with a very slight depression, anterior spine small (not always visible in the light microscope); trichocyst pores mainly around margin of plates, surface of plates covered with minute spines; chloroplasts with associated pyrenoids. Size: 14-22 µm long; 10-15 µm wide (Dodge, 1982).

Harmful Effect:

It is a toxic species, which caused shellfish poisoning and fish kills (Steidinger and Tangen, 1997). Ingested cells can cause detrimental effects in mollusks. Some strains excrete substances toxic to *Artemia*-nauplii (IOC list, 2002).

Dimensions:

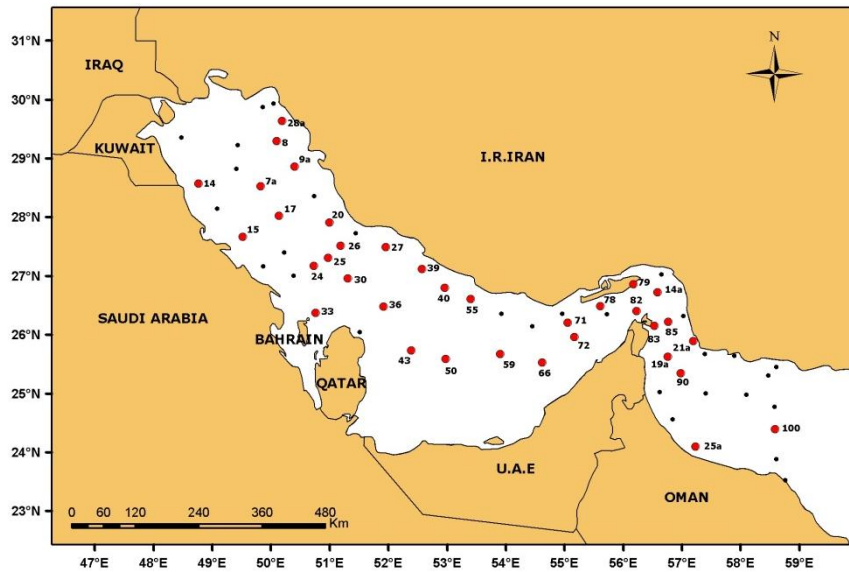
Cells 12-14 µm long; 10 µm wide.

Distribution:

Planktonic; mostly estuarine, but also neritic, oceanic; cosmopolitan in cold temperate to tropical waters. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at sporadic sites (refer sites map), usually in small numbers; however, it was quite abundant at some localities; maximum abundance (2.9×10^3 cells/l) was recorded in the southern part of the inner RSA (St. 71).



Sites of occurrence of *Prorocentrum minimum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Prorocentrales Lemmermann, 1910

Family: Prorocentraceae Stein, 1883

Genus: *Prorocentrum* Ehrenberg, 1834

(= *Exuviaella* Cienkowski, 1881)

Species: *rhathymum*

Scientific name: *Prorocentrum rhathymum* Loeblich, Sherley and Schmidt

Plate A153: 1, m (Annex A)

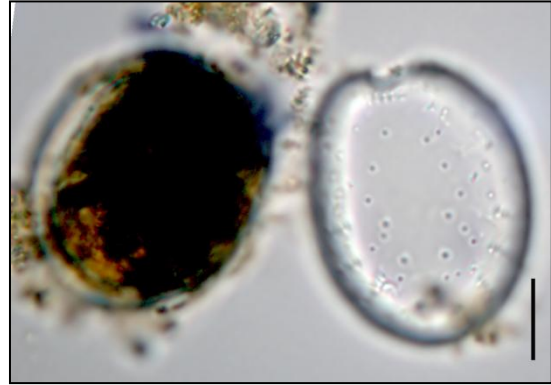
References:

Loeblich *et al.*, 1979: p. 115-116, 118-119, Figs. 8-13; Fukuyo, 1981: p. 968, Figs. 5-7, 47; Cortés-Altamirano and Sierra-Beltrán, 2003: p. 223-224, Figs. 1 o-q, 3; Mohammad-Noor *et al.*, 2007: p. 652-653, Figs. 10 a-i, 21 a, b.

Description:

The cell wall consists of a theca formed by two large valves. The left valve has an indentation at the anterior end in which at least seven small plates are located. These plates are arranged

to form two pores. The larger pore is the flagellar pore. A small spine is located at the ventral side of the auxillary pore. Trichocyst pores which lie in shallow circular depressions are located in grooves perpendicular to the valve margin near the posterior end of both valves. The trichocyst pores form a semicircle on the left valve near the pore region. The



intercalary band has fine, closely spaced grooves perpendicular to the suture. The cell is oval in shape, 32-39 μm long, 20-22 μm wide. The nucleus is located in the posterior half of the cell. The cells are embedded in mucilage, and consequently, they are not actively motile (Loeblich *et al.*, 1979). A row of six to seven trichocysts pores emerges from the anterior ventral side of the right valve, forming a 45-degree angle with the intercalary band margin, almost surrounding the periflagellar region. There is no ornamentation in the anterior region of the left valve (Cortés-Altamirano and Sierra-Beltrán, 2003).

Harmful Effect:

This species may produce toxins with hemolytic activity (Nakajima *et al.* 1981), and also water-soluble fast-acting toxins (Tindall *et al.* 1989). It is not a true DSP-producer, as it does not produce okadaic acid or dinophysistoxin, but it has been related to diarrhetic symptoms (Levasseur *et al.*, 2003).

Dimensions:

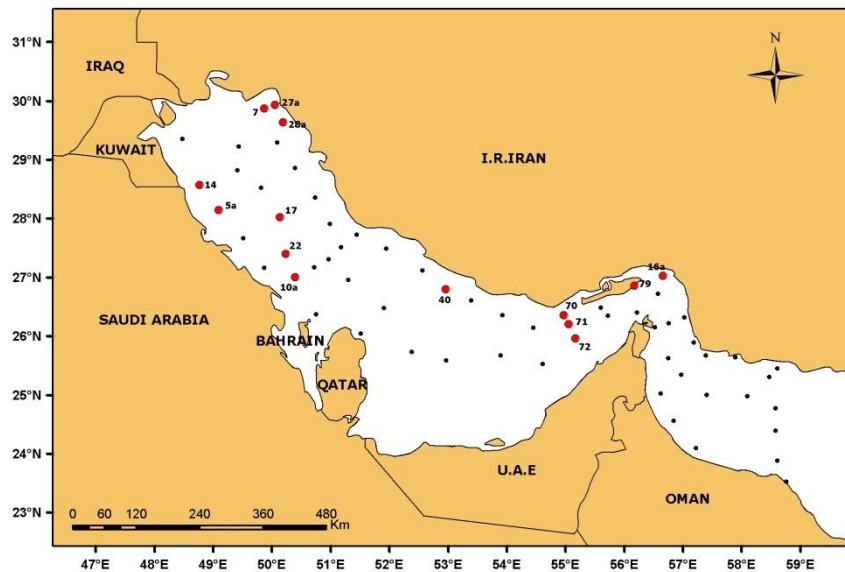
Cells 35-40 μm long; 27 μm wide.

Distribution:

Prorocentrum rhathymum has been originally described from the clone isolated from a surface water of the Cinnamon Bay, St. Johns, Virgin Islands (Loeblich *et al.*, 1979) and subsequently from macroalgae in coral reefs of the New Caledonia and the Ryukyu Islands (Japan) (Fukuyo, 1981). It was reported as associated with macroalgae, dead coral and seagrasses in the Malaysia (Mohammad-Noor *et al.*, 2007).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at inner RSA and Strait of Hormuz (refer sites map), never in large numbers; maximum abundance (2.8×10^2 cells/l) was associated with the northwestern part of the inner RSA (St. 27a). *Prorocentrum rhathymum* has been previously reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009) and contributed to the 1999 fish kill incidence.



Sites of occurrence of *Prorocentrum rhathymum* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Prorocentrales Lemmermann, 1910

Family: Prorocentraceae Stein, 1883

Genus: *Prorocentrum* Ehrenberg, 1834

(= *Exuviaella* Cienkowski, 1881)

Species: *sigmoides*

Scientific name: *Prorocentrum sigmoides* Bohm

Plate A154: g-j (Annex A)

References:

Taylor, 1976: p. 22-23.

Description:

Elongated cell, sometimes in S shape. Apical spine sharp and tiny; protruded from the anterior side. Two flagella at the anterior end; with thick and hard plates. Nucleus in U shape, normally at the posterior side; 60-85 μm long; 20-30 μm wide.

Harmful Effect:

It is a nontoxic species, but it is harmful to marine organisms due to oxygen depletion at high cell concentration (Fukuyo *et al.*, 2003).

Dimensions:

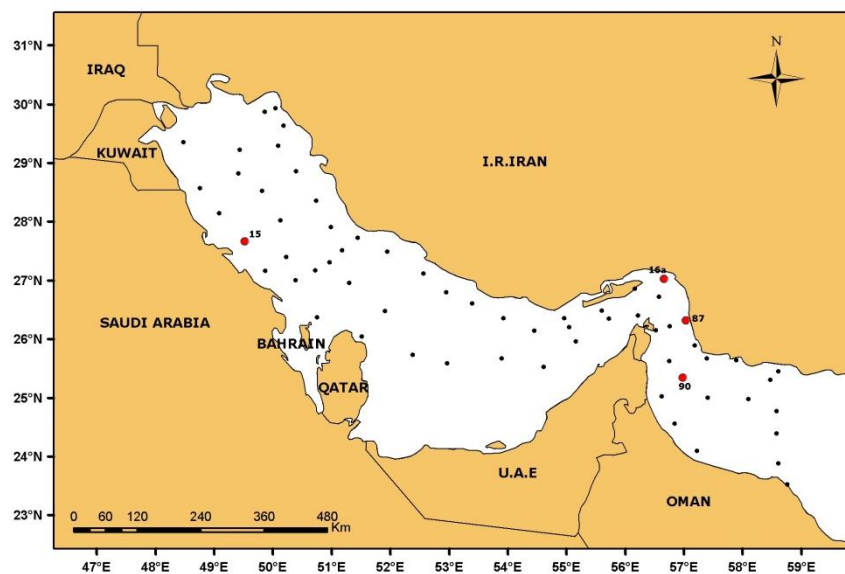
Cells 76-80 μm long; 16-19 μm wide.

Distribution:

Widely distributed in tropical and subtropical waters. Caused algae blooms at sheltered waters.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred in small numbers at scattered stations (refer sites map).



Sites of occurrence of *Prorocentrum sigmoides* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Prorocentrales Lemmermann, 1910

Family: Prorocentraceae Stein, 1883

Genus: *Prorocentrum* Ehrenberg, 1834

(= *Exuviaella* Cienkowski, 1881)

Scientific name: *Prorocentrum* sp.

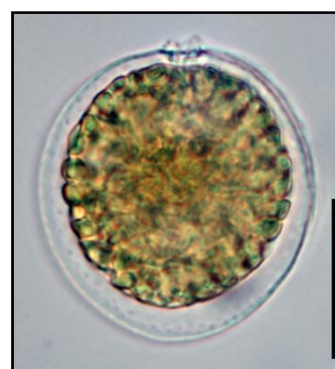
Plate A155: e-g (Annex A)

Description:

Cell rotundate in valve view, compressed in side view; anterior end with very slight depression and two small projections; thecal plates covered with pores; chloroplasts present.

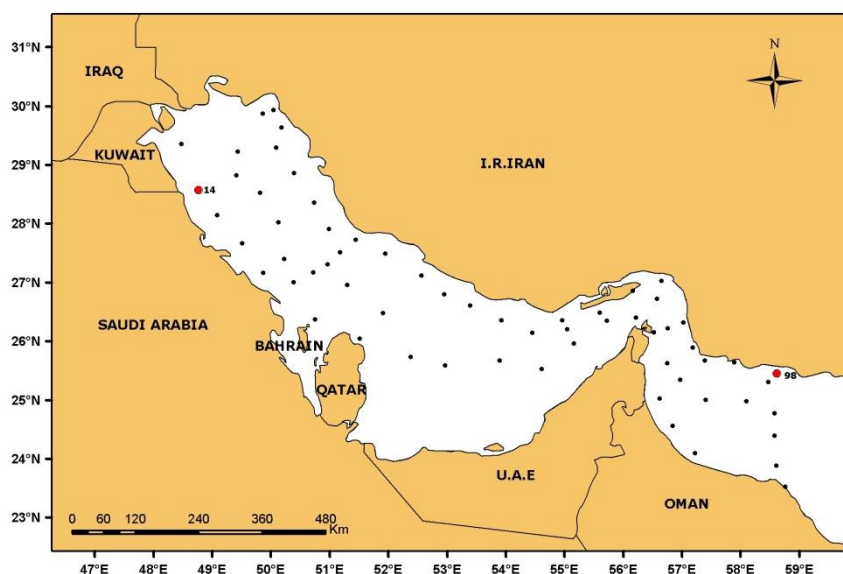
Dimensions:

Cells 37-40 μm long; 33-34 μm wide.



Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was encountered in small numbers at two stations (refer sites map).



Sites of occurrence of *Prorocentrum* sp. in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Pyrocystales Apstein, 1909

Family: Pyrocystaceae (Schütt) Lemmermann, 1899

Genus: *Dissodinium* Klebs in Pascher *emend.* Elbrächter *et* Drebes, 1978

Parasitic (e.g. on copepod eggs) dinoflagellates with complicated life cycle which also include planktonic cyst stage with strongly vacuolized cells and free-swimming gymnodinioid cells (dinospores) (Throndsen *et al.*, 2007).

Scientific name: *Dissodinium pseudolunula* Swift *ex* Elbrächter *et* Drebes

Plate A157: e, f (Annex A)

Reference:

Throndsen *et al.*, 2007: p. 108.

Description:

The secondary cyst is shaped as a crescent moon (lunate), with large vacuole and yellow-green to light brown chloroplasts. A number (up to 16) of dinospores are produced in the secondary cyst; cell shape, gymnodinioid, slightly longer than wide, with median cingulum, somewhat displaced, with pale (yellow-brown) chloroplasts. Flagellar movements can be seen when the dinospores are still inside the secondary cyst. Size: secondary cyst 100-200 µm from end to end, dinospores c. 30 µm long; distinguished from *Pyrocystis lunula* which has a similar lunate cyst stage, but only two dinospores in each cyst (Throndsen *et al.*, 2007).

**Harmful Effect:**

Secondary cysts with dinospores were frequently observed in net hauls from fish farms. Probably parasitic on salmon lice eggs (Throndsen *et al.*, 2007).

Dimensions:

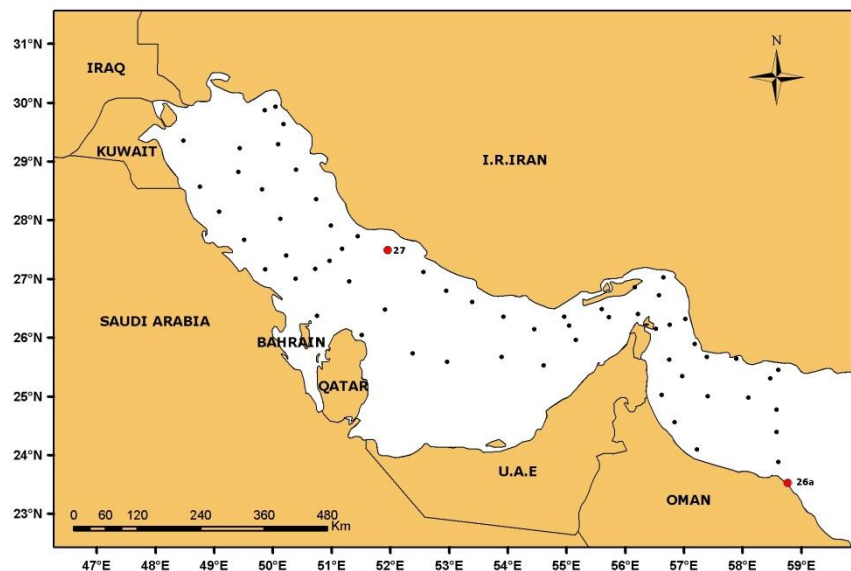
Cells 100-120 µm long; 19-25 µm wide.

Distribution:

Coastal and open waters.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was found in small numbers at two stations (refer sites map).



Sites of occurrence of *Dissodinium pseudolunula* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Pyrocystales Apstein, 1909

Family: Pyrocystaceae (Schütt) Lemmermann, 1899

Genus: *Pyrocystis* Murray *ex* Haeckel, 1890

(= *Gymnodinium* Stein, 1883 *partim.*, Klebs in Pascher *emend.*

Elbrächter *et* Drebes, 1978 *partim.*)

The genus comprises species with large spherical stage, lunate to horseshoe-shaped cells and motile gymnodinioid or peridinioid swimmers (Thronsdon *et al.*, 2007).

Scientific name: *Pyrocystis fusiformis* (Wyville-Thomson *ex* Haeckel) Blackman

Plate A157: a, b (Annex A)

References:

Wood, 1968: p. 125, Fig. 391 a, b; Taylor, 1976: p. 178, Pl. 39: 466-468, 471-473; Balech, 1988: p. 224, L. 2: 9, 10.

Description:

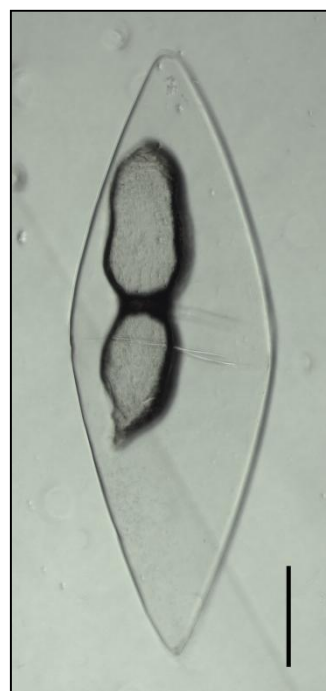
Vegetative cells large, thin and fusiform or wider and shorter with rounded ends; protoplasmic strands, marginal; spores gymnodinium-like. Length to 600 μm (Wood, 1968).

Dimensions:

Cells 295-340 μm long; 67-96 μm wide.

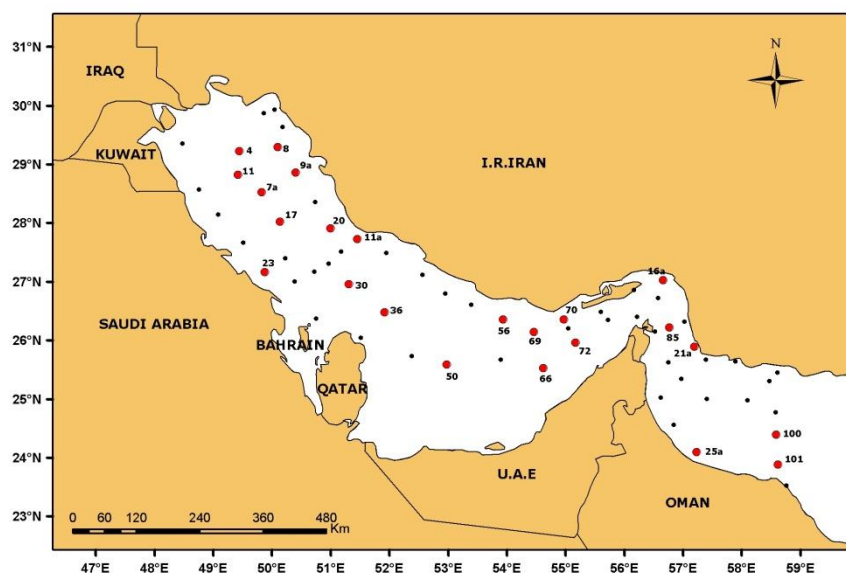
Distribution:

Interoceanic warm-water species. Species has previously been reported from the Indian Ocean (Taylor, 1976).



Sites of occurrence in RSA:

In Winter 2006 Cruise, vegetative stages of this species were occasionally observed (refer sites map), never in large numbers. This species has previously been reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Pyrocystis fusiformis* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Pyrocystales Apstein, 1909

Family: Pyrocystaceae (Schütt) Lemmermann, 1899

Genus: *Pyrocystis* Murray *ex* Haeckel, 1890

(= *Gymnodinium* Stein, 1883 *partim.*, Klebs in Pascher *emend.*

Elbrächter *et* Drebes, 1978 *partim.*)

Species: *noctiluca*

Scientific name: *Pyrocystis noctiluca* Murray *ex* Schütt

Plate A157: c (Annex A)

Synonyms:

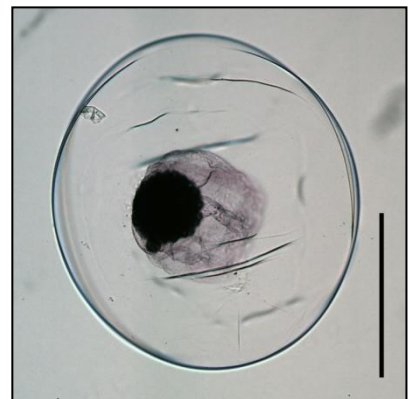
Pyrocystis pseudonociluca Wyville-Thomson *ex* Murray;

Pyrocystis pseudonociluca Schiller; *Goniodoma concava*

Gaarder; *Gonyaulax concava* (Gaarder) Balech

References:

Wood, 1968: p. 127, Fig. 395; Taylor, 1976: p. 180, Pl. 38: 461-465; Dodge, 1982: p. 140, Fig. 16 G, H; Balech, 1988: p. 224, L. 2: 2.

**Description:**

A globular coccoid dinophyte which is sparsely filled with cytoplasm, most of which are clustered around the nucleus. A motile thecate stage is produced which has delicate plates in the tabulation 4', 0a, 6'', 6c, 6''', 1p, 1'''' which is correct for the genus *Gonyaulax*. Smaller globose cysts may form within the large ones. Strongly bioluminescent. Coccoid cyst 350-800 µm diameter; thecate stage 60-80 µm diameter (Dodge, 1982).

Dimensions:

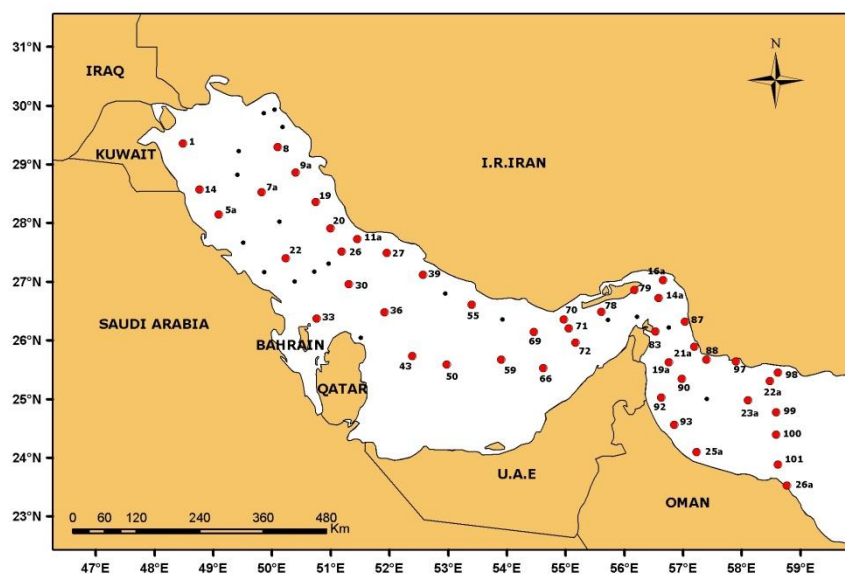
Cells 100-240 µm in diameter.

Distribution:

Warm-water oceanic species. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at many sites (refer sites map), although never in large numbers; maximum abundance (1.5×10^2 cells/l) was associated with the central part of the inner RSA off Bahrain (St. 33).



Sites of occurrence of *Pyrocystis noctiluca* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Pyrocystales Apstein, 1909

Family: Pyrocystaceae (Schütt) Lemmermann, 1899

Genus: *Pyrocystis* Murray *ex* Haeckel, 1890

(= *Gymnodinium* Stein, 1883 *partim.*, Klebs in Pascher *emend.*
Elbrächter *et* Drebes, 1978 *partim.*)

Species: *obtusa*

Scientific name: *Pyrocystis obtusa* Pavillard

Plate A157: d (Annex A)

Reference:

Wood, 1968: p. 126, Fig. 394.

Description:

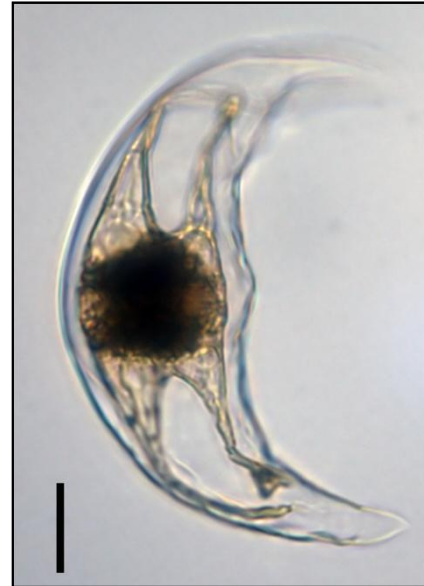
Body lunate with blunt ends directed toward each other. Length 150-250 μm (Wood, 1968).

Dimensions:

Cells 70-120 μm long; 25-30 μm wide.

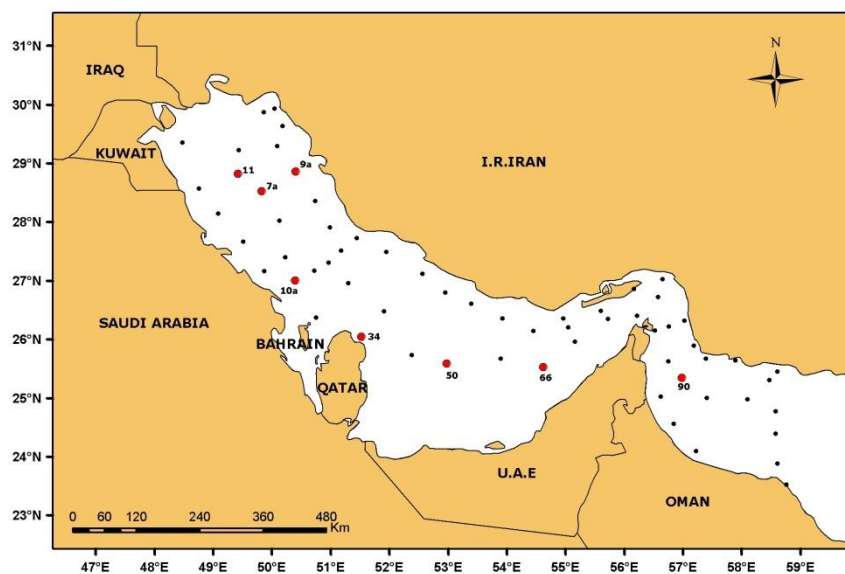
Distribution:

Oceanic species.



Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was found in small numbers at few scattered stations (refer sites map). This species has been previously reported from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Pyrocystis obtusa* in RSA

Division: Chromophyta

Class: Class Dinophyceae West *et* Fritch, 1927

Order: Pyrocystales Apstein, 1909

Family: Pyrocystaceae (Schütt) Lemmermann, 1899

Genus: *Pyrocystis* Murray *ex* Haeckel, 1890

(= *Gymnodinium* Stein, 1883 *partim.*, Klebs in Pascher *emend.*

Elbrächter *et* Drebes, 1978 *partim.*)

Species: *robusta*

Scientific name: *Pyrocystis robusta* Kofoid

Plate A80: d, e (Annex A)

References:

Wood, 1968: p. 126, Fig. 394; Taylor, 1976: p. 181, Pl. 38: 460; Balech, 1988: p. 224, L. 2: 7.

Description: Body lunate with incurved extremities forming an almost complete circle; midbody wide. Length 500 µm (Wood, 1968).



Dimensions:

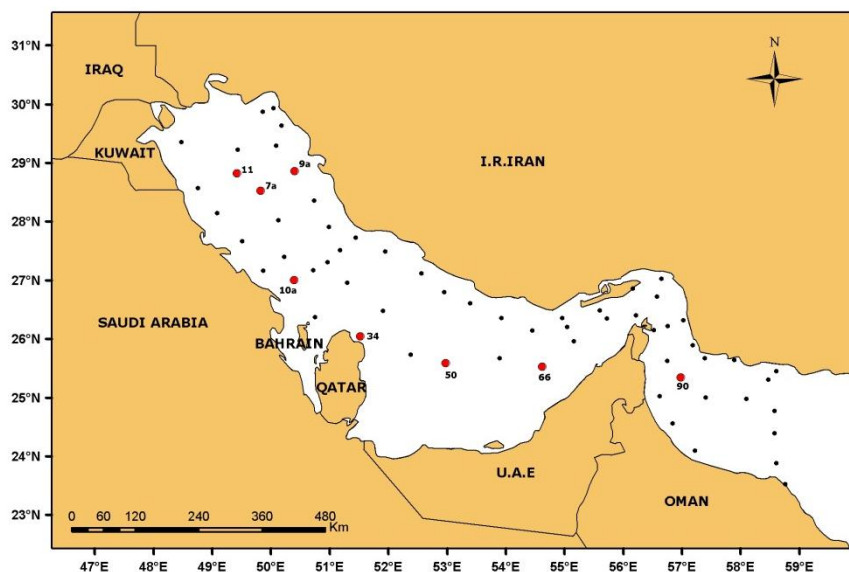
Cells 110-120 µm long; 40 µm wide.

Distribution:

Tropical and subtropical waters. Species has previously been reported from the Indian Ocean (Taylor, 1976).

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was recorded in small numbers at few scattered stations (refer sites map).



Sites of occurrence of *Pyrocystis robusta* in RSA

5.2.1 Division: Chromophyta

5.2.1.5 Class: Dictyochophyceae Silva

Order: Dictyochaes Haeckel

Family: Dictyochaceae Lemmermann

Genus: *Dictyocha* Ehrenberg

The cells are naked with one main flagellum and many yellow (brown) chloroplasts, often with an outer silica skeleton with radial spines (Throndsen *et al.*, 2007).

In Winter 2006 Cruise, silicoflagellates were commonly found in the samples but in low abundance – concentrations of *Dictyocha* spp. did not reach higher than 6.7×10^2 cells/l (4 % of total phytoplankton abundance). Relatively high abundance ($> 10^2$ cells/l) of this group was recorded in the waters of the Sea of Oman.

Scientific name: *Dictyocha fibula* Ehrenberg

Plate A158: a-e (Annex A)

References:

Throndsen *et al.*, 2007: p. 218.

Description:

Skeleton box-shaped; basal ring quadrate, rhombic or rhomboid with spines at corners and spinules or teeth along the limbs of the skeleton. Length 50-70 μm (Wood, 1968).

Harmful Effect:

It is a non-toxic species, but the spiny skeleton may irritate fish gills when present in high concentration (Hansen *et al.*, 2001).

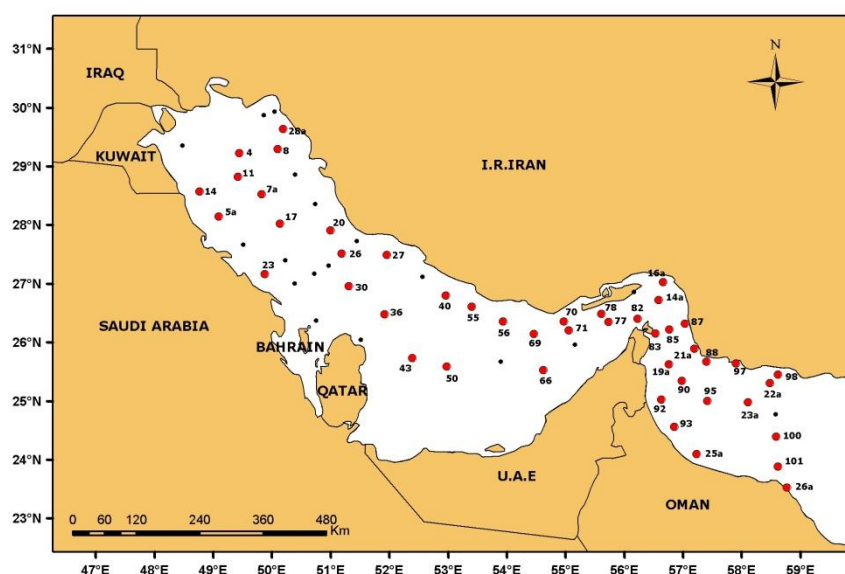
Dimensions:

Cells 44-65 μm long; 40-60 μm wide.

Distribution: Cosmopolitan, living or fossil.

**Sites of occurrence in RSA:**

In Winter 2006 Cruise, this species was commonly observed at many sites (refer sites map), although never in large numbers; maximum abundance (6.7×10^2 cells/l) was associated with the Sea of Oman (St. 90). It has been previously reported from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Dictyocha fibula* in RSA

Division: Chromophyta

Class: Dictyochophyceae Silva

Order: Dictyochales Haeckel

Family: Dictyochaceae Lemmermann

Genus: *Dictyocha* Ehrenberg

Species: *speculum*

Scientific name: *Dictyocha speculum* Ehrenberg

Plate A158: f (Annex A)

Synonyms:

Distephanus speculum (Ehrenberg) Haeckel; *Cannopilus calyptra* Haeckel

References:

Scott and Marchant, 2005: p. 254, Fig. 4.2 a-f; Throndsen *et al.*, 2007: p. 217.

**Description:**

Cells uniflagellate. Silica skeleton to 70 µm diameter (distance between the tips of the longest spines), comprising 2 hexagonal rings of different sizes connected by 6 bars and 6 conspicuous protruding spines; cytoplasm, contained between the hexagonal rings. Bars are attached to corners of a small ± circular ring. Large hexagonal ring c. 17-23 µm diameter; small hexagonal ring c. 7-11 µm diameter. Spines are radiating from the corners of the large ring, c. 15 µm long; smaller spines (usually 1-3), projecting from the small ring. Flagellum is located near one radial spine, c. 25 µm long, covered in flagellar hairs. Protoplast with a large central nucleus is surrounded by numerous discoid golden brown chloroplasts and other organelles (Scott and Marchant, 2005).

Harmful Effect:

The naked stage of this species has been suspected to produce ichthyotoxic substances (Moestrup and Thomsen, 1990). However, it was not possible to demonstrate a toxic effect in laboratory experiments, and the fish kills in the Danish waters were most likely caused by

anoxic conditions (Henriksen *et al.*, 1993). The skeleton-bearing stage may cause gill irritation (Hansen *et al.*, 2001).

Dimensions:

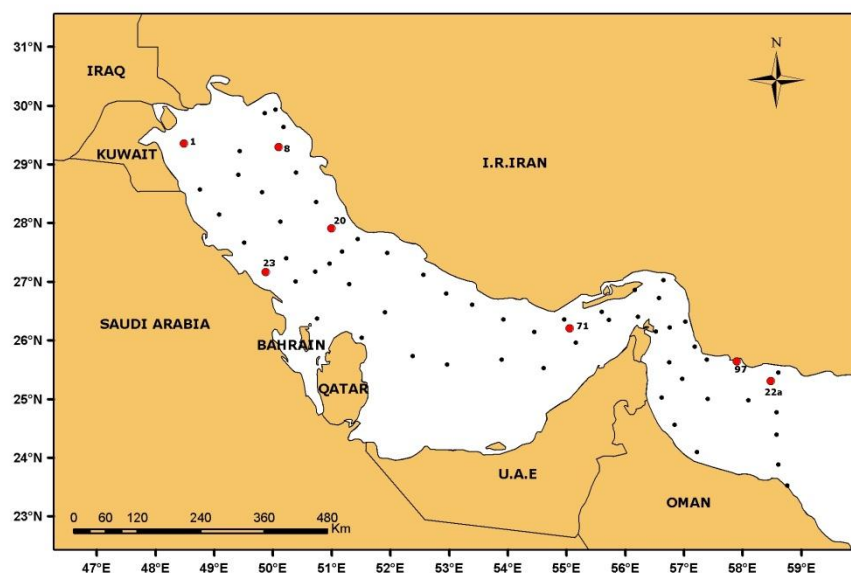
Cells 60-65 μm in diameter with spines.

Distribution:

Oceanic species.

Sites of occurrence in RSA:

in Winter 2006 Cruise, this species occurred in small numbers at few scattered stations (refer sites map). This species has been previously reported from Kuwaiti waters of the inner RSA (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).



Sites of occurrence of *Dictyocha speculum* in RSA

5.2.2 Division: Chlorophyta

5.2.2.1 Class: Euglenophyceae Schoenichen

Euglenophyceans are unicellular forms characterized by having a pellicular, a closed system of proteinaceous ribbons which run in helix around the cell just beneath the cell membrane. The borders between the ribbons often give the cell a characteristic striped ornamentation.

Some species are rigid, whereas, the pellicular ribbons in other species have many slides relative to each other and give the cell a marked change in shape: euglenoids movement. The same species may therefore be very variable in appearance, e.g., in preserved material (Thronsdén *et al.*, 2007).

Division: Chlorophyta

Class: Euglenophyceae Schoenichen

Order: Euglenales Engler

Family: Eutreptiaceae Hollande

Genus: *Eutreptiella* Perty

Autotrophic cells with two heterodynamic flagella and green numerous chloroplasts.

Scientific name: *Eutreptiella* sp.

Plate A159: a, b (Annex A)

Description:

Cells pointed cylindrical; with a relatively short canal-reservoir complex, and with two heterodynamic flagella.

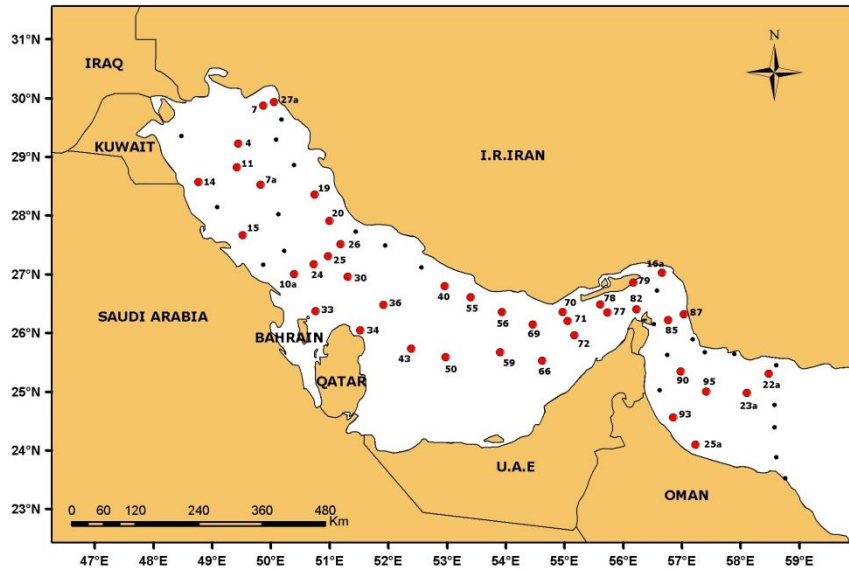
Dimensions:

Cells 38-45 µm long; 9-11 µm wide.

Sites of occurrence in RSA:

In Winter 2006 Cruise, *Eutreptiella* sp. was frequently encountered at various sites (refer sites map) in the RSA samples, but never reached high concentrations. The abundance of this species was lower compared to that of the other main taxonomical groups of phytoplankton, such as diatoms and dinoflagellates. Maximum contribution of *Eutreptiella* sp. to the total phytoplankton abundance did not exceed 2%; the highest concentration reached was 5.4×10^3 cells/l. Maximum abundances ($> 10^3$ cells/l) were noted in the southern part of the inner RSA and in the Sea of Oman.





Sites of occurrence of *Eutreptiella* sp. in RSA

5.2.2 Division: Chlorophyta

5.2.2.2 Class: Prasinophyceae Moestrup ex Trondsen

Prasinophyceans are characterized by having submicroscopic organic scales both on the flagella and the cell surface (in motile phase). In the light microscope the chloroplast color often appears more dirty-green than the bright green color in the chlorophyceans. In marine plankton, prasinophyceans are by far the most common among the green flagellates, but many species are small and often difficult to identify in preserved material. Coccoid prasinophyceans are most often phycoma stages (e.g., *Pterosperma*) which also have flagellate stages. Some species are only known as non-motile cells. Most species with phycoma stage are best characterized by this in the light microscope, whereas EM may be required for identification of the flagellate stage to species (Thronsen *et al.*, 2007).

Division: Chlorophyta

Class: Prasinophyceae Moestrup ex Trondsen

Order: Chlorodendrales Fritch.

Family: Halosphaeraceae Haeckel

Genus: *Prerosperma* Pouchet

In the phycoma stage, the cell is spherical with a more or less porous wall with a single hyaline equatorial brim or with a polygonal pattern of transparent lists of the surface. In the phycoma stage, the species can be identified in LM, for some few, also in the flagellate stage, which usually has to be identified to species in EM. The cells are spherical with many yellow-green to golden-brown chloroplasts, surrounded by a cell wall with brims or wings (alae). Variations in the polygon pattern within the same species require additional criteria as wall pores and/or proportion between lists and cell size for a reliable species identification (Thronsdén *et al.*, 2007).

Scientific name: *Pterosperma undulatum* Ostenfeld

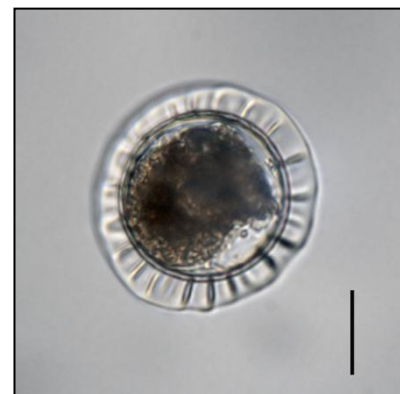
Plate A159: e, f (Annex A)

References:

Thronsdén *et al.*, 2007: p. 255.

Description:

Phycoma spherical or elongated with flattened poles, with smooth equatorial brim. Ala band with a ring of pores, but the outer phycoma wall is without pores. Diameter 35-47 µm ala inclusive. Ratio between phycoma diameter with and without wing is 1.5:1 (Thronsdén *et al.*, 2007).

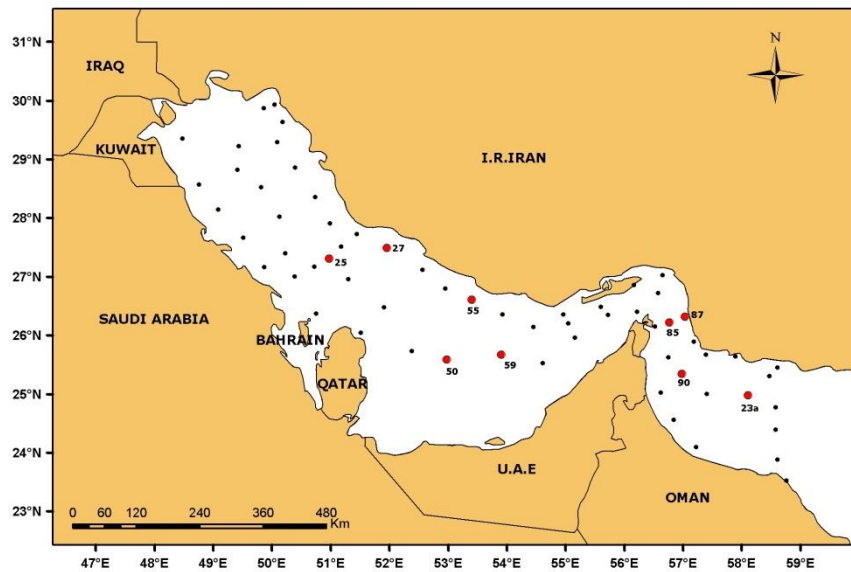


Dimensions:

Cells 46-61 µm in diameter including ala.

Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred in small numbers at few scattered stations (refer sites map). This species has been previously reported from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).



Sites of occurrence of *Pterosperma undulatum* in RSA

Division: Chlorophyta

Class: Prasinophyceae Moestrup *ex* Trondsen

Order: Chlorodendrales Fritch.

Family: Halosphaeraceae Haeckel

Genus: *Prerosperma* Pouchet

Scientific name: *Pterosperma* sp.

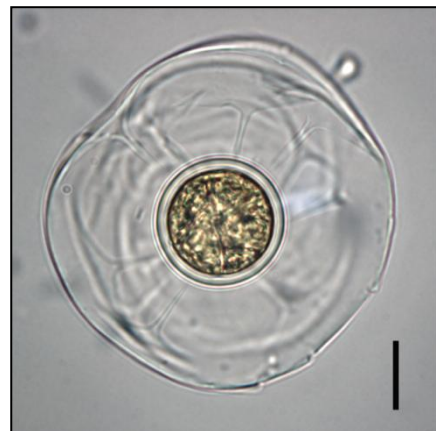
Plate A159: g, h (Annex A)

Description:

Phycoma spherical with an equatorial brim (ala) with irregular radial ribs.

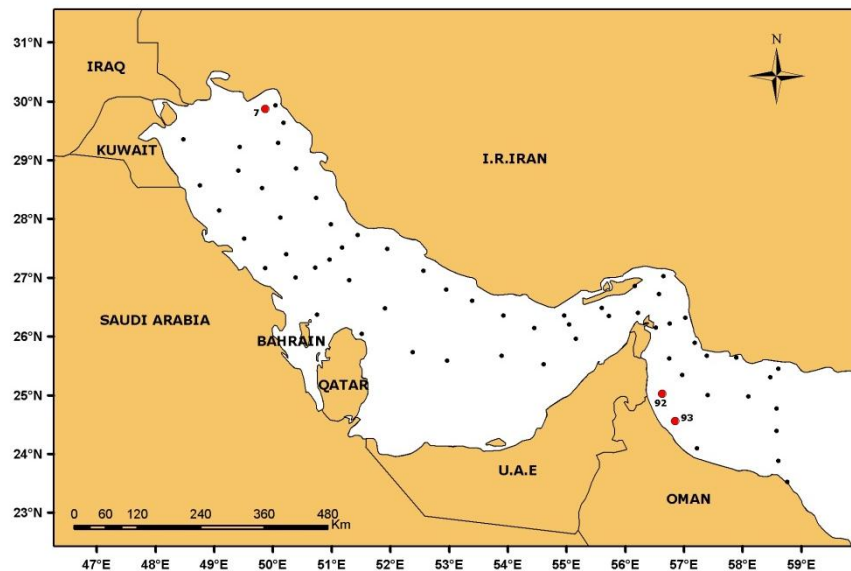
Dimensions:

Diameter 60-65 μm ala inclusive.



Sites of occurrence in RSA:

In Winter 2006 Cruise, this species occurred in small numbers at three stations (refer sites map).



Sites of occurrence of *Pterosperma* sp. in RSA

Division: Chlorophyta

Class: Prasinophyceae Moestrup *ex* Trondsen

Order: Chlorodendrales Fritsch.

Family: Halosphaeraceae Haeckel

Genus: *Pyramimonas* Schmarda

The typical cell is more or less rounded pyramid-shaped with four flagella from an apical cup-shaped depression. The chloroplast is campanulate with eyespot, apical lobes and basal pyrenoid covered by a starch shield. Numbers of flagella are 4, 8, 16, in one species, 32. The cell size varies from 4 to 35 μm within the genus. Species identification in EM (Thronsen *et al.*, 2007).

Scientific name: *Pyramimonas* sp.

Plate A159: c, d (Annex A)

Description:

Cell rounded pyramid-shaped with four flagella from an apical cup-shaped depression.

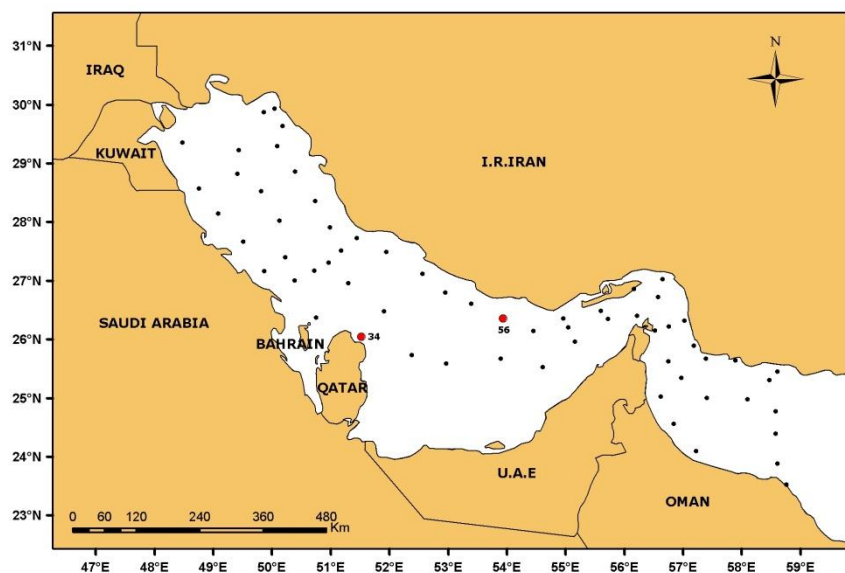
Dimensions:

Cells 8-9 μm long; 4-5 μm wide.



Sites of occurrence in RSA:

In Winter 2006 Cruise, this species was observed at two sites (refer sites map), never in large numbers; maximum abundance (9×10^2 cells/l) was associated with the central part of the inner RSA, off Qatar (St. 34).



Sites of occurrence of *Pyramimonas* sp. in RSA

5.3 Phylum: Zoomastigophora

5.3.1 Class: Class Ebriidea

The cells are naked, but enclosed in a delicate theca or membrane, colorless, with two flagella and a silica skeleton, which possibly lies in a fold in the cell surface (Throndsen *et al.*, 2007).

Phylum: Zoomastigophora

Class: Class Ebriidea

Order: Ebriida Poche

Family: Ebriidae (Lemmermenn) Deflandre

Genus: *Ebria* Borgert

Scientific name: *Ebria tripartita* (Schumann) Lemmermann

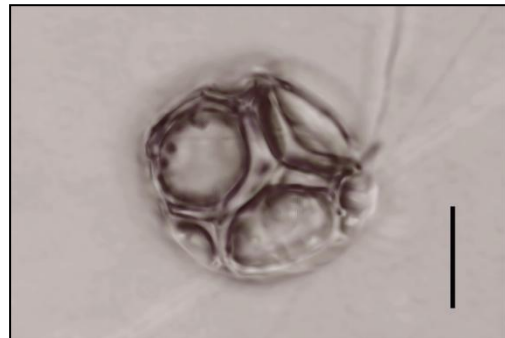
Plate A158: g, h (Annex A)

Synonym:

Dictyocha tripartita Schumann

Reference:

Throndsen *et al.*, 2007: p. 276.



Description:

Cell colorless with a *Patella*-shaped perforated skeleton which when resting on the object slide show three large oval apertures. Rim of the skeleton may be slightly jagged. In swimming cells the concave shape is evident, preserved cells usually show the broad side. Nucleus large, located apically where the two flagella protrude. Cell surrounded by a membrane and the cytoplasm keeps the shape to some extent even after fixation. Cell length 30-40 μm , flagella length about equal to the cell length (Throndsen *et al.*, 2007).

Dimensions:

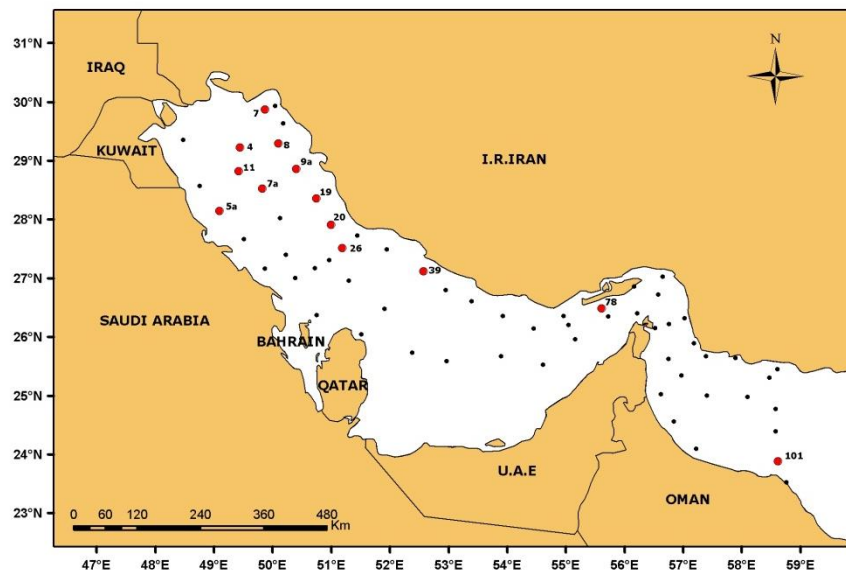
Cells 35-39 μm long; 28-30 μm wide.

Distribution:

Cosmopolitan; living and fossil.

Sites of occurrence in RSA:

In Winter 2006 Cruise, *Ebria tripartita* was observed in samples in very low concentrations (not higher than 1.3×10^2 cells/l, less than 2% of total phytoplankton abundance). It was sporadically distributed mainly within the northwestern part of the inner RSA (refer sites map).



Sites of occurrence of *Ebria tripartita* in RSA

5.4 Species Rarely Found in the Samples of Winter 2006 Cruise

Division: Chromophyta

Class: Bacillariophyceae

Order: Biddulphiales

Suborder: Coscinodiscineae

Family: Stellarimaceae Nikolaev *ex* Sims *et* Hasle

Genus: *Stellarima* Hasle *et* Sims

Prominent morphological features are several labiate processes in valve center and non along the margin (Throndsen *et al.*, 2007).

Scientific name: *Stellarima stellaris* (Roper) Hasle *et* Sims

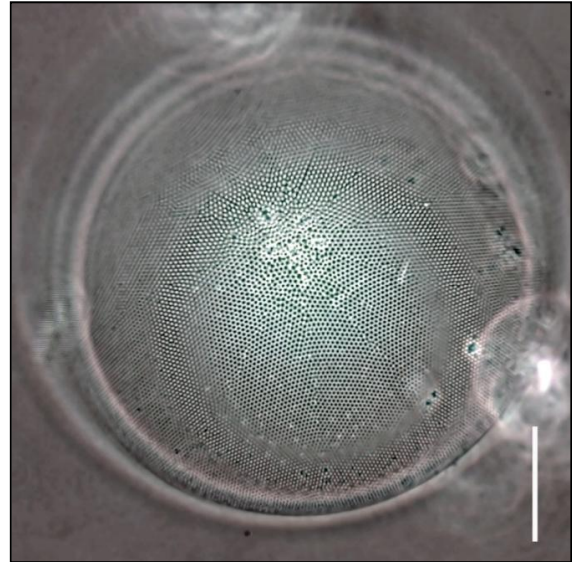
Plate A13: e (Annex A)

Synonym:

Coscinodiscus stellaris Roper

References:

Pavillard, 1925: p. 15, Fig. 20 (as *Coscinodiscus stellaris*); Hustedt, 1930: p. 396, Fig. 207 (as *Coscinodiscus stellaris*); Cupp, 1943: p. 54, Fig. 16 (as *Coscinodiscus stellaris*); Hendey, 1964: p. 81 (as *Coscinodiscus stellaris*); Simonsen, 1974: p. 18 (as *Coscinodiscus stellaris*); Throndsen *et al.*, 2007: p. 152.



Description:

Cells with convex valves; 50-105 μm in diameter, thin-walled. Valve surface areolated, areolae in more or less broad radial sectors within which the middle rows are nearly parallel, and tangential secondary rows are concave toward the outside. Areolae 13 in 10 μm at center, 15-16 midway, and 17-20 near edge. In the center of the valve, there are three to six irregular dark thickenings making a starlike formation. No spinulae or apiculi. No intercalary bands (Cupp, 1943).

Dimensions:

Valve diameter 84-95 μm .

Distribution:

Oceanic temperate species.

Sites of occurrence in RSA:

This species occurred in very small numbers at Transect 3 of northern inner RSA during Leg 3 of the Winter 2006 Cruise. It has also been reported previously from the inner RSA (Simonsen, 1974).

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Naviculaceae Kützing

Genus: *Mastoneis* Cleve

Species: *biformis*

Scientific name: *Mastoneis biformis* (Grunow) Cleve

Plate A56: j, k (Annex A)

Synonyms:

Navicula biformis (Grunow) Mann; *Stauroneis biformis* Grunow

Reference:

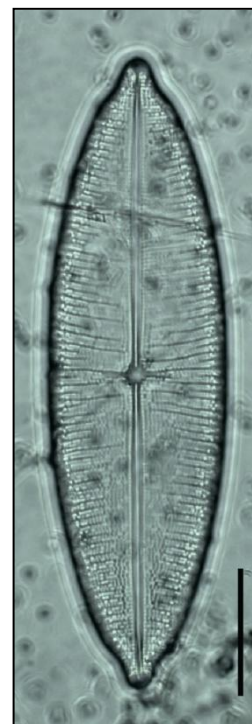
Hendey, 1970.

Description:

Valve elliptic to elliptic-oblong, with rostrate apices; valve surface complex, the outer lamina furnished with striae composed of fine puncta, 7 in 10 μm ; striae weakly radial throughout; the inner lamina bearing numerous costae directed from the valve margins to about half the distance from the margin to the raphe. Costae 8-9 in 10 μm ; raphe oblique, undulating; axial area very narrow, dilated at the central nodule to form a small pseudostauros which extend to less than one third in the width of the valve. Length 80-111 μm ; breadth 30 μm (Hendey, 1970).

Dimensions:

Cells length 96 μm ; width 28 μm .



Distribution:

Mainly, littoral species, but is sometimes found in the plankton.

Sites of occurrence in RSA:

This species occurred rarely in small numbers at Tansect 6 of northern inner RSA during Leg 3 of the Winter 2006 Cruise. It has been previously reported from Kuwaiti shore (Hendey, 1970).

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Naviculaceae Kützing

Genus: *Navicula* Bory

Cells are usually free, motile. In plankton, species are usually united into ribbonlike chains. Valves linear to elliptical, with rounded, capitate or rostrate ends. Axial and central areas usually distinct. Striae or costae parallel or radiate, finely or coarsely punctate, lineate or apparently smooth. Both valves with raphe and central nodule but without keel. Chromatophores two, in bands, one on each zone, sometimes extending over the valves. In some species, the chromatophores are on the valves. Some with four bands, others eight. One species known in which chromatophores are granular (Cupp, 1943).

Species occurrence in RSA:

Species of this genus were commonly observed, often in large numbers; maximum abundance of *Navicula* spp. (1.2×10^4 cells/l) was associated with the Strait of Hormuz area (Stations 77, and 78).

Scientific name: *Navicula directa* (Smith) Ralfs in Pritchard

Plate A62: i, j (Annex A)

Synonym:

Pinnularia directa Smith

References:

Hendey, 1964: p. 202; Hendey, 1970: p. 132.

Description:

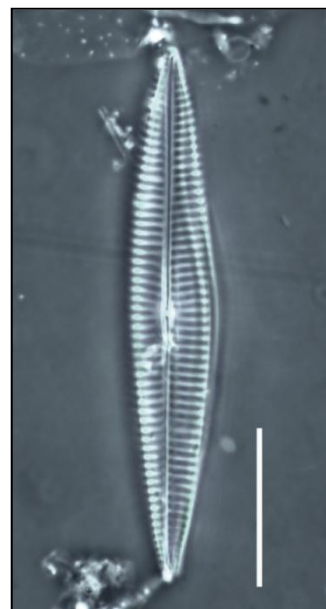
Valves linear-lanceolate, with sub-acute apices; axial area indistinct; central area small, polar nodules, small; valve surface with coarse striae; striae finely lineolate and arranged at right angles to the axial area throughout the length of the valve. Length of valve 80-120 μm , breadth 8-12 μm (Hendey, 1964).

Dimensions:

Cells length 68 μm ; width 12 μm ; transapical striae 8-9 in 10 μm .

Distribution:

Mainly, littoral species, but is frequently found in the plankton.

**Sites of occurrence in RSA:**

This species occurred rarely in small numbers at scattered stations in Transect 9 of southern inner RSA during Leg 2 of the Winter 2006 Cruise. It has also been reported previously from Kuwaiti shore (Hendey, 1970).

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Naviculaceae Kützinger

Genus: *Navicula* Bory

Species: *palpebralis*

Scientific name: *Navicula palpebralis* de Brébisson ex Smith

Plate A62: k, l (Annex A)

References:

Hendey, 1964: p. 216, Pl. XXXIV: 13-19; Hendey, 1970: p. 139.

Description:

Valves elliptic-lanceolate to lanceolate, with either broadly rounded or acute or acuminate-apiculate apices. Axial area very broad, widening to produce a lanceolate or lanceolate-rhombic area with either straight margins, or margins that are curved to follow those of the valves, or incurved or concave; striae in the form of sub-marginal band occupying about half or sometimes less than half the area between the raphe and the valve margin. Striae usually straight, transverse or weakly radiate, all more or less of the same length, 10-11 in 10 μm . Striae not distinctly punctate; in most specimens, the striae are completely smooth and of the elongated alveolar type. Very variable species (Hendey, 1964); valve length 56-60 μm ; breadth 18-20 μm (Hendey, 1970).

**Dimensions:**

Cells length 66 μm ; width 19 μm ; transapical striae 5.5 in 10 μm .

Distribution:

Mainly littoral species, but is frequently found in the plankton.

Sites of occurrence in RSA:

This species occurred rarely in small numbers at scattered stations in Transect 2a of northern inner RSA during Leg 3 of the Winter 2006 Cruise. It has been previously reported from Kuwaiti shore (Hendey, 1970).

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Naviculaceae Kützing

Genus: *Pleurosigma* Smith

Species: *formosum*

Scientific name: *Pleurosigma formosum* Smith

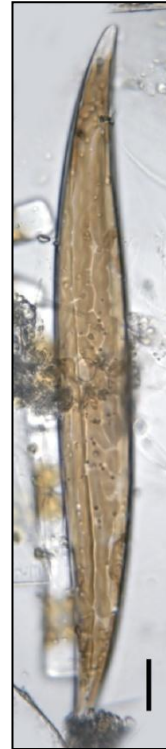
Plate A56: d-f (Annex A)

References:

Hendey, 1964: p. 242; Hendey, 1970: p. 151.

Description:

Valves elongated, linear to linear-lanceolate; sigmoid, with subacute apices. Raphe strongly sigmoid and toward the ends, eccentric, sweeping across the valve at about middle distance and becoming almost coincident with the convex margin as it approaches the apices; polar and central nodules, small; axial area absent. Valve surface striate, striae punctate and arranged in oblique lines, 10-14 in 10 μm , and in transverse lines, 14-16 in 10 μm . Oblique striae crossing each other at an angle of about 90°. Length of valve 360-500 μm , breadth 34-46 μm (Hendey, 1964).



Dimensions:

Cells length 280 μm ; width 38 μm .

Distribution:

Mainly littoral species, but is frequently found in the plankton.

Sites of occurrence in RSA:

This species occurred rarely in small numbers at scattered stations in Transects 1, 2, 3 and 4 of northern inner RSA during Leg 3 of the Winter 2006 Cruise. It has also been reported previously from Kuwaiti shore (Hendey, 1970).

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Catenulaceae Mereschowsky

Genus: *Amphora* Ehrenberg

Species: *obtusa*

Scientific name: *Amphora obtusa* Gregory

Plate A58: f (Annex A)

References:

Hendey, 1964: p. 268; Ricard, 1987: p. 259, Fig. 910-914.

Description:

Cells elliptical to oblong-elliptic, with rounded or slightly produced truncate ends; valves broadly linear, with weakly arcuate dorsal margin flattened in the middle and rounded at the ends, and a straight or nearly straight ventral margin. Raphe biarcuate; axial area absent; central area very small and confined to the dorsal side; valve surface striate, striae 10-12 in 10 μm .

Girdle is composed of several striate longitudinal segments. Length of valve 160-250 μm (Hendey, 1964).



Dimensions:

Cells length 83 μm ; width 18 μm .

Distribution:

Mainly littoral species, but is frequently found in the plankton.

Sites of occurrence in RSA:

This species occurred very rarely at Transect 5 in the central part of the inner RSA during Leg 3 of the Winter 2006 Cruise. It has also been reported previously from Kuwaiti waters of the inner RSA (Al-Kandari *et al.*, 2009).

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Bacillariaceae Ehrenberg

Genus: *Nitzschia* Hassall

Cells spindle-shaped, single or united into colonies. Valves keeled, the keel including a concealed raphe, usually diagonally opposite, either central or excentric. Keel puncta short or prolonged. Striae transverse, punctate. No central nodule. Chromatophores two bands placed transversely upon one zone. In certain forms the number of plates may vary from four to six. A pyrenoid sometimes found in center of a chromatophore (Cupp, 1943).

Scientific name: *Nitzschia distans* v. *tumescens* Grunow in Cleve and Möller
Plate A61: e, f (Annex A)

Reference:

Witkowski *et al.*, 2000: p. 378, Pl. 203: 10.

Description:

Frustules linear with truncate and slightly inflated corners and short wing-like expansions observed in girdle view. Valves, lanceolate with acutely rounded apices, 130-220 µm long. Raphe central, fibulae more than 3 in 10 µm; transapical striae 25-30 in 10 µm (Witkowski *et al.*, 2000).

Dimensions:

Cells length 125 µm; width 26 µm; fibulae 3 in 10 µm.

Distribution:

Mainly littoral species, but is found in the plankton.



Sites of occurrence in RSA:

This species occurred rarely in small numbers at Transect 9 of southern inner RSA during Leg 2 of the Winter 2006 Cruise.

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Bacillariaceae Ehrenberg

Genus: *Nitzschia* Hassall

Species: *panduriformis*

Variety: *panduriformis*

Scientific name: *Nitzschia panduriformis* Gregory v. *panduriformis* (sensu De Toni)

Plate A59: a-c (Annex A)

References:

Hendey, 1964: p. 279; Hendey, 1970: p. 157, Pl. 5: 56;
Simonsen, 1974: p. 54; Ricard, 1987: p. 273, Figs. 1029-1035;
Witkowski *et al.*, 2000: p. 397, Pl. 184: 13, 14; 186: 1-3.

Description:

Cells solitary, narrowly rectangular in girdle view. Valves linear-elliptic, with concave or slightly constricted sides, dividing the valve into two tongue-shaped segments. Apices broadly cuneate, sometimes subacuminate. margin with strongly marked keel, keel puncta 6 in 10 μm . Valve surface with a distinct longitudinal fold, more or less in the apical axis, but usually displaced slightly toward the keel margin. Valve surface striate; striae arranged in transverse and oblique lines, 14-19 in 10 μm . Sometimes, the striae cross the apical fold, or the fold may appear to be hyaline. Length of valve 60-120 μm , breadth 12-30 μm (Hendey, 1964).



Dimensions:

Cells length 90 μm ; width 28 μm ; transapical striae 16 in 10 μm ; fibulae 6 in 10 μm .

Distribution:

Cosmopolitan benthic species, occasionally found in plankton.

Sites of occurrence in RSA:

This species occurred rarely in small numbers at Transect 9 of southern inner RSA during Leg 2 of the Winter 2006 Cruise. It has also been reported previously from the inner RSA (Simonsen, 1974) and from Kuwaiti shore (Hendey, 1970) and coastal waters (Al-Yamani *et al.*, 2004; Al-Kandari *et al.*, 2009).

Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Bacillariaceae Ehrenberg

Genus: *Nitzschia* Hassall

Scientific name: *Nitzschia* sp. 2

Plate A60: d (Annex A)

Description:

Valves narrowly lanceolate tapering toward apices, which are cuneate, acutely rounded. Raphe strongly eccentric. Fibulae evenly spaced.

Dimensions:

Cell length 41 μm ; width 4 μm ; fibulae 16-17 in 10 μm .

Sites of occurrence in RSA:

This species occurred rarely in very small numbers at Transect 10 of southern inner RSA during Leg 2 of the Winter 2006 Cruise.



Division: Chromophyta

Class: Bacillariophyceae

Order: Bacillariales

Suborder: Bacillariineae

Family: Bacillariaceae Ehrenberg

Genus: *Nitzschia* Hassall

Scientific name: *Nitzschia* sp. 3

Plate A60: e (Annex A)

Description:

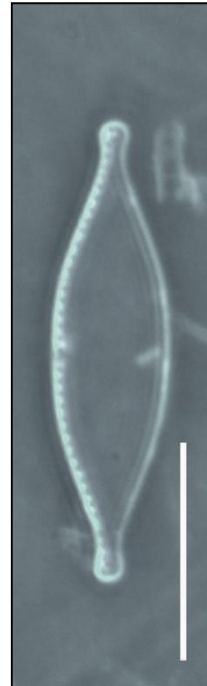
Valves narrowly lanceolate tapering toward apices, which are cuneate, acutely rounded. Raphe strongly eccentric; fibulae evenly spaced.

Dimensions:

Cells 32 μm long; 5 μm wide; fibulae 18-19 in 10 μm .

Sites of occurrence in RSA:

This species occurred rarely at Transects 6, 7 and 10 of both northern and southern inner RSA during Legs 2 and 3 of the Winter 2006 Cruise.



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7. Glossary of Terms Applicable to Diatoms

- acicular** - needle shaped.
- alveoli** - transversely linear chambers in the valve with a small opening externally and large opening internally.
- apex** - pole (end) of diatom valve.
- apical axis** - axis connecting the two poles of a valve.
- apiculate** - pole (apex) of valve tapering to a point.
- araphid** - diatoms without any raphe.
- arcuate** - strongly curved.
- areolae** - chambered pores in the diatom valve.
- axial area** - the area between the raphe and striae on the valve face.
- bifurcate** - divided into two branches.
- biraphids** - diatoms with raphe on both valves.
- biseriate** - two rows of pores or areolae.
- canal raphe** - raphe lying in a distinct groove.
- capitate** - pole (end) swollen.
- central area** - the clear area at the center of the valve face.
- central ending** - the external groove of the raphe slit at the center of the valve.
- central nodule** - the thickly silicified area in between the central endings of the raphe slits.
- cingulum** - girdle.
- clavate** - club-shaped.
- convergent striae** - striae converging (angling) towards the poles.
- copulae** - girdle bands.
- costae** - distinctly thickened ribs on the valve face.
- cruciform** - cross-shaped.
- cuneate** - wedge-shaped.
- dorsal margin** - the convex margin.
- dorsiventral** - valve with one convex, and one straight or concave margin.
- eccentric raphe** - raphe deviating from the apical axis.
- elliptical** - shape of valve ellipsoid.
- epitheca** - the larger overlapping valve.
- fascia** - a distinct central area extending to the margins of the valve, without any marking.
- fibula(e)** - siliceous bridge on either side of a raphe.
- foot pole** - narrow half (basal) of a club-shaped valve.
- frustule** - the cell walls of a diatom connected by girdle bands.
- girdle view** - side view of cell with girdle bands.
- head pole** - broad (upper) half of a club-shaped valve.
- heteropolar** - poles (apices) of valve being dissimilar.
- hyaline area** - clear area (siliceous) without any marking.
- hypotheca** - smaller underlying valve.

isopolar - poles of a valve being similar shape and size.

keel wing - a raised part of a valve face eccentrically located to the apical axis.

lanceolate - lance shaped.

lenticular - lens shaped.

linear - long and narrow almost uniform in width.

linear-clavate - elongated club-shaped.

linear-elliptic - elongated with inflated ellipsoid margins.

longitudinal striae - striae parallel to the longitudinal axis (apical axis) of the valve.

lunate - crescent shaped.

mantle - the side (outermost) part of valve bending downwards from the surface to the girdle.

monoraphid - diatom with a raphe only on one valve.

mucilage - viscous polysaccharide secreted by diatoms.

multiseriate - many rows of pores or areolae.

orbicular - spherical.

ovate - oval shaped.

panduriform - shaped like a fiddle ('8' shaped).

parallel striae - striae arranged more or less parallel to each other.

pennate - valve with laterally symmetrical.

polar nodule - thickened silicified area of the pole where the terminal ends of the raphe are located.

proraphid - diatoms with a small raphe at the poles.

puncta - poroid opening of the siliceous valve – a traditional term for areolae.

radiate striae - striae pointing to the center of the valve.

raphe - a longitudinal slit (groove) in the valve face located between the two polar nodules, with two raphe branches.

raphe branch - refers to the raphe branch from the center to the pole. A raphe consists of two raphe branches.

raphe-sternum - thickened hyaline axial area in pennate diatom (pseudoraphe).

rostrate - the apex of a valve ending like a beak.

septum - the inward expanded plate from the valvocopula (girdle band).

sigmoid - shaped like 'S' with the ends curving in opposite direction.

stauros - thickened central nodule extending to the margin of valve.

stellate - star shaped.

stigma(ta) - an isolated pore different from the pores of the striae usually located lateral to the central area.

stria(e) - row of pores in valve.

terminal endings (terminal fissures) - polar endings of raphe.

transapical axis - axis through the center connecting the margins across.

transverse striae - striae running across the valve face.

undulate - wavy.

uniseriate - single row of pores or areolae.

valve face - the surface of valve surrounded by the mantle.

valve margin - the edge of valve face.

valvocopula - copula (girdle element) closest to the valve – different in structure from the rest of the cingulum.

ventral - margin (straight or concave) opposite to the dorsal side.

8. Glossary of Terms Applicable to Dinoflagellates

antapex - the posterior-most part of the cell.

antapical - in dinokonts, the posterior pole of the cell.

antapical plates - in thecate dinokont species, the plates covering the posterior end of the cell (designated with "'") not in contact with the cingulum.

anterior - in desmokonts, the top part of the cell.

apex - the anterior-most part of the cell.

apical - in dinokonts, the anterior pole of the cell.

apical collar - a topographic feature of some prorocentroids (desmokonts). It is an extension of the intercalary band on the left valve along the anterior margin bordering the periflagellar area. This feature can be curved, flared, rounded or flattened. Oftentimes, this feature can only be viewed via SEM.

apical horn - a prominent apical extension of the cell formed by apical plates; it is a feature only found on thecate species. In these species, the apical horn constitutes the apex of the cell.

apical plates - in thecate dinokont species, the thecal plates that surround and are in contact with the apex of the cell (designated with ' ') not in contact with the cingulum. In those species with an apical pore complex (APC), the plates that touch the APC.

apical pore (ap) - pore located on the Po plate. This feature is not always a round or oval hole, but can be long and narrow and/or curved, or even fishhook shaped. In *Alexandrium* spp. the ap is referred to as a foramen. If the ap is a hole, then it may have a closing/cover plate (cp) or canopy.

apical pore complex (APC) - this feature is located on the epitheca of many marine, armoured (thecate) dinokont species. It includes an apical pore plate (Po), which bears an apical pore (ap), and often times, small peripheral pores. In addition, there can be a ventral apical plate or canal plate (X plate). The X plate is always posterior and ventral to the Po.

apical pore plate (Po) - part of the apical pore complex (APC); a feature located on the epitheca of many marine, armoured (thecate) dinokont species. The Po houses an apical pore (ap), and often times, small peripheral pores. The Po can be long and narrow, or wide and triangular.

areolae - surface ornamentation on thecal plates that approximates deep depressions with or without raised sides. The sides may be round to polygonal and are closely appressed. Areolae can contain pores, even double pores.

armored - dinoflagellate species that have thecal plates of varying thickness and orientation in identifiable tabulation series. Often the plates are thickened or ornamented with reticulations, spines, grooves, etc which are often characteristic to a species.

bloom - high concentrations of planktonic organisms due to enhanced cell division (growth) rates. Seasonal blooms are often related to periodical increase in nutrient and light conditions (e.g. spring bloom). Exceptional blooms are often dominated by one or a few species and may discolor the water a reddish-brown color, hence the name 'red tide'.

canal plate (X-plate) - a narrow elongated plate found on the epitheca of some thecate dinokont species ventral to the APC.

ciguatera - a human intoxication caused by ingestion of tropical piscivorous reef fishes contaminated with toxin-producing benthic/epiphytic dinoflagellates. These fish accumulate biotoxins through the food chain. More than 175 separate gastrointestinal, neurotoxic, or cardiovascular symptoms may be associated with this poisoning. In extreme cases death can result from respiratory failure. Although incidence is high, human mortality is low.

cingular plates - in thecate dinokont species, the plates that make up the cingulum (designated with a 'c').

cingulum - in dinokont species, this structure is usually a furrow (girdle) encircling the cell once or several times, and it can be displaced. In thecated species, the cingulum is made up of plates. This structure is missing in some desmokont-type cells (e.g. *Prorocentrum*).

closing plate (cp) - a small plate located in the apical pore complex (APC) of some marine, armoured dinokont species, and associated with the apical pore (ap).

concave - hollowed or rounded inward resembling the inside of a bowl.

convex - curved or rounded resembling the exterior of a sphere or circle.

costae - a rib or rib-like structure, often located in the apical pore complex of thecated species.

cyst - any dormant or resting nonmotile cell possessing a distinct cell wall.

desmokont - a dinoflagellate cell type in which two dissimilar flagella emerge from the anterior part of the cell; e.g. *Prorocentrum* sp. This morphological type does not have a cingulum or a sulcus.

Diarrhetic Shellfish Poisoning (DSP) – a human gastrointestinal disease caused by the ingestion of toxic marine shellfish (filter-feeding bivalves) from cold and warm temperate regions of the Atlantic and Pacific Oceans. Shellfish can accumulate and store large quantities of red tide dinoflagellate toxins without apparent harm to themselves. Symptoms include diarrhea, nausea and vomiting lasting a few days. No human deaths have been reported.

dinokont - a dinoflagellate cell type in which two flagella are inserted ventrally; one flagellum is transverse and housed in a cingulum and the other is longitudinal and housed in a sulcus. A dinokont dinoflagellate can be a thecate species (with thecal plates) or an athecate species (without thecal plates).

dinophysoid - group of dinokont type dinoflagellates. Members of this group are the only thecate dinoflagellates fundamentally divisible into two lateral halves and have an anterior cingulum and a narrow sulcus. They are laterally compressed, and their shapes in lateral view are essential for genus and species identification.

displaced cingulum - a cingulum in which the distal end is either above (ascending) or below (descending) the proximal end which is always on the left side of the cell.

dorsal - of or relating to the back side of an organism. In dinokonts, opposite the ventral side (front side).

dorsoventral - extending along the axis joining the dorsal and ventral sides.

epifluorescence microscopy - a method of microscopy used to view light-excited regions of an organism stained with a fluorochrome dye.

epitheca - the anterior part of the dinokont-type cell above the cingulum.

eukaryote - a cell with a membrane-bound nucleus.

flagellar pore - in desmokont dinoflagellates, the pore in which flagella emerge located in the periflagellar area (flagellar pore area).

flagellum - whip-like structures arising from the cell and responsible for propelling cells in a watery fluid. All dinoflagellates at some time in their life cycle have two dissimilar flagella: a transverse flagellum (provides propulsion) and a longitudinal flagellum (provides direction). They either emerge through one pore or two separate pores.

foramen - a relatively large comma-shaped cavity (apical pore) on the Po plate of *Alexandrium* spp. (sometimes fishhook shaped as in *Alexandrium catenella* and *A. tamarense*). It is a diagnostic feature of the APC.

hepatotoxic - toxic to the liver.

horn - in armoured cells an extension of the apical or antapical plates.

hypotheca - the posterior part of a dinokont-type cell below the cingulum.

intercalary band - marginal growth zones between thecal plates; usually striated horizontally or transversely.

lateral - in desmokonts oriented toward the left or right side of the cell.

lateral view - the lateral view of cell is the left or the right side view which usually represents the depth contour of a cell. In dinokonts, to orient to left and right, focus on the ventral surface with the sulcus and think of the left as the left side of the cell, not the left side of microscope field.

left - plate series in armored dinokonts are tabulated starting from the left side of the cell. Unarmored dinoflagellates also have left sides, for example, the posterior left side may contain the nucleus.

list - membranous thecal extensions of armoured dinoflagellates (often associated with the cingulum and sulcus); some extensions are curved or ribbed.

lobe - a rounded projection on a structure.

Neurotoxic Shellfish Poisoning (NSP) – a human neurological disease caused by the ingestion of toxic marine shellfish (filter-feeding bivalves). Symptoms are similar to those of ciguatera poisoning and include temperature reversal sensations, as well as headache, chills, and muscle and joint pain. Cases have been reported from the southeast US and eastern Mexico.

Paralytic Shellfish Poisoning (PSP) - a human neurological disease caused by the ingestion of toxic marine shellfish (filter-feeding bivalves) as well as other harvested seafood. PSP has been reported from cold and warm seas. Shellfish can accumulate and store large quantities of bloom or red tide dinoflagellate toxins without apparent harm to themselves. Symptoms include: tingling sensation around lips gradually spreading to face and neck; prickly sensation in fingertips and toes; headache, dizziness, nausea, vomiting, diarrhea. In extreme cases, muscular paralysis occurs resulting in death from respiratory paralysis.

periflagellar area - in prorocentroids (desmokonts) this region is located on the anterior end of the right valve within a notched area (V-shaped triangular depression). It consists of several plates or platelets around one or two periflagellar pores, the auxilliary pore (A) and the flagellar pore (F). Accessory pores, apical spine(s), periflagellar collars and/or periflagellar plates may also be present.

periflagellar collar - a topographic feature of the periflagellar area of some prorocentroids (desmokonts). It is a thecal extension of a periflagellar plate that can lie adjacent to the periflagellar pores (flagellar and auxiliary) and/or surround one or both pores. A

periflagellar collar can be flared and/or protuberant, or appear as a winged spine. Oftentimes, this feature can only be viewed via SEM.

periflagellar plates - a topographic feature of the periflagellar area of some prorocentroids (desmokonts); platelets situated around the periflagellar pores.

periflagellar pores - in prorocentroids (desmokonts), large apical pores found in the periflagellar area: auxiliary pore (A) and/or the flagellar pore (F). A periflagellar collar can surround these pores.

plate formula (tabulation) - plate patterns of armored dinoflagellates reflect orientation, as well as which plates are adjoining one another or what type ornamentation they produce. Tabulation refers to counting the plates in a specific designates series.. The plate formula is the combined tabulations for the plate series. A plate formula is generally stable within a genus.

pore - openings or channels in the theca of dinoflagellates that can be involved in extrusion of trichocysts or mucocysts and other active processes. Pore number and location are variable within a species, but in many groups, the pattern is a reliable, but variable character for identification of species.

poroid - shallow surface depressions on the valve surface.

post-cingular plates - in thecated dinokont species, the plates touching the cingulum in the hypotheca (designated with "'").

posterior - in desmokonts, the bottom end of the cell.

pre-cingular plates - in thecated dinokont species, the plates touching the cingulum in the epitheca (designated with " ").

premedian cingulum - in dinokont-type cells when the cingulum is above the midpoint of the cell.

prokaryote - a cell that contains a primitive nucleus where the DNA-containing region lacks a definitive membrane; e.g. bacteria and cyanobacteria.

prorocentroids - group of desmokont type dinoflagellate. Two anteriorly inserted flagella and two large laterally flattened valves easily distinguish the species of this group. The right valve has a small indentation, the periflagellar area, that houses the flagellar pore(s).

pyrenoid - cytoplasmic structure made of protein or appended to the chloroplasts in most phytoflagellates. They are associated with the formation or storage of polysaccharide food reserves (usually starch).

reticulae - surface ornamentation on thecal plates where raised straight lines or ridges cross one another creating a complex pattern resembling a network of fibers, veins or lines.

right - to orient to right, you first have to determine the ventral and dorsal surfaces of the cell. If you were looking directly at the ventral surface of a dinokont cell it would be on your left.

rugose - uneven surface covered with shallow minute depressions.

Scanning Electron Microscopy (SEM) - instrumentation used to observe minute surface details of small organisms/objects at high magnification by means of electron lenses. SEM techniques are often employed and needed to correctly identify a dinoflagellate species.

striae - surface ornamentation on unarmoured or armoured dinoflagellates that appear as longitudinal lines, ridges or grooves; on armoured species the striae can be interrupted by pores and may be associated with other markings, such as reticulations.

sulcus - longitudinal area on the ventral surface of dinokont-type cells that forms a pronounced furrow or depression that houses the longitudinal flagellum. In thecate species, the sulcus is made up of sulcal platelets (designated by 'st'). This feature is not present in some desmokont-type cells.

sutures - in armored species, visible linear boundaries between thecal plates.

theca - dinoflagellate membrane system encompassing the whole cell consisting of a complex of three to six membranes.

thecal plates - plates of armoured (thecate) species which are composed of cellulose or polysaccharide microfibrils. Their particular size, shape and arrangement on the cell are characteristic to a species.

trichocysts - a cytoplasmic ejectile organelle; a minute structure that emerges through pores in the theca of armoured dinoflagellates that releases filamentous or fibrillar threads when discharged.

tycoplanktonic - benthic dinoflagellate species found at some time in the water column.

unarmoured - dinokont-type cells that do not have an identifiable plate series and do not have apical pore complexes.

vacuole – a cytoplasmic membrane-bound cavity within a cell that may function in digestion, storage, secretion or excretion.

valves - in the thick-walled desmokonts, two opposing halves of the theca are called valves (right and left). The right valve is the one most indented anteriorly by the periflagellar plates.

ventral - the front side of an organism (opposite dorsal side): in dinokonts, side of sulcus and juncture of the cingulum-sulcus; in dinokonts, the side of flagellar insertion.

ventral pore (vp) - in some armored species, a ventral pore may be present at the juncture of the first apical plate (1') and an anterior intercalary or another apical plate on the epitheca. Sometimes the pore is in one of the apical plates. The presence of a ventral pore or its placement may be diagnostic for certain species.

ventral ridge - in dinokonts, an identifiable ridge on the right side of the sulcal intrusion onto the epitheca.

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Annex A

Microphotographic Plates

Abbreviations:

- LM** – Light Microscopy
- BF** – Bright Field
- DF** – Dark Field
- PhC** – Phase Contrast
- SEM** – Scanning Electron Microscopy

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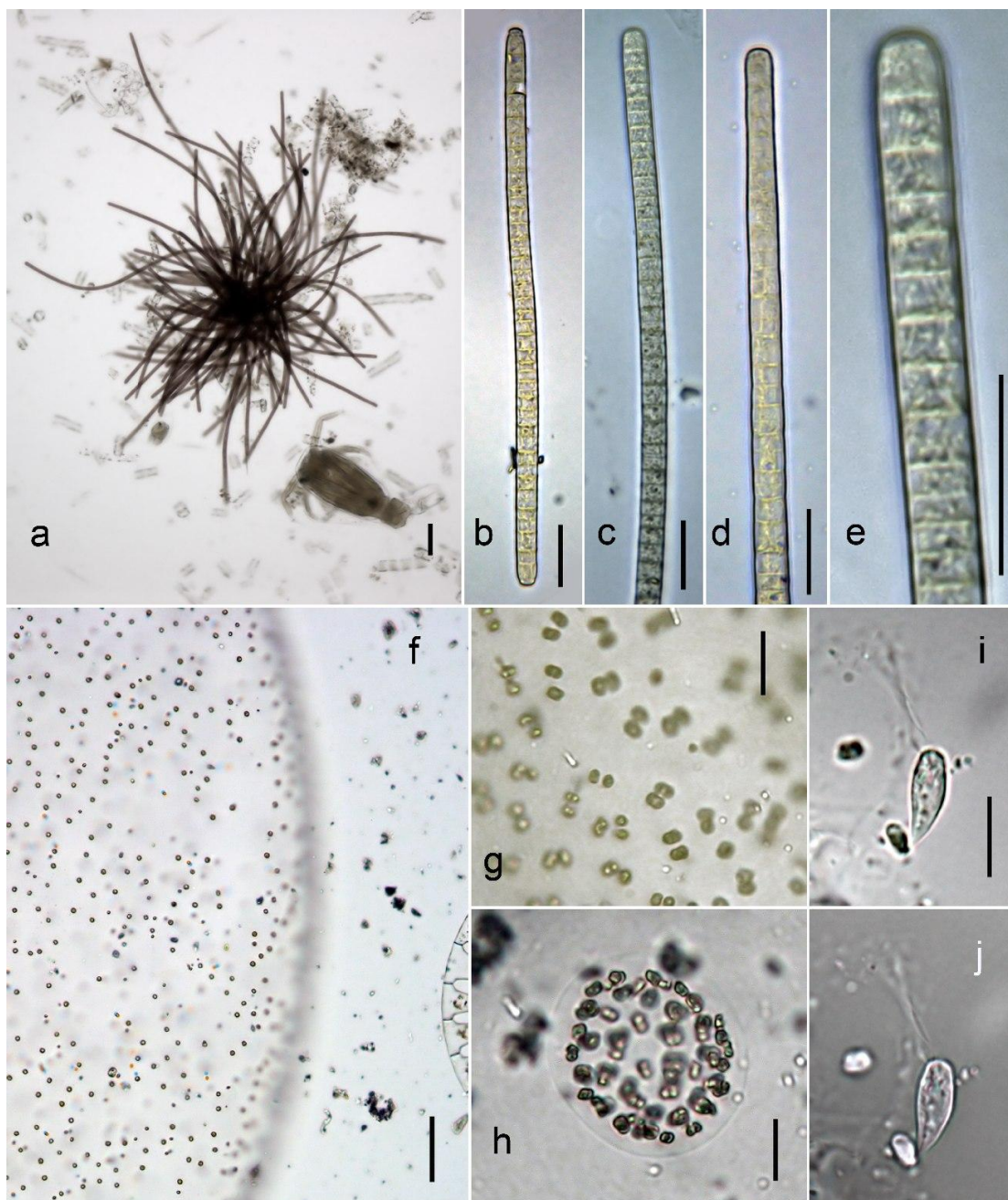


Plate A1. *Trichodesmium* sp. (a-e); *Phaeocystis* sp. (f-h); *Teleaulax* sp. (i, j).
a-i – LM, BF; j – PhC, DF. Scale bars: a-e – 20 μm; g-j – 10 μm; f – 50 μm.

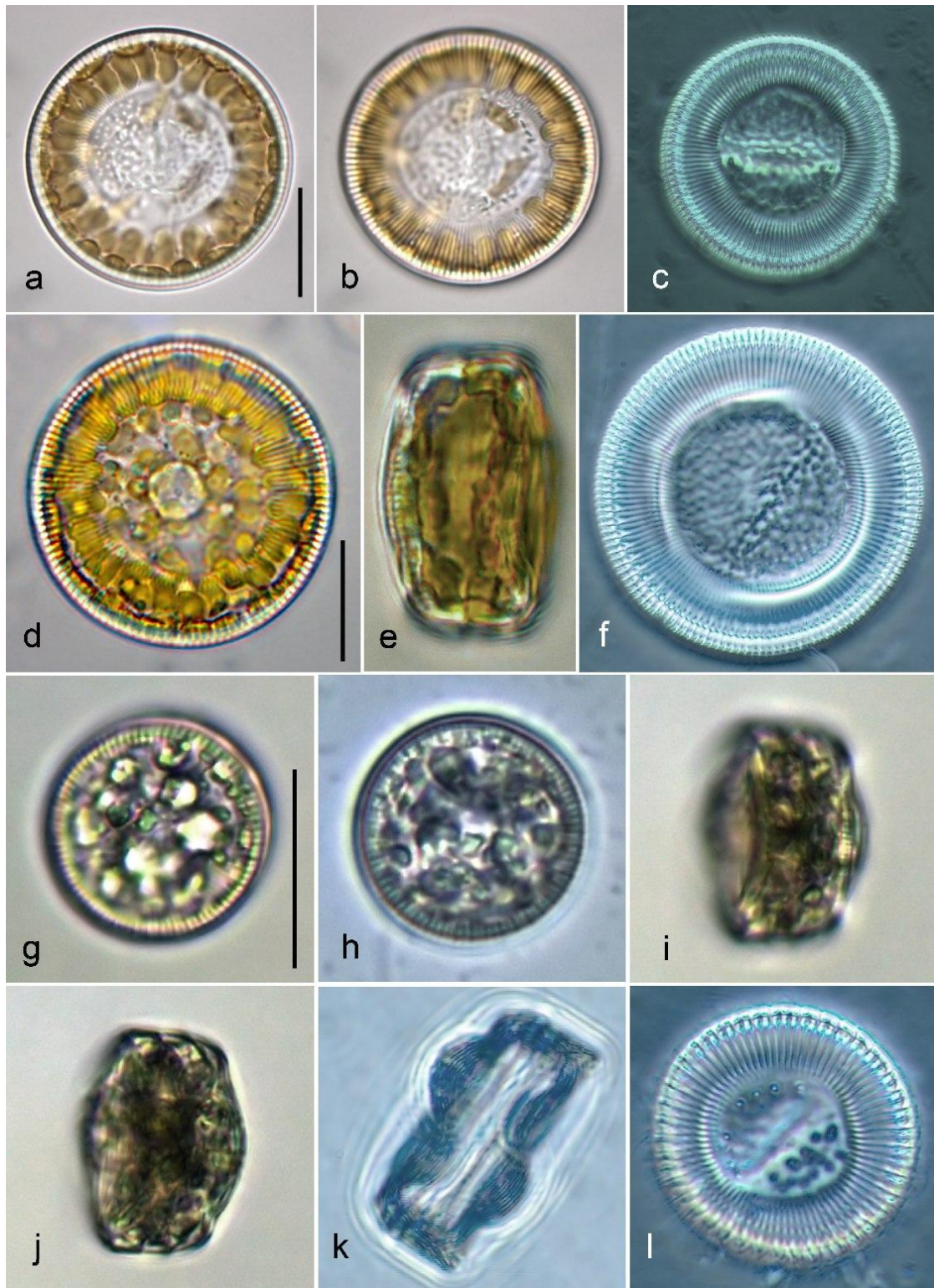


Plate A2. *Cyclotella stylorum* (a-f); *Cyclotella striata* (g-l).
a, b, d, e, g-j – LM, BF; c, f, k, l – PhC, DF. Scale bars: a-l – 20 μ m.

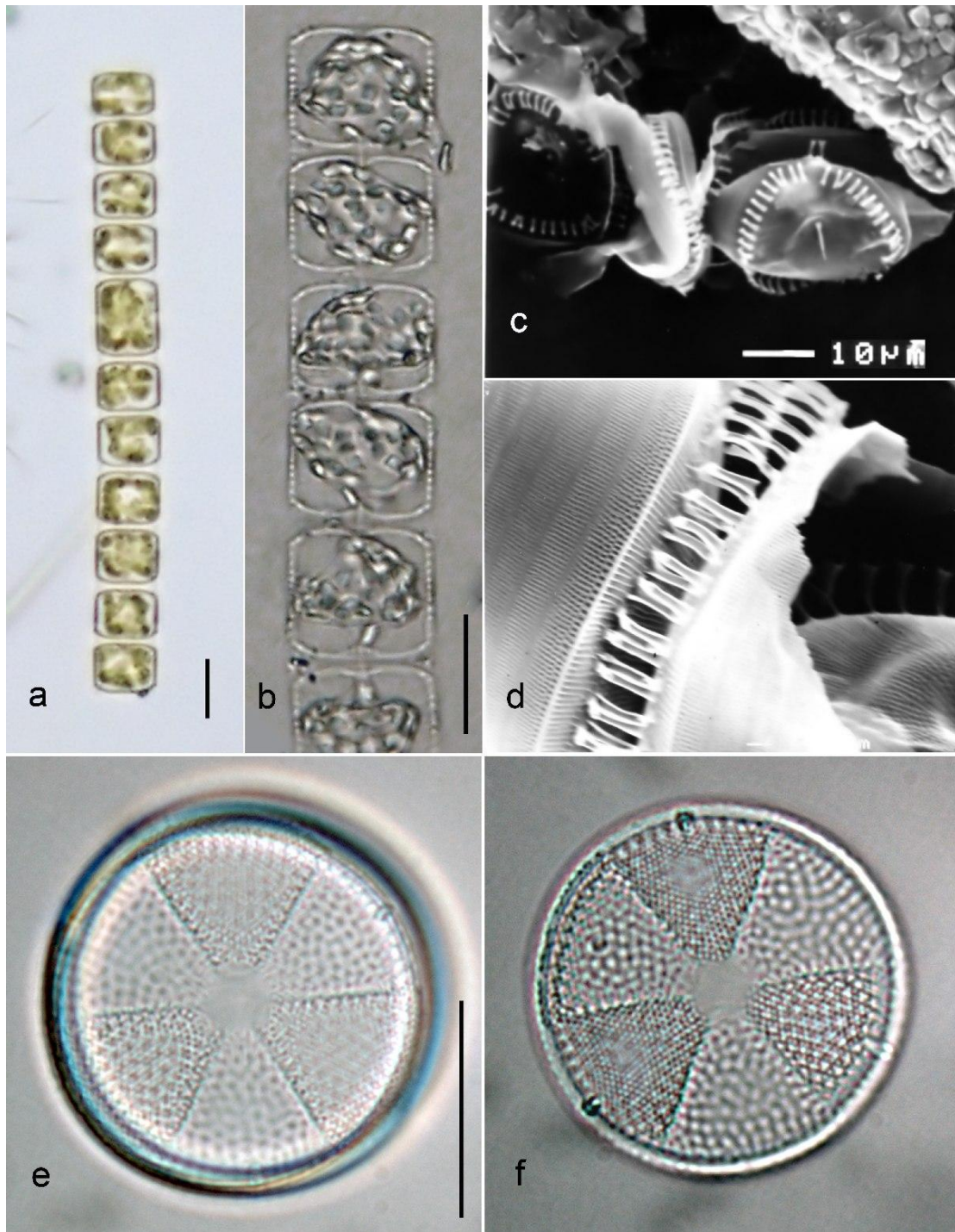


Plate A3. *Detonula pumila* (a-d); *Actinoptychus senarius* (e, f).
a, b, e, f – LM, BF; c, d – SEM. Scale bars: a, e, f – 20 μm; b, c – 10 μm.

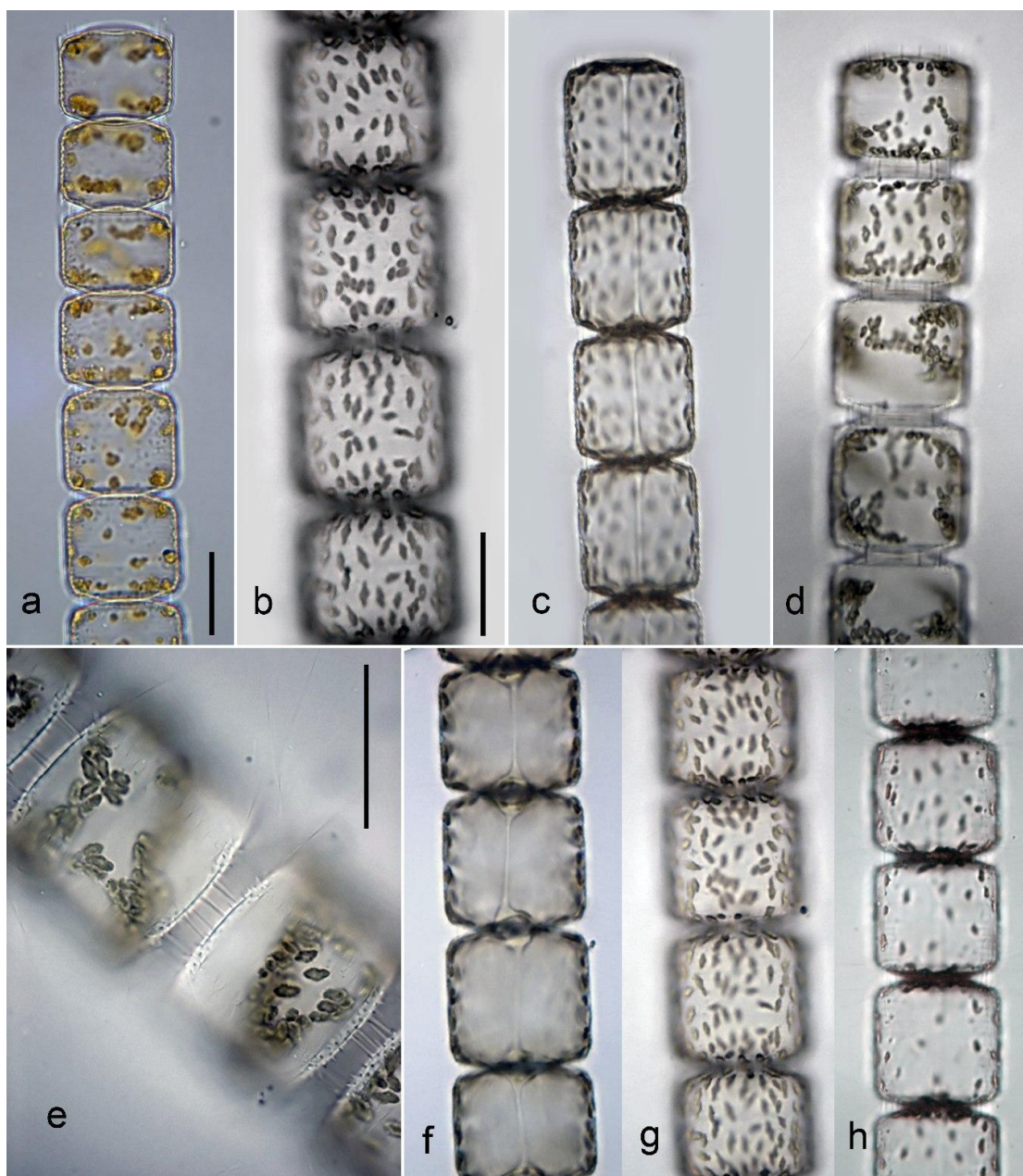


Plate A4. *Lauderia borealis* (a-h).
a-h – LM, BF. Scale bars – 50 μm .

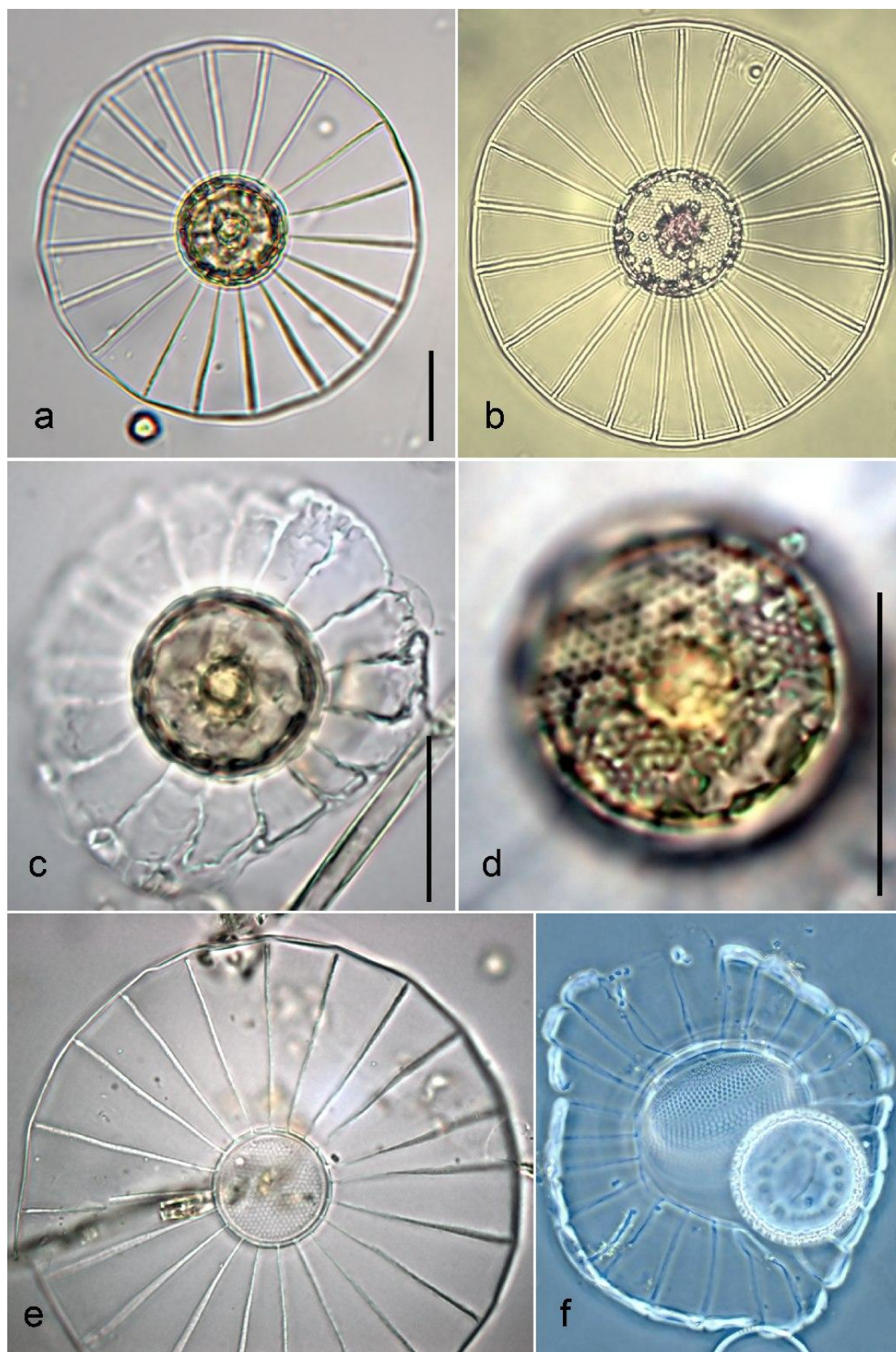


Plate A5. *Planktoniella sol* (a-f).
a-e – LM, BF; f – PhC, DF. Scale bars – 20 μm.

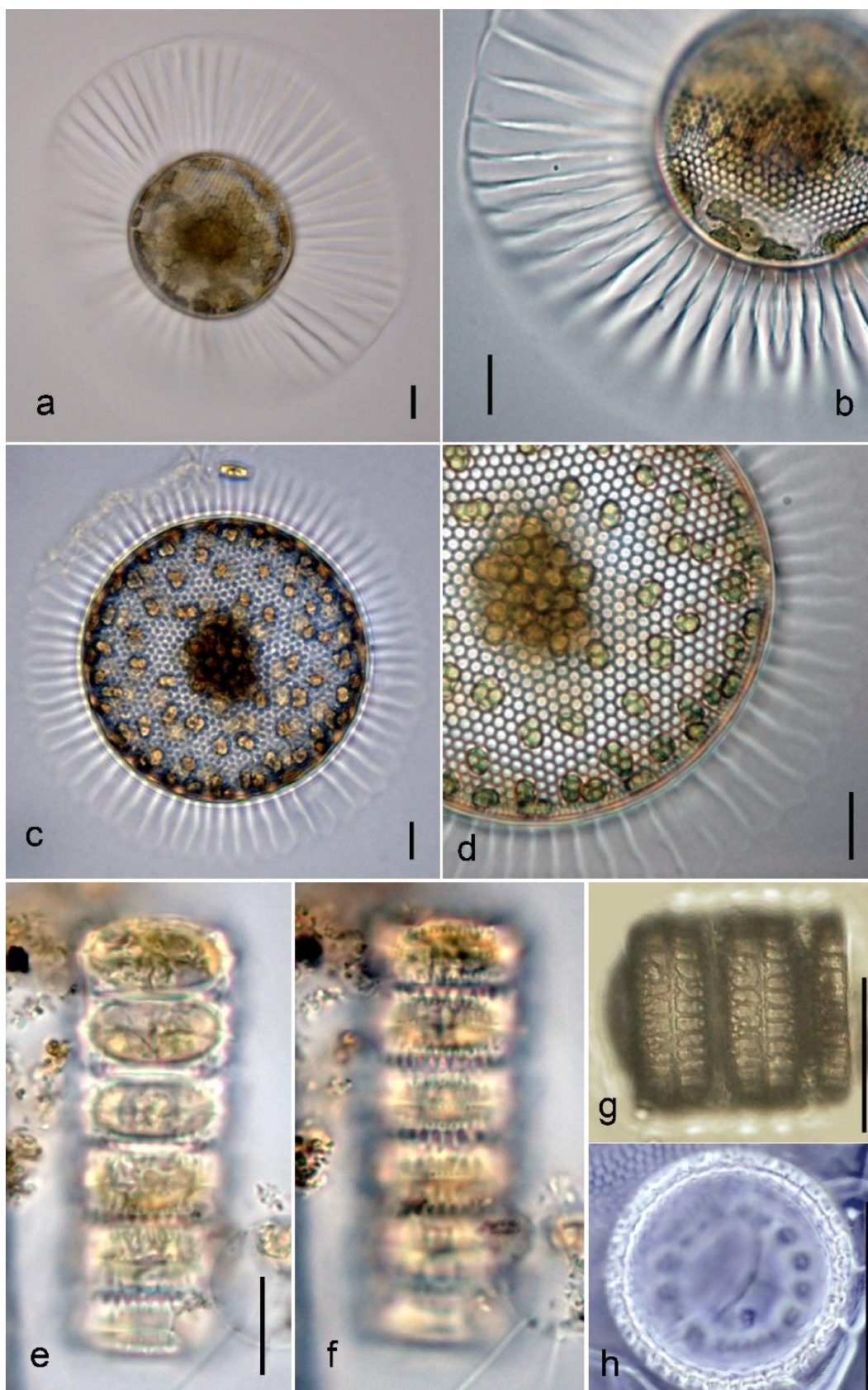


Plate A6. *Planktoniella sol* (a-d); *Paralia sulcata* (e-h).
a-f – LM, BF; g, h – PhC. Scale bars: a-d – 20 μm ; e-h – 10 μm .

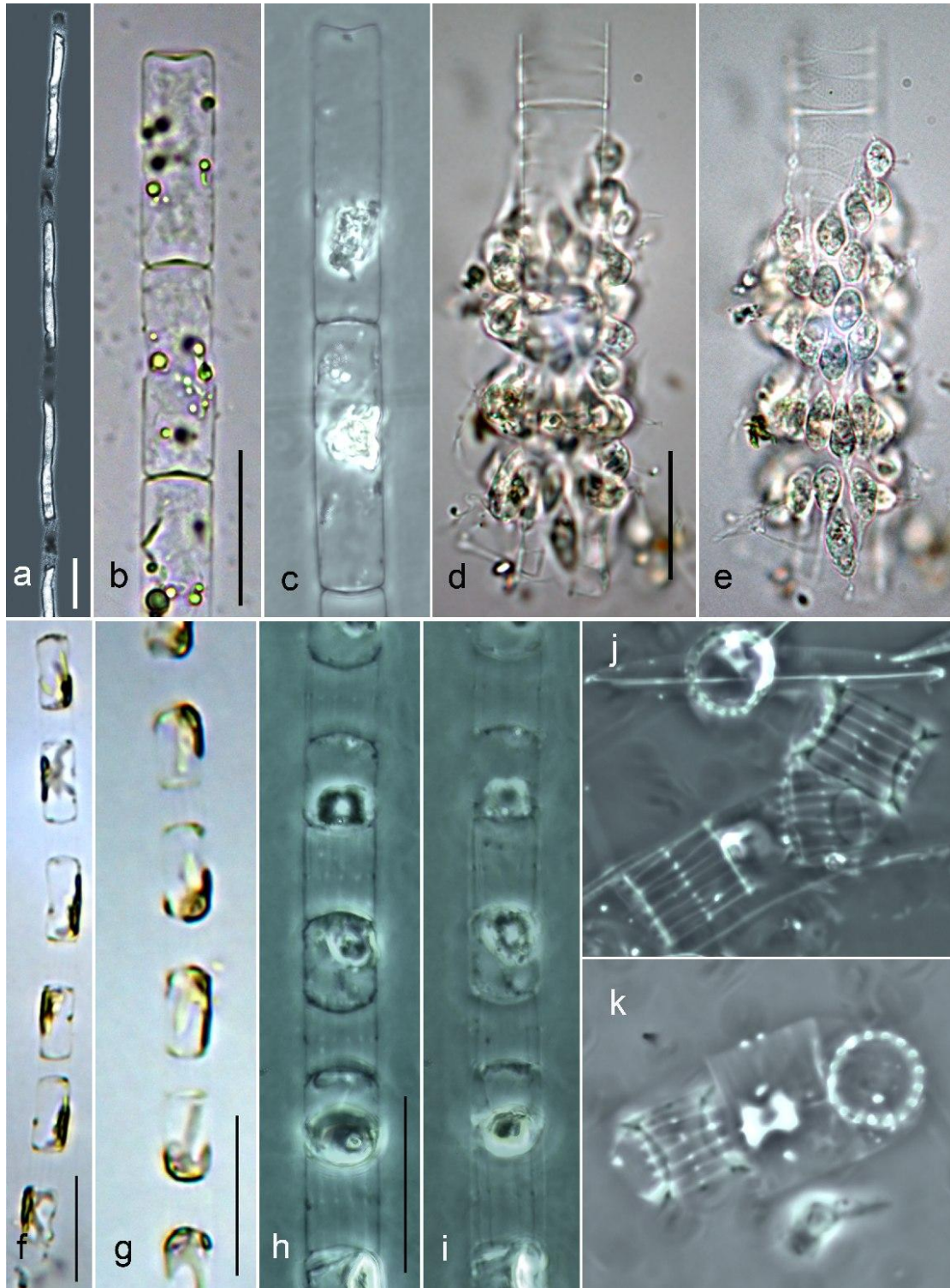


Plate A7. *Leptocylindrus minimus* (a); *Leptocylindrus danicus* (b, c); *Leptocylindrus mediterraneus* (d, e); *Skeletonema cf. costatum* (f-k).
b, d-g – LM, BF; a, c, h-k – PhC, DF. Scale bars: a-c, f-k – 10 µm; d, e – 20 µm.

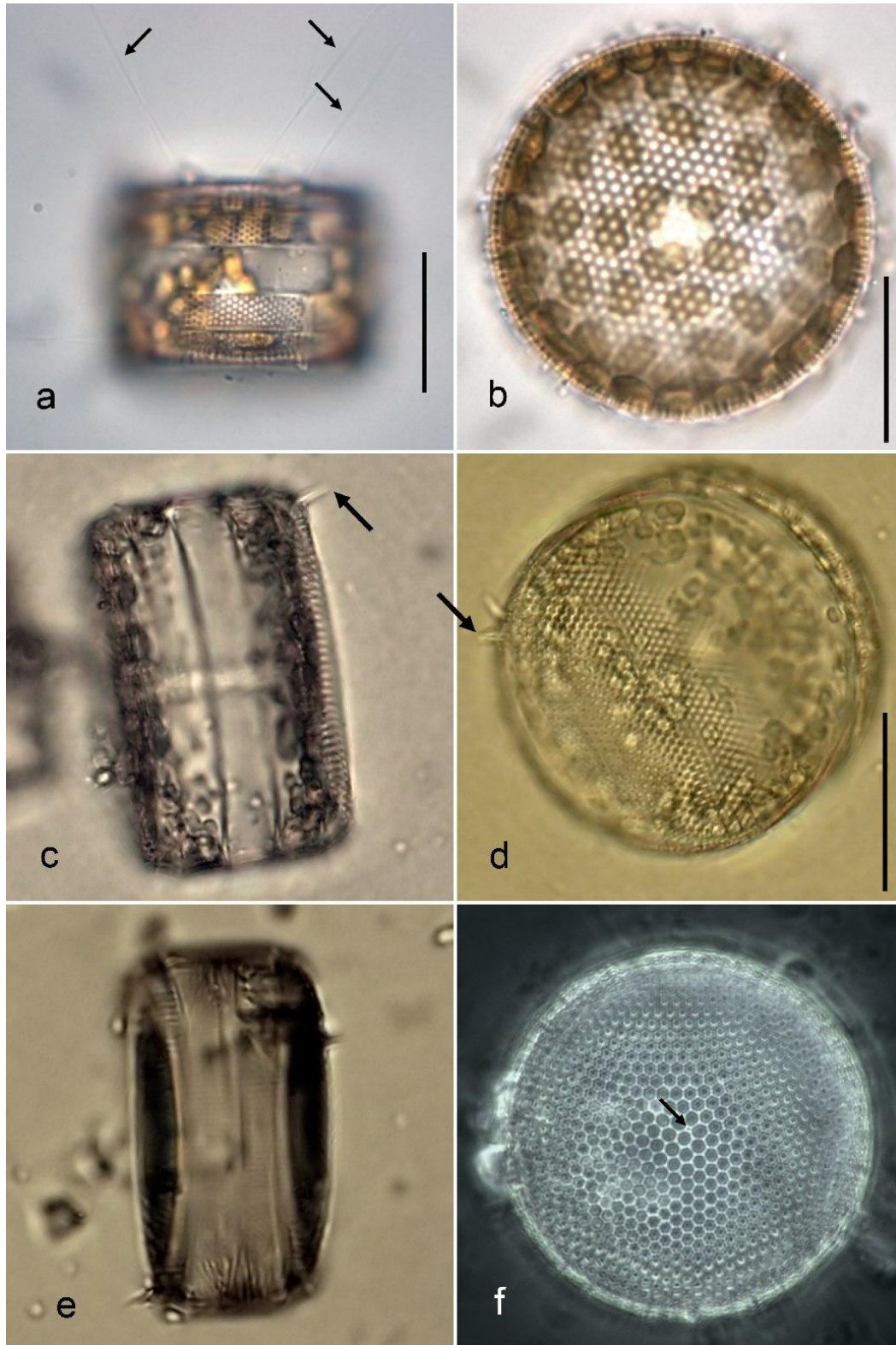


Plate A8. *Thalassiosira eccentrica* (a-f).

a – mucous threads are indicated by arrows; c, d – labiate process is indicated by arrows; f – central strutted process is indicated by arrow.

a-e – LM, BF; f – PhC, DF. Scale bars – 20 μ m.

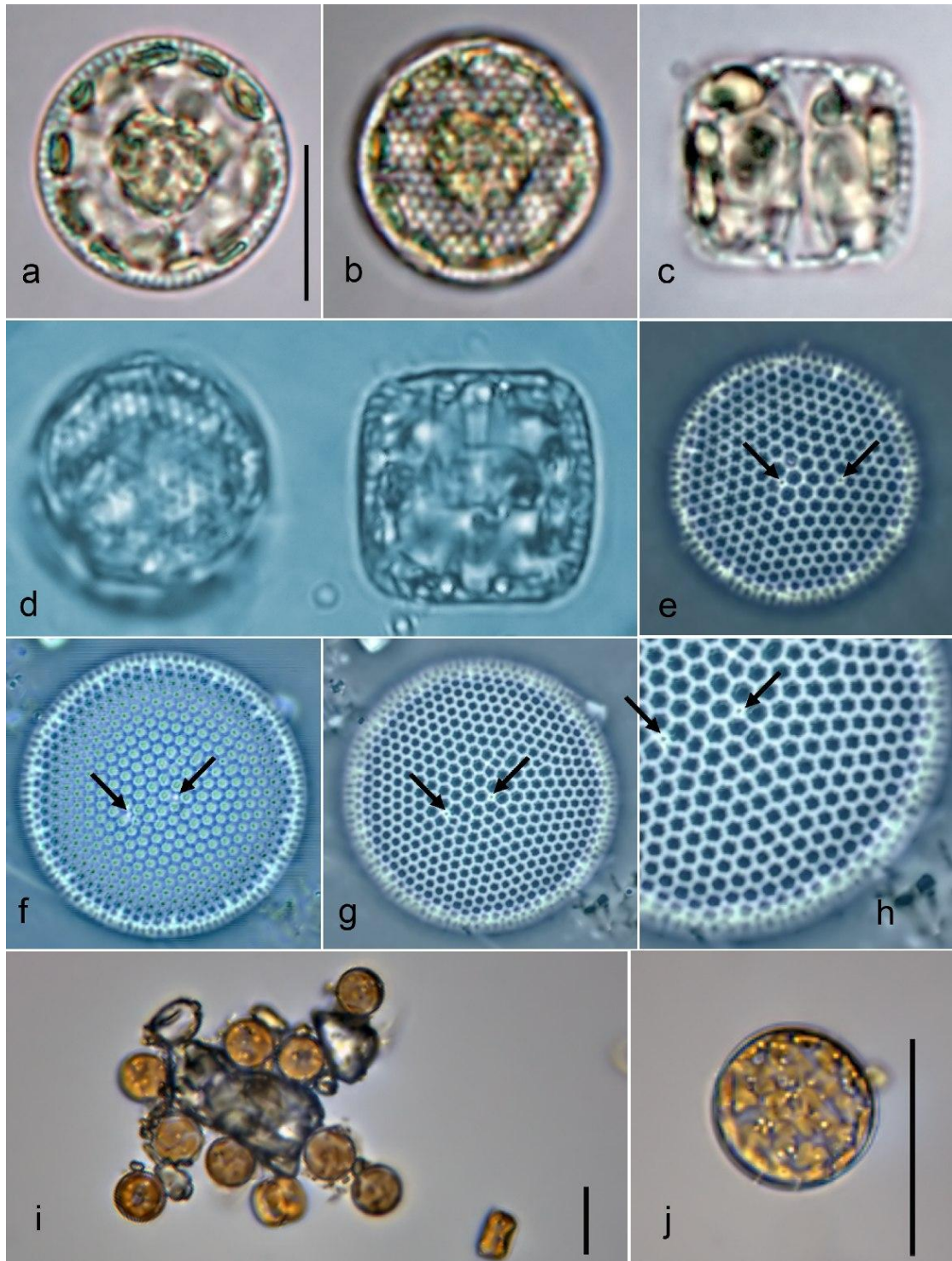


Plate A9. *Thalassiosira oestrupii* (a-h); *Thalassiosira* sp. (i, j).
e-h – two central strutted processes are indicated by arrows.
a-d – LM, BF; e-h – PhC, DF. Scale bars – 10 μ m.

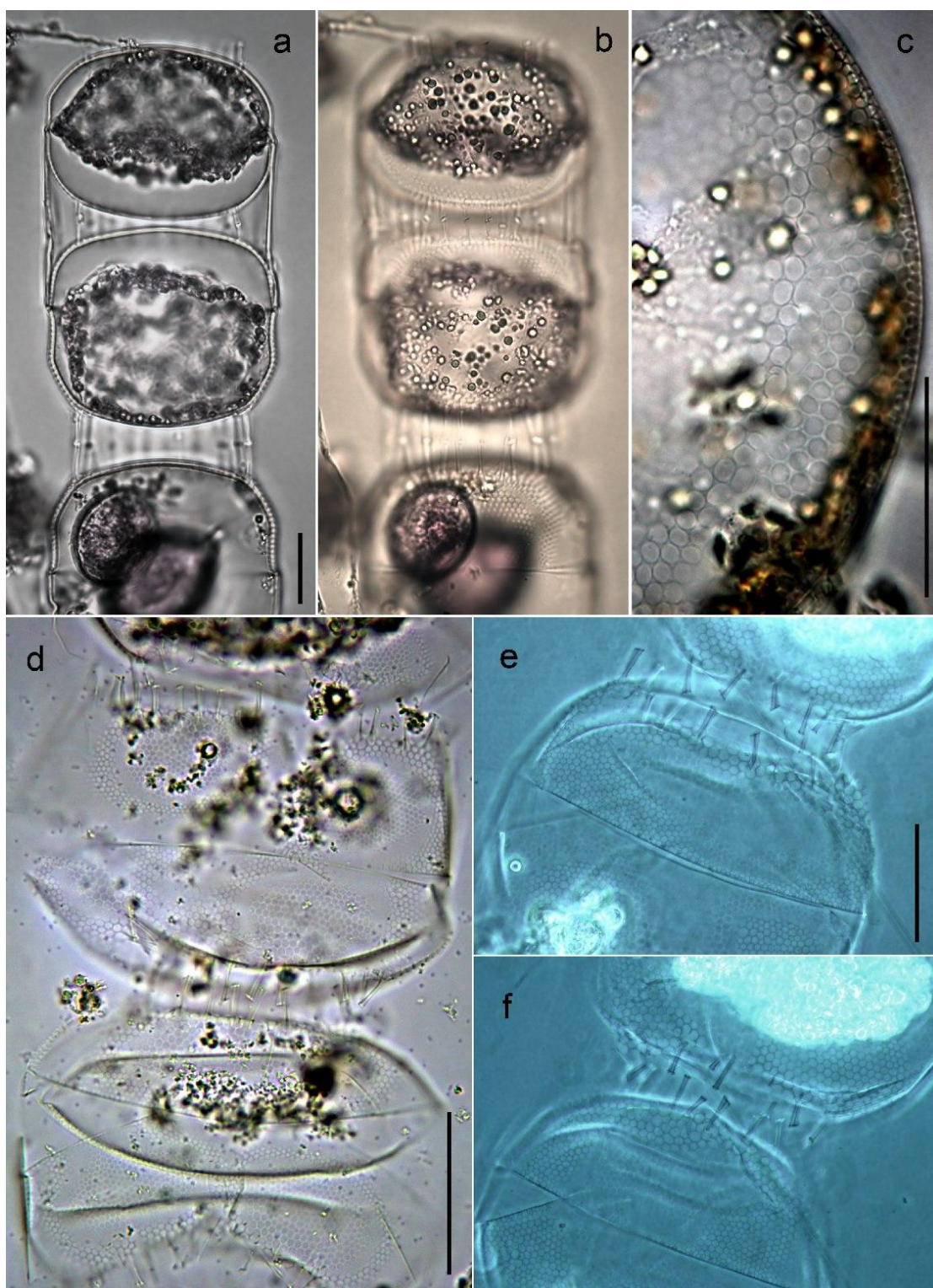


Plate A10. *Stephanopyxis palmeriana* (a-f).
a-d – LM, BF; e, f – PhC, DF. Scale bars – 20 μm.

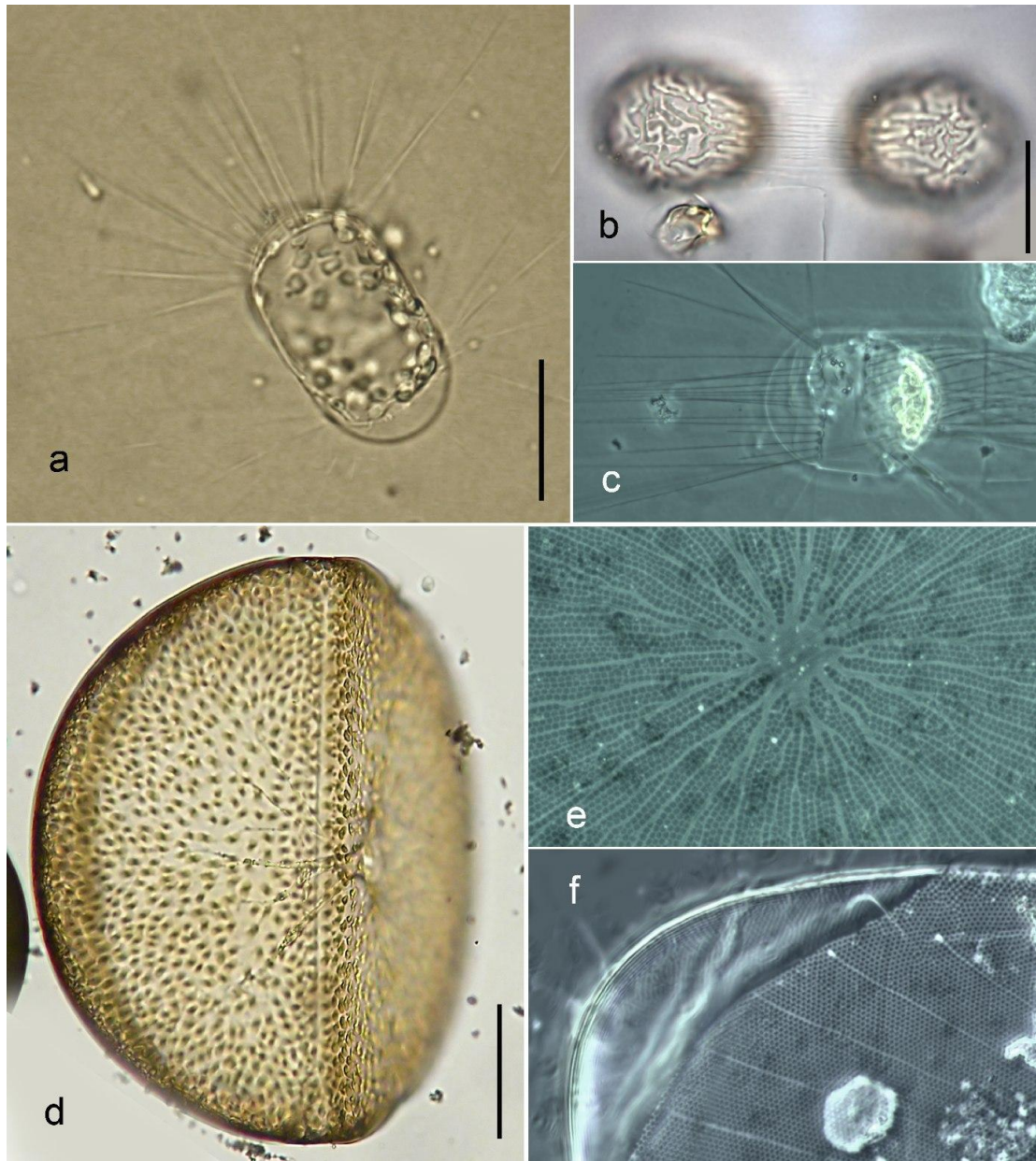


Plate A11. *Corethron hystrix* (a-c); *Palmeria hardmaniana* (d-f).
 a, b, d – LM, BF; c, e, f – PhC, DF. Scale bars: a-c – 20 μm ; d – 100 μm .

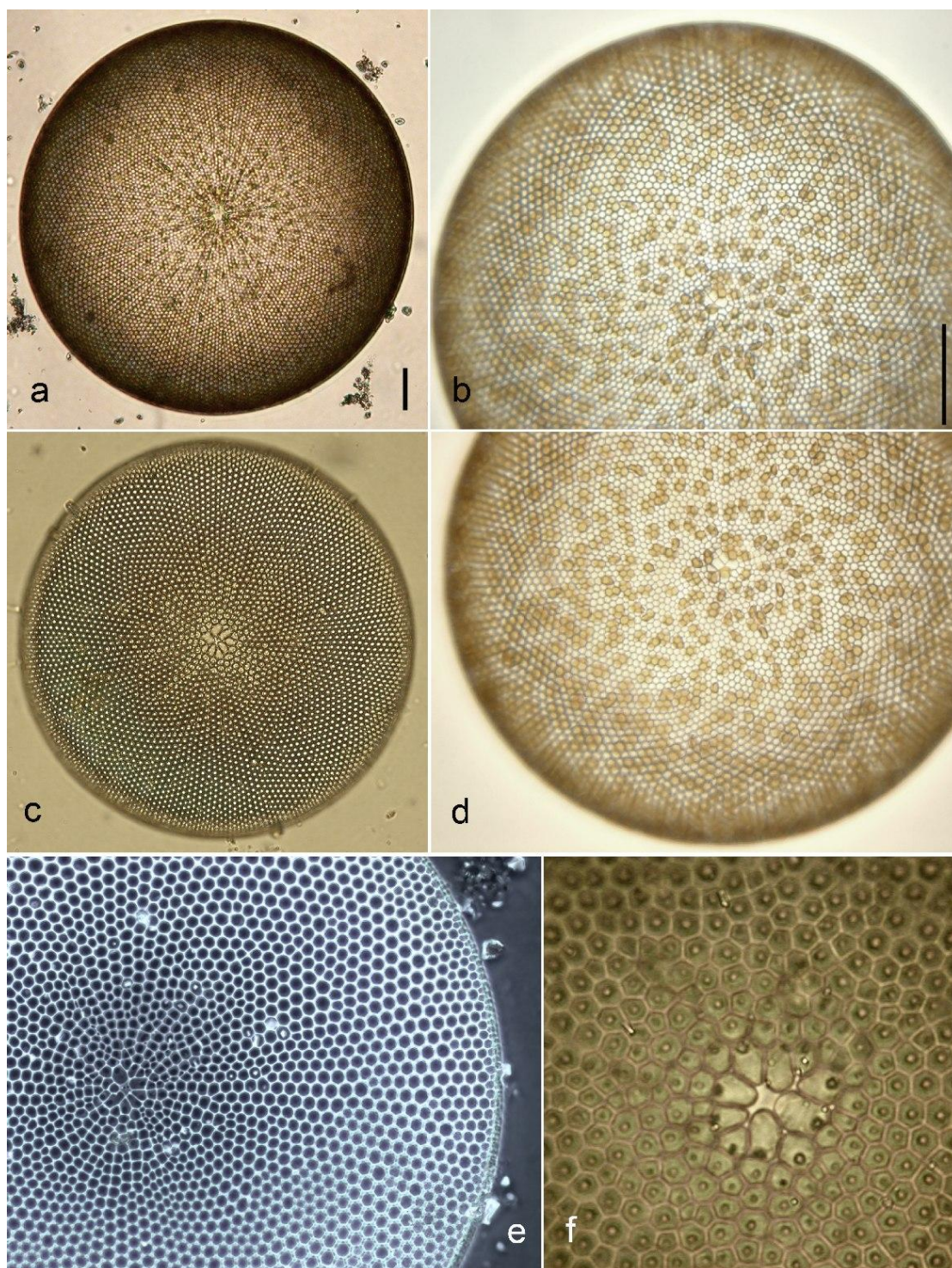


Plate A12. *Coscinodiscus asteromphalus* (a-f).
a-d, f – LM, BF; e – PhC, DF. Scale bars – 20 μm.

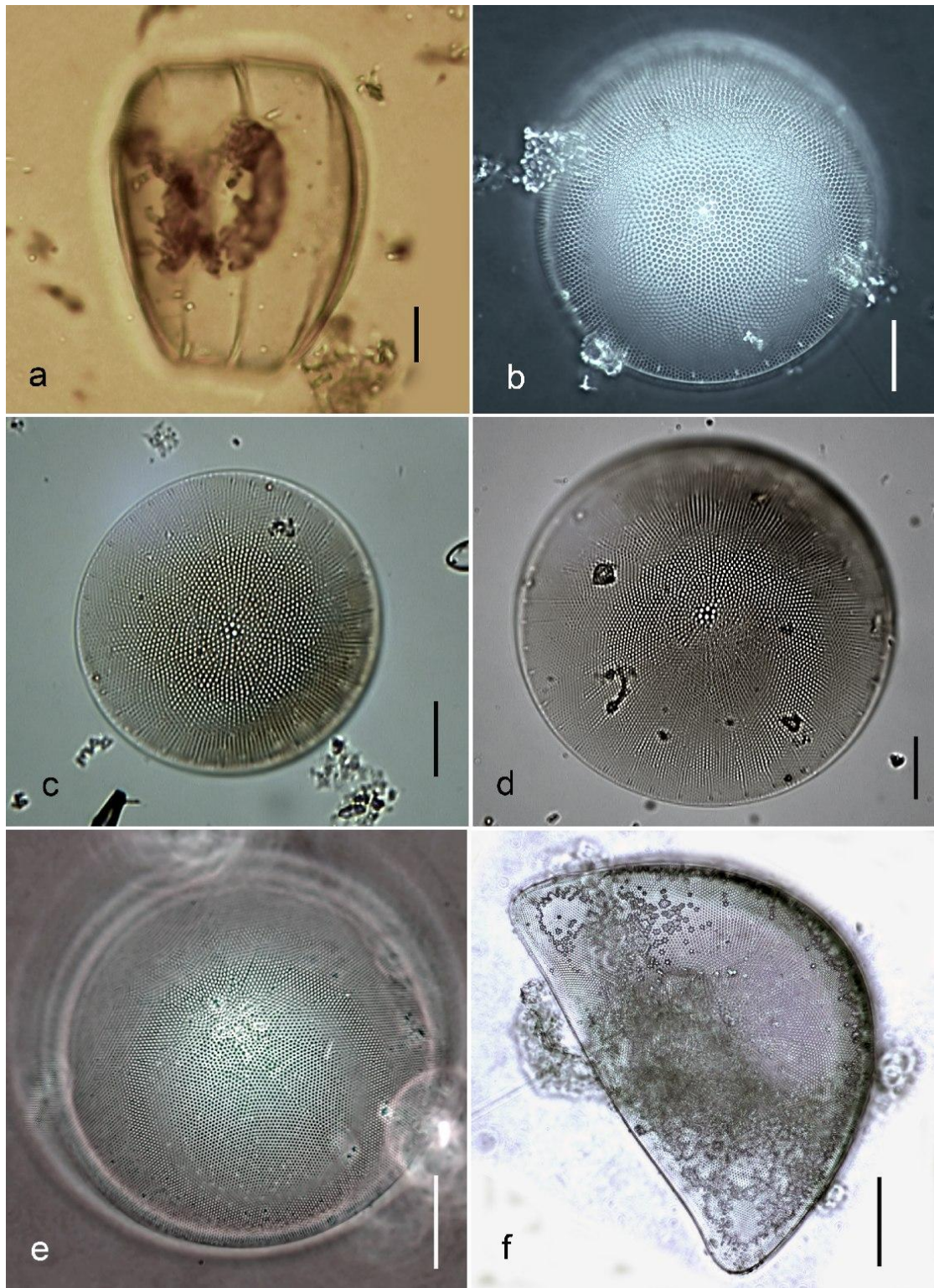


Plate A13. *Coscinodiscus granii* (a-d); *Stellarima stellaris* (e); *Hemidiscus cuneiformis* (f).
a, c, d – LM, BF; b, e – PhC, DF; f – PhC, BF. Scale bars – 20 µm.

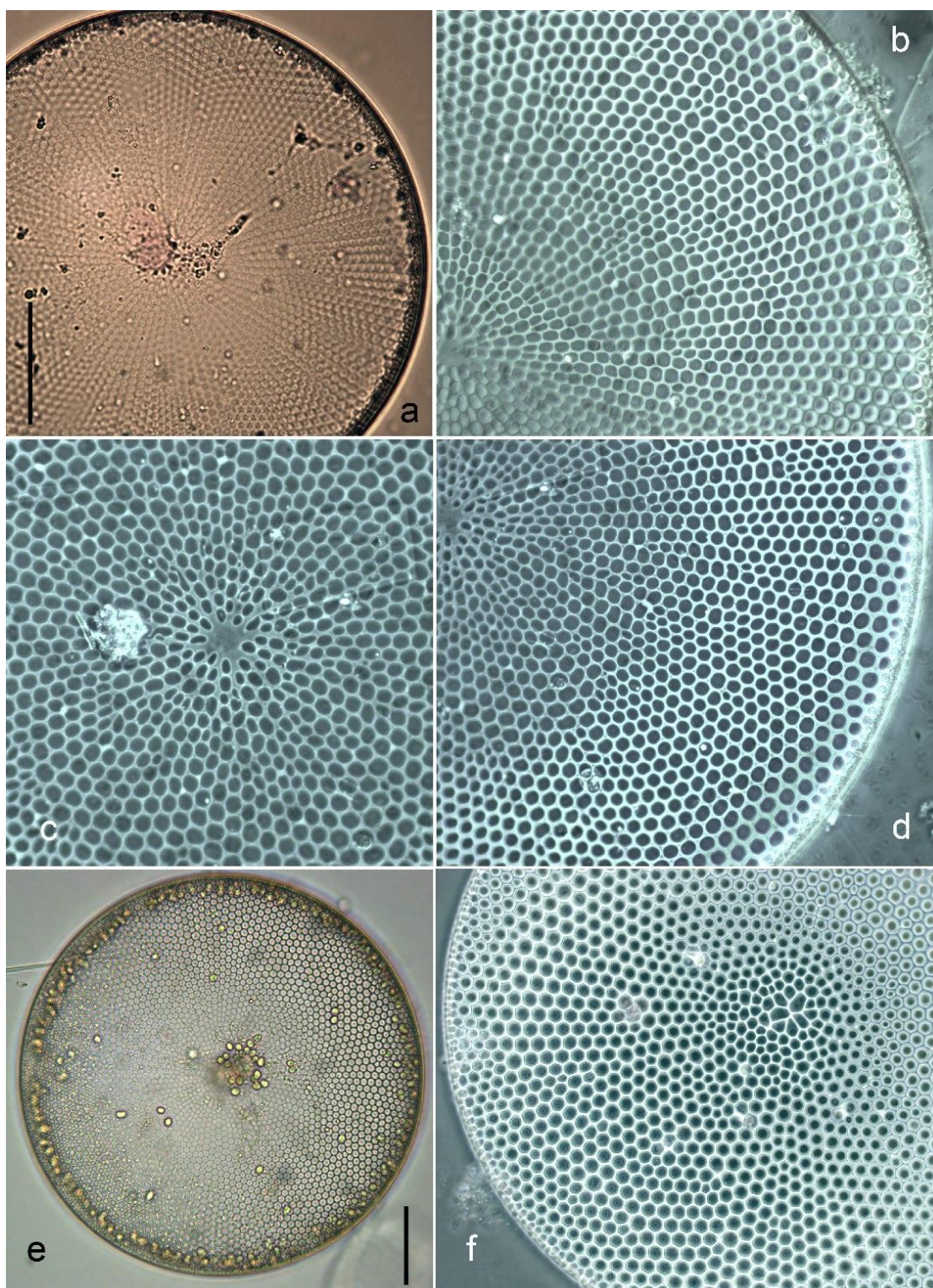


Plate A14. *Coscinodiscus janischii* var. *arafurensis* (a-d); *Coscinodiscus perforatus* (e, f).
a, e – LM, BF; b-d, f – PhC, DF. Scale bars – 50 μ m.

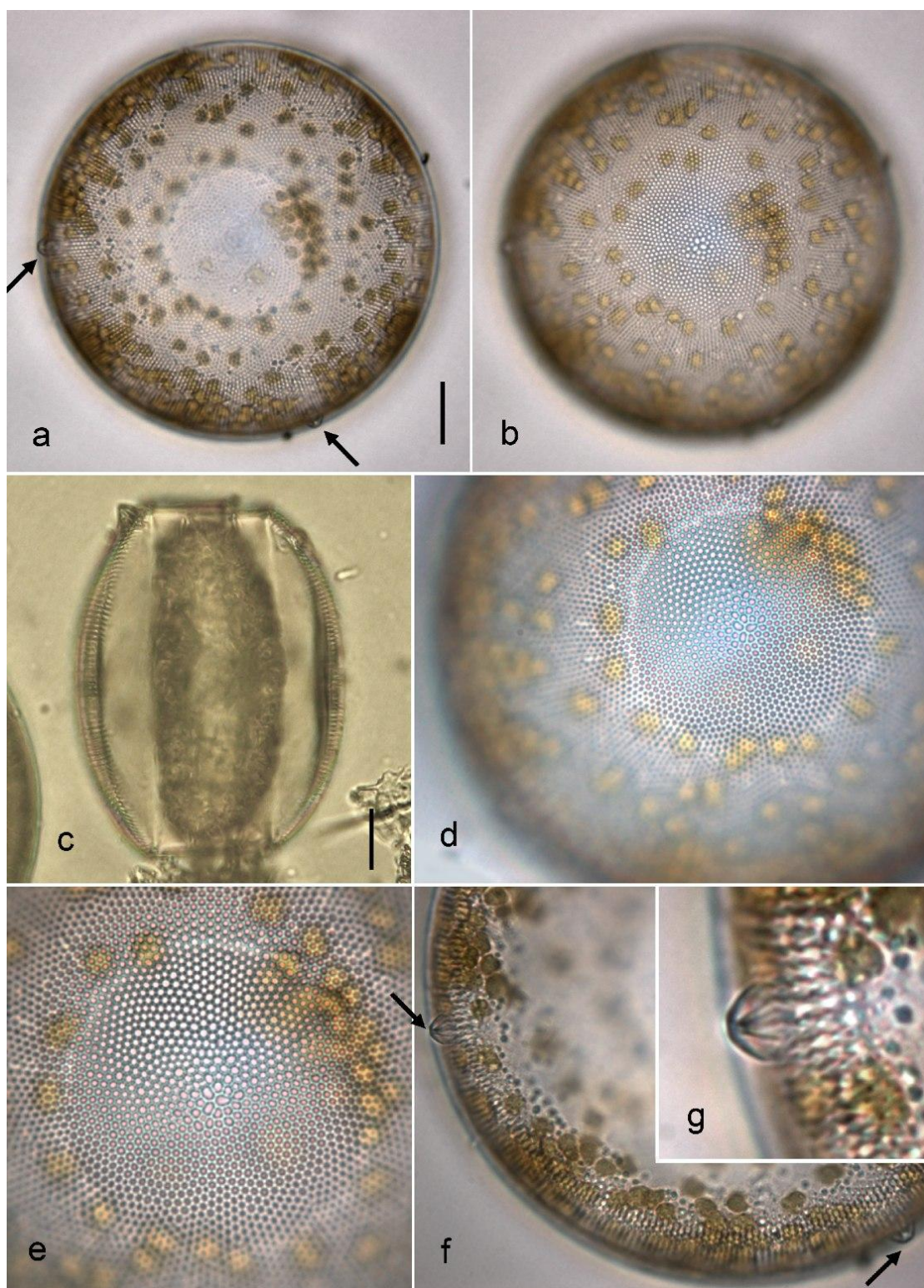


Plate A15. *Coscinodiscus jonesianus* (a-g).
 a, f – two large apiculi are indicated by arrows.
 a-g – LM, BF. Scale bars – 20 μ m.

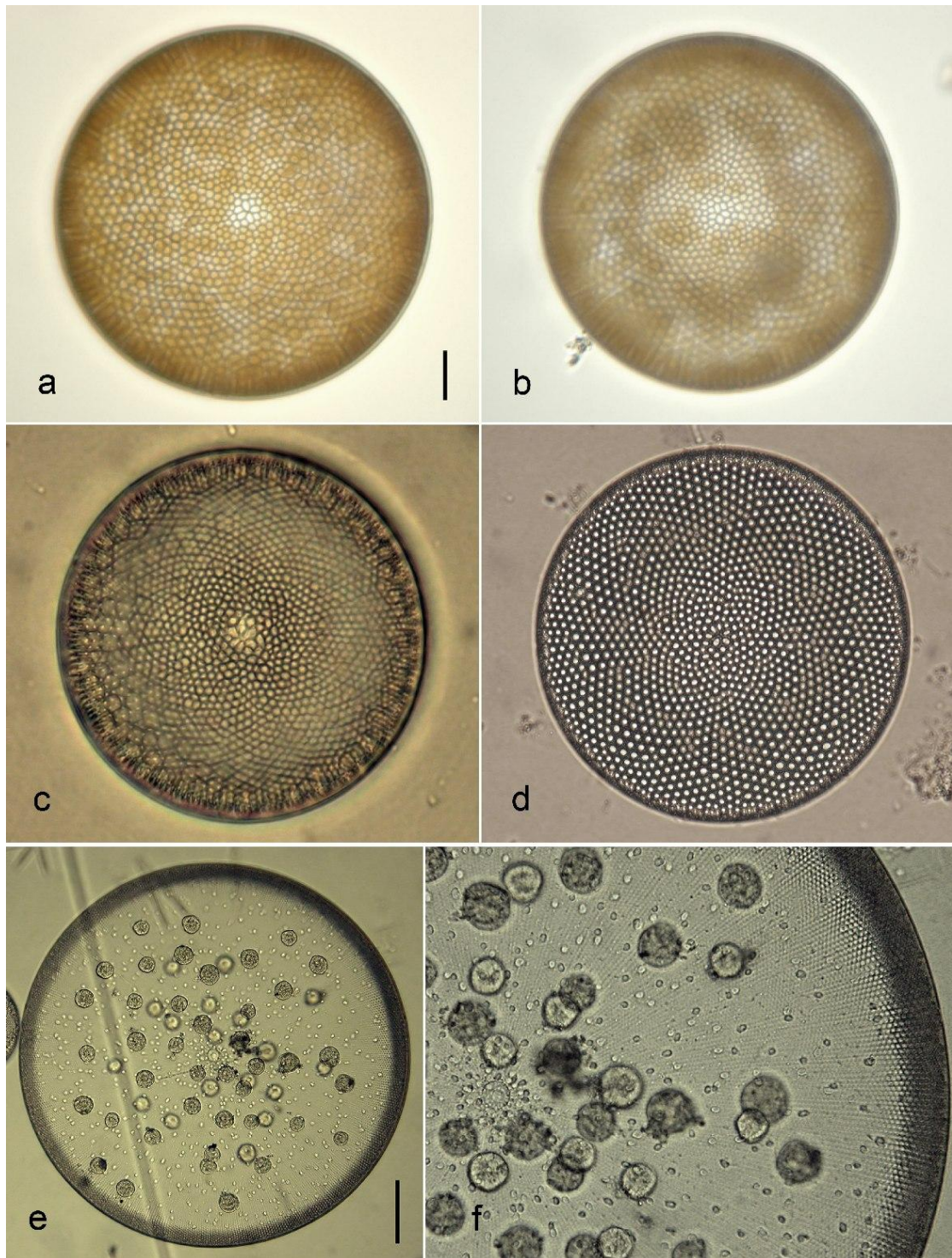


Plate A16. *Coscinodiscus oculus-iridis* (a-d); *Coscinodiscus wailesii* (e, f).
a-f – LM, BF. Scale bars: a-d – 20 μ m; e – 50 μ m.

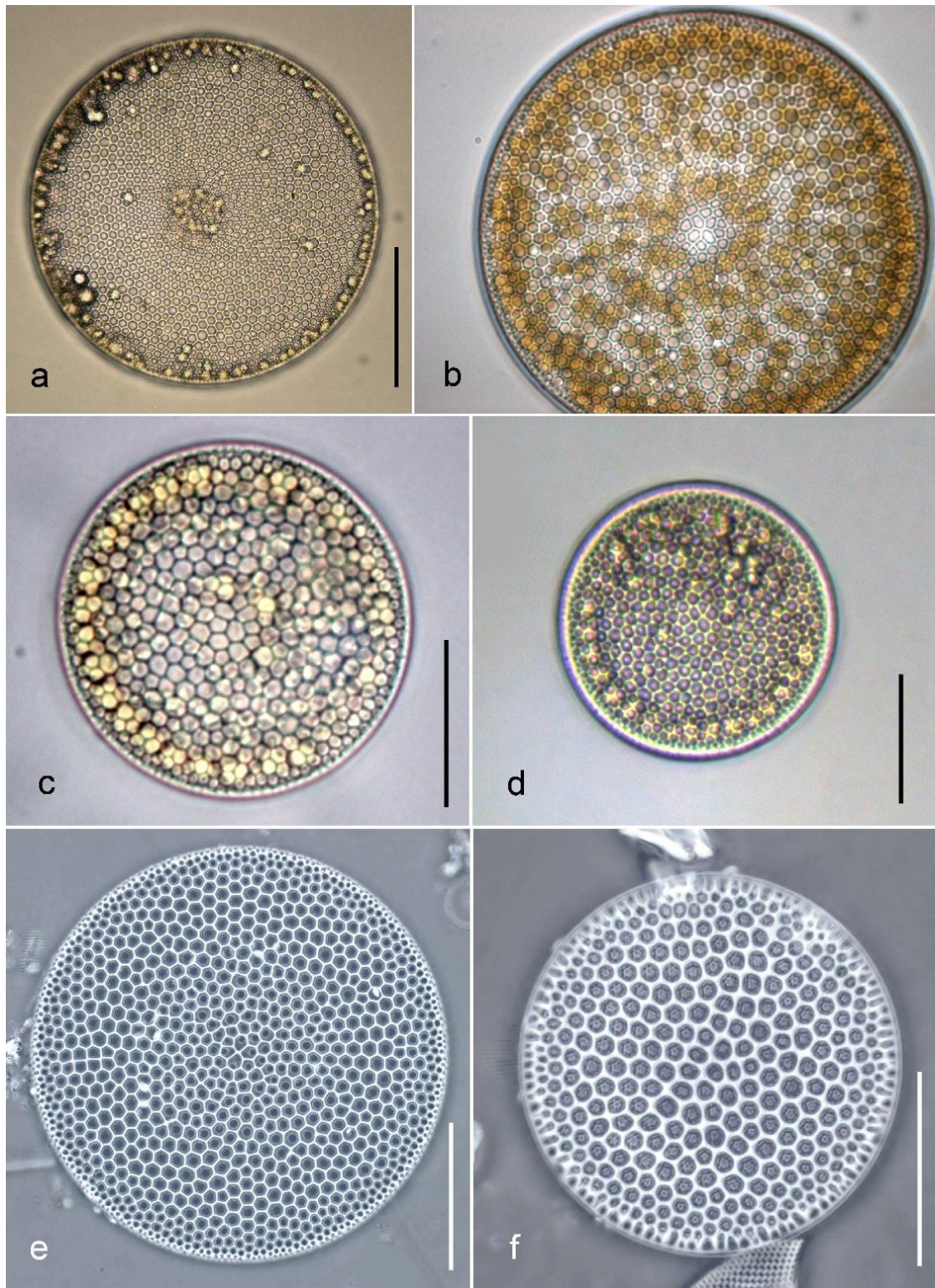


Plate A17. *Coscinodiscus radiatus* (a-f).
a-d – LM, BF; e, f – PhC, DF. Scale bars – 20 μm.

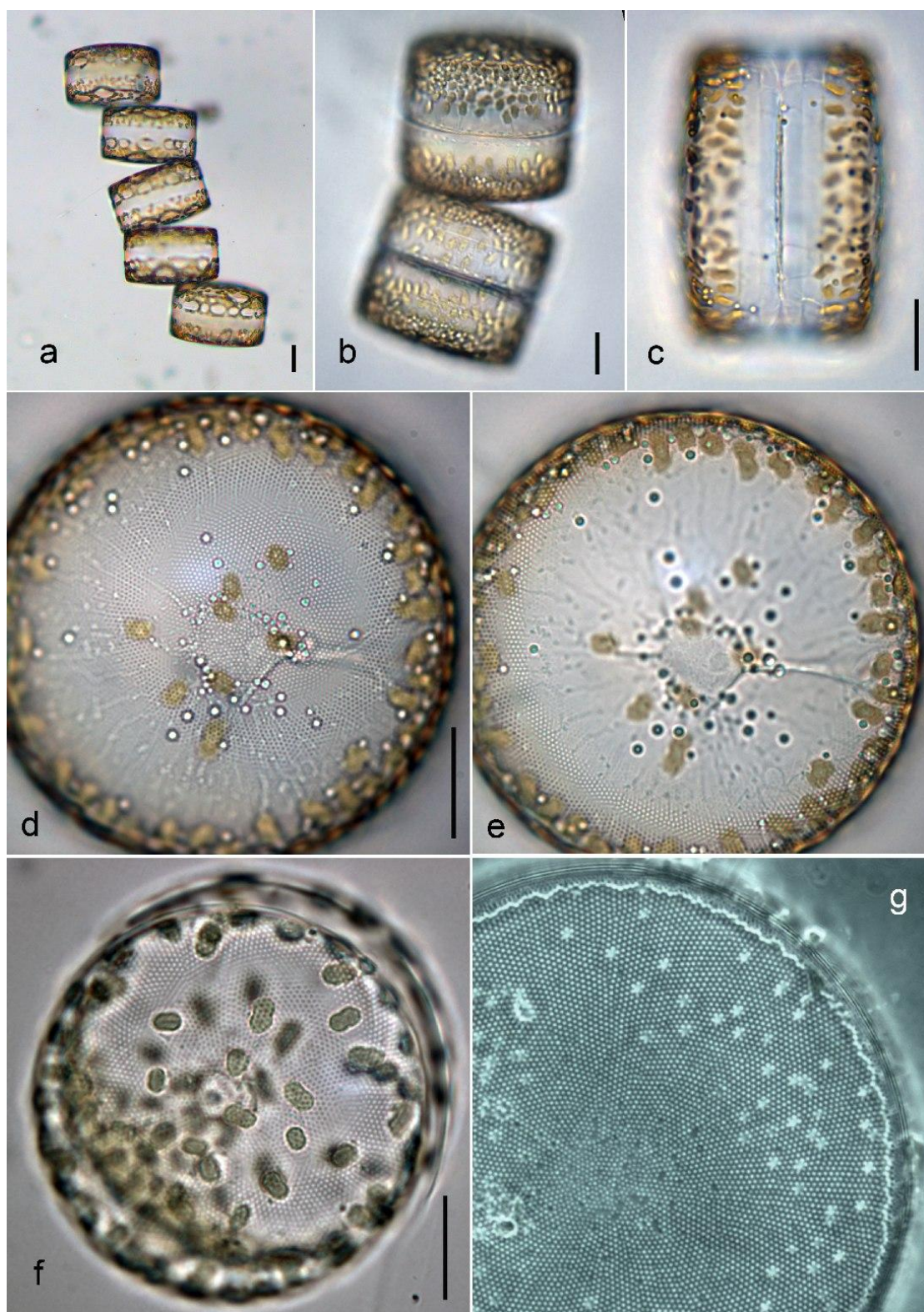


Plate A18. *Coscinodiscus* sp. (a-g).
a-f – LM, BF; g – PhC, DF. Scale bars – 20 μm.

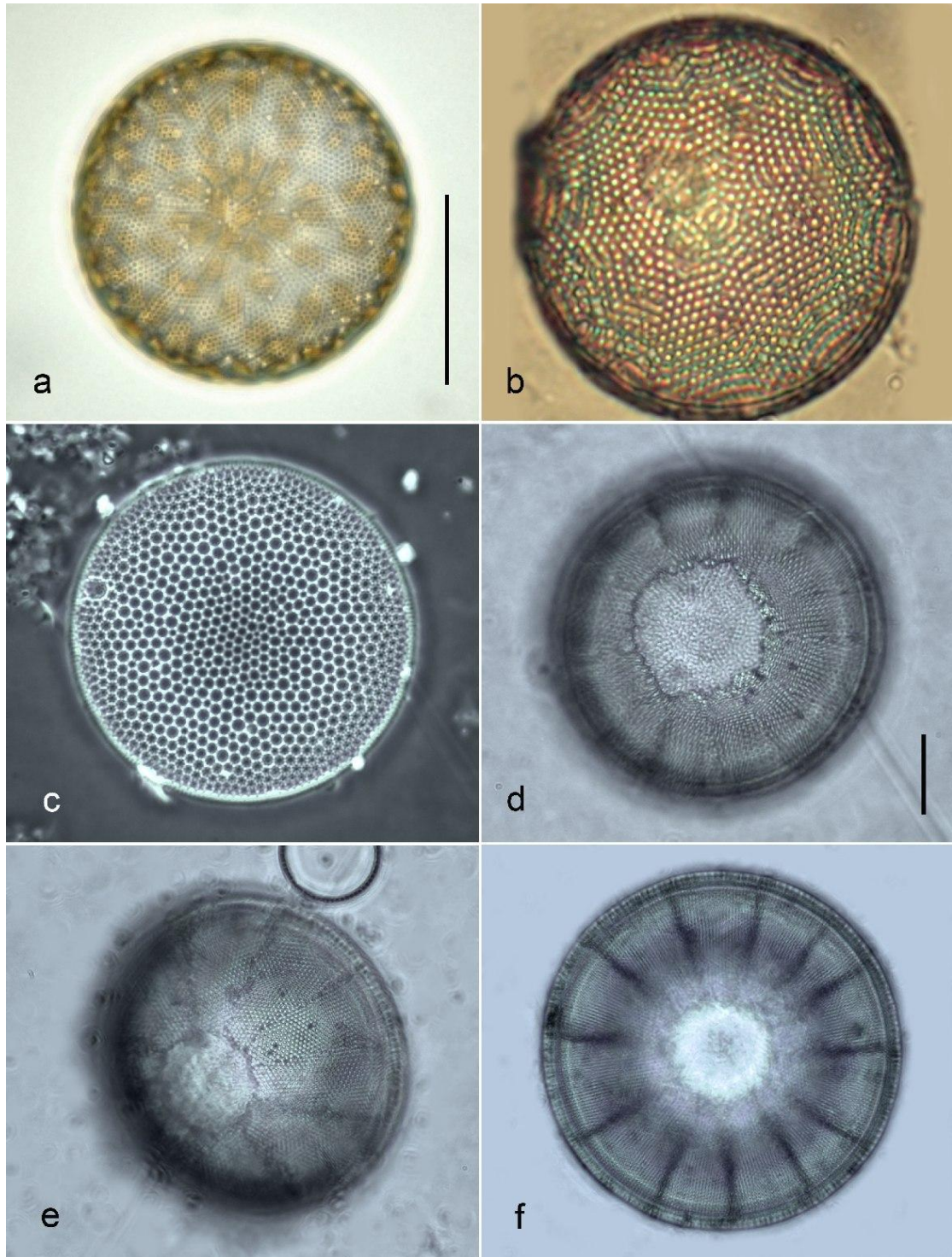


Plate A19. *Actinocyclus curvatulus* (a-c); *Podosira stelliger* (d-f).
 a-b – LM, BF; c – PhC, DF; d-f – PhC, BF. Scale bars – 20 μm .

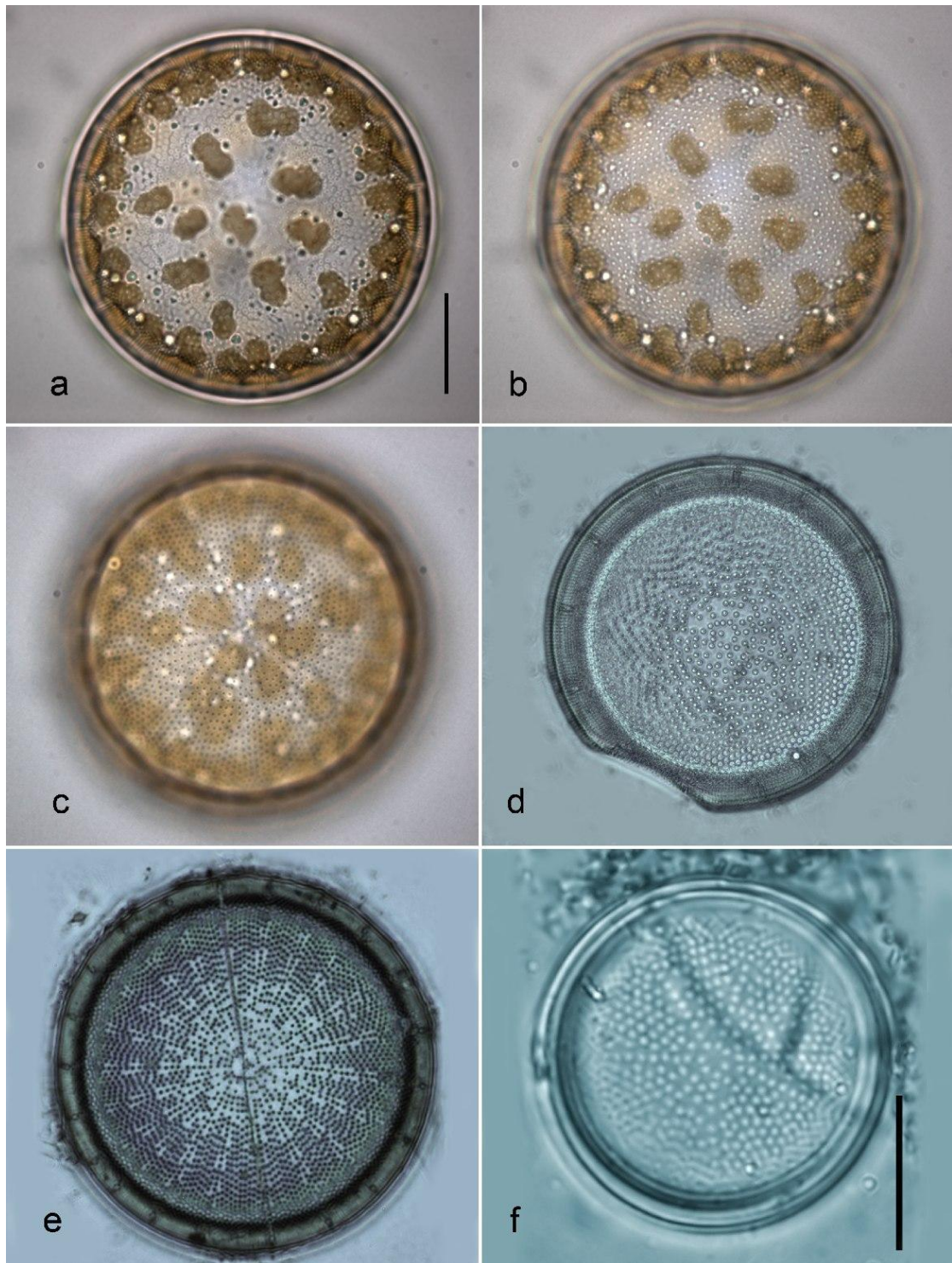


Plate A20. *Actinocyclus octonarius* (a-e); *Actinocyclus octonarius* var. *tenellus* (f).
a-c – LM BF; d-f – PhC, BF. Scale bars – 20 μ m.

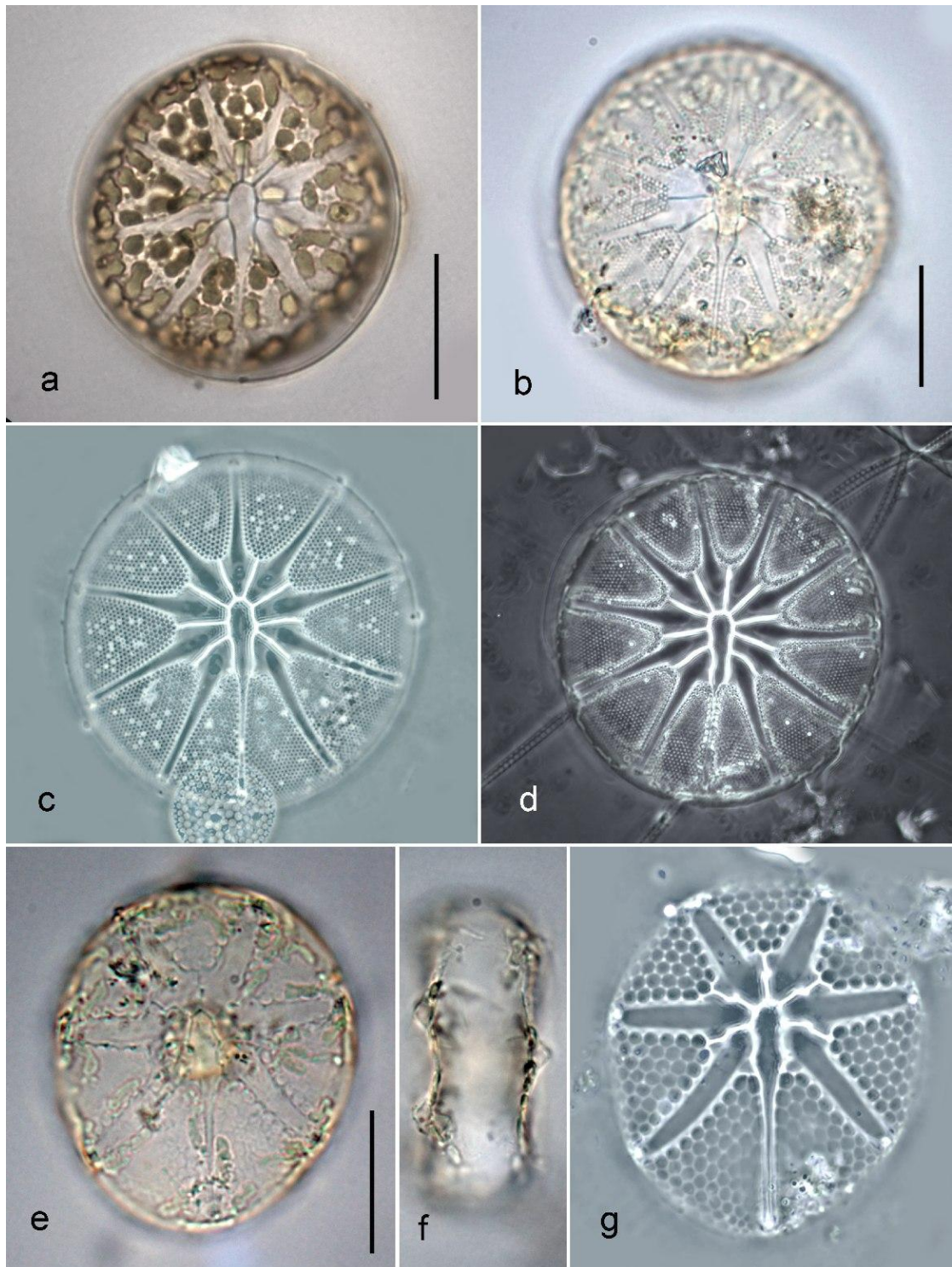


Plate A21. *Asteromphalus* sp. (a-d); *Asteromphalus heptactis* (e-g).
a, b, e, f – LM, BF; c, d, g – PhC, DF. Scale bars – 20 μ m.

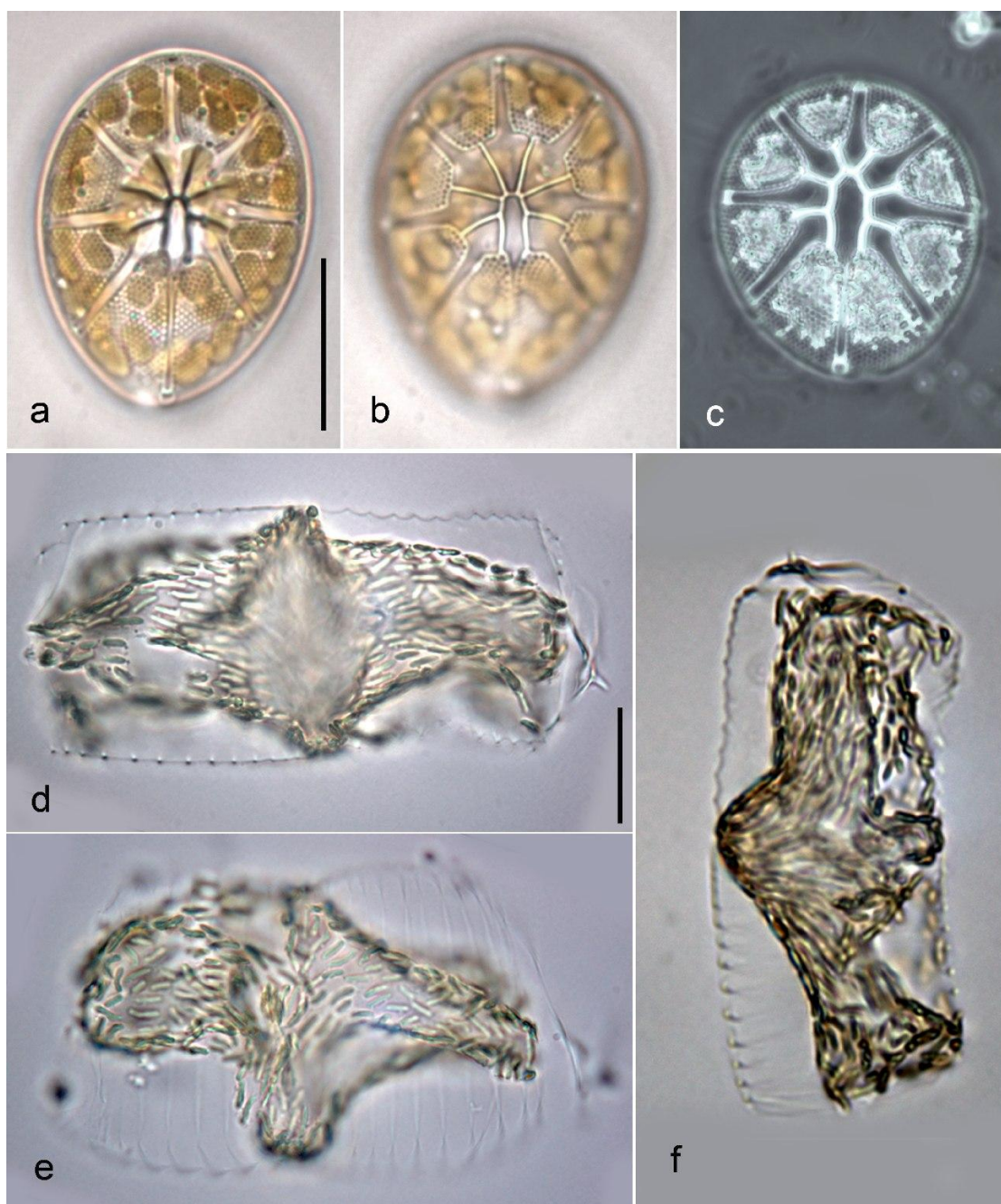


Plate A22. *Asteromphalus flabellatus* (a-c); *Dactyliosolen phuketensis* (d-f).
a, b, d-f – LM, BF; c – PhC, DF. Scale bars – 20 μm .

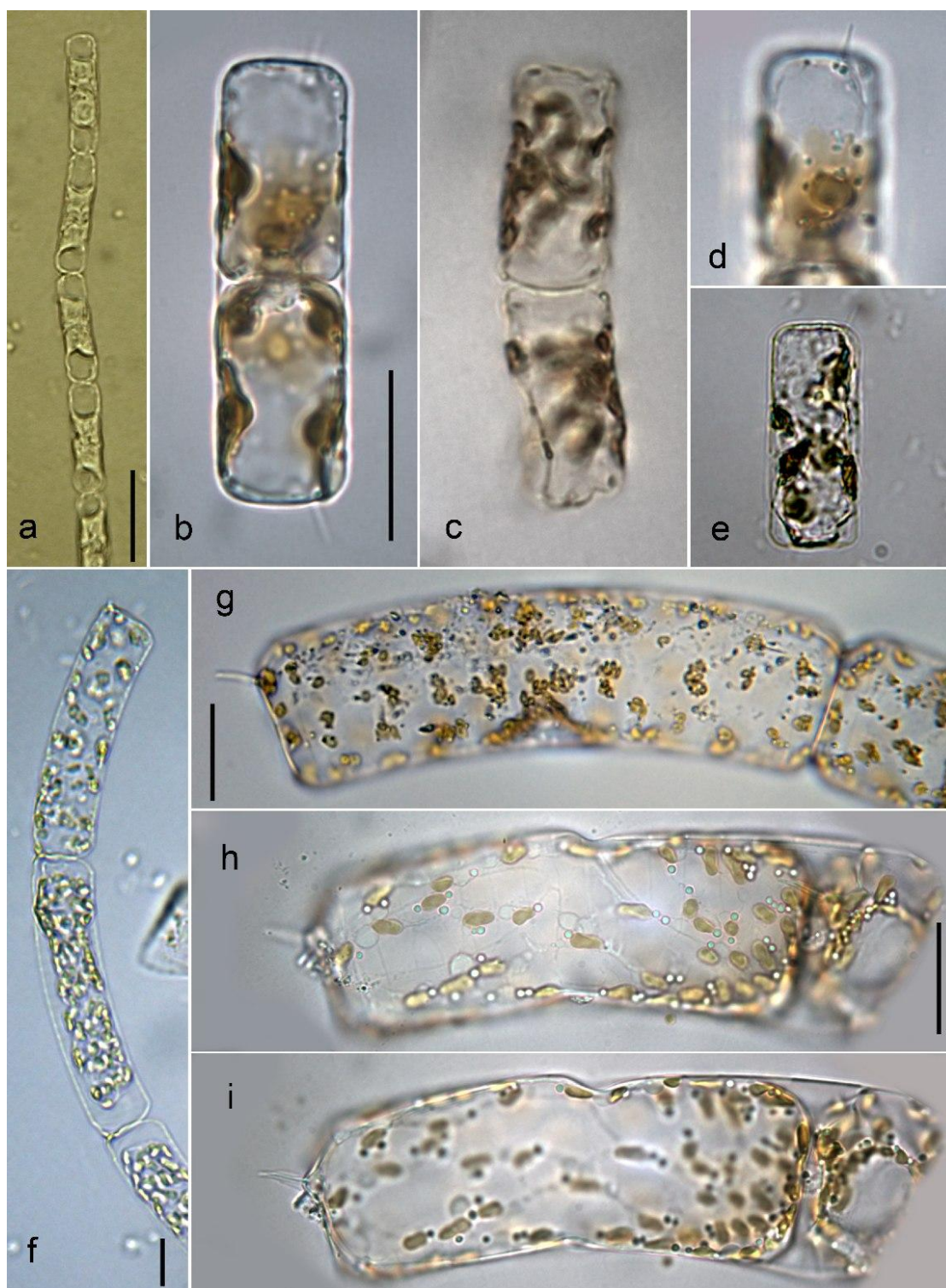


Plate A23. *Guinardia delicatula* (a-e); *Guinardia striata* (f-i).
a-i – LM, BF. Scale bars – 20 μm .

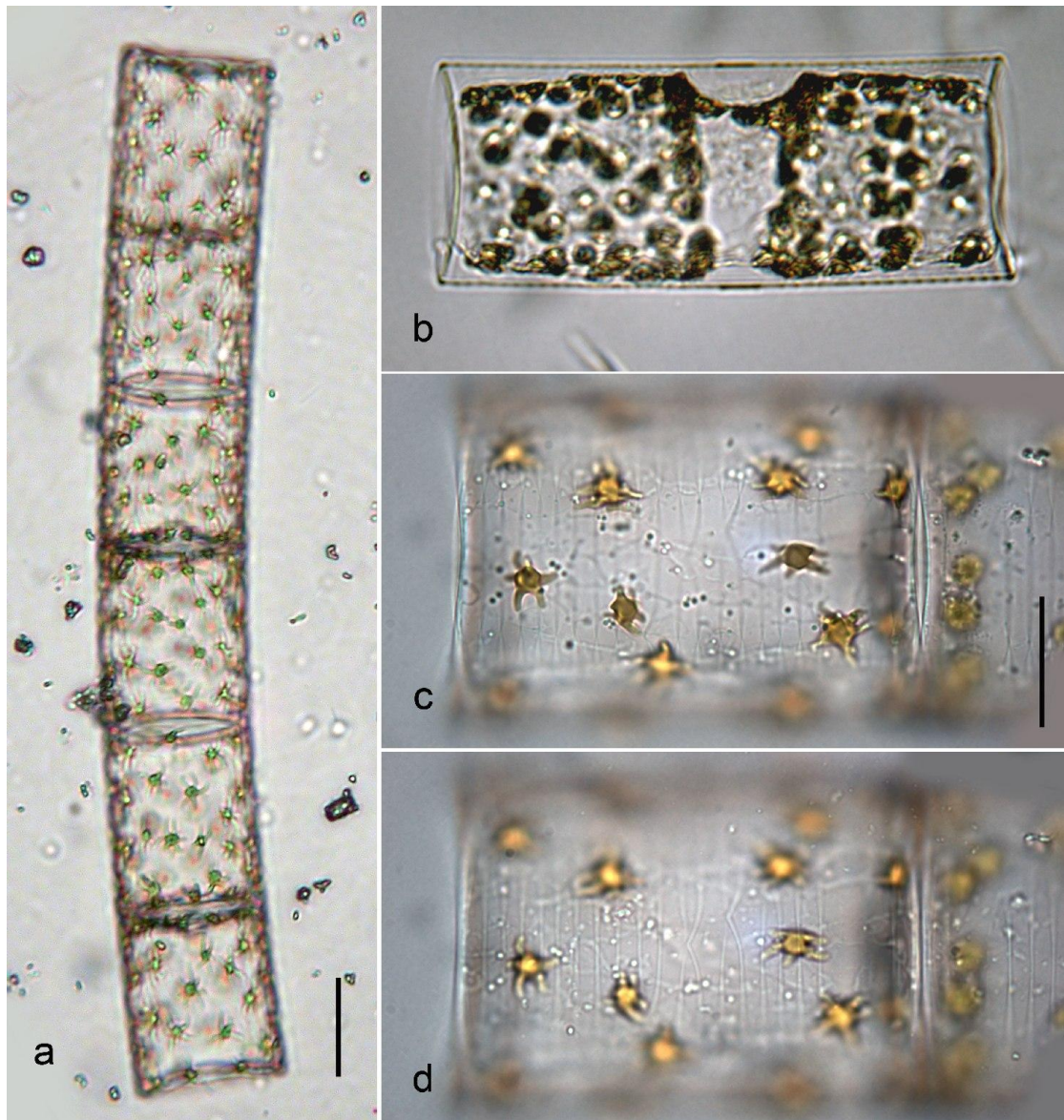


Plate A24. *Guinardia flaccida* (a-d).
a-d – LM, BF. Scale bars – 20 μm .

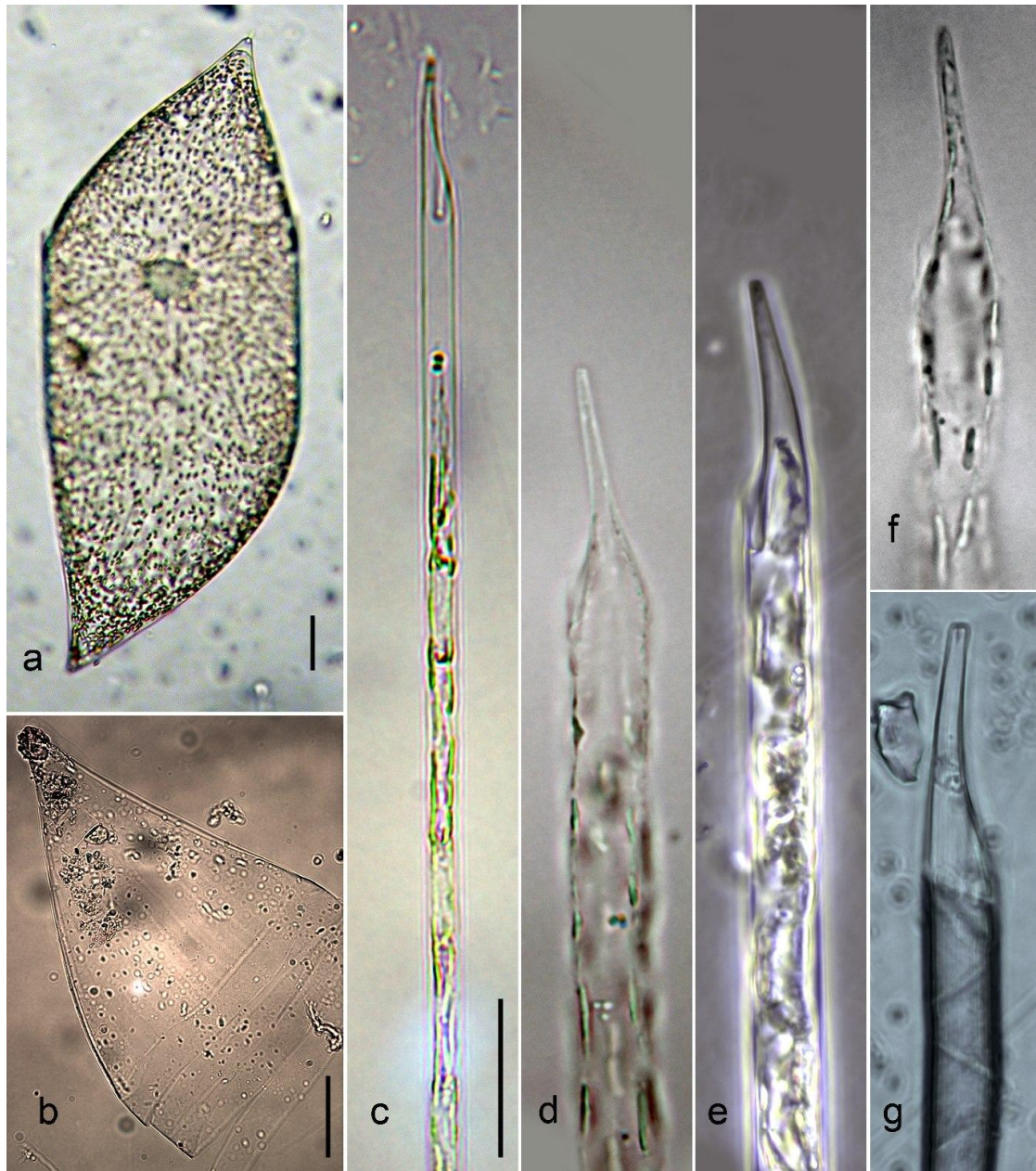


Plate A25. *Neocalyptrella robusta* (a, b); *Proboscia alata* f. *gracillima* (c-g).
 a-d, f – LM, BF; e, g – PhC, DF. Scale bars: a, b – 50 μ m; c-g - 20 μ m.

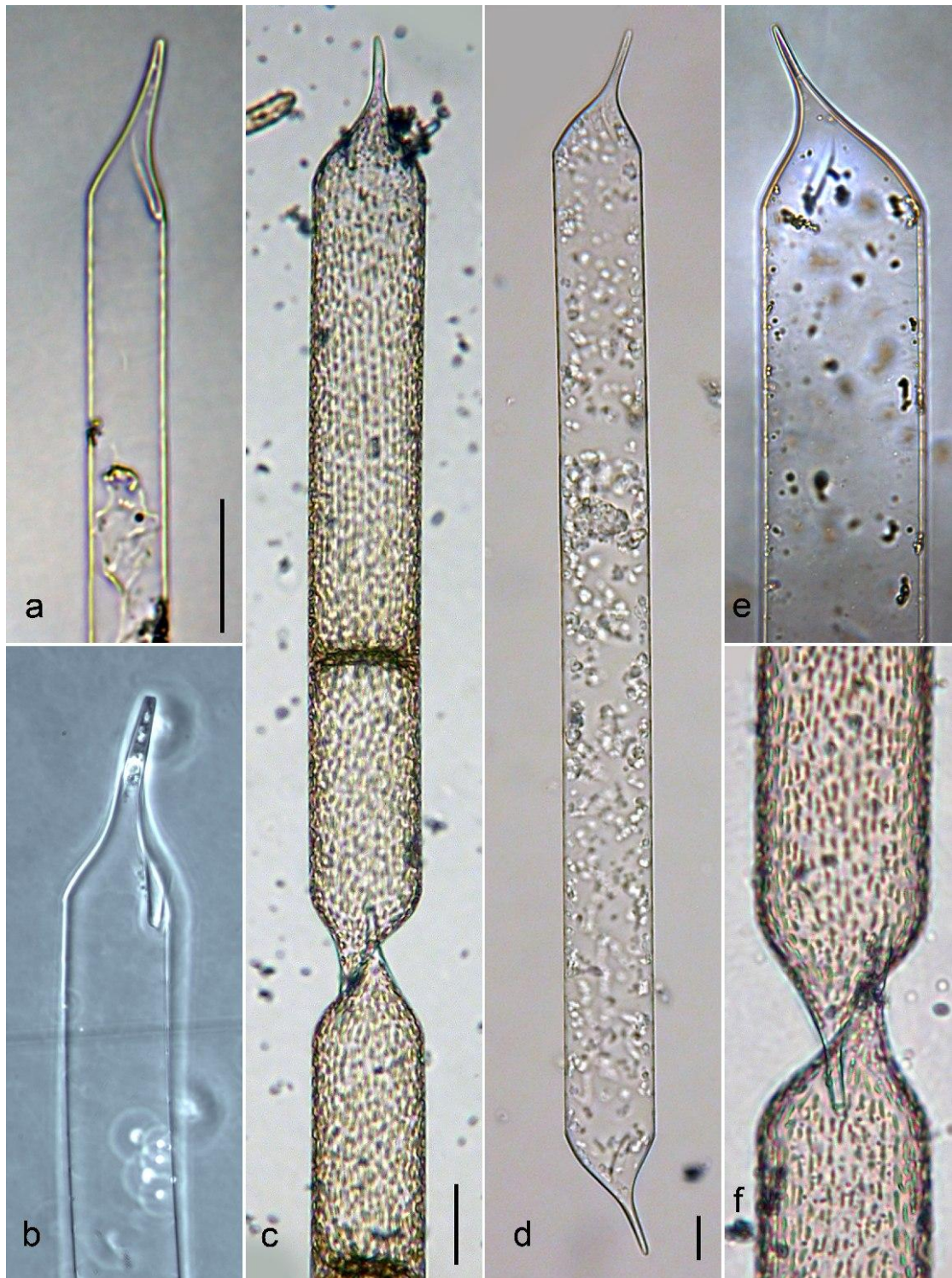


Plate A26. *Proboscia alata* (a, b); *Proboscia indica* (c-f).
a, c-f – LM, BF; b – PhC, DF. Scale bars – 20 μ m.

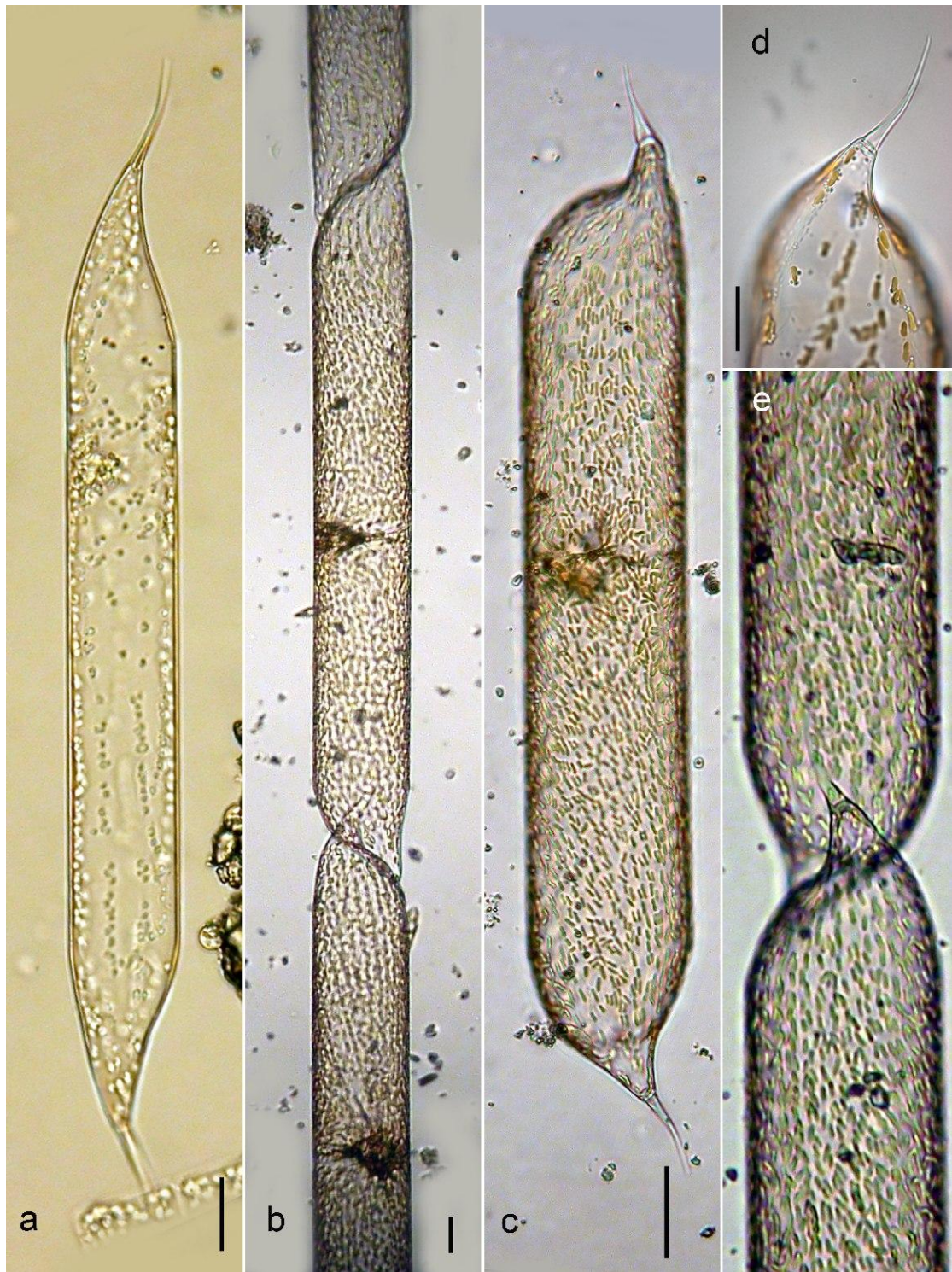


Plate A27. *Pseudosolenia calcar-avis* (a); *Rhizosolenia cochlea* (b-e).
a-e – LM, BF. Scale bars – 20 μm .

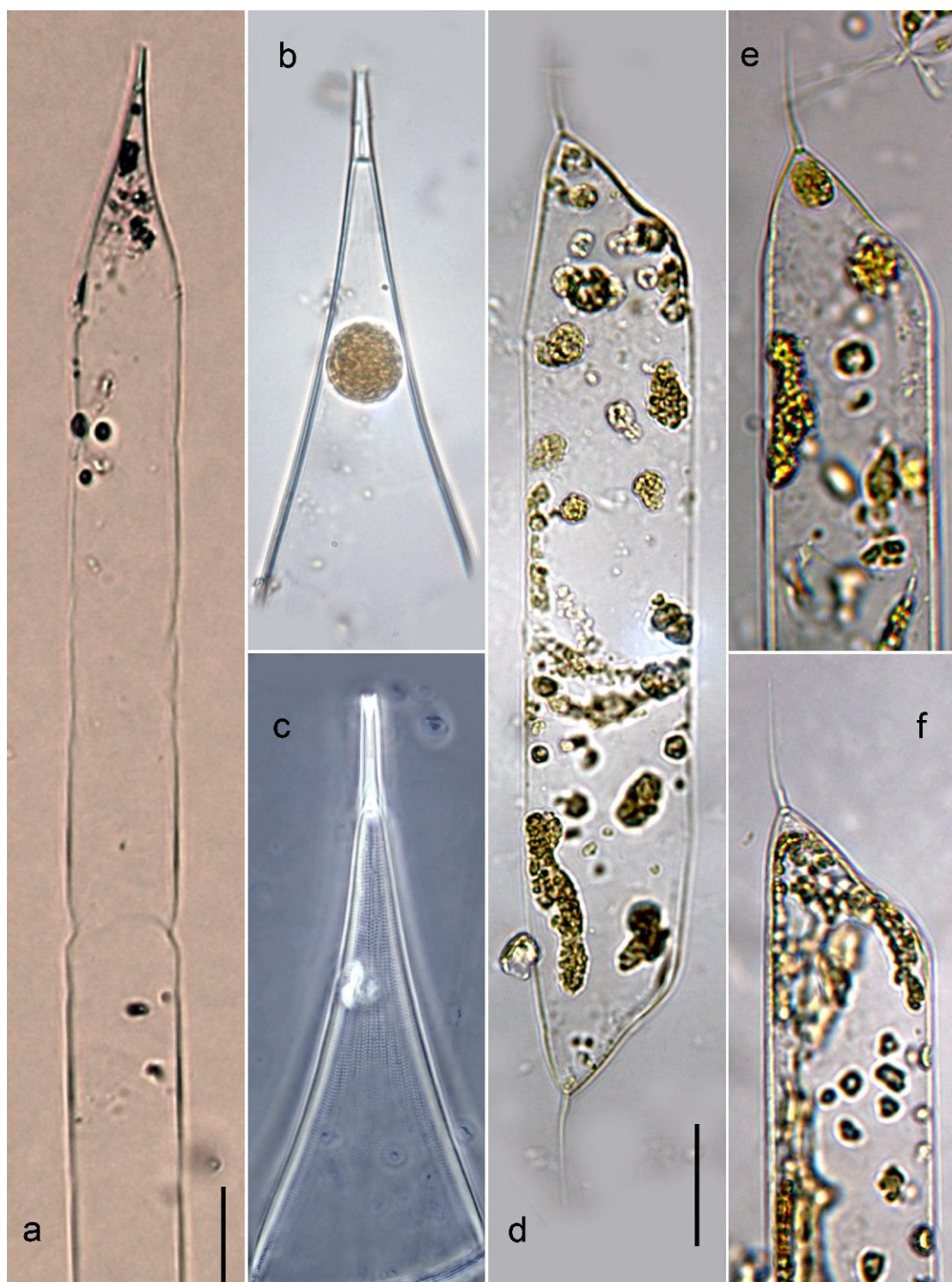


Plate A28. *Rhizosolenia bergonii* (a-c); *Rhizosolenia hyalina* (d-f).
a, b, d-f – LM, BF; c – PhC, DF. Scale bars – 20 μ m.

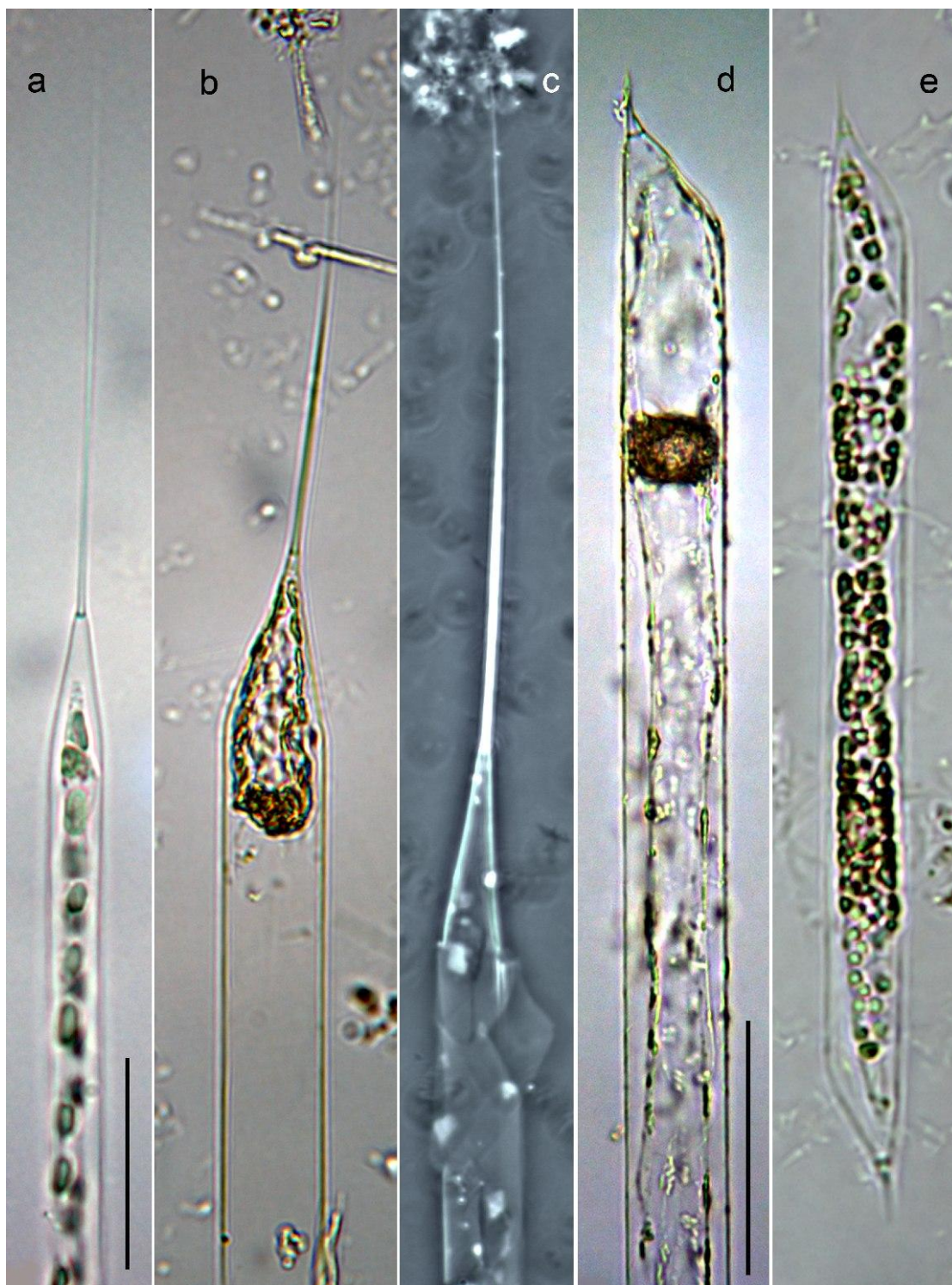


Plate A29. *Rhizosolenia hebetata* f. *semispina* (a-c); *Rhizosolenia shrubsolei* (d, e).
a, b, d, e – LM, BF; c – PhC, DF. Scale bars – 20 μ m.



Plate A30. *Rhizosolenia imbricata* (a-f).
a-e – LM, BF. Scale bars – 20 μ m.



Plate A31. *Rhizosolenia setigera* (a-d); *Rhizosolenia sp.* (e).
a-e – LM, BF. Scale bars – 20 μm.

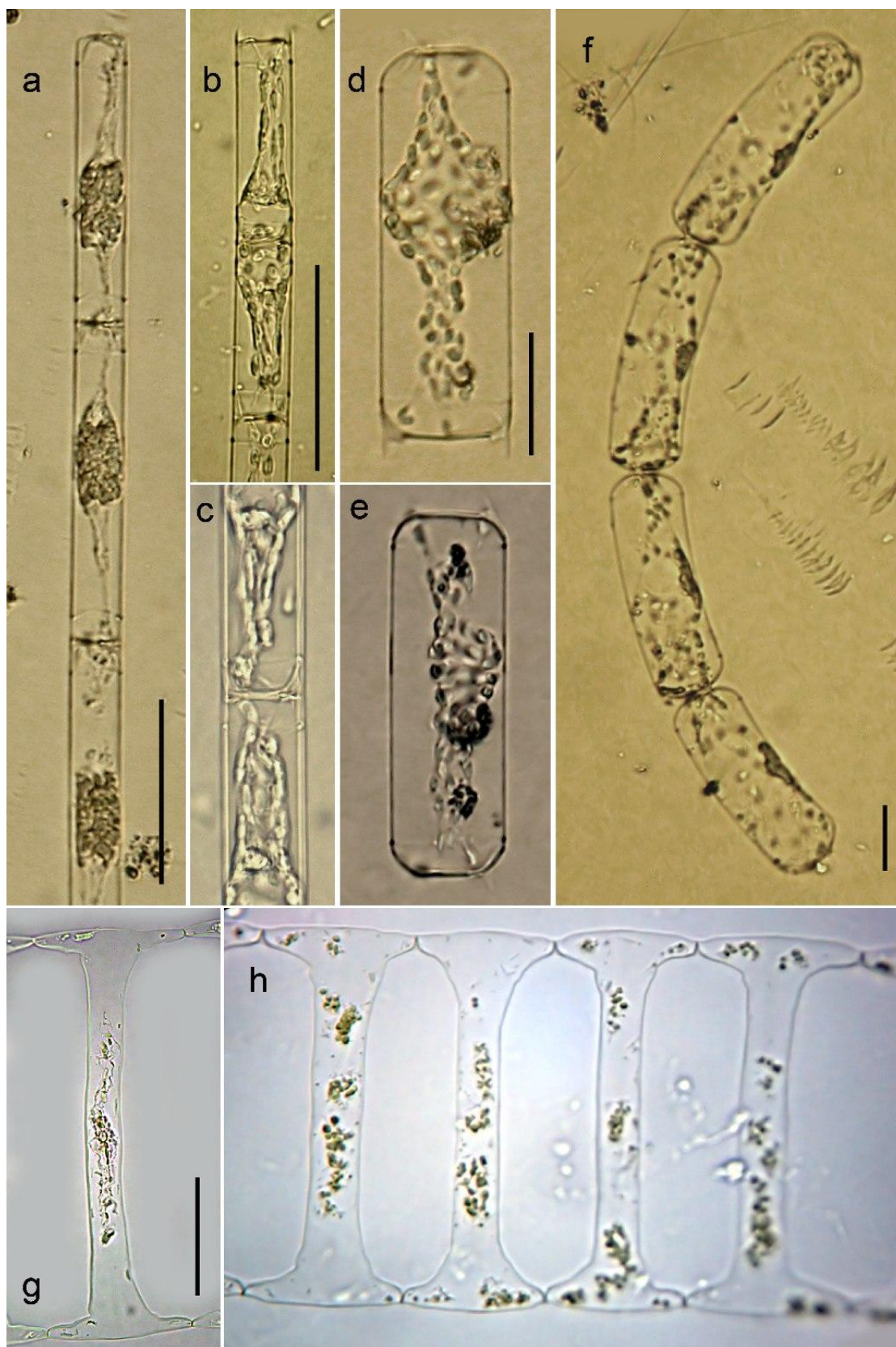


Plate A32. *Cerataulina bicornis* (a-c); *Cerataulina pelagica* (d-f); *Climacodium frauenfeldianum* (g, h).

a-h – LM, BF. Scale bars – 20 μm.

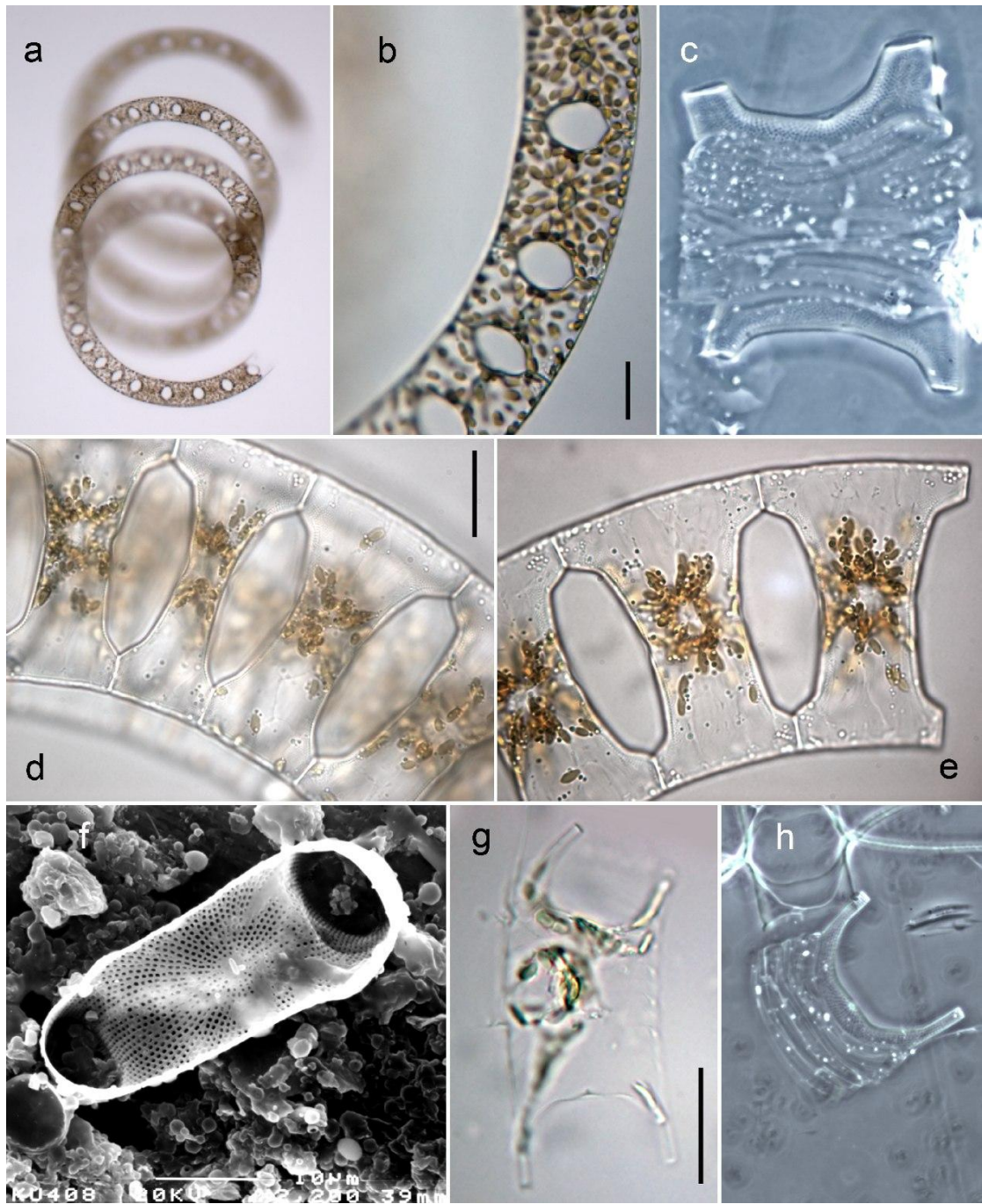


Plate A33. *Eucampia zodiacus* (a-e); *Eucampia cornuta* (g, h).
 a, b, d, e, g – LM, BF; c, h – PhC, DF; f – SEM. Scale bars: b, d, g – 20 μ m; f – 10 μ m.

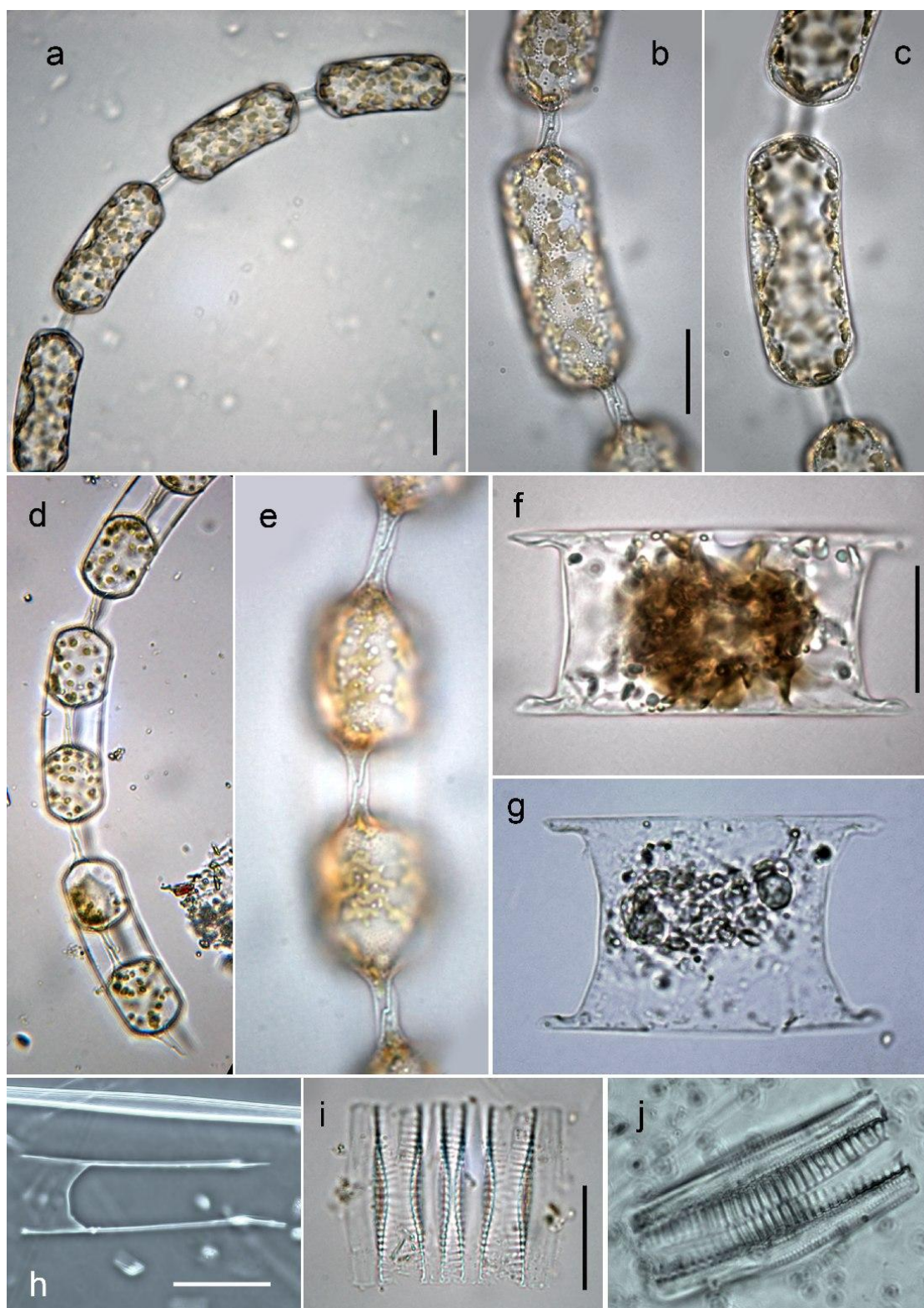


Plate A34. *Hemiaulus sinensis* (a-e); *Hemiaulus membranaceus* (f, g); *Hemiaulus hauckii* (h); *Cymatosira cf. lorenziana* (i, j).
 a-g, i – LM, BF; h – PhC, DF; j – PhC, BF. Scale bars – 20 μm.

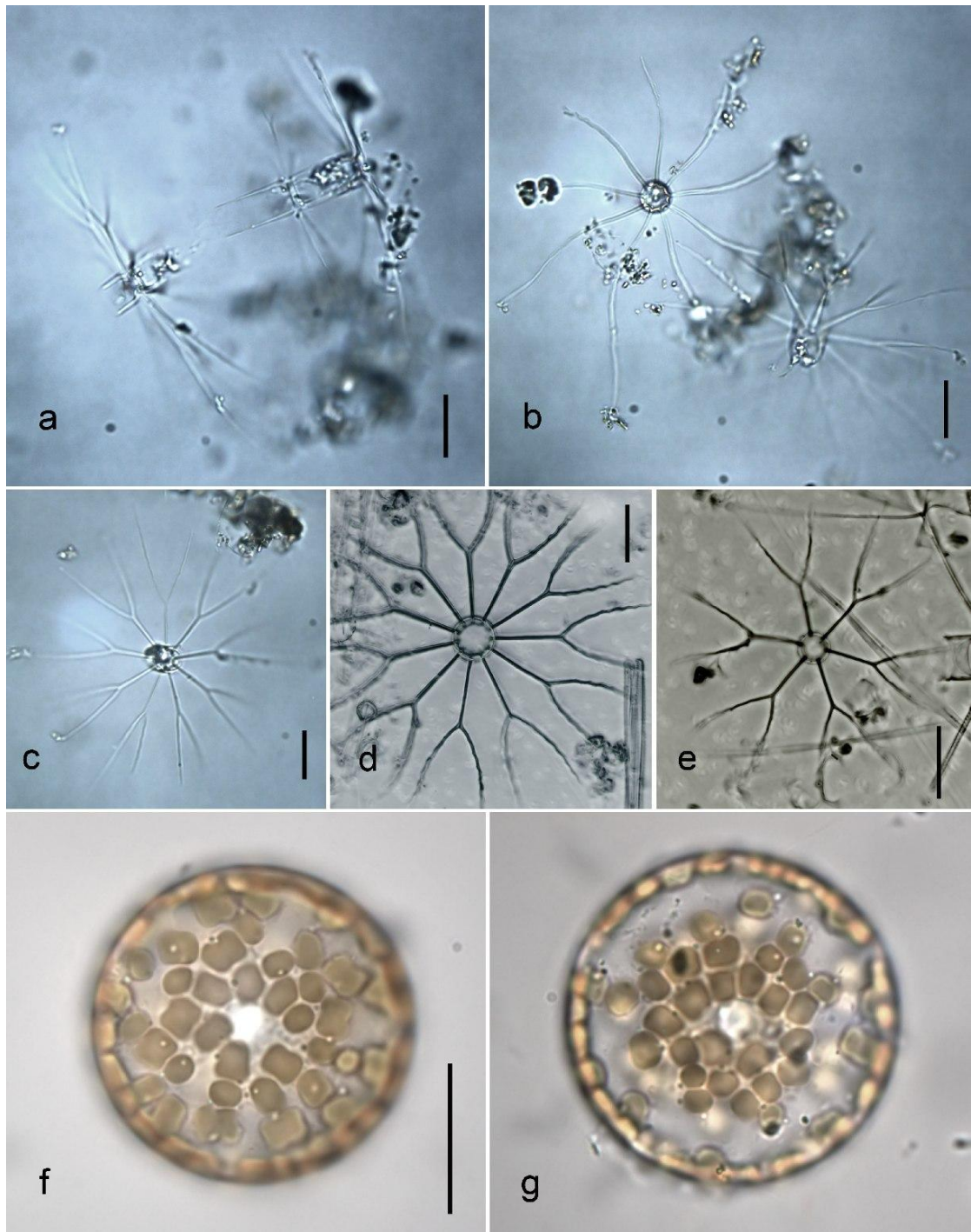


Plate A35. *Bacteriastrum delicatulum* (a-e); *Porosira* sp. (f, g).
a-c, f, g – LM, BF; d, e – PhC, BF. Scale bars – 20 μ m.

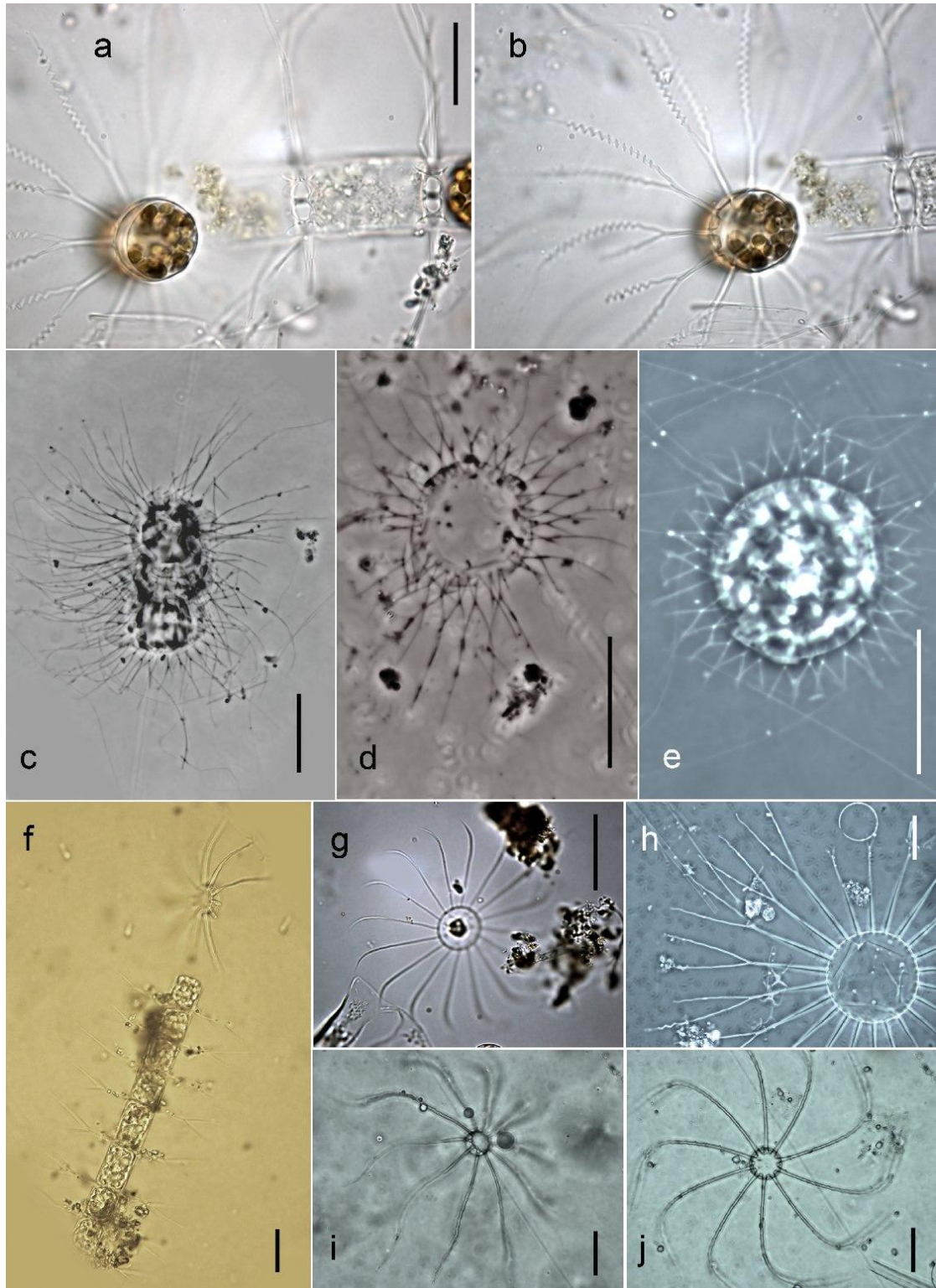


Plate A36. *Bacteriastrum hyalinum* var. *princeps* (a, b); *Bacteriastrum hyalinum* (c-e); *Bacteriastrum furcatum* (f-j).

a, b, f, g – LM, BF; c, d, i, j – PhC, BF; e, h – PhC, DF. Scale bars – 20 μ m.

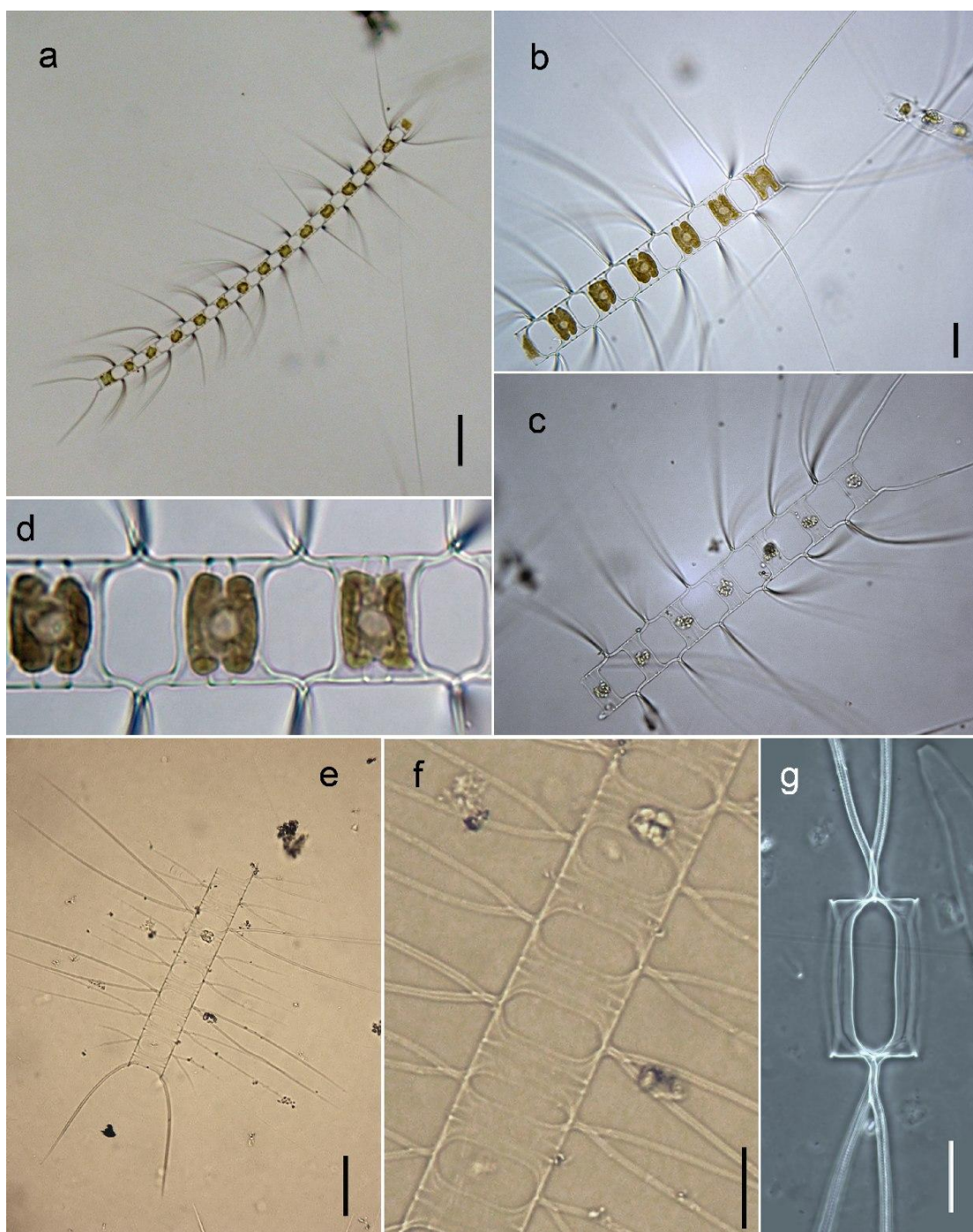


Plate A37. *Chaetoceros brevis* (a-d); *Chaetoceros decipiens* (e-g).
a-f – LM, BF; g – PhC, DF. Scale bars: a, e – 50 µm; b, f, g – 20 µm.

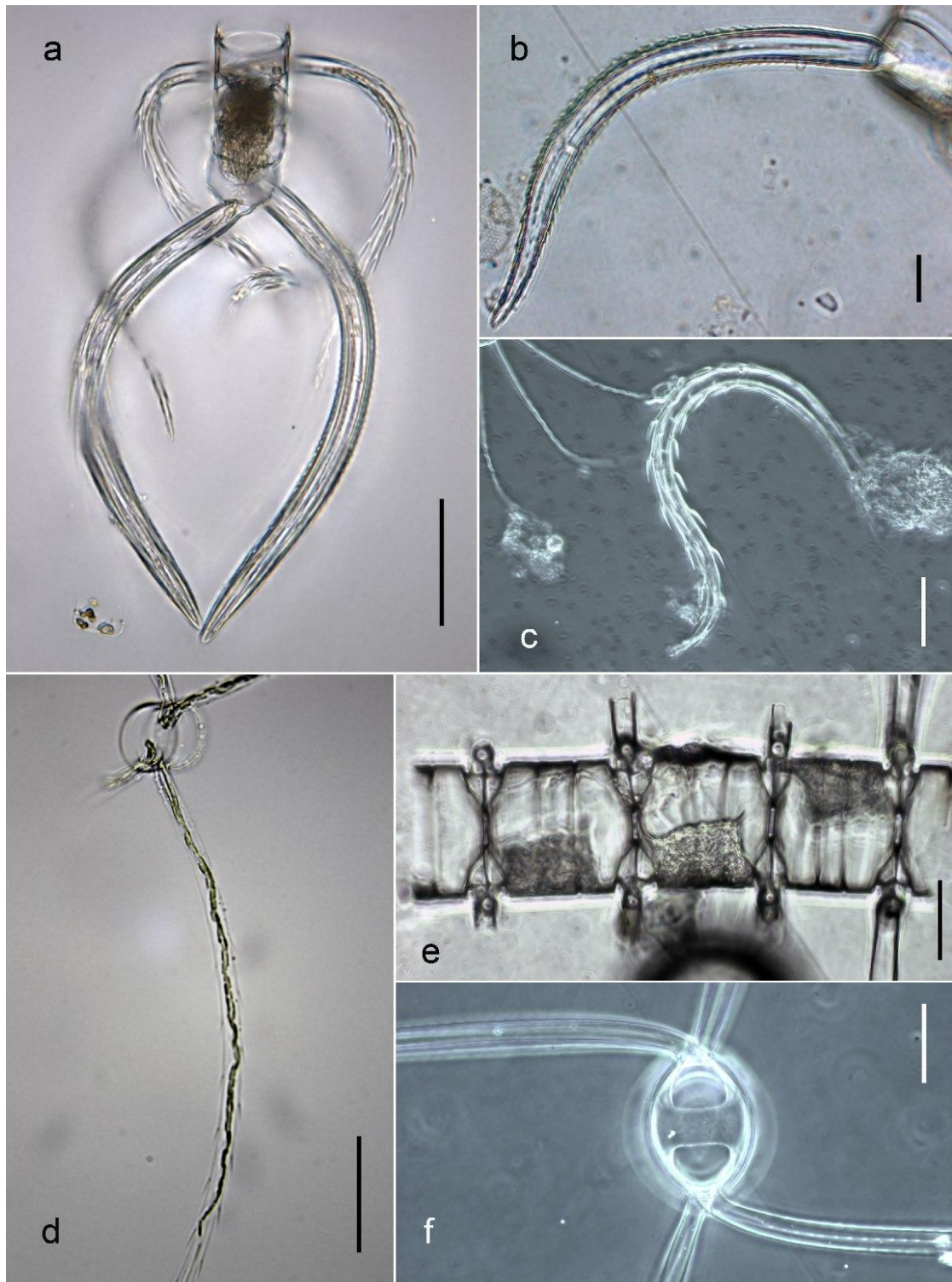


Plate A38. *Chaetoceros coarctatus* (a-c); *Chaetoceros eibenii* (d-f).
a, d – LM, BF; b, e – PhC, BF; c, f – PhC, DF. Scale bars: a, d – 50 μm ; b, c, e, f – 20 μm .

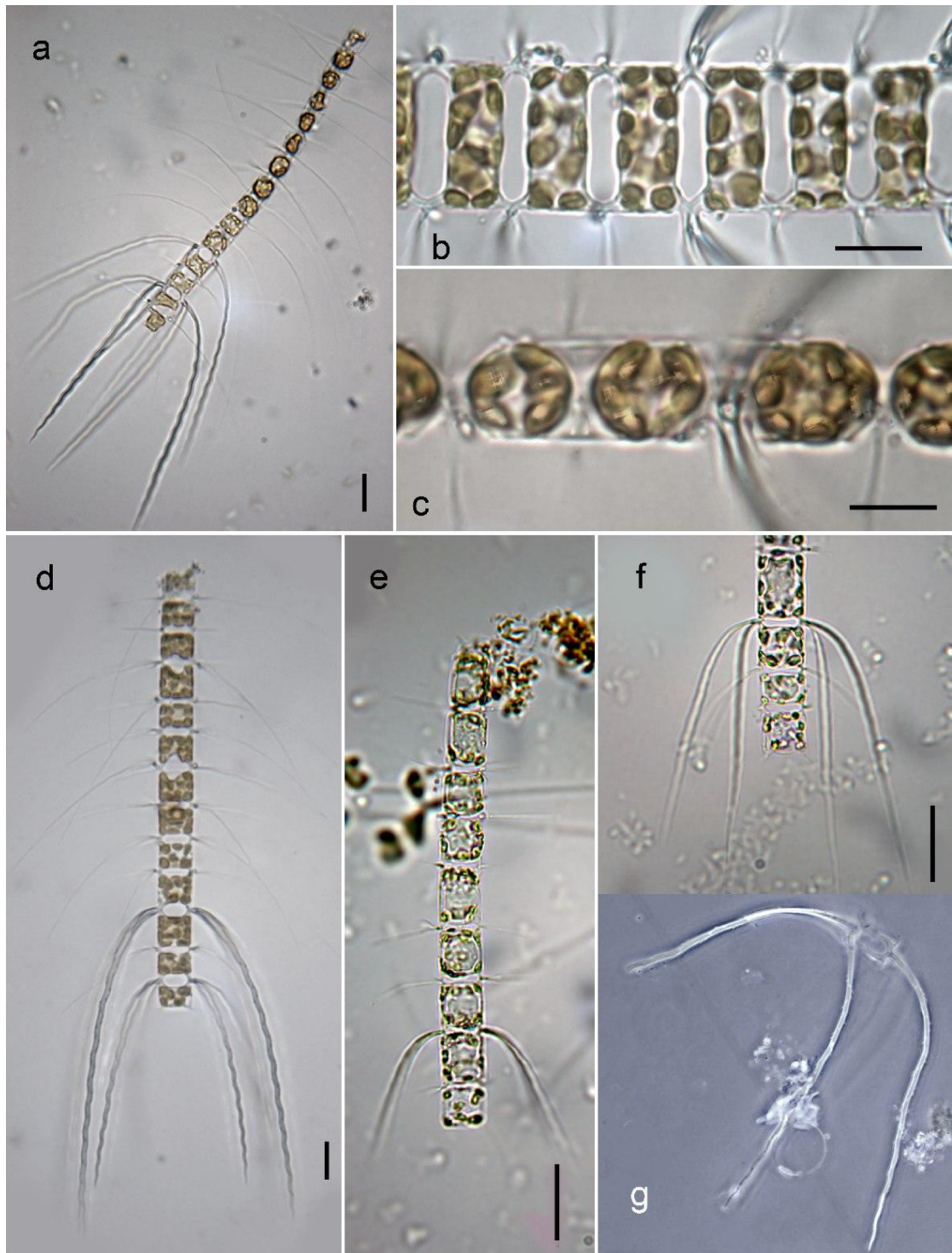


Plate A39. *Chaetoceros compressus* (a-g).
a-f – LM, BF; g – PhC, DF. Scale bars – 20 μ m.

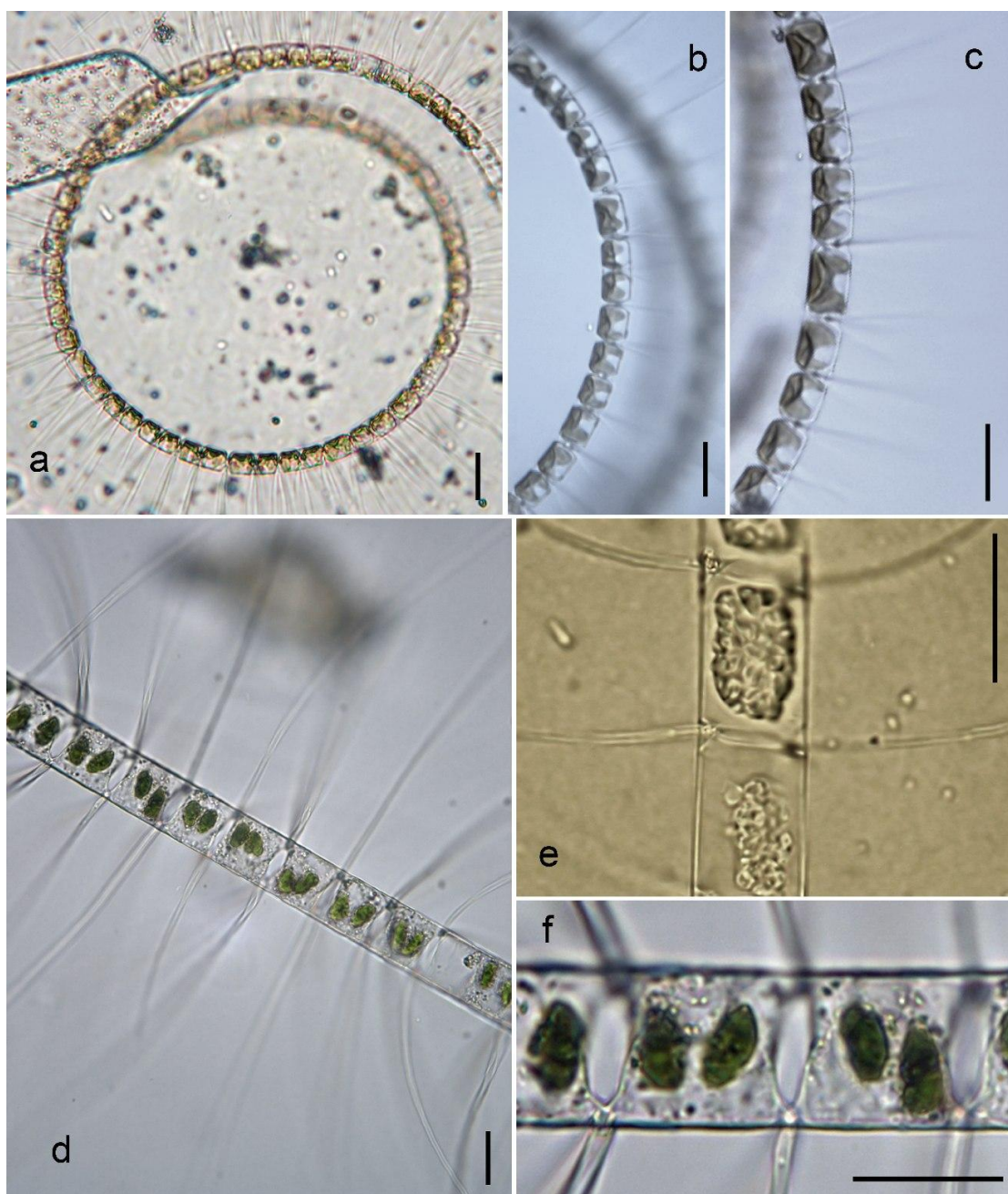


Plate A40. *Chaetoceros curvisetus* (a-c); *Chaetoceros lauderi* (d-f).
a-f – LM, BF. Scale bars – 20 μm .

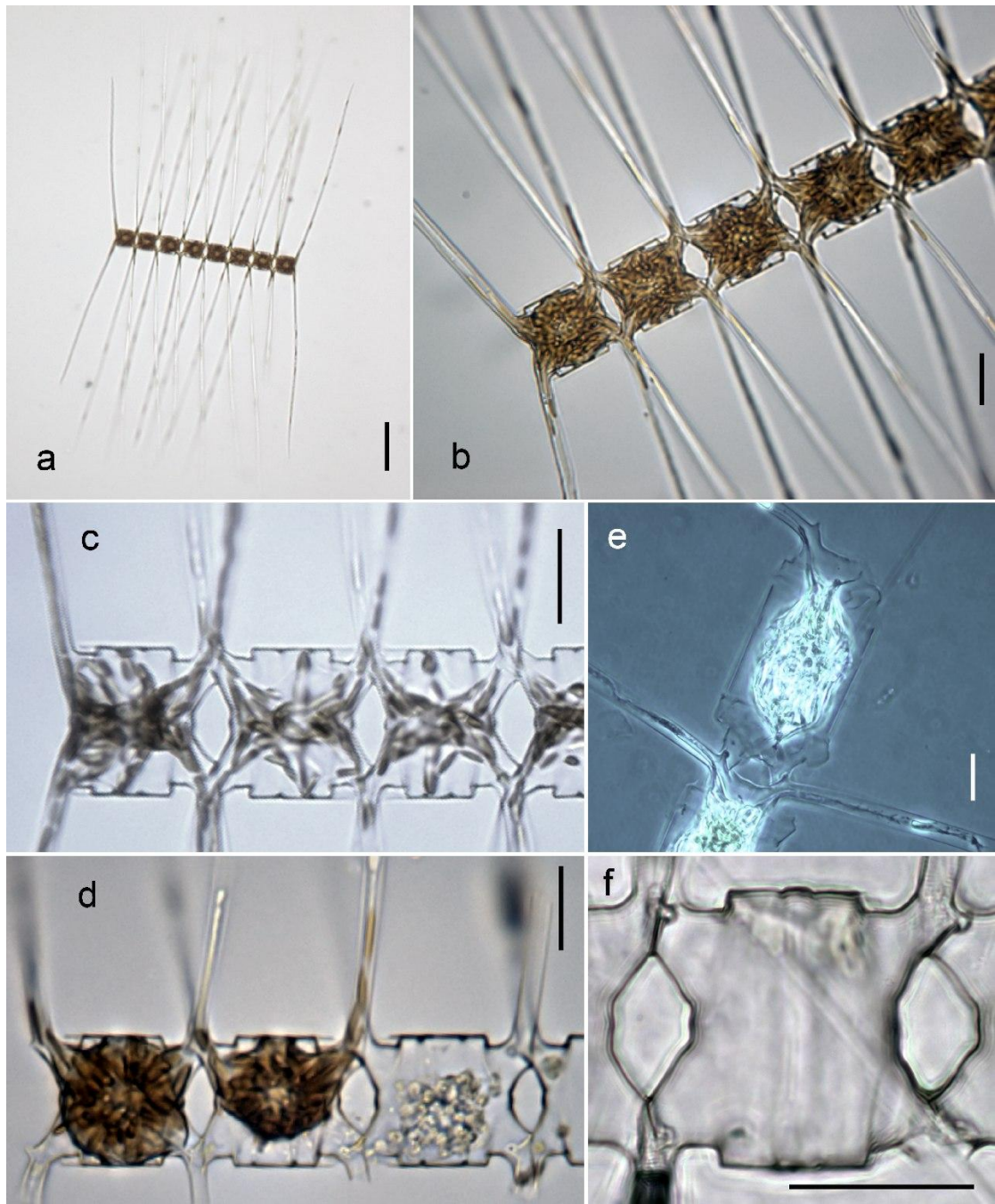


Plate A41. *Chaetoceros denticulatus* (a-f).

a-c, d – LM, BF; e – PhC, DF; f – PhC, BF. Scale bars: a – 50 μm ; b-f – 20 μm .

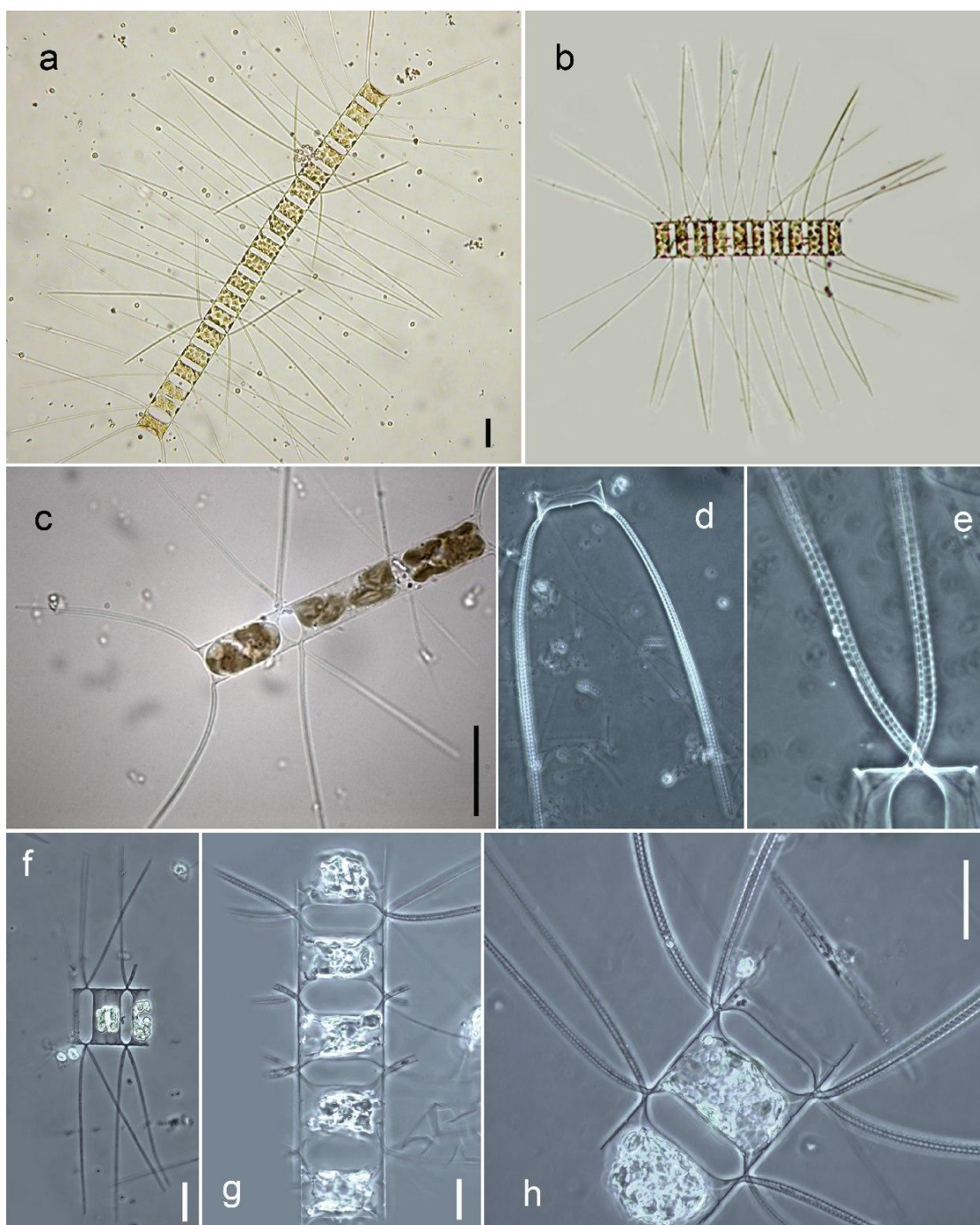


Plate A42. *Chaetoceros lorenzianus* (a-h).
a-c – LM, BF; d-h – PhC, DF. Scale bars – 20 μ m.

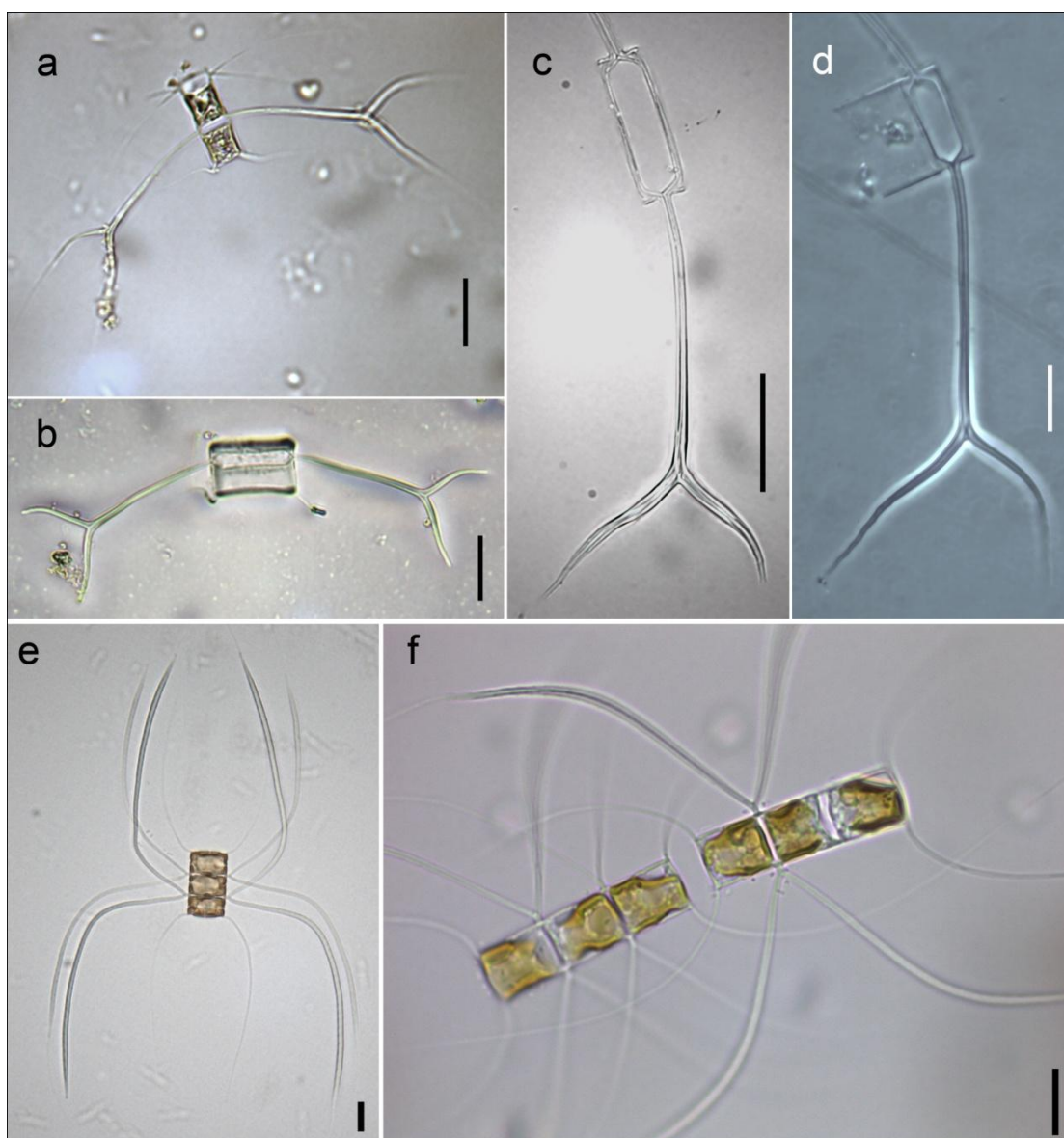


Plate A43. *Chaetoceros messanensis* (a-d); *Chaetoceros diversus* (e, f).
 a-c, e, f – LM, BF; d – PhC, DF. Scale bars: a-d – 20 µm; e, f – 10 µm.

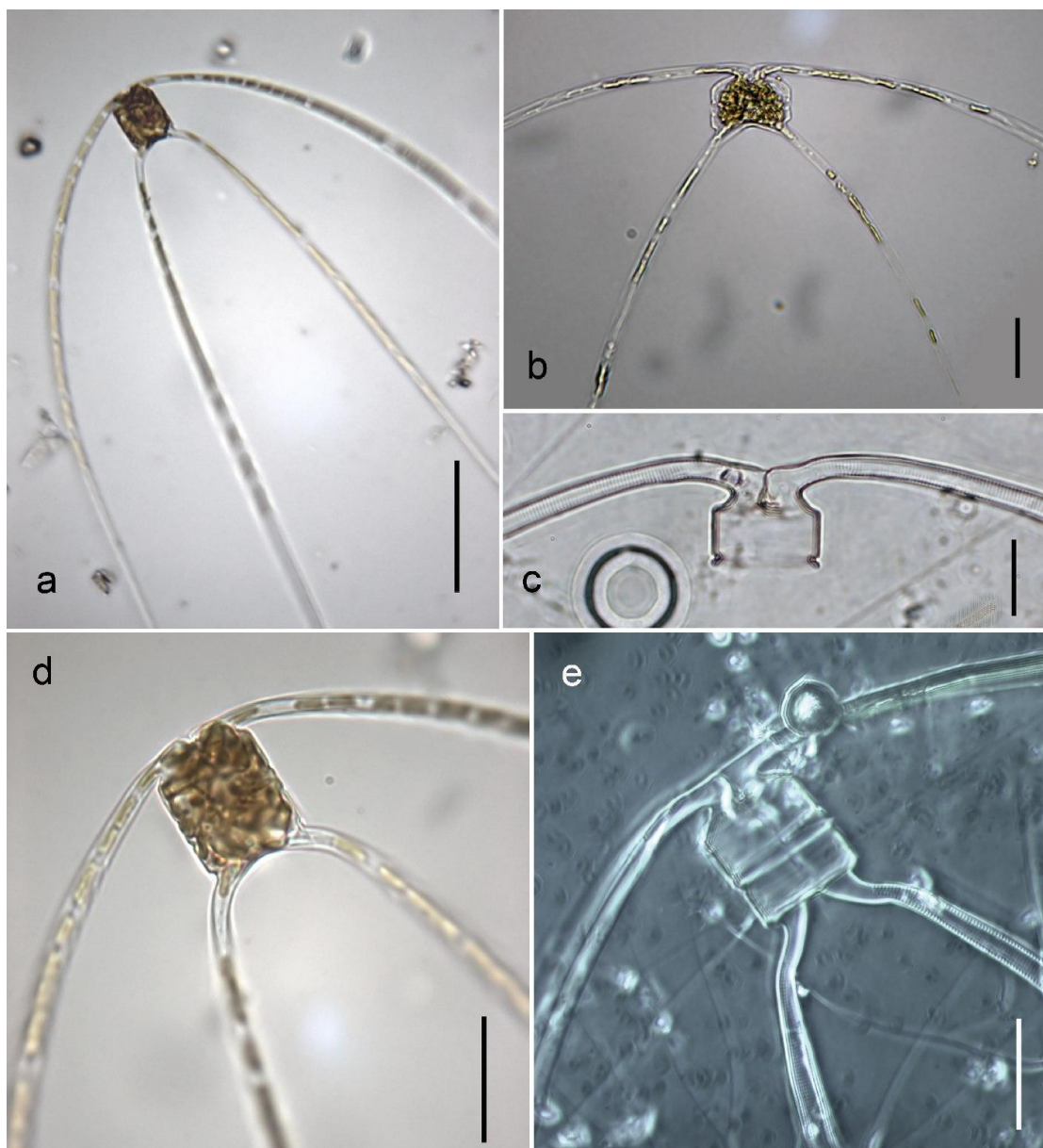


Plate A44. *Chaetoceros peruvianus* (a-e).

a, b, d – LM, BF; c, e – PhC, BF, DF. Scale bars: a – 50 µm; b-e – 20 µm.

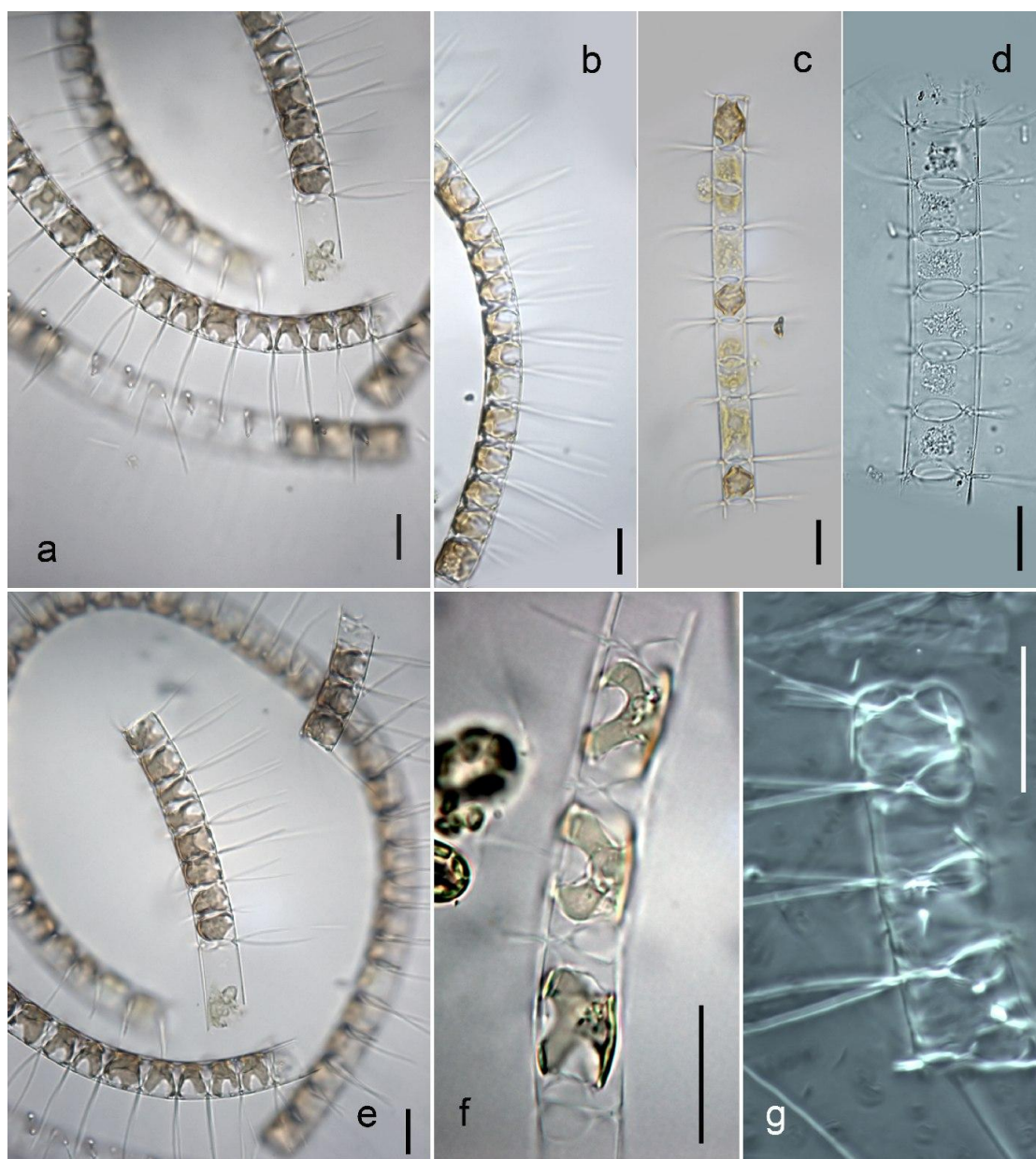


Plate A45. *Chaetoceros pseudocurvisetus* (a-g).
a-f – LM, BF; g – PhC, DF. Scale bars – 20 μm.

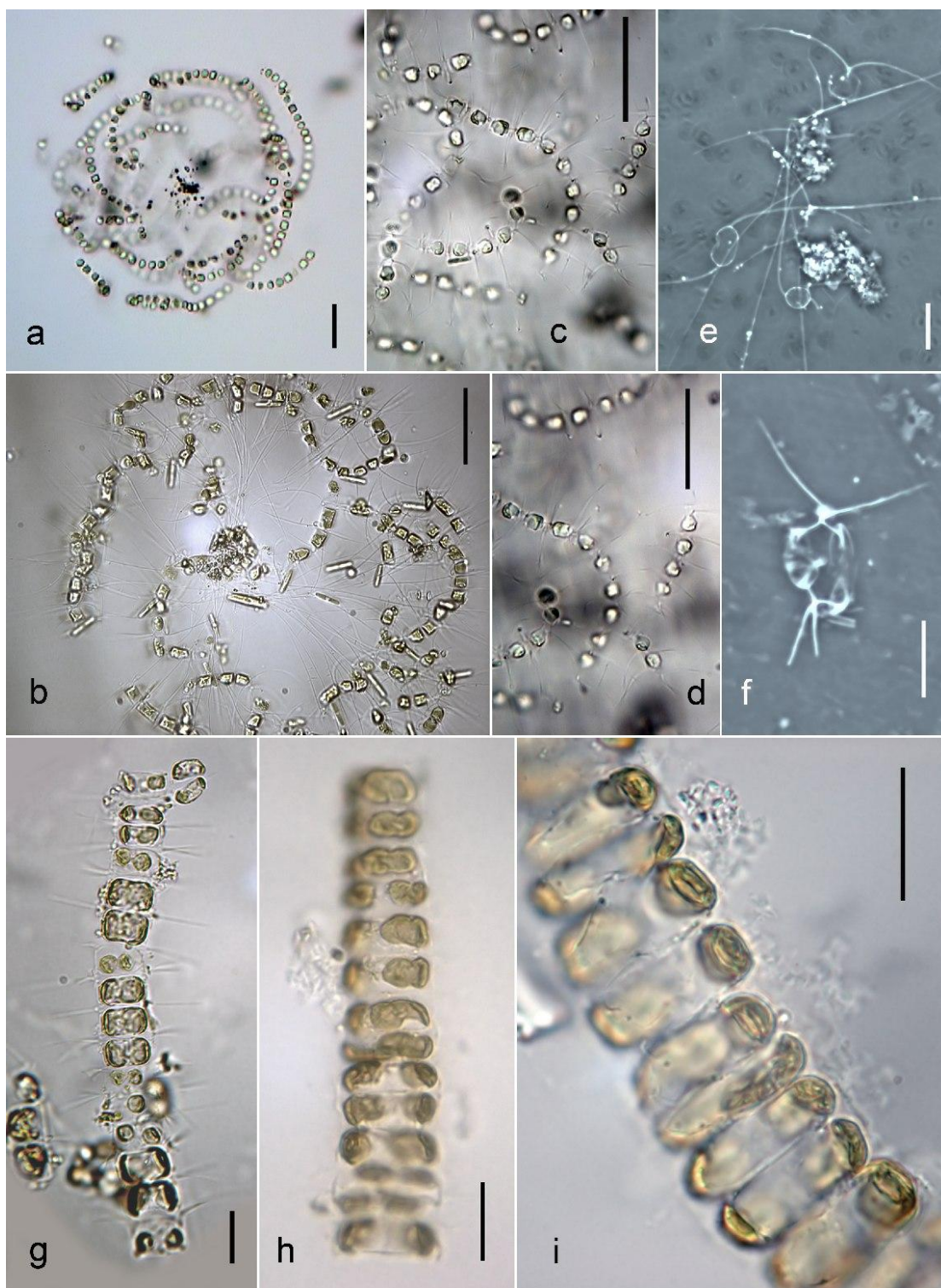


Plate A46. *Chaetoceros socialis* (a-f); *Chaetoceros tortissimus* (g-i).
a-d, g-i – LM, BF; e, f – PhC, DF. Scale bars: a-d, g-i – 20 μm ; e, f – 10 μm .

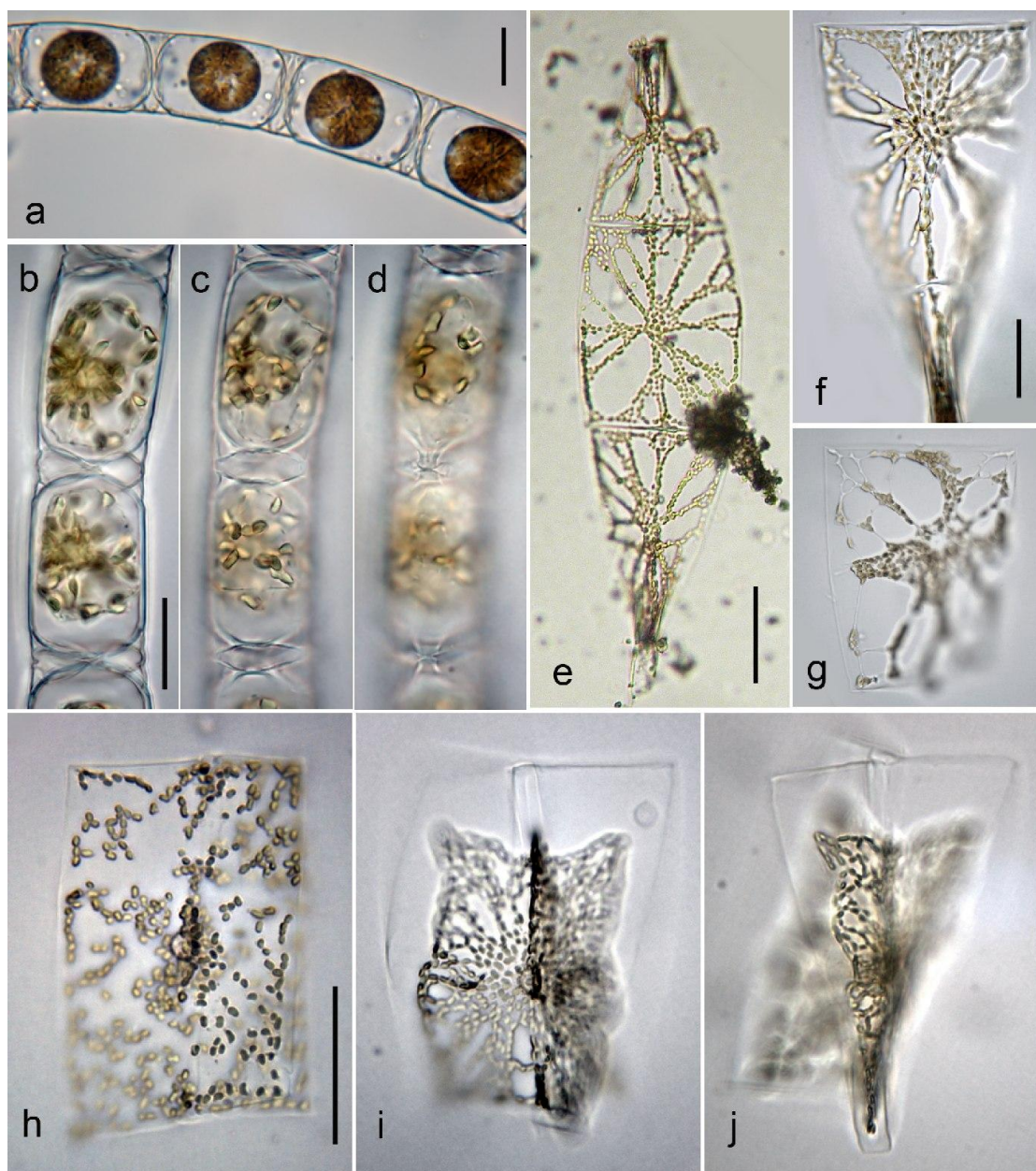


Plate A47. *Bellerochea horologicalis* (a-d); *Streptotheca tamesis* (e-g); *Streptotheca indica* (h-j).

a-j – LM, BF. Scale bars: a-d – 20 μm ; e-j – 50 μm .

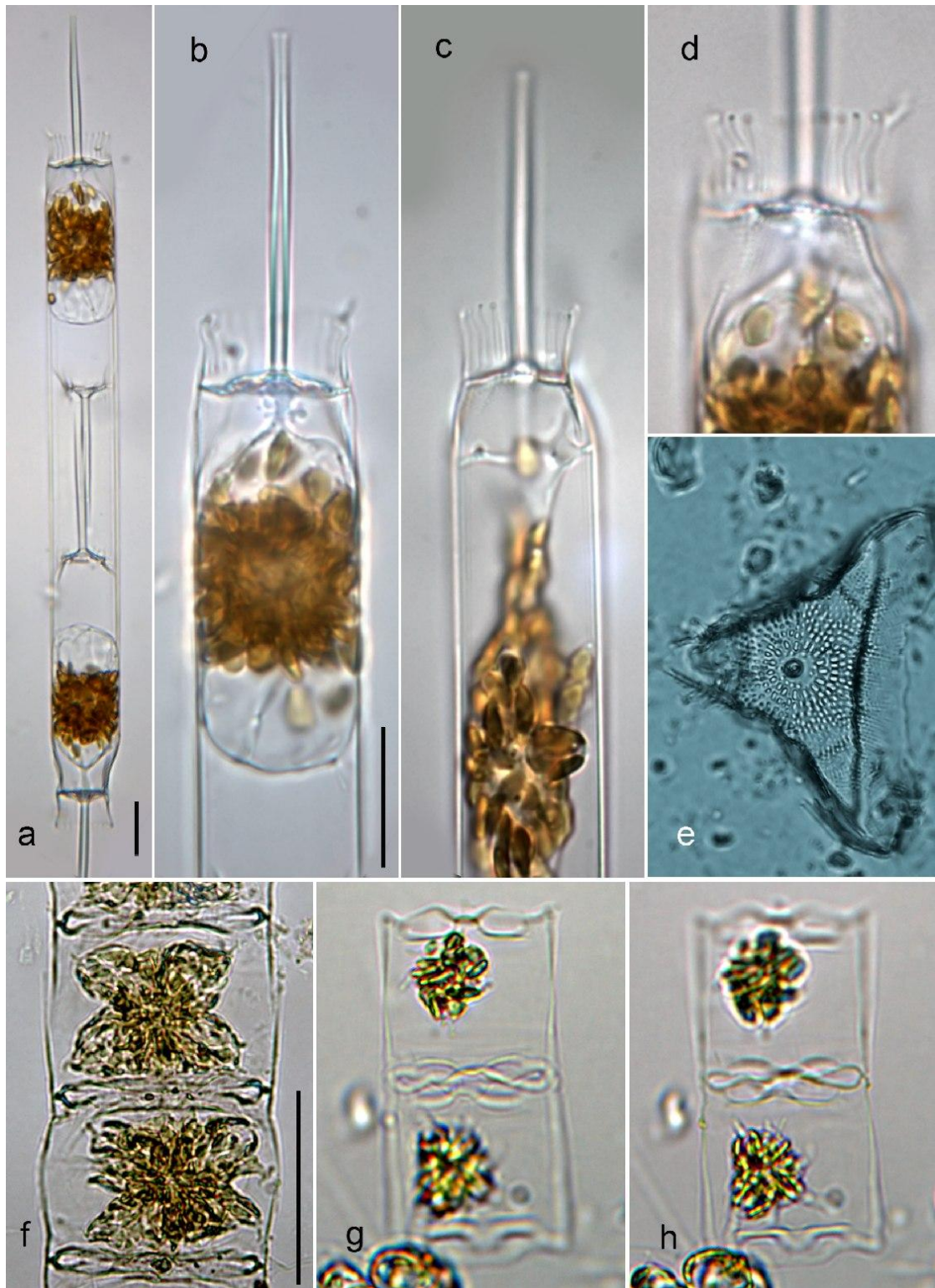


Plate A48. *Ditylim brightwellii* (a-e); *Lithodesmium undulatum* (f-h).
a-d, f-h – LM, BF; e – PhC, BF. Scale bars – 20 μ m.

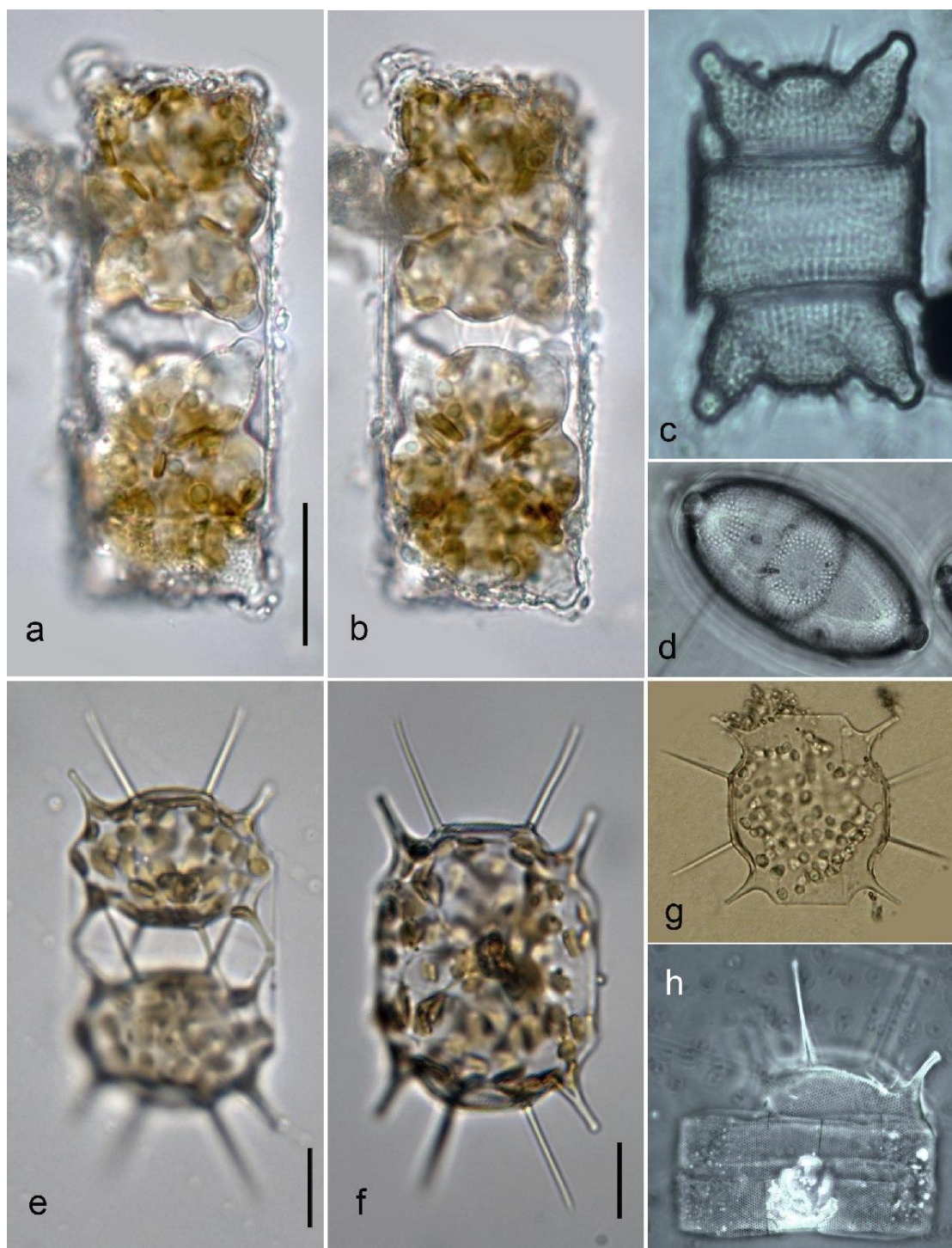


Plate A49. *Odontella aurita* (a-d); *Odontella mobiliensis* (e-h).
a,b, e-g – LM, BF; c, d, h – PhC, BF, DF. Scale bars – 20 μ m.

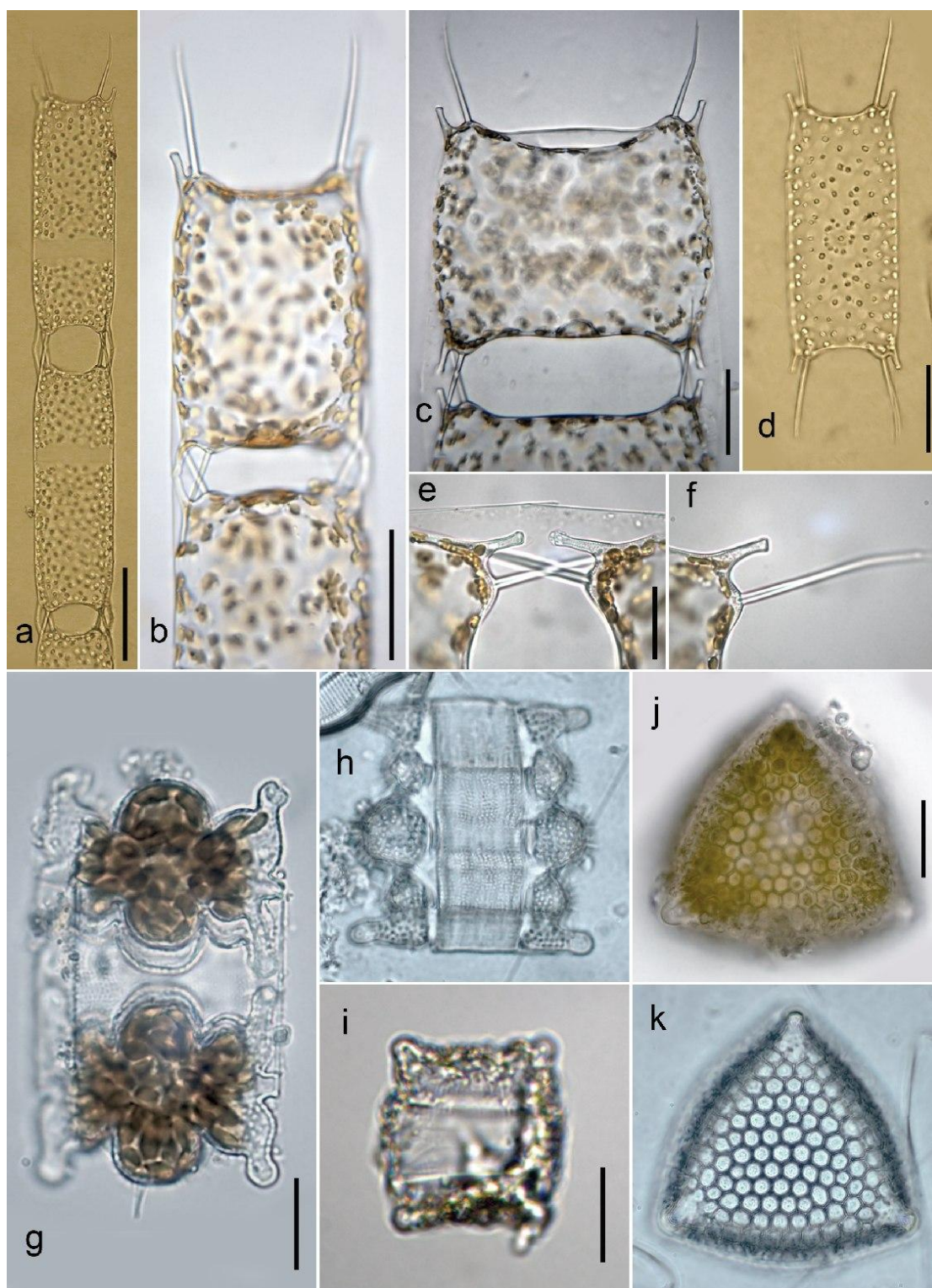


Plate A50. *Odontella sinensis* (a-f); *Biddulphia tuomeyi* (g, h); *Buddulphia pulchella* (i); *Triceratium robertsonianum* (j, k).

a-g, i, j – LM, BF; h, k – PhC, BF. Scale bars: a-d – 50 μm; e-k – 20 μm.

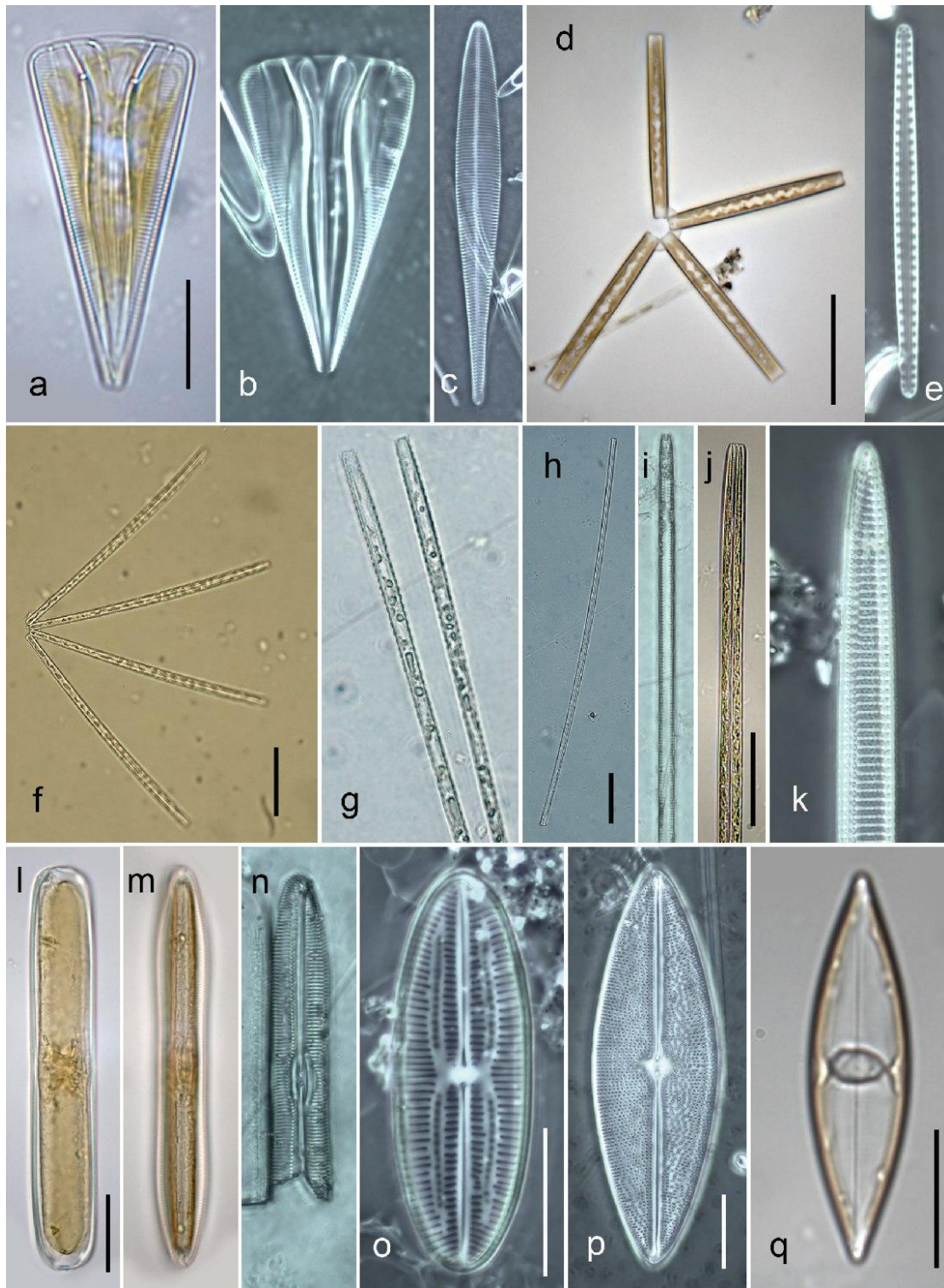


Plate A51. *Licmophora abbreviata* (a-c); *Thalassionema nitzschioides* (d, e); *Thalassiothrix frauenfeldii* (f, g); *Thalassiothrix longissima* (h, i); *Synedra* sp. (j, k); *Caloneis liber* (l-n); *Lyrella abrupta* (o); *Petroneis granulata* (p); *Mastogloia* sp. (q).

a, d, f, g, j, l, m, q – LM, BF; b, c, e, h, i, k, n-p – PhC, BF, DF. Scale bars – 20 μm.

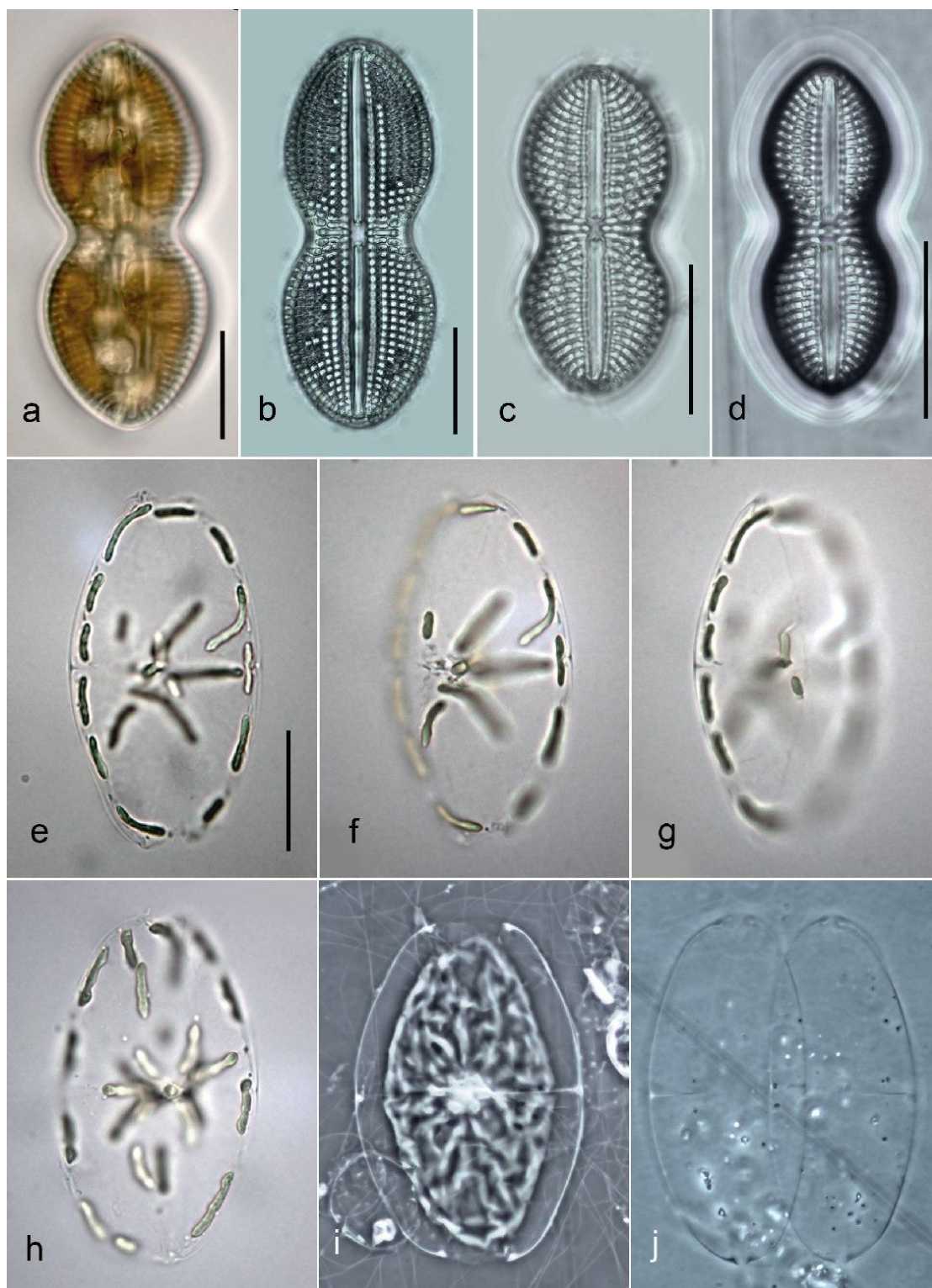


Plate A52. *Diploneis didyma* (a, b); *Diploneis weissflogii* (c, d); *Ephemera planamembranacea* (e-j).

a, e-h – LM, bf; b-d – PhC, BF; i, j – PhC, DF. Scale bars – 20 µm.

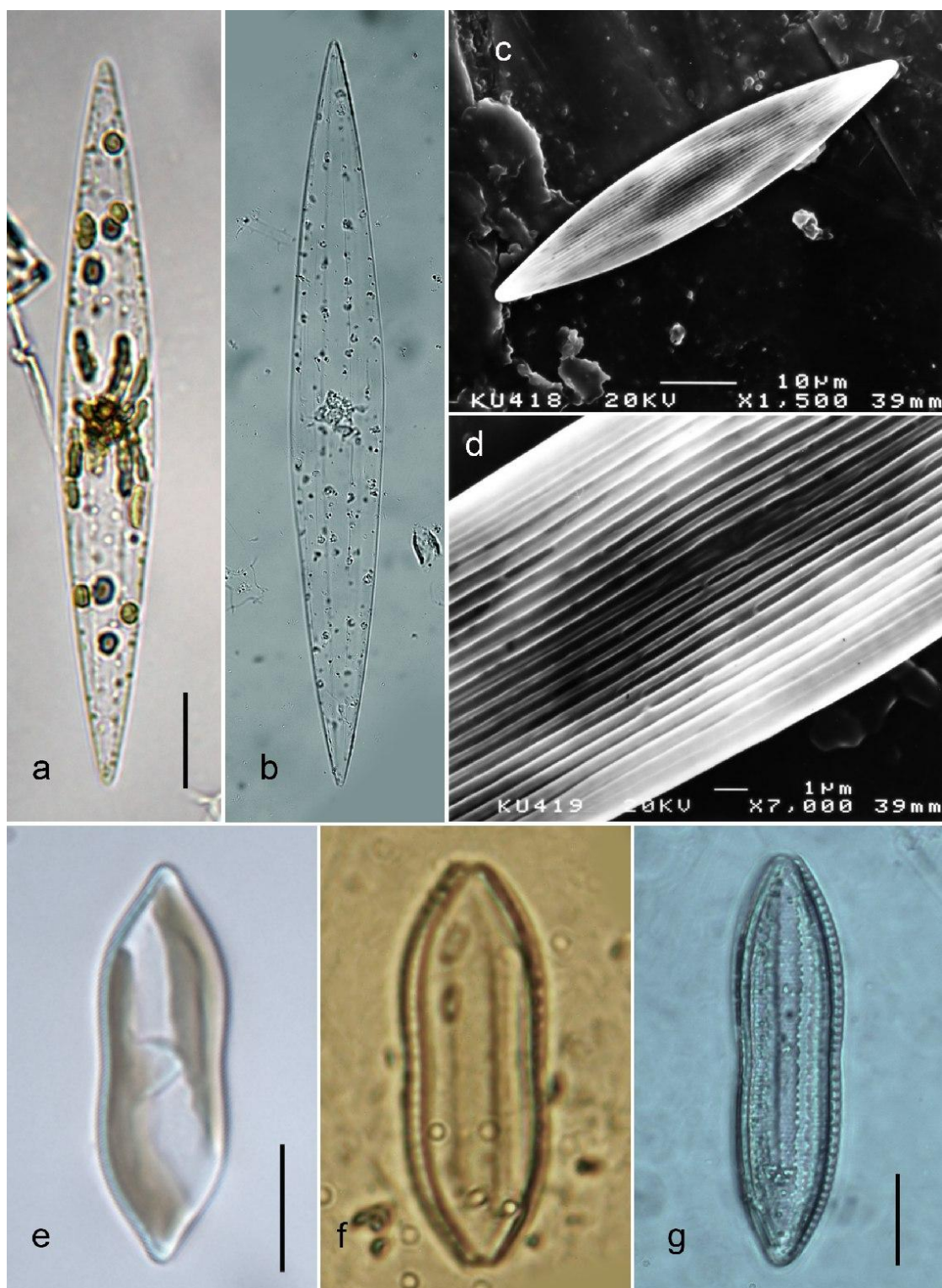


Plate A53. *Haslea cf. balearica* (a-d); *Nitzschia rorida* (e-g).
a, e, f – LM, BF; b, g – PhC, BF; c, d – SEM. Scale bars – 10 μm .

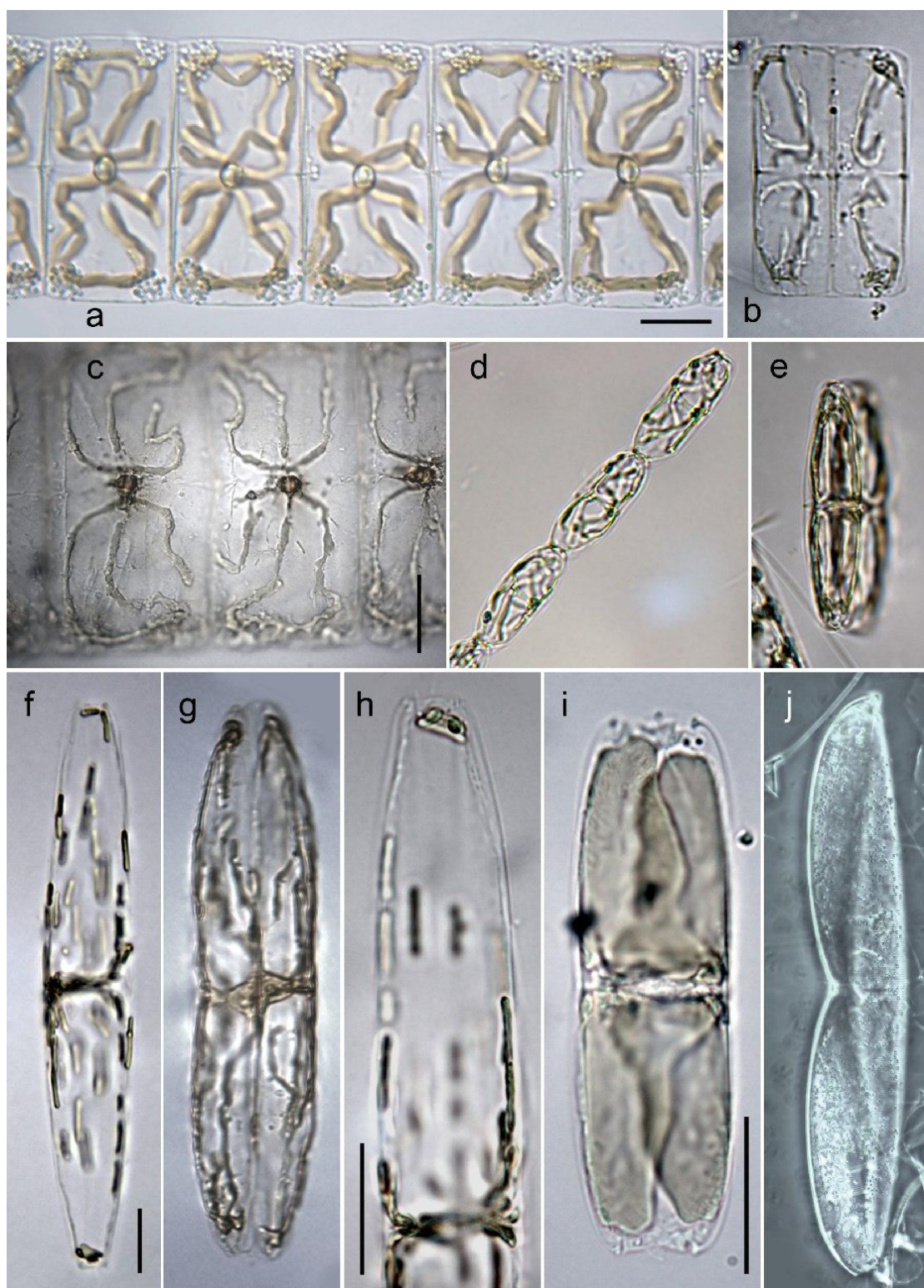


Plate A54. *Meuniera membranacea* (a-e); *Plagiotropis* sp. (f-h); *Plagiotropis lepidoptera* (i, j).
 a-i – LM, BF; j – PhC, DF. Scale bars: a-e – 20 μ m; f-j – 50 μ m.

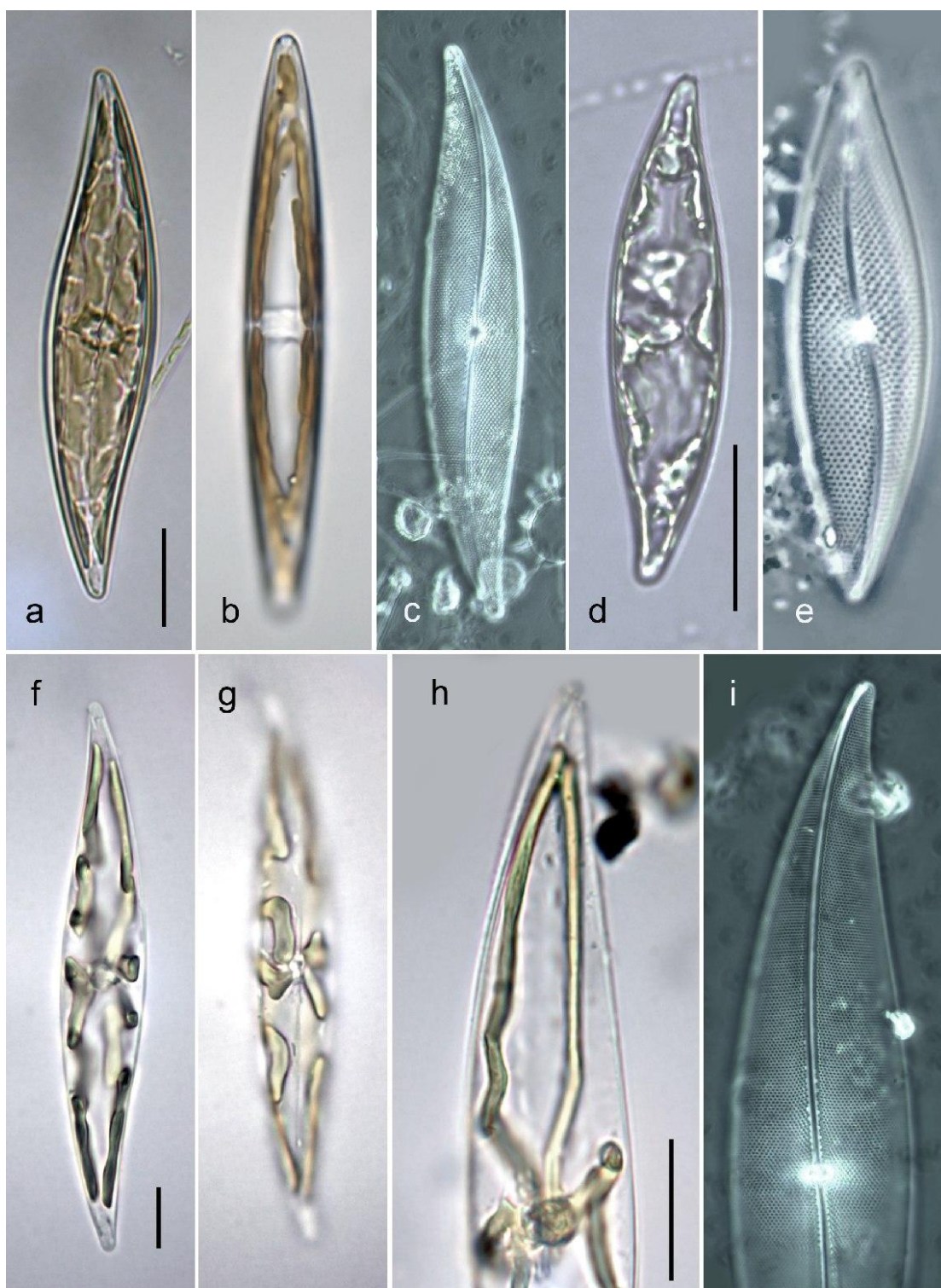


Plate A55. *Pleurosigma diverse-striatum* (a-c); *Pleurosigma naviculaceum* (d, e); *Pleurosigma strigosum* (f-i).

a, b, d, f-h – LM, BF; c, e, i – PhC, DF. Scale bars – 20 μm .

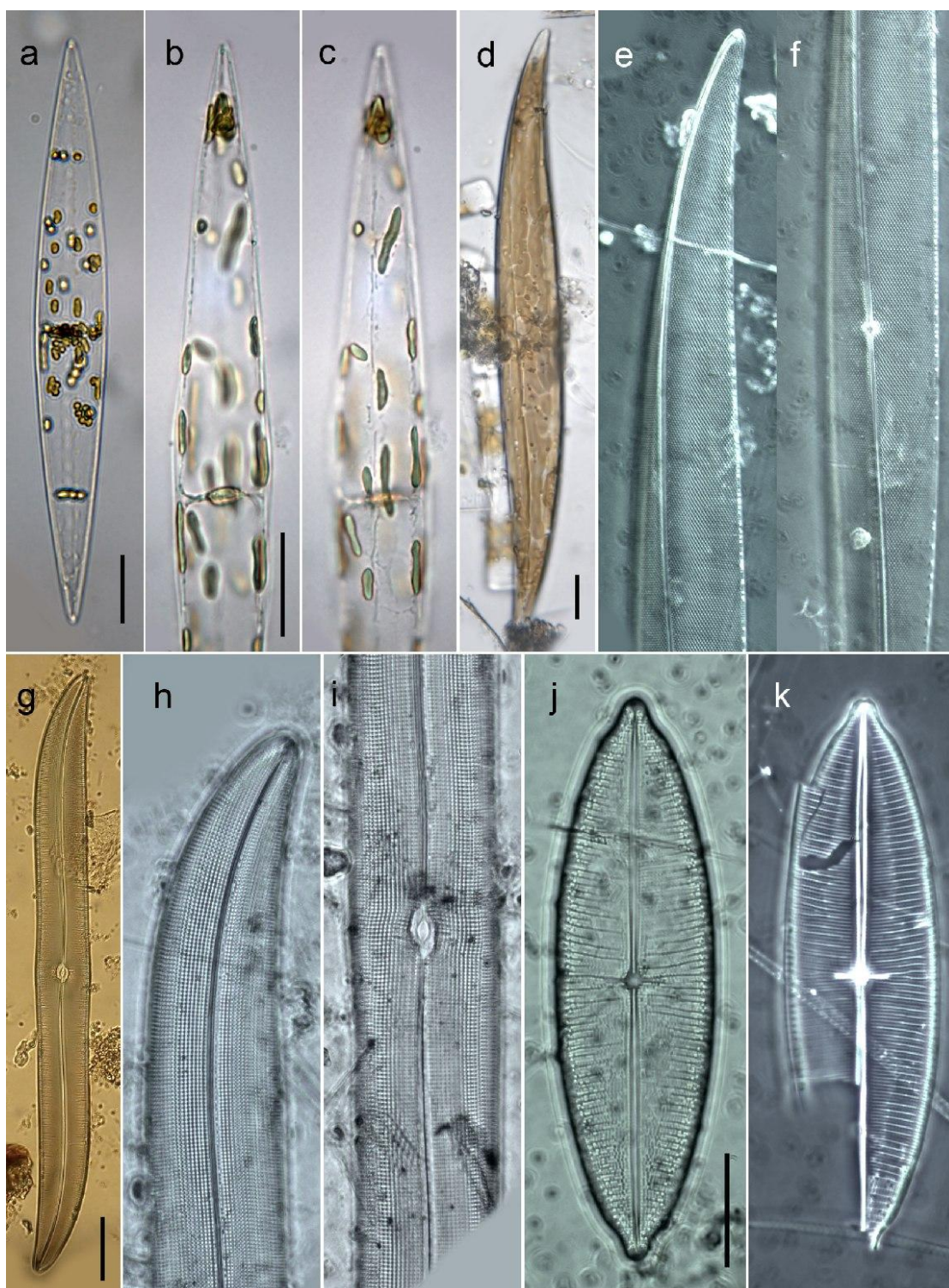


Plate A56. *Pleurosigma* cf. *planctonicum* (a-c); *Pleurosigma formosum* (d-f); *Gyrosigma balticum* (g-i); *Mastoneis bififormis* (j, k).

a-d – LM, BF; e-k – PhC, DF, BF. Scale bars: a-c – 40 μ m; d-k – 20 μ m.

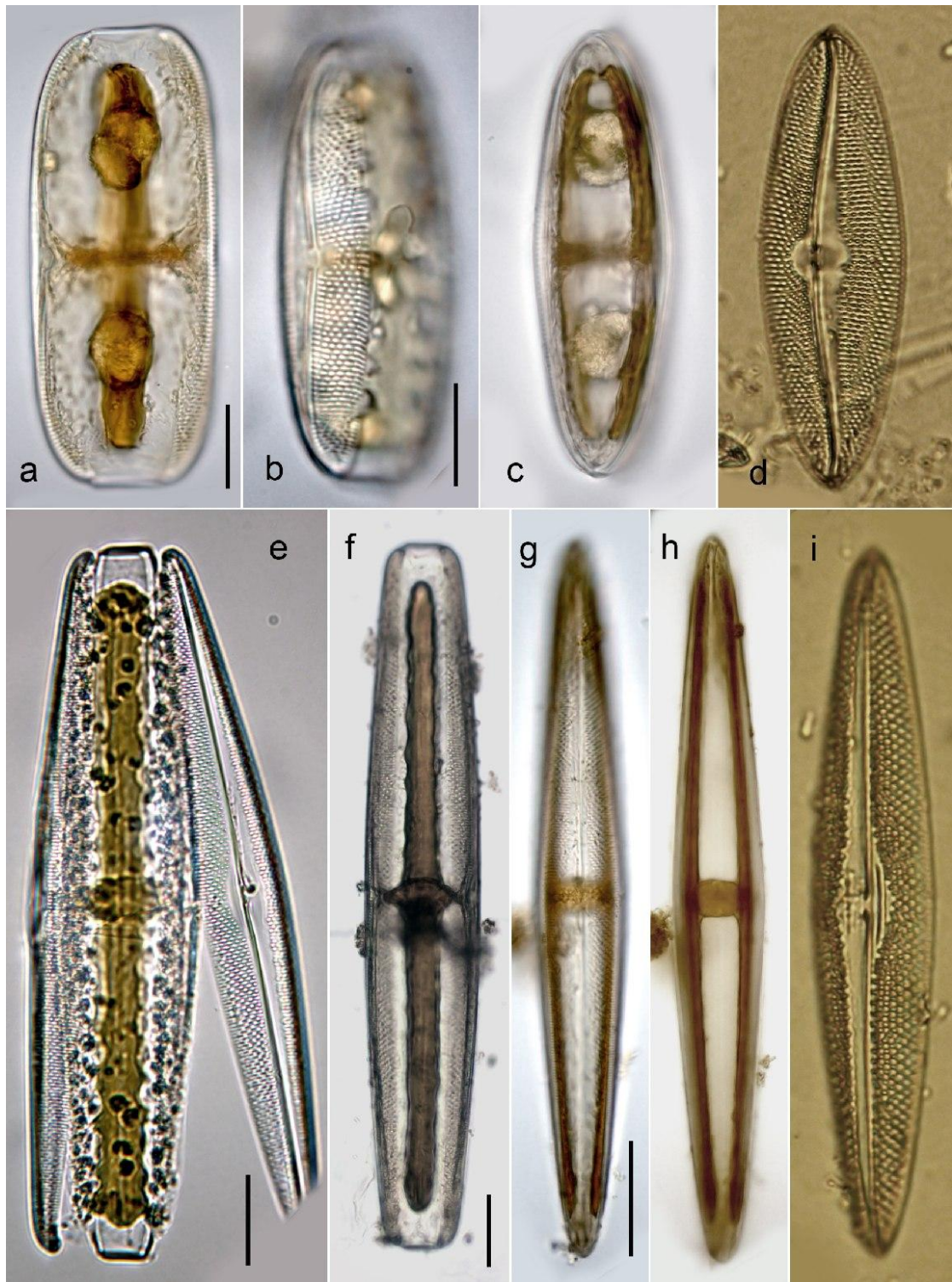


Plate A57. *Trachyneis antillarum* (a-d); *Trachyneis debyi* (e-i).
a-c, e-h – LM, BF; d, i – PhC, BF. Scale bars – 20 μ m.

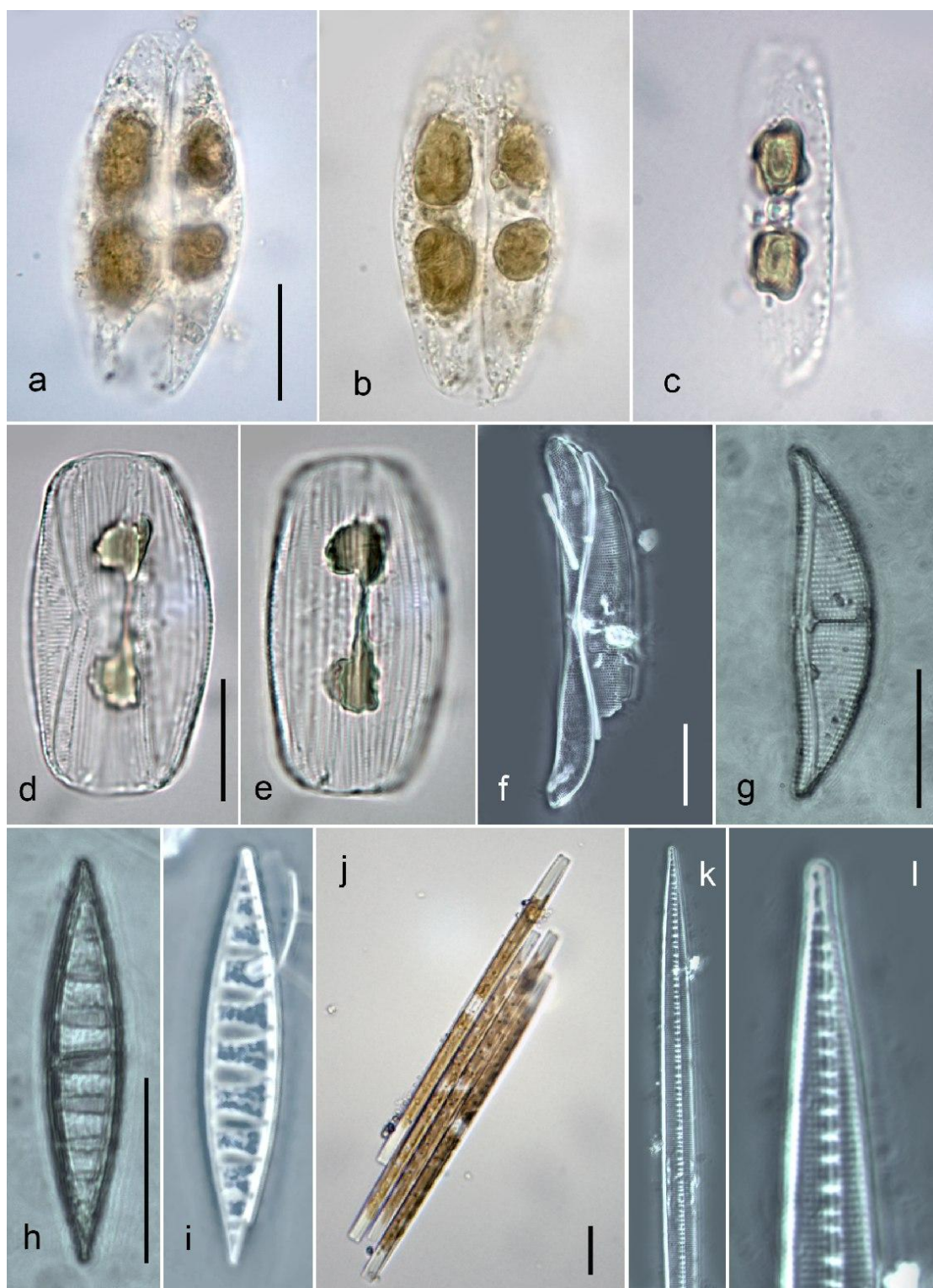


Plate A58. *Amphora* sp. (a-c); *Amphora lineolata* (d, e); *Amphora obtusa* (f); *Amphora ostrearia* var. *ostrearia* (g); *Cymatonitzschia marina* (h, i); *Bacillaria paxillifera* (j-l). a-e, j – LM, BF; f-i, k, l – PhC, BF, DF. Scale bars – 20 μ m.

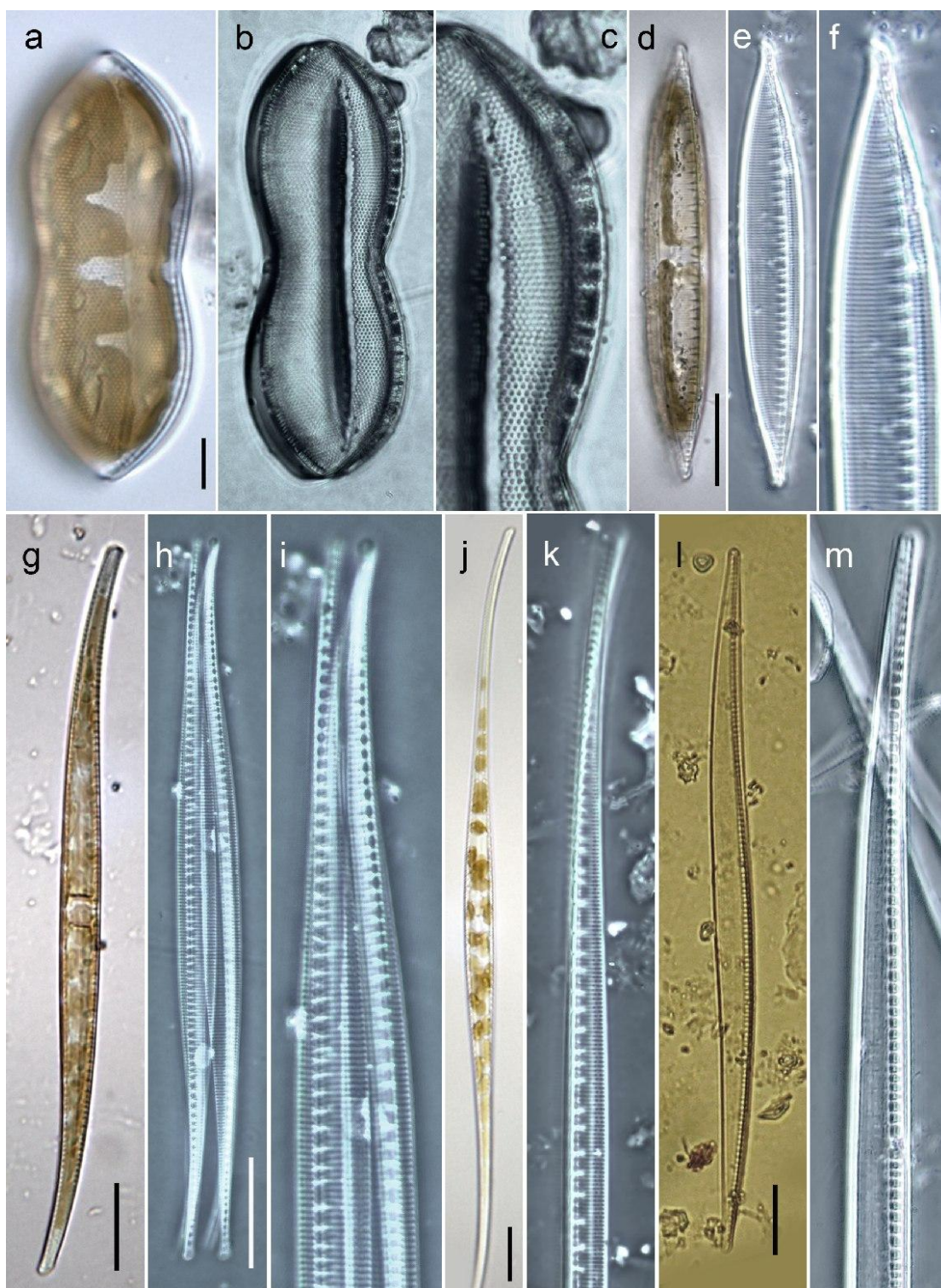


Plate A59. *Nitzschia panduriformis* v. *panduriformis* (a-c); *Nitzschia fluminensis* (d-f); *Nitzschia lorenziana* (g-i); *Nitzschia sigmaformis* (j, k); *Nitzschia sigma* (l, m).
a, d, g, j, l – LM, BF; b, c, e, f, h, i, k, m – PhC, BF, DF. Scale bars – 20 μ m.

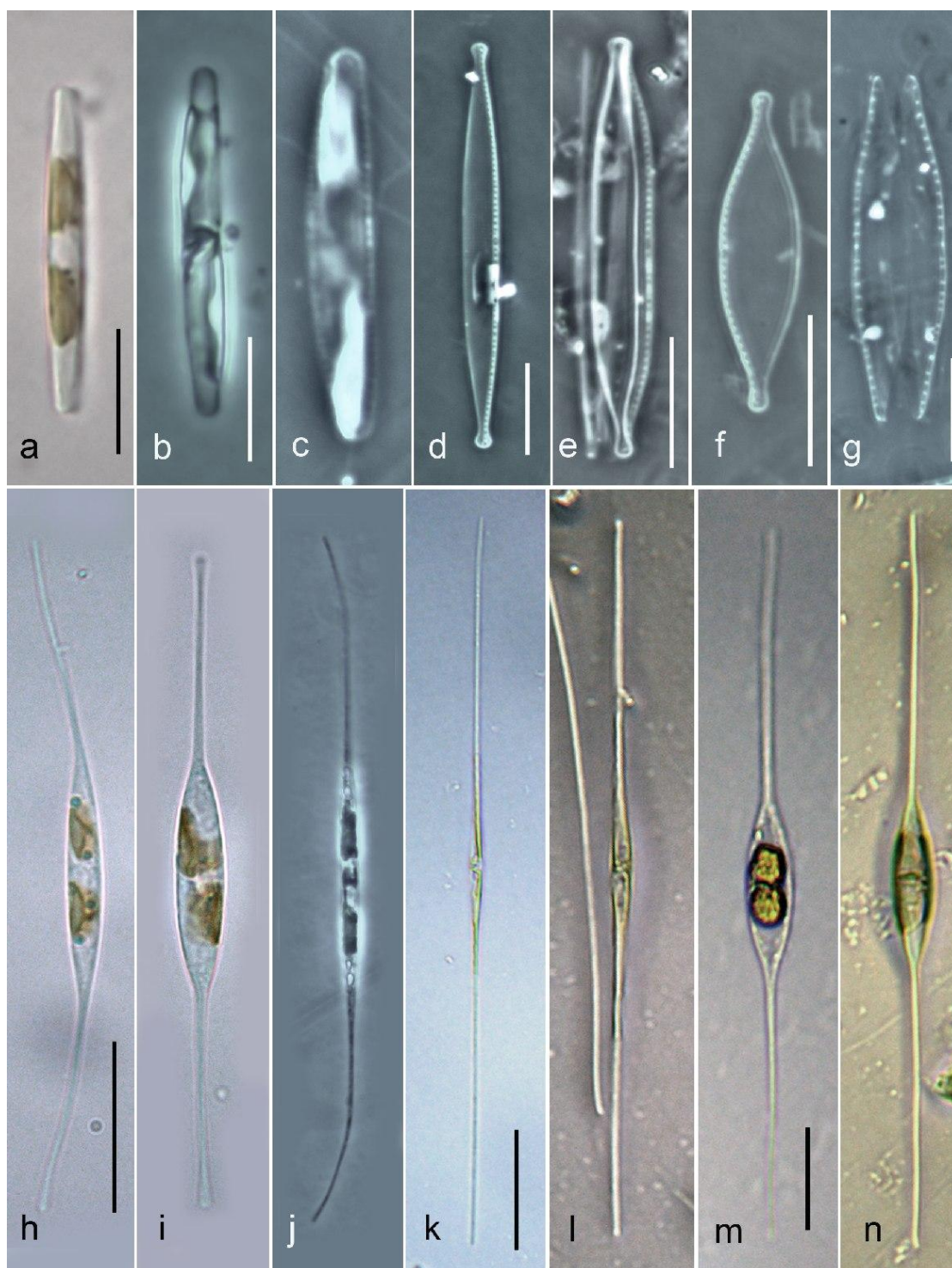


Plate A60. *Nitzschia* sp. 1 (a-c); *Nitzschia* sp. 2 (d); *Nitzschia* sp. 3 (e); *Nitzschia* sp. 4 (f); *Nitzschia* sp. 5 (g); *Cylindrotheca closterium* (h-j); *Nitzschia longissima* var. *longissima* (k, l); *Nitzschia longissima* var. *parva* (m, n).
 a, h, i, k, l-n – LM, BF; b-g, j – PhC, DF. Scale bars: a-g – 10 μ m; h-n – 20 μ m.

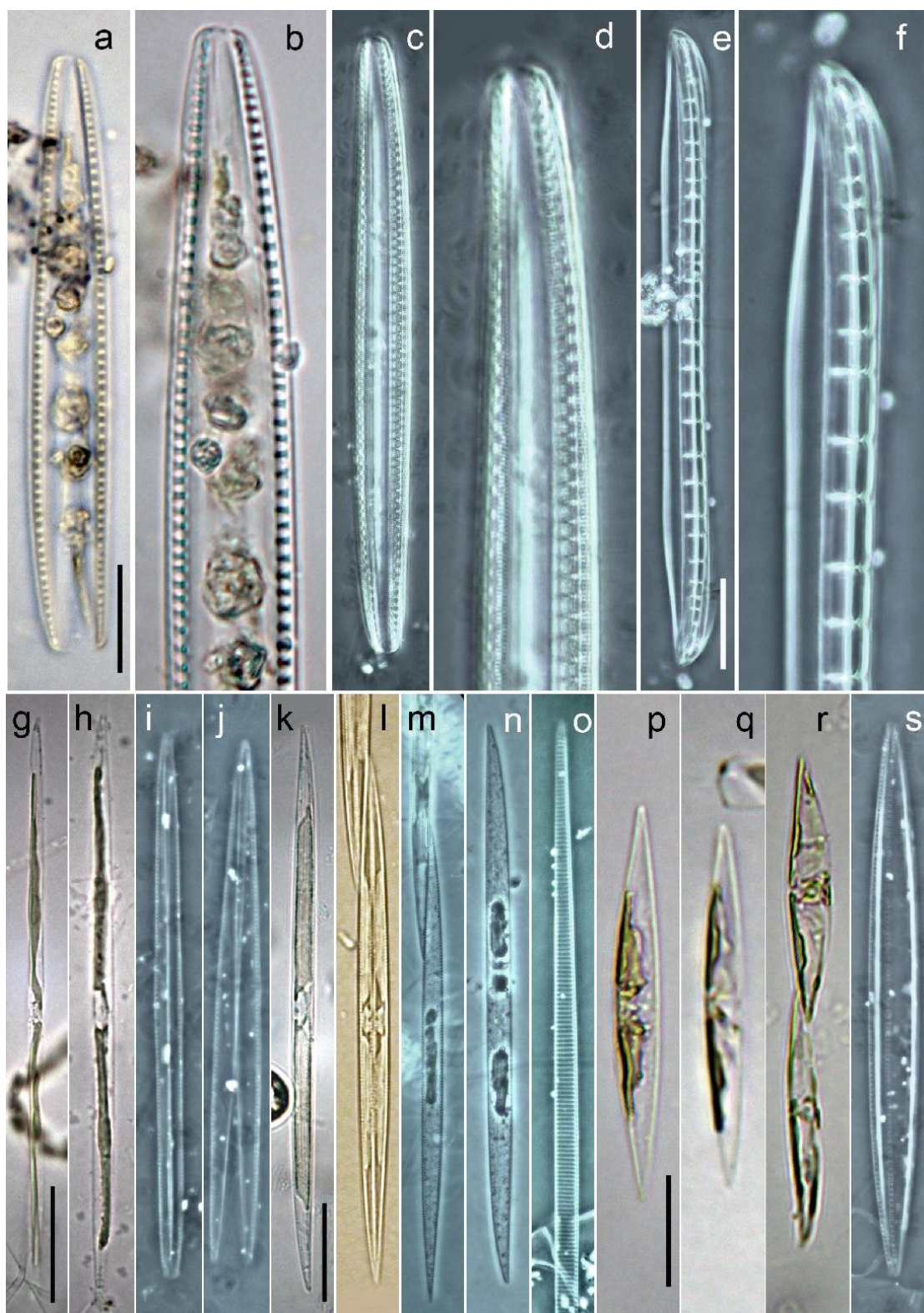


Plate A61. *Nitzschia* sp. 6 (a-d); *Nitzschia distans* var. *tumescens* (e, f); *Pseudo-nitzschia delicatissima* complex (g-j); *Pseudo-nitzschia pungens* (k-o); *Pseudo-nitzschia seriata/australis* complex (p-s).

a, b, g, h, k, l, p-r – LM, BF; c-f, i, j, m-o, s – PhC, DF. Scale bars – 20 μ m.

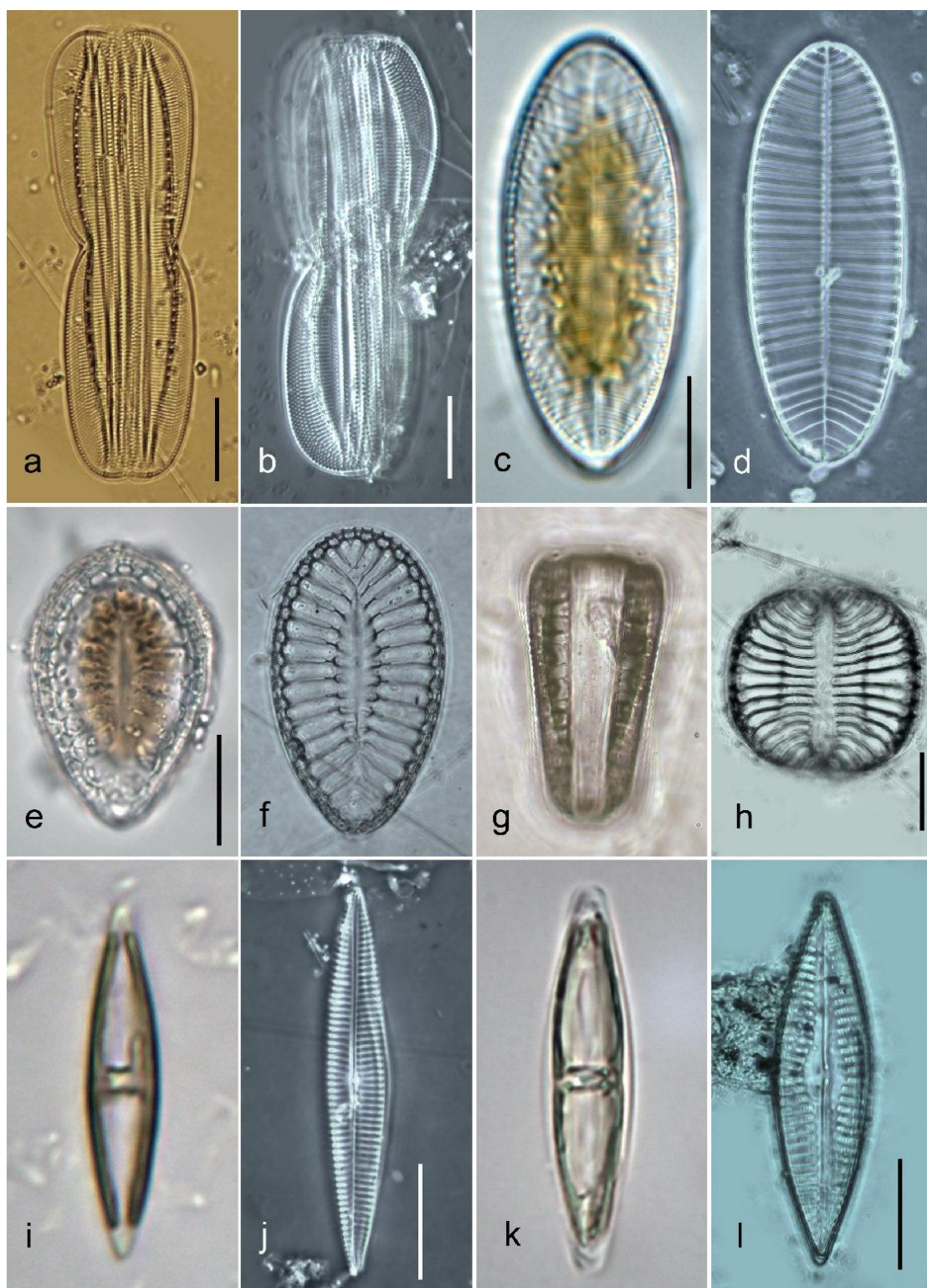


Plate A62. *Amphiprora sulcata* (a, b); *Petrodictyon gemma* (c, d); *Surirella fastuosa* (e-g); *Campylodiscus* sp. (h); *Navicula directa* (i, j); *Navicula palpebralis* (k, l).
a, c, e, i, k – LM, BF; b, d, f-h, j, l – PhC, BF, DF. Scale bars – 20 µm.

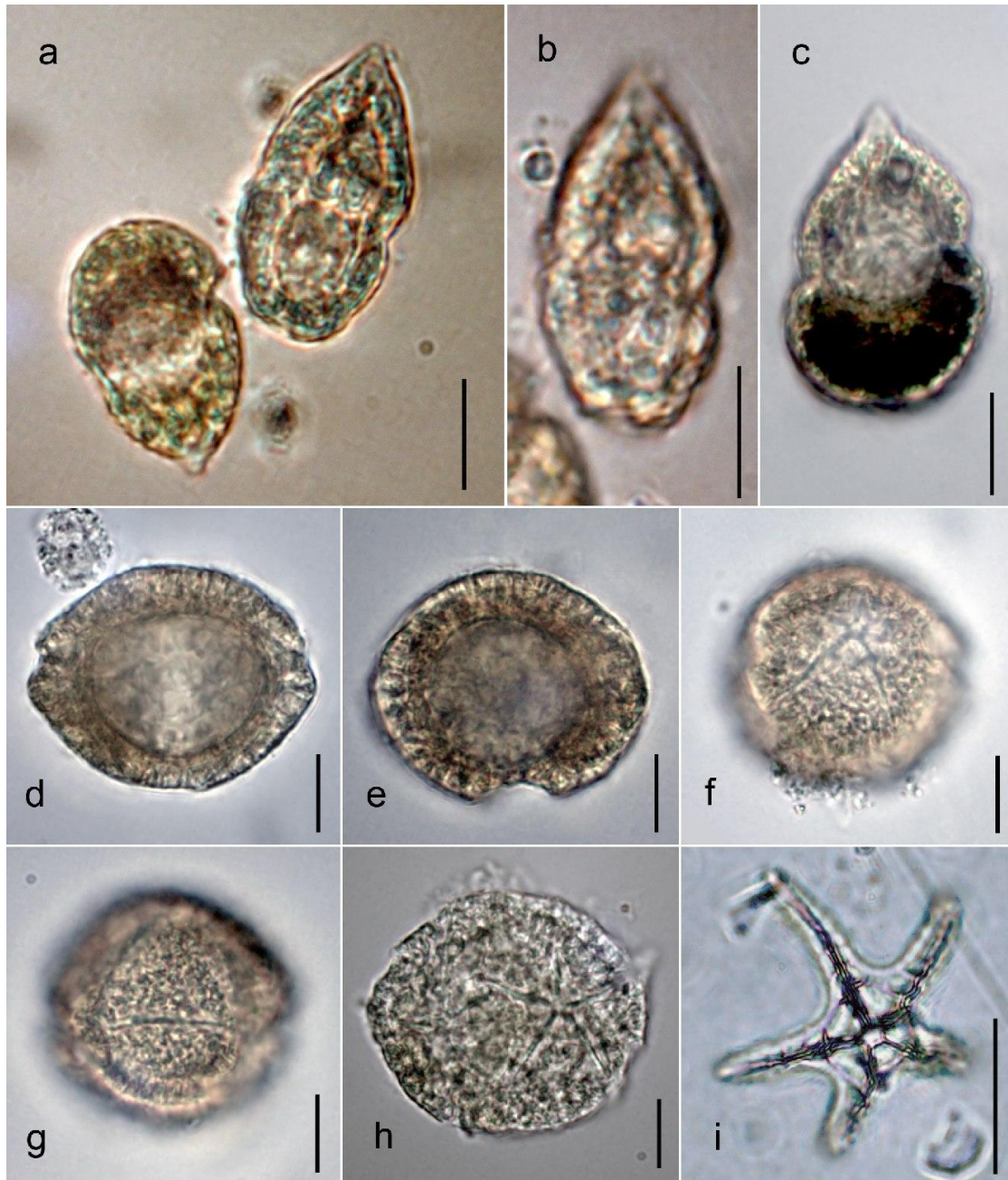


Plate A63. *Achradina pulchra* (a-c); *Actiniscus pentasterias* (d-i).
a-h – LM, BF; i – PhC, BF. Scale bars: a-c – 10 μm ; d-i – 20 μm .

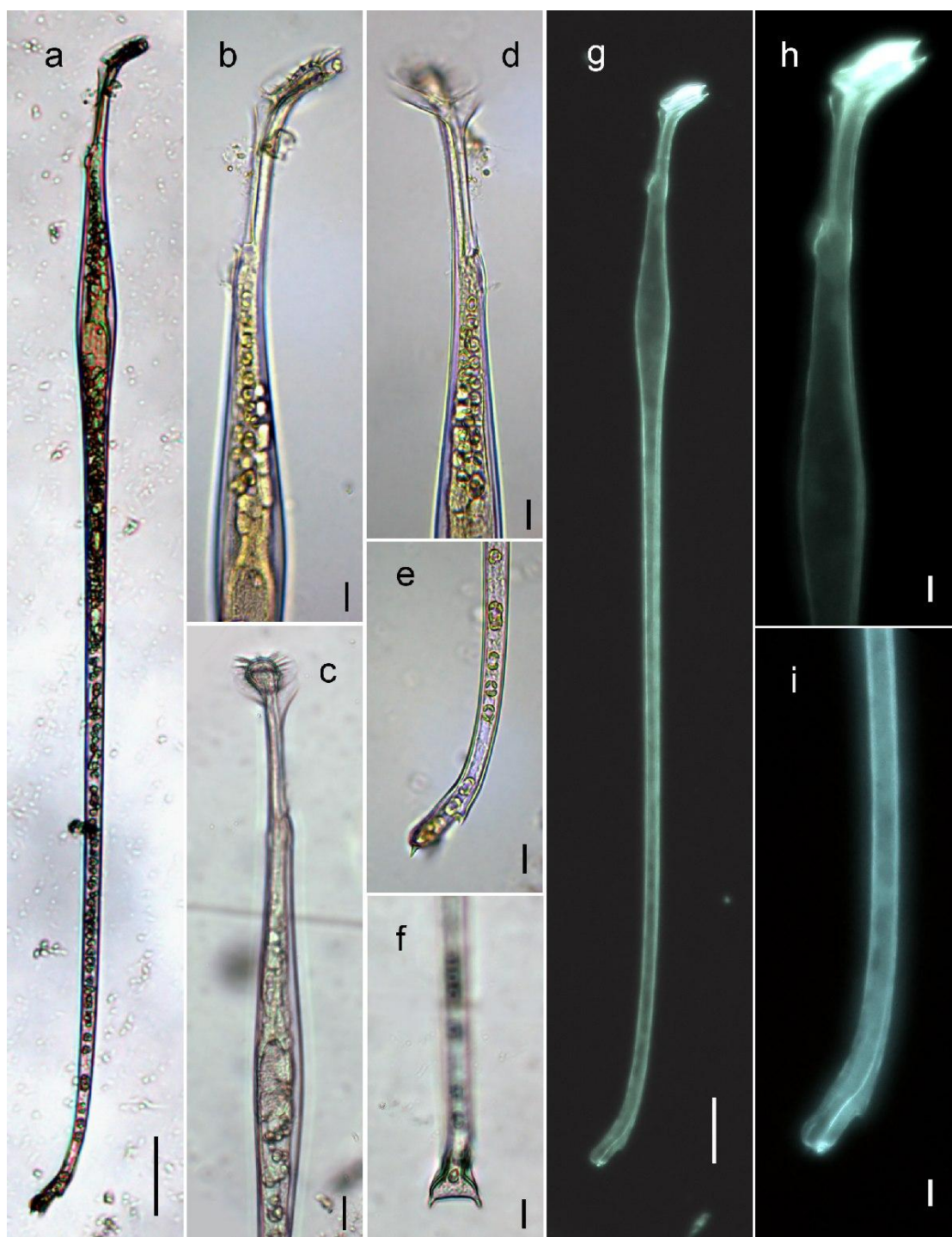


Plate A64. *Amphisolenia bidentata* (a-i).

a-f – LM, BF; g-i – LM, epifluorescence. Scale bars: a – 50 μm ; b-i – 10 μm .

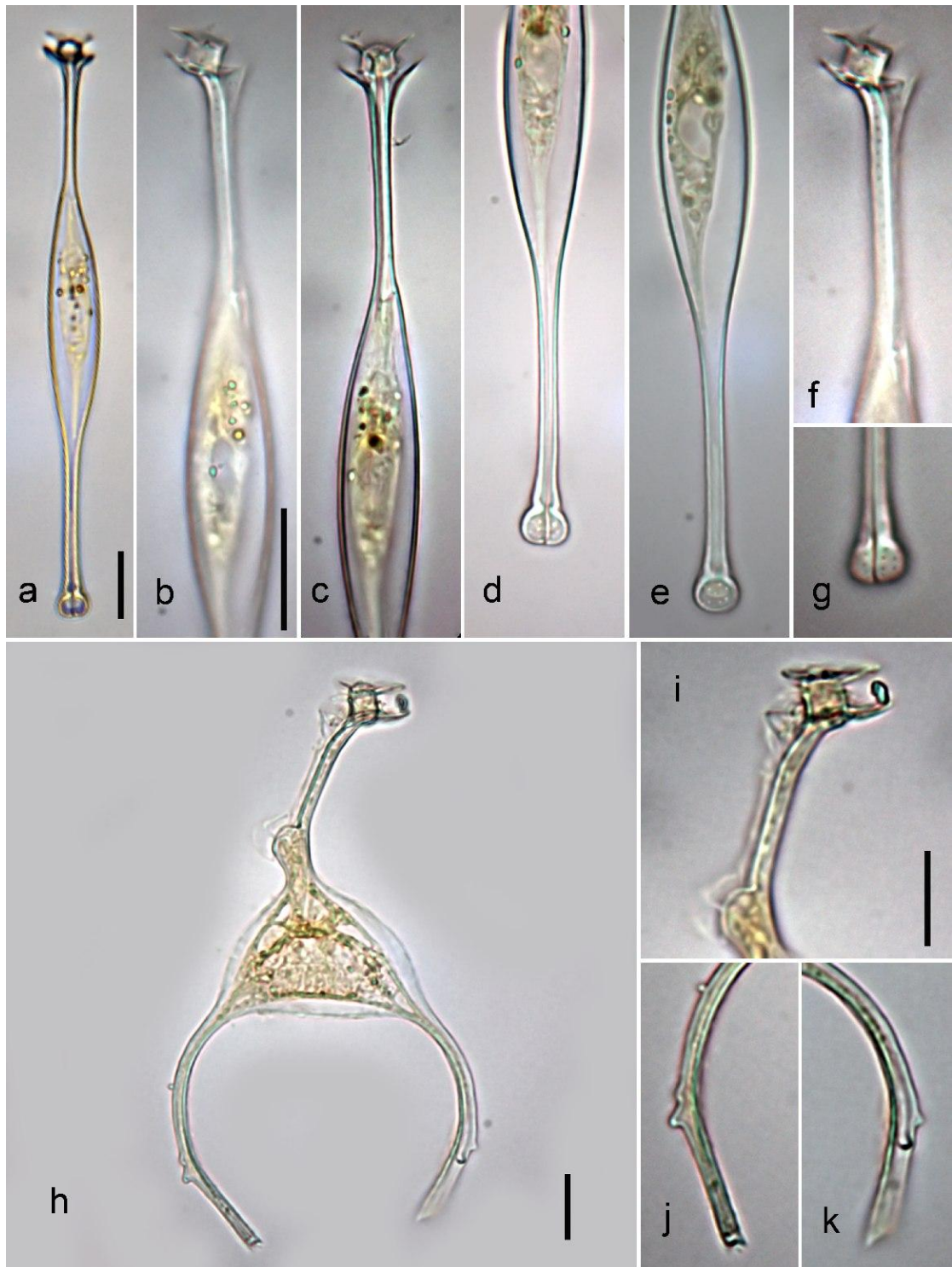


Plate A65. *Amphisolenia globifera* (a-g); *Triposolenia bicornis* (h-k).
a-k – LM, BF. Scale bars – 20 μ m.

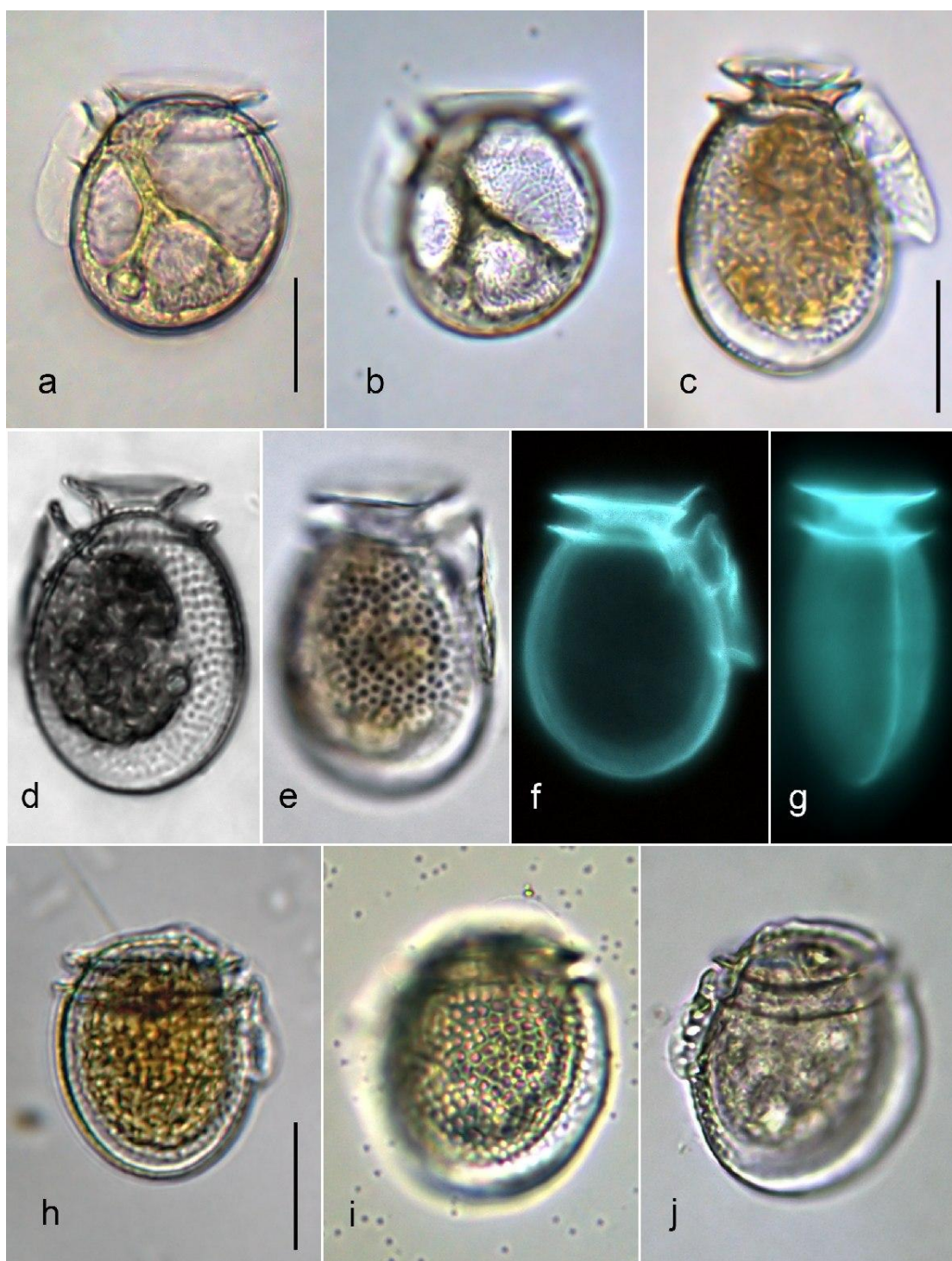


Plate A66. *Dinophysis cf. rotundata* (a, b); *Dinophysis acuminata* (c-g): c – typical specimen; d, e – specimen with rightward bending of the left sulcal list; *Dinophysis nasutum* (h-j).
a-c, e, h-j – LM, BF; d – PhC, BF; f, g – LM, epifluorescence. Scale bars – 20 μm .

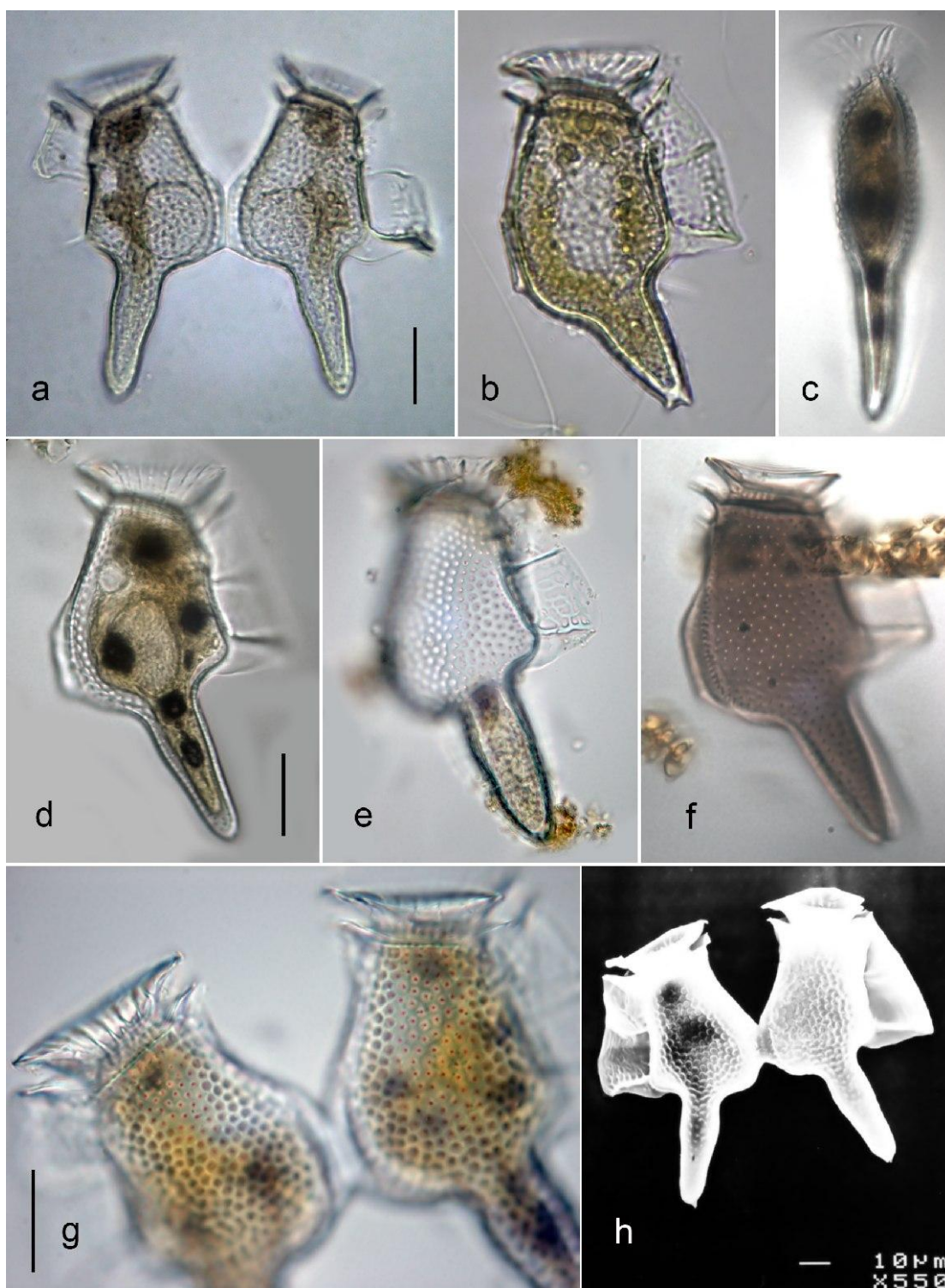


Plate A67. *Dinophysis caudata* (a-h).
a-g – LM, BF; h – SEM. Scale bars: a-g – 20 µm; h – 10 µm.

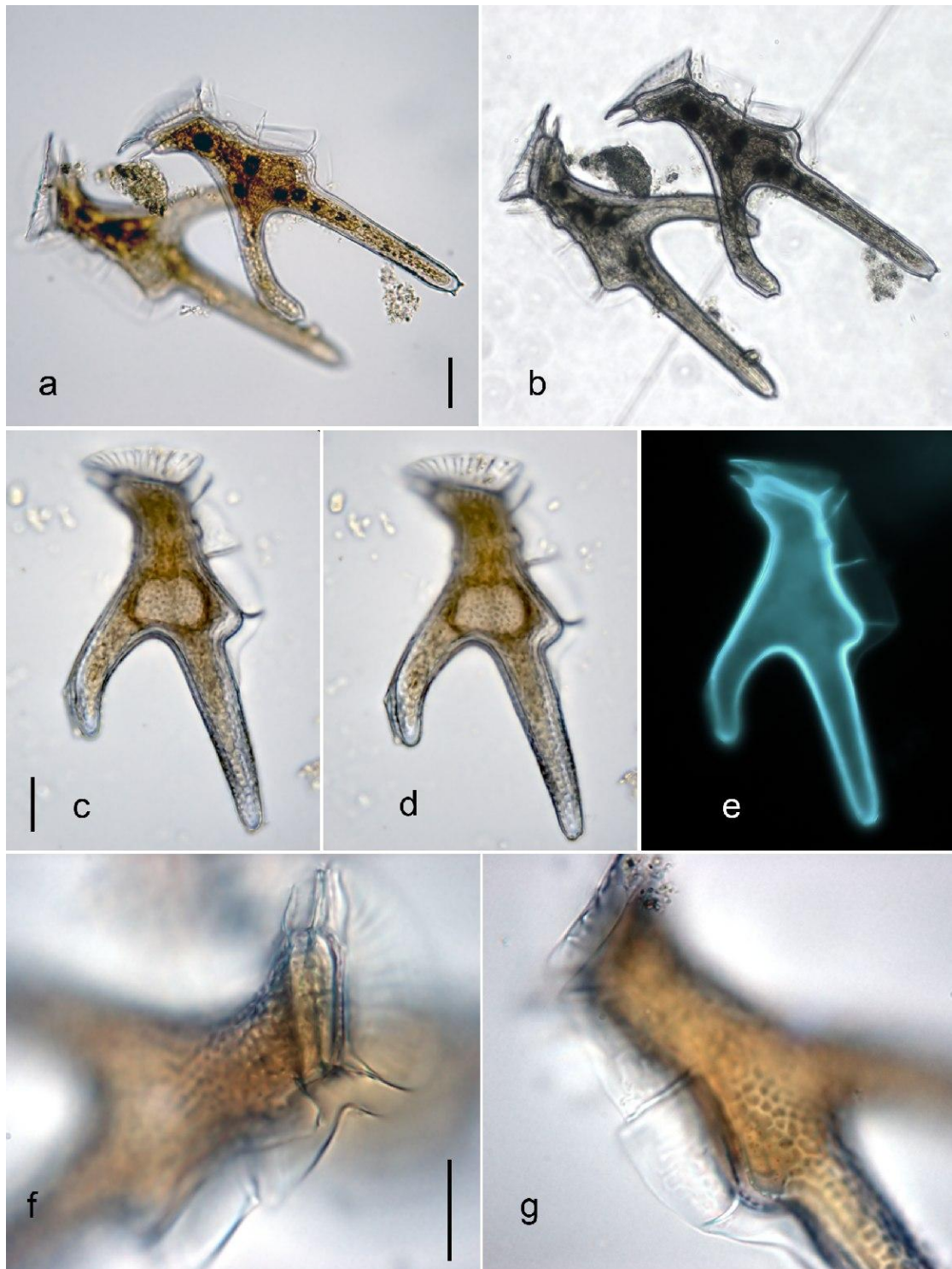


Plate A68. *Dinophysis miles* (a-g).

a, c, d, f, g – LM, BF; b – PhC, BF; e – LM, epifluorescence. Scale bars – 20 μm .

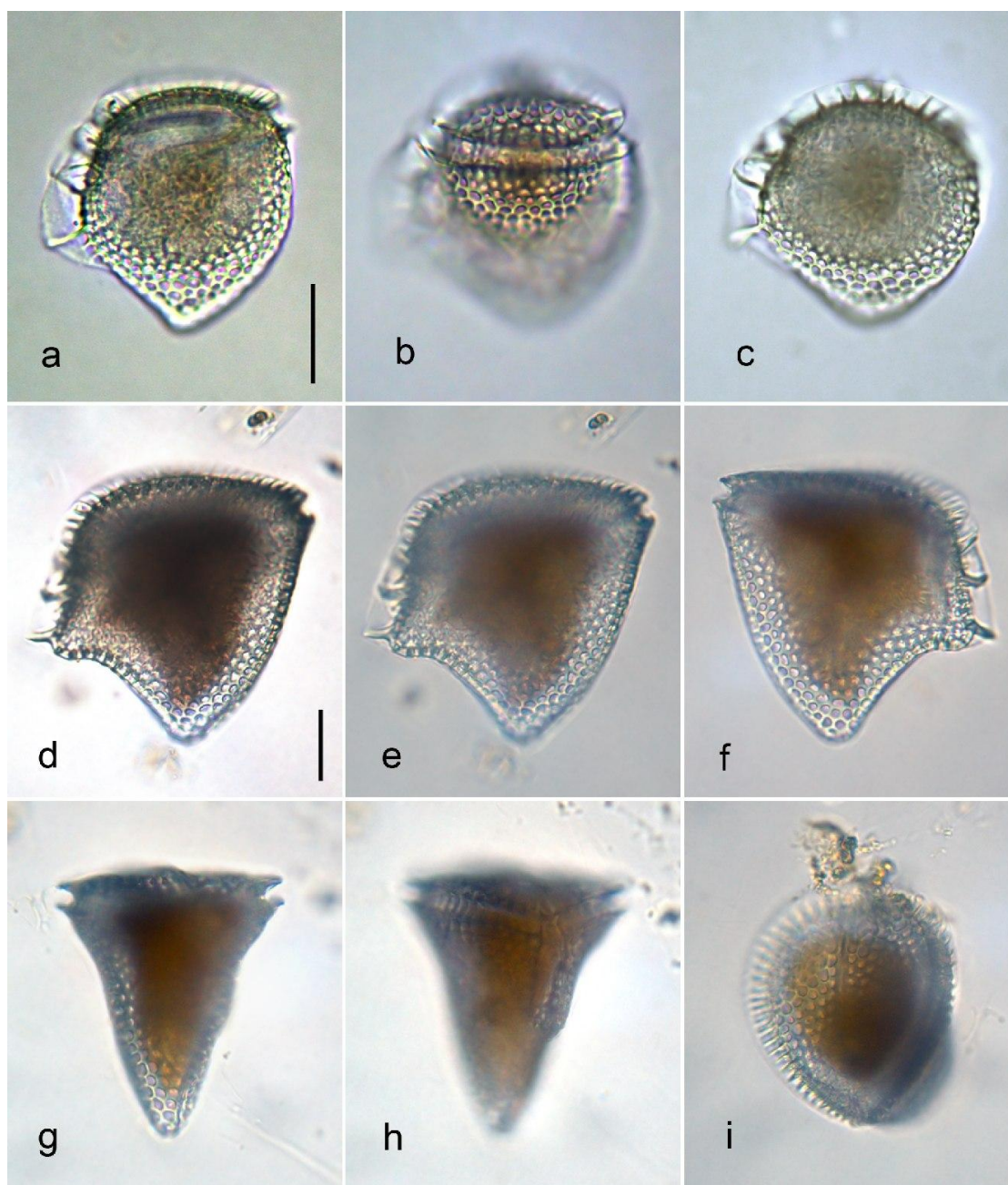


Plate A69. *Dinophysis mitra* (a-c); *Dinophysis rapa* (d-i).
a-i – LM, BF. Scale bars – 20 μm .

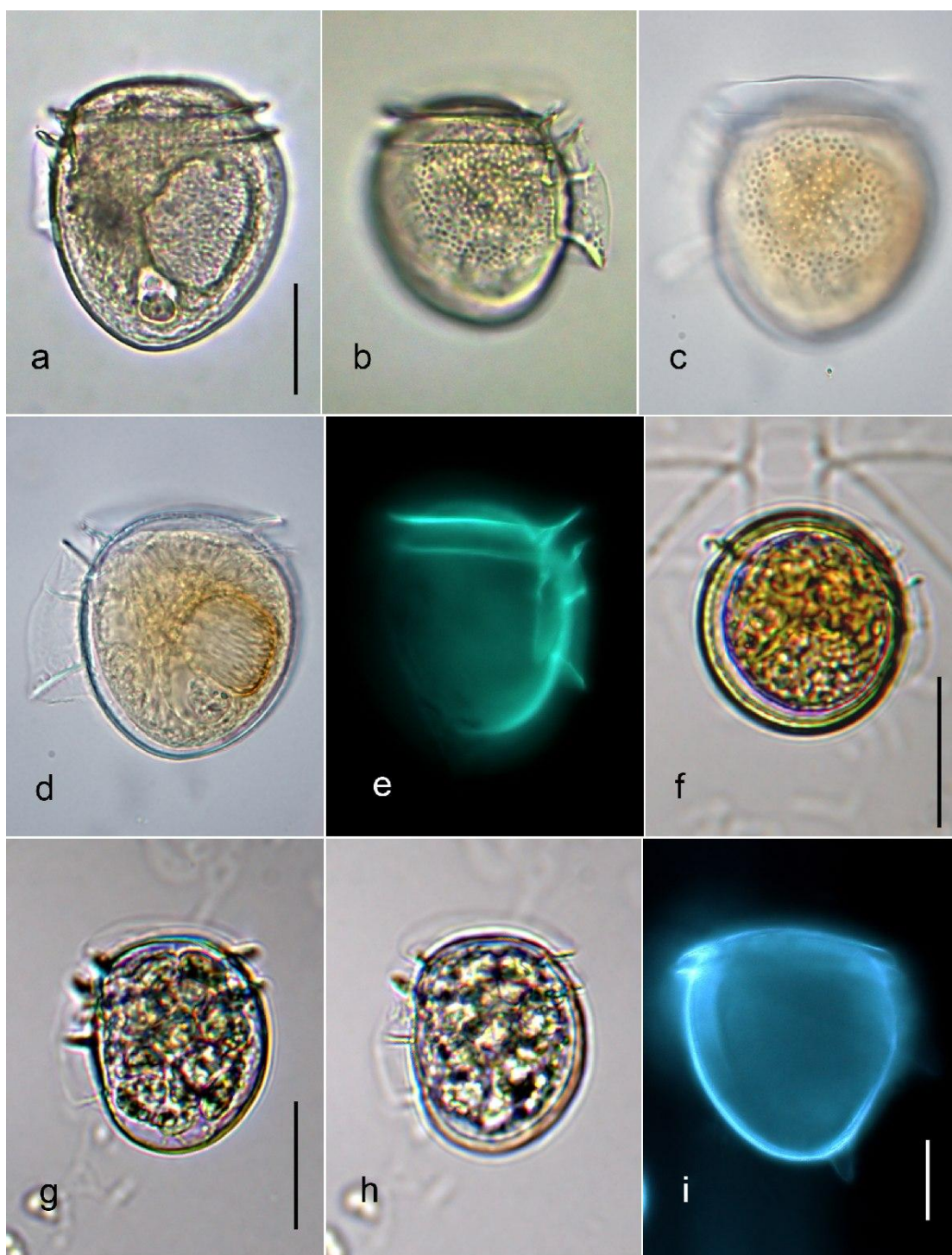


Plate A70. *Dinophysis* sp. 3 (a-e); *Dinophysis* sp. 1 (f); *Dinophysis* sp. 2 (g, h); *Dinophysis doryphorum* (i).
 a-d, f-h – LM, BF; e, i – LM, epifluorescence. Scale bars – 20 μm.

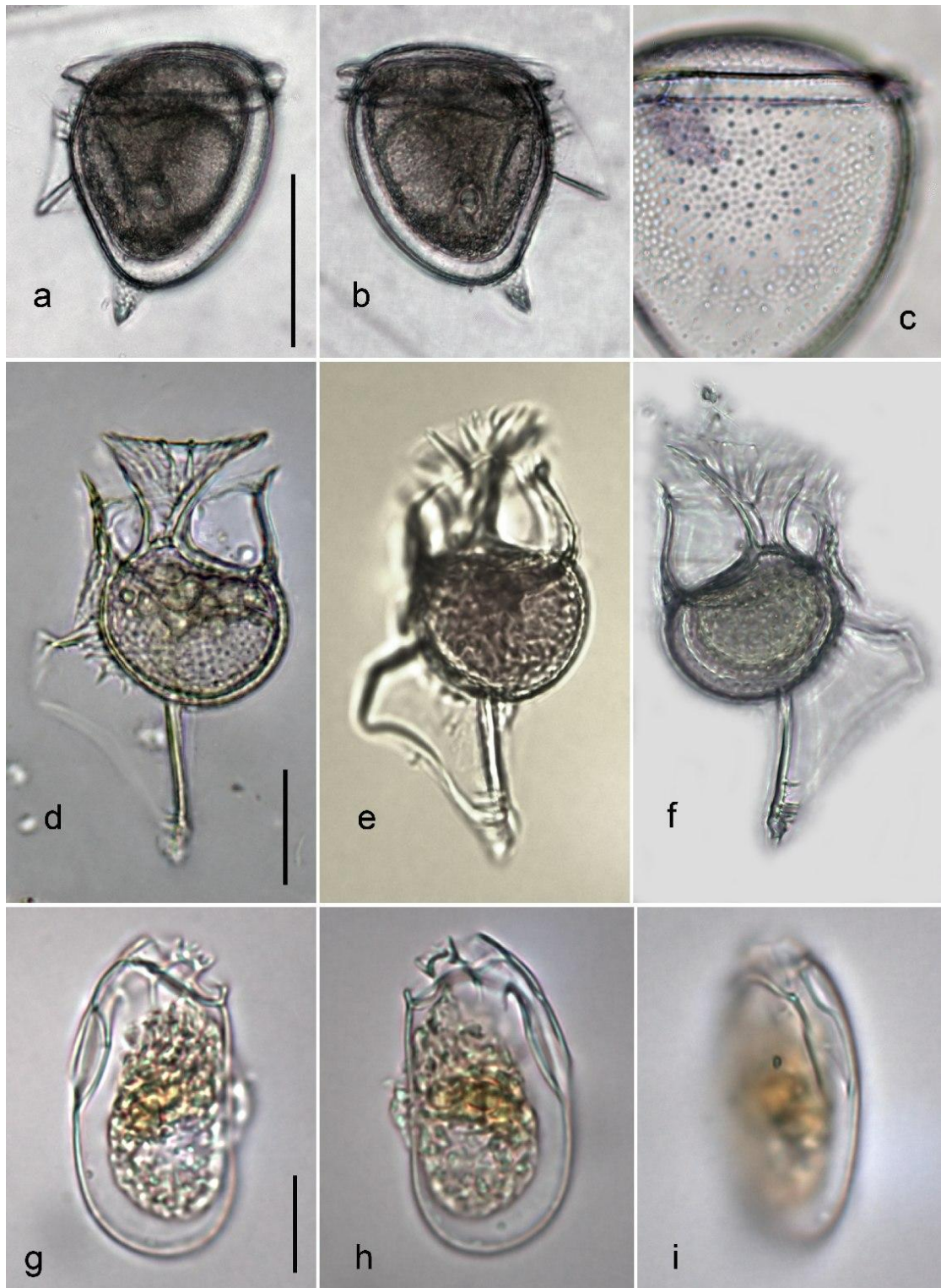


Plate A71. *Dinophysis doryphorum* (a-c); *Histioneis costata* (d-f); *Sinophysis stenosoma* (g-i).

a-c, f – PhC, BF; d, e, g-i – LM, BF; Scale bars: a-f – 20 μm ; g-i – 10 μm .

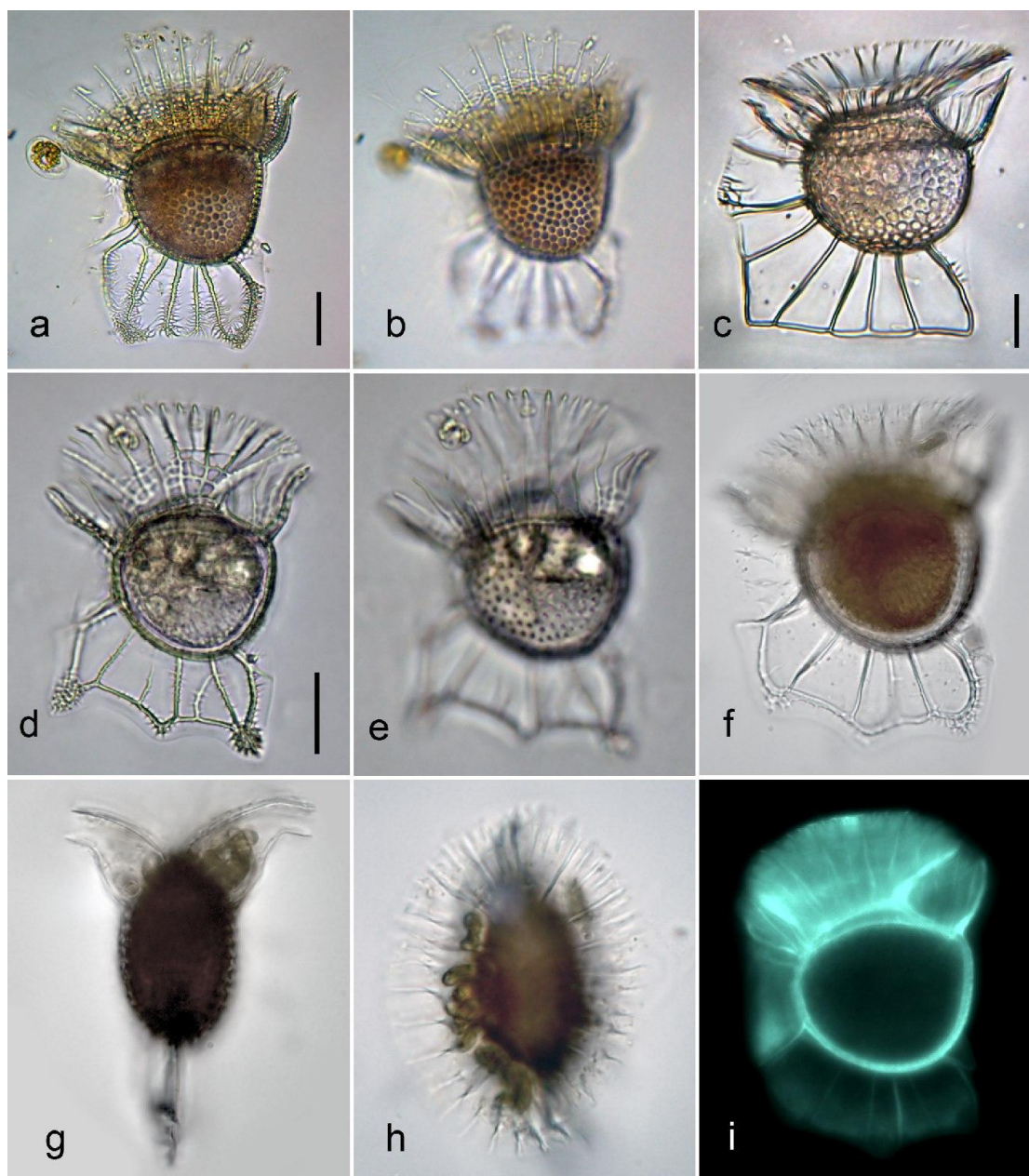


Plate A72. *Ornithocercus quadratus* (a-c) : a, b – immature cell soon after fission with unusual left sulcal list; c – specimen with typical shape of the left sulcal list; *Ornithocercus magnificus* (d-i).

a-h – LM, BF; i – LM, epifluorescence. Scale bars – 20 μm.

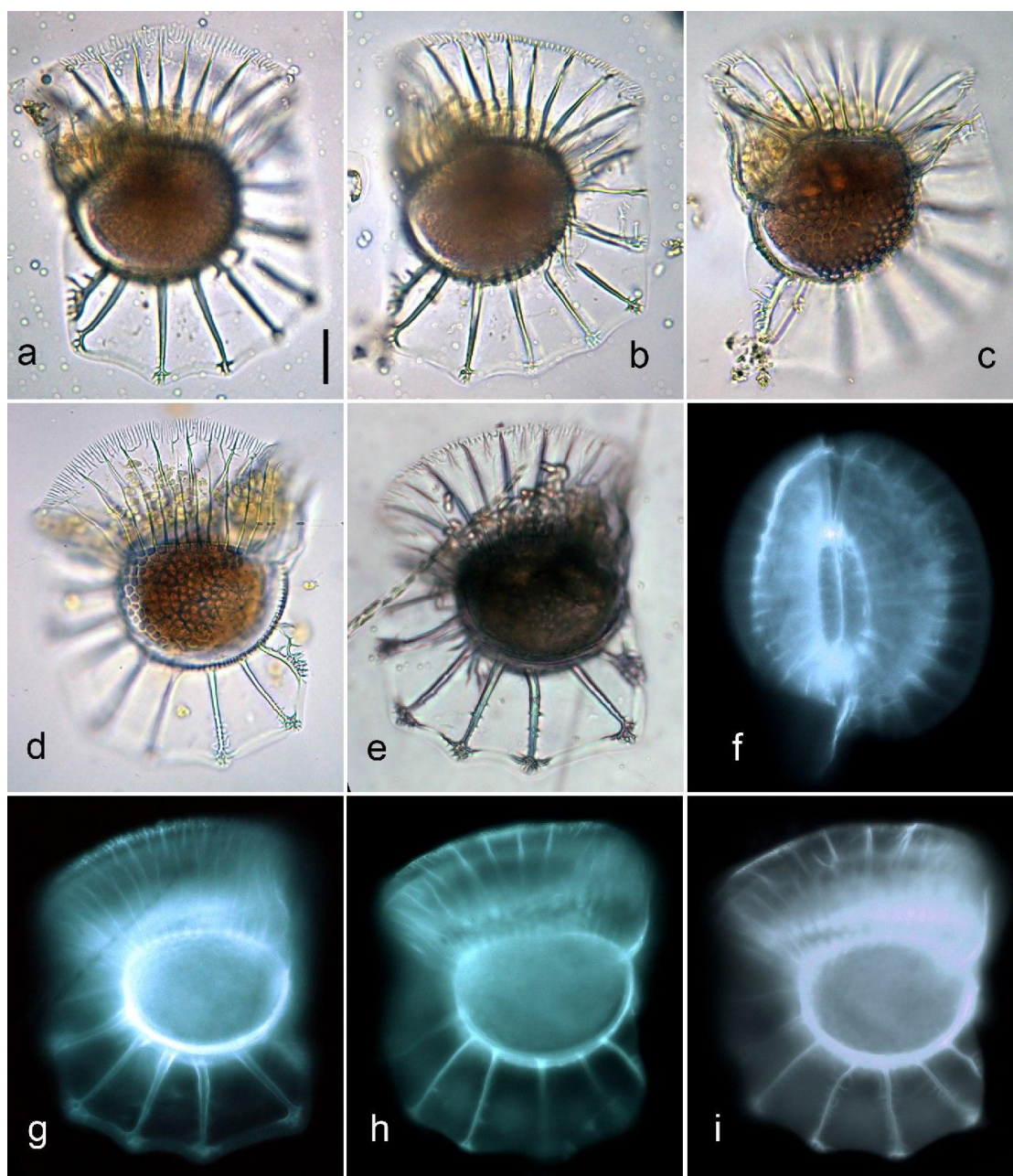


Plate A73. *Ornithocercus steinii* (a-i).
 a-e – LM, BF; f-i – LM, epifluorescence. Scale bars – 20 μm .

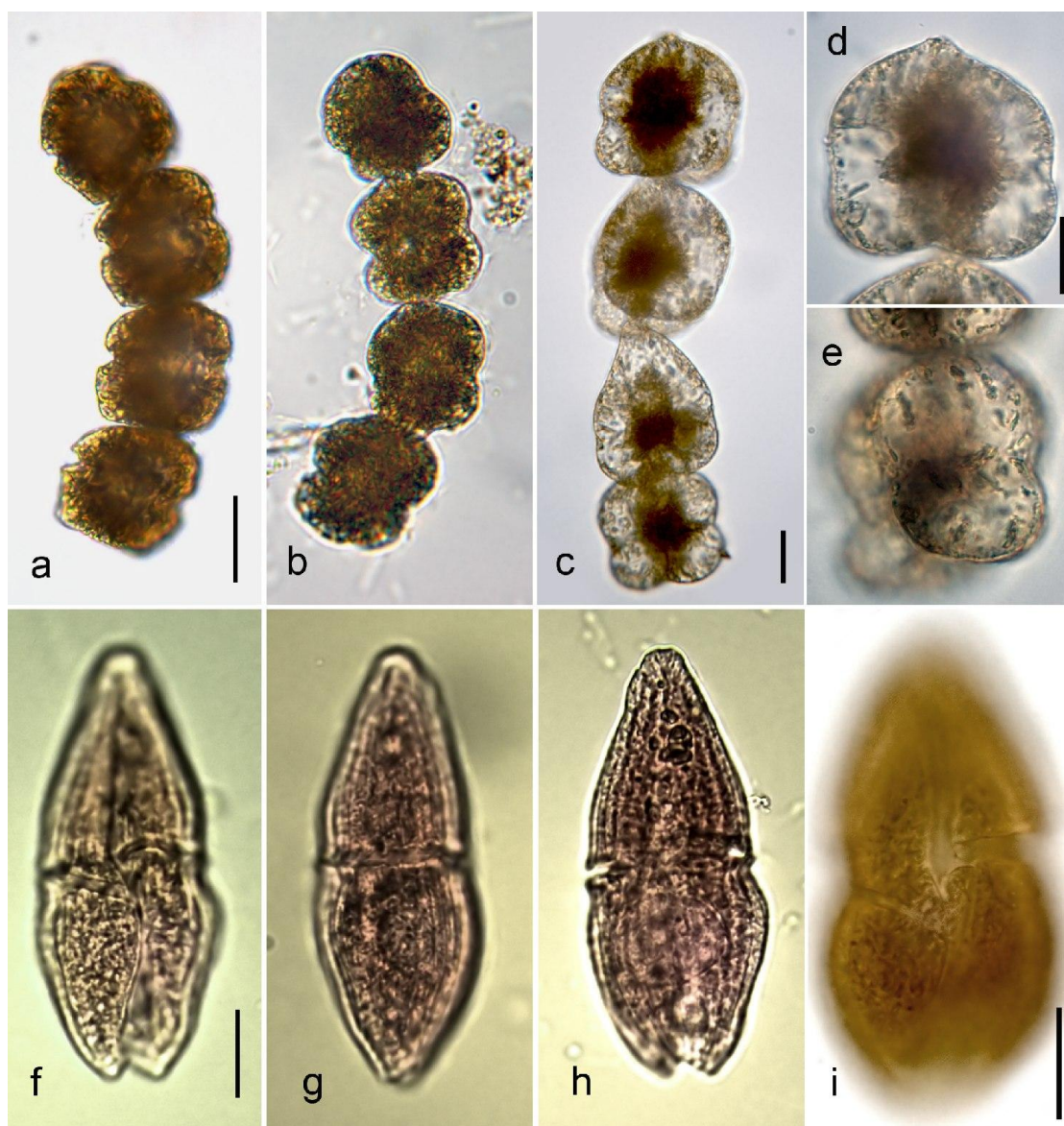


Plate A74. *Gymnodinium catenatum* (a-e); *Balechina coerulea* (f-i).
a-i – LM, BF. Scale bars – 20 µm.

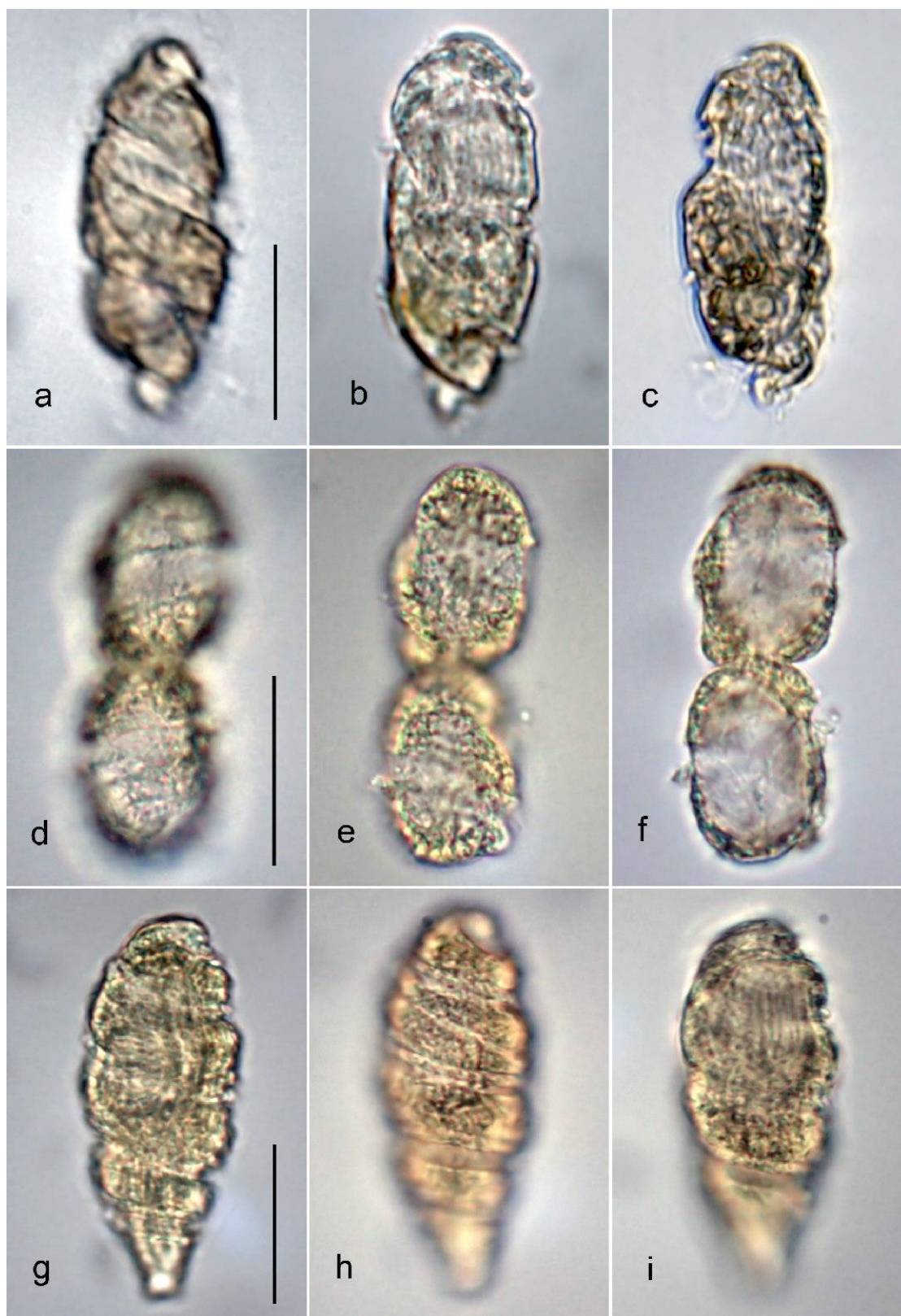


Plate A75. *Cochlodinium brandtii* (a-c); *Cochlodinium polykrikoides* (d-f); *Warnowia violescens* (g-i).
a-i – LM, BF. Scale bars – 20 μm.

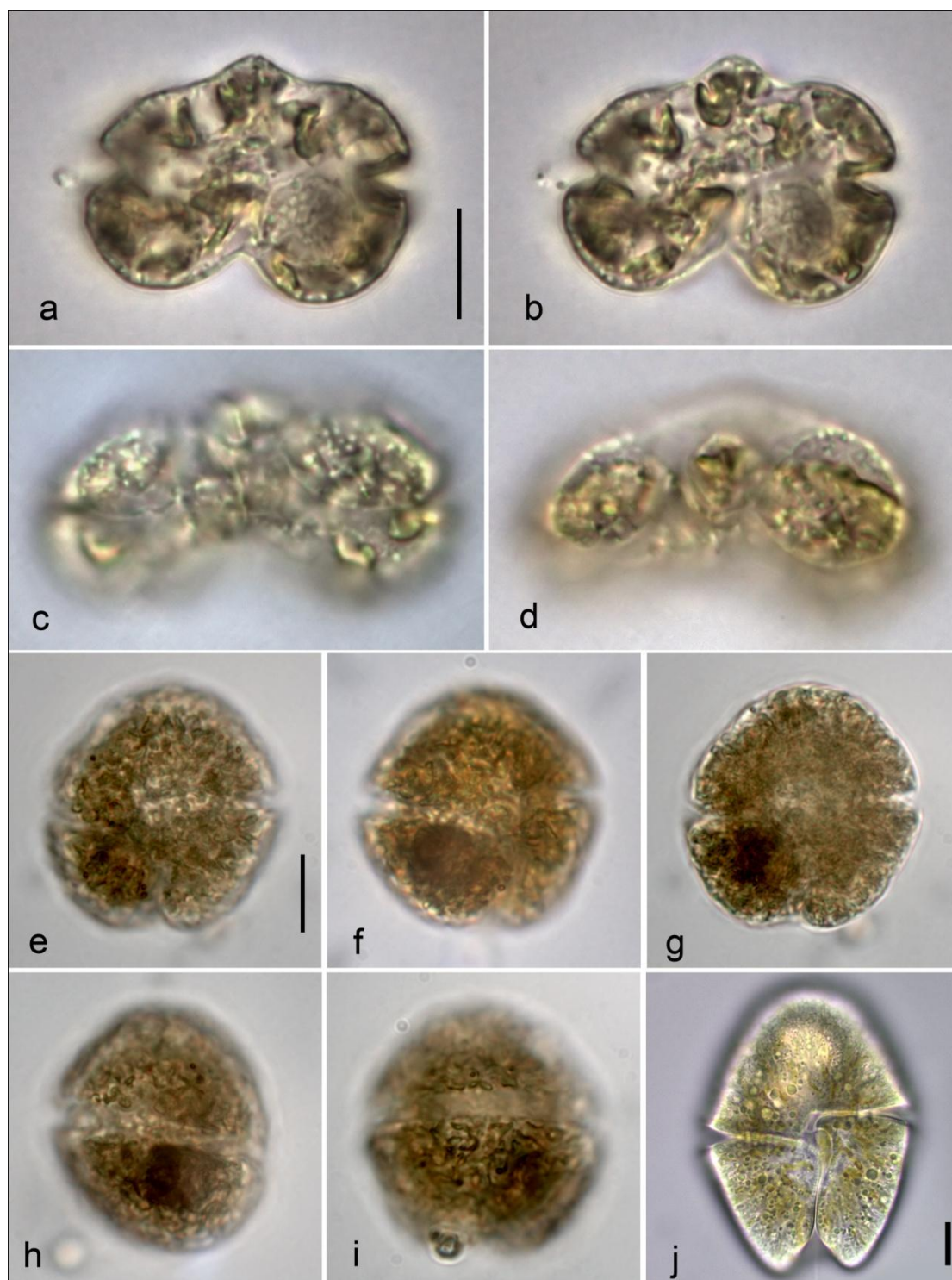


Plate A76. *Karenia papilionacea* (a-d); *Gymnodinium sp. 1* (e-i); *Akashiwo sanguinea* (j). a-j – LM. Scale bars – 10 µm.

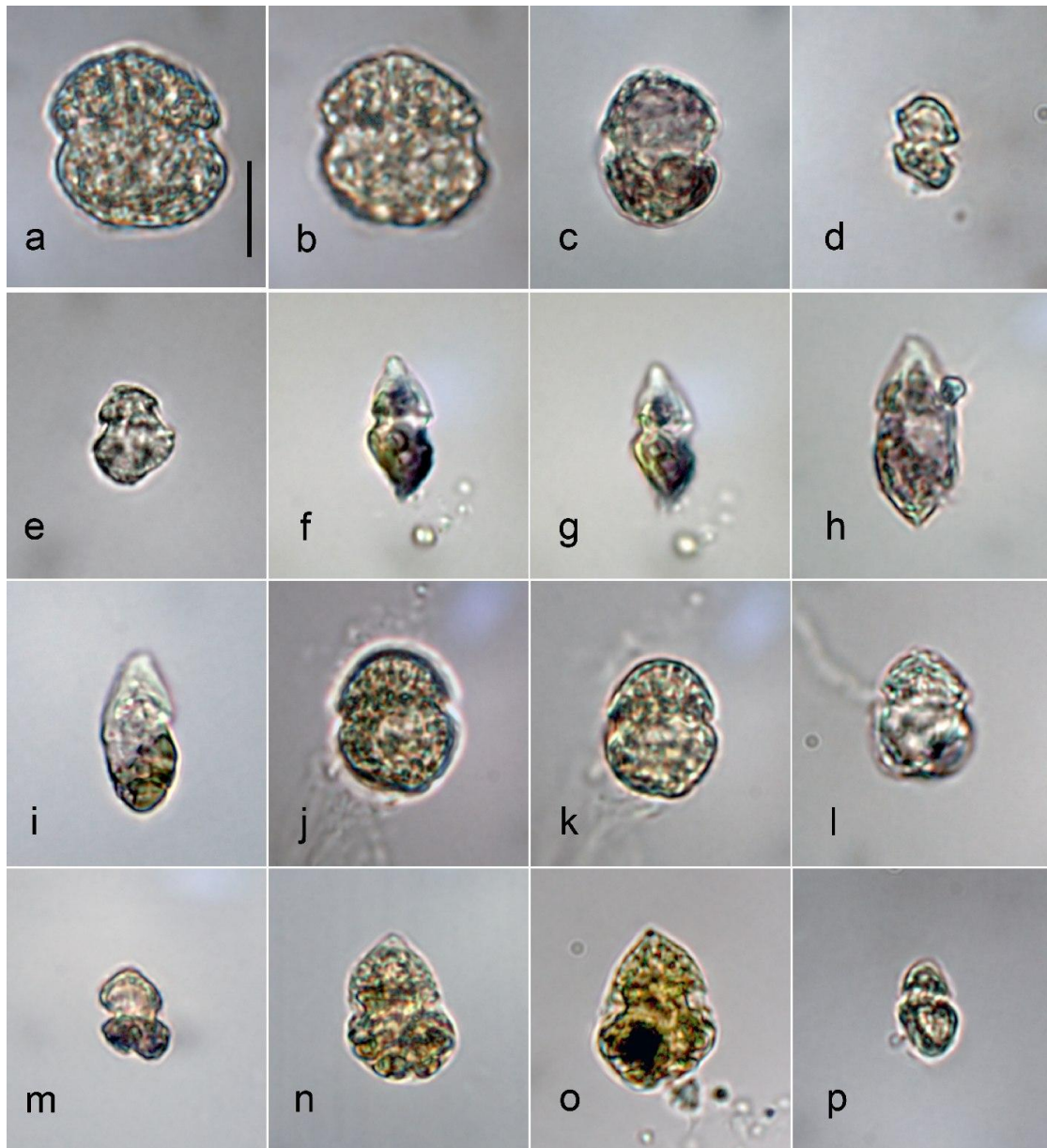


Plate A77. *Gymnodinium*-like group (a-p): **species 1** (a, b); **species 2** (c); **species 3** (d); **species 4** (e); **species 5** (f, g); **species 6** (h, i); **species 7** (j, k); **species 8** (l); **species 9** (m); **species 10** (n, o); **species 11** (p).
a-p – LM, BF. Scale bar – 10 μm .

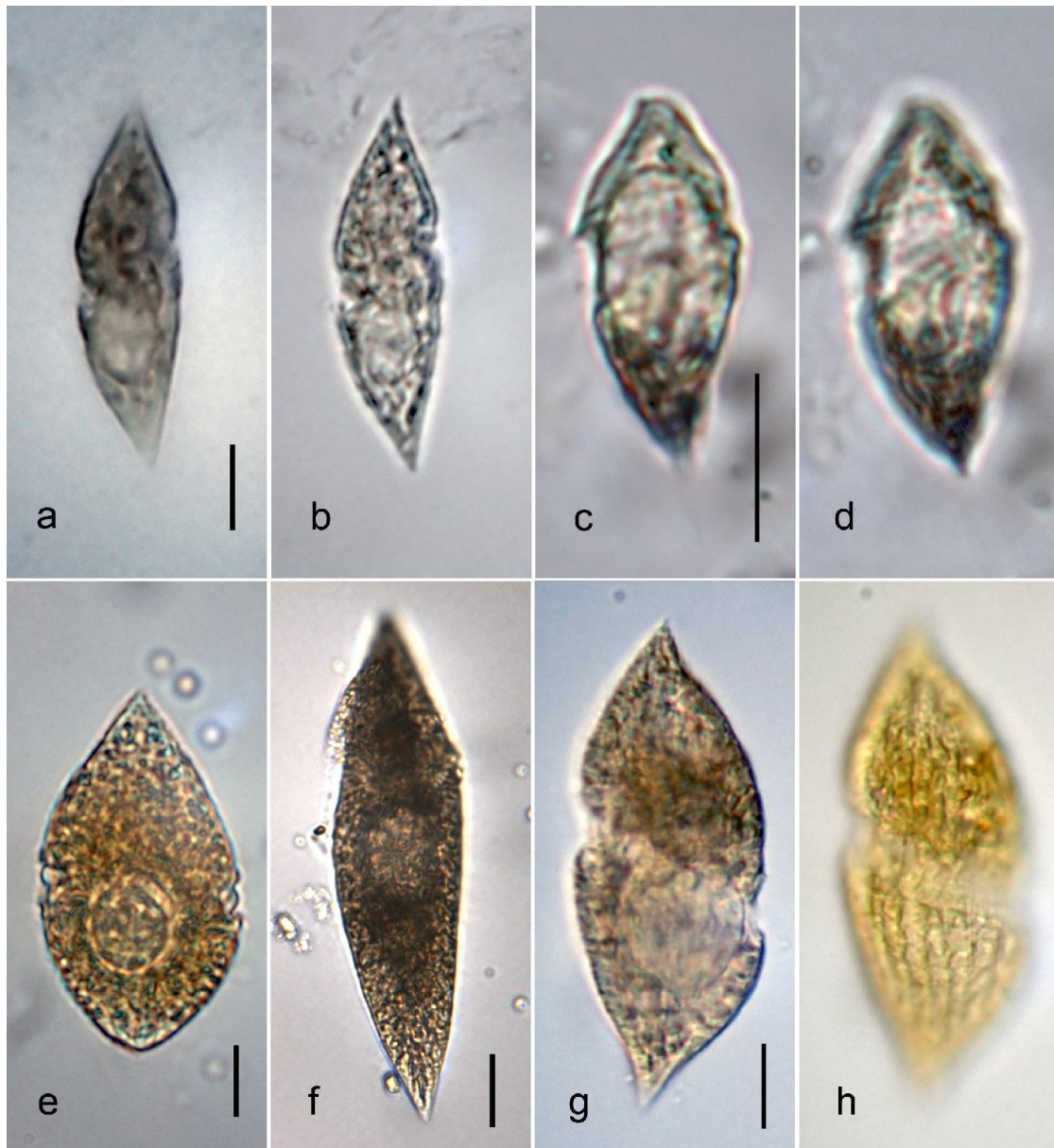


Plate A78. *Gyrodinium fusiforme* (a, b); *Gyrodinium* sp. 1 (c, d); *Gyrodinium* sp. 2 (e); *Gyrodinium spirale* (f-h).
a-h – LM, BF. Scale bars – 20 μ m.

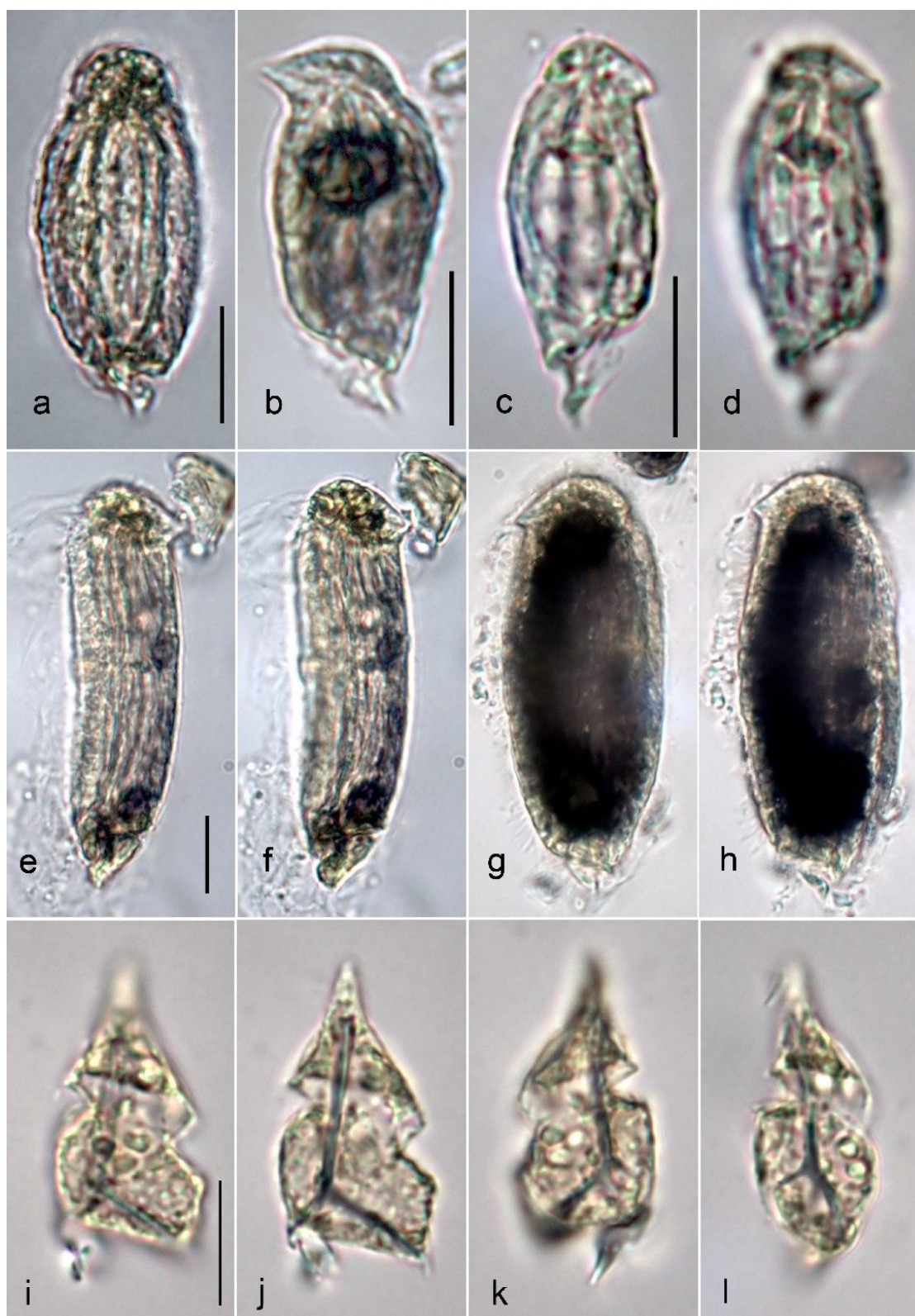


Plate A79. *Torodinium robustum* (a-d); *Torodinium teredo* (e-h); *Dicroerisma psilonereiella* (i-l)
 a-l – LM, BF. Scale bars – 10 μm.

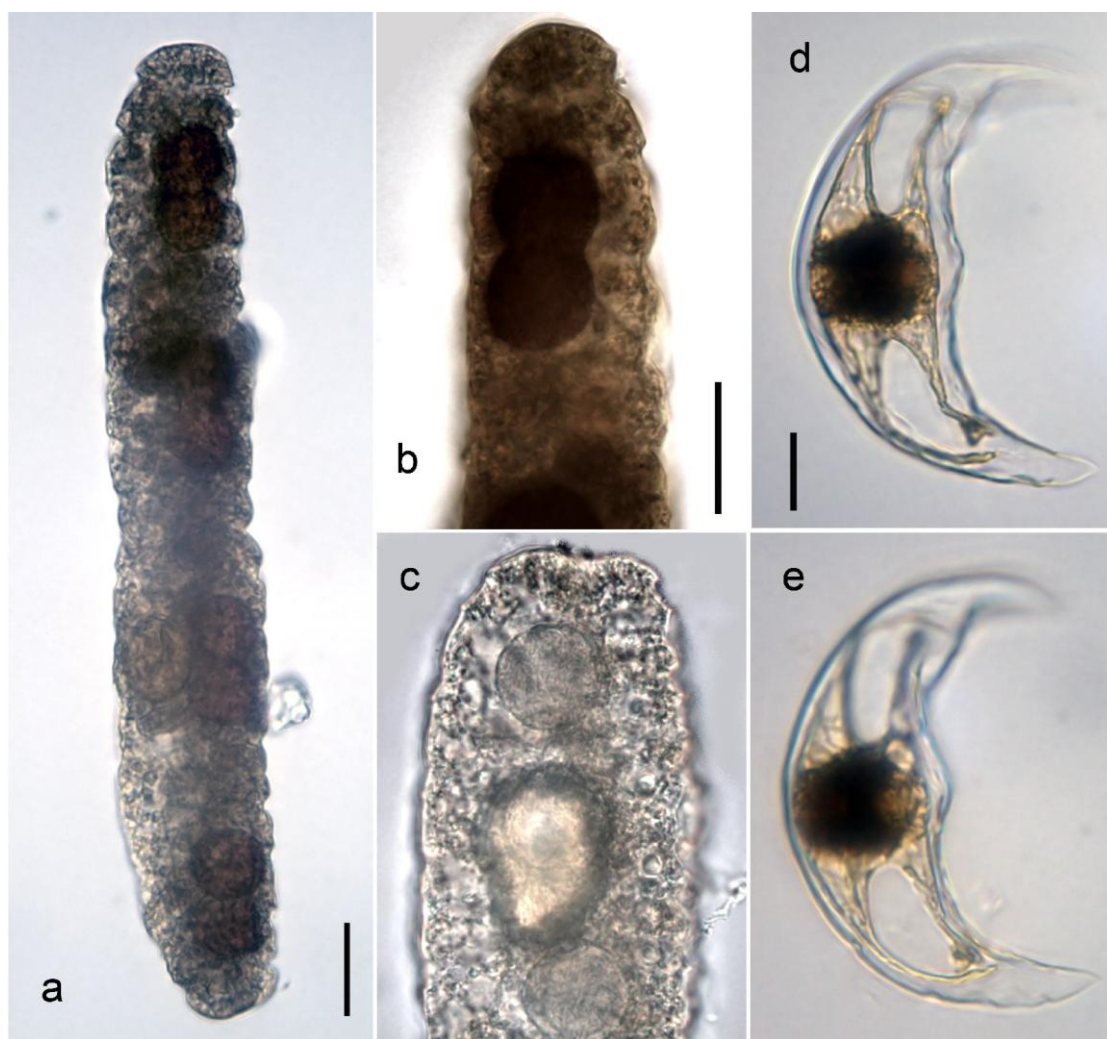


Plate A80. *Polykrikos schwarzii* (a-c); *Pyrocystis robusta* (d, e).
a-e – LM, BF. Scale bars – 20 μm.

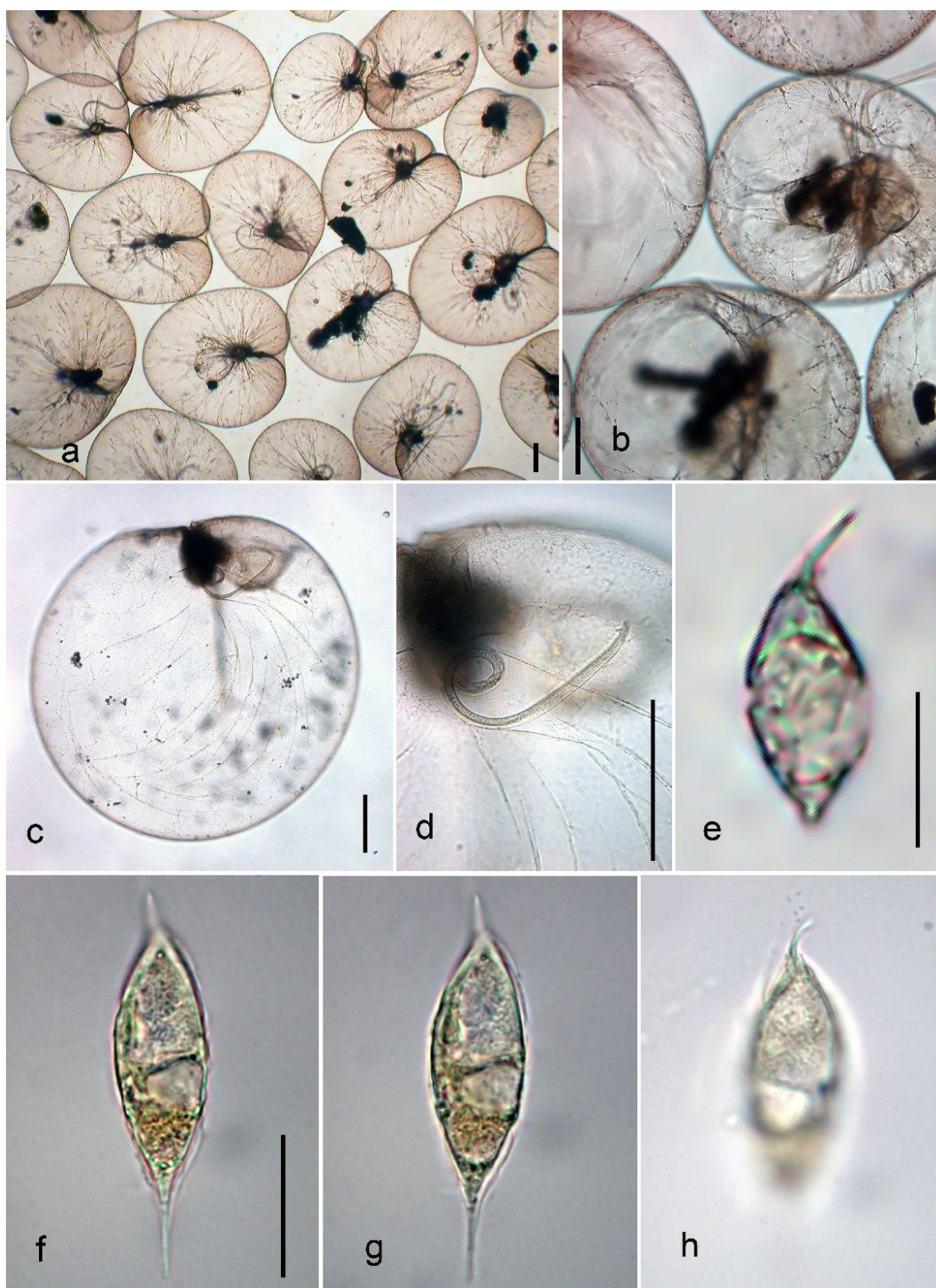


Plate A81. *Noctiluca scintillans* (a-d); *Pronoctiluca pelagica* (e); *Pronoctiluca spinifera* (f-h).
a-h – LM, BF. Scale bars: a-d – 100 μ m; e-h – 20 μ m.

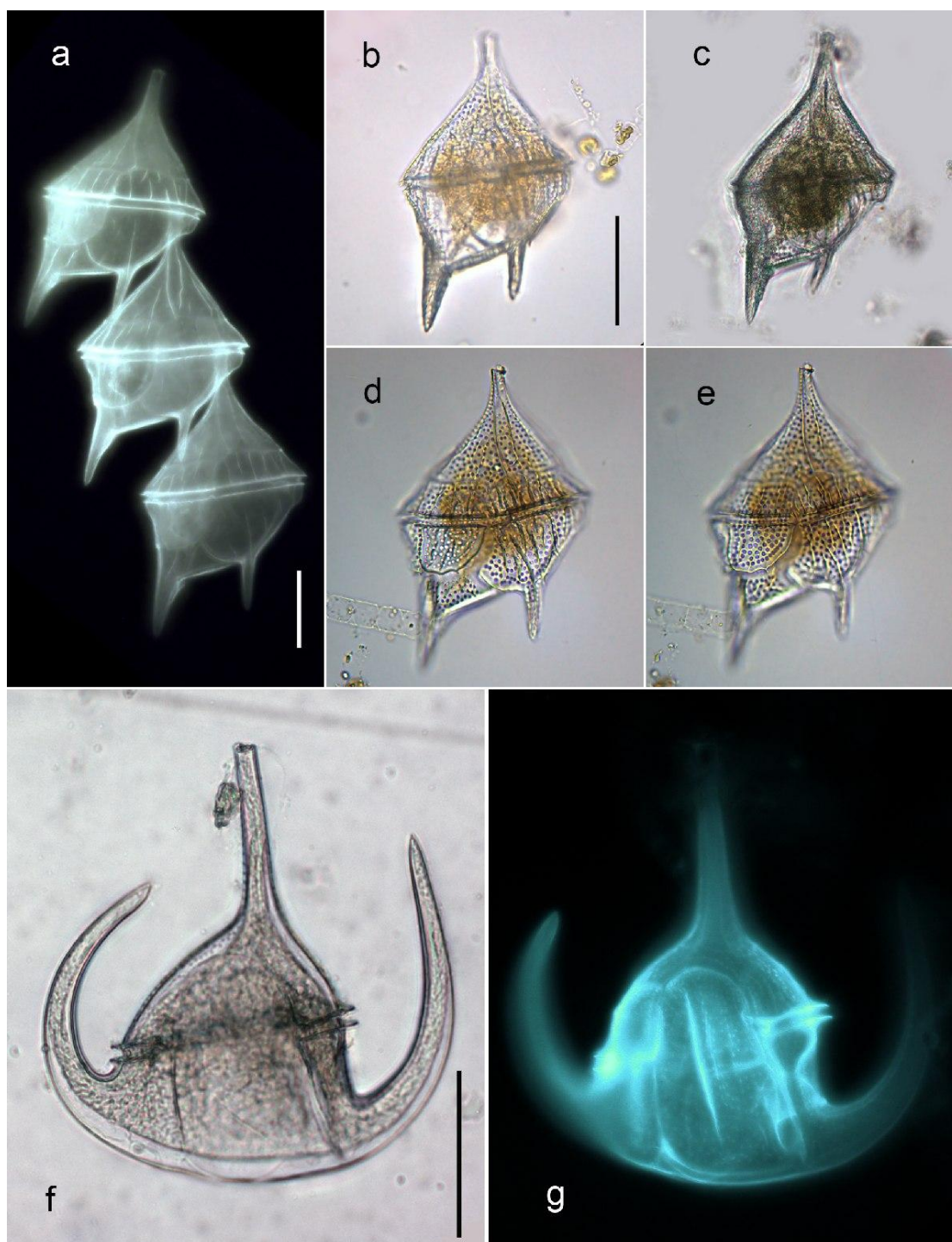


Plate A82. *Ceratium lineatum* (a-e) : a - recently divided specimens with juvenile apical horns in chain; b-e – short apical-horned specimens from chains; *Ceratium breve* (f, g). b-e – LM, BF; f – PhC, BF; a, g – LM, epifluorescence. Scale bars – 50 μ m.



Plate A83. *Ceratium breve* (a); *Ceratium tripos* (b-e).
a, d – LM, BF; b, c, e – LM, epifluorescence. Scale bars – 20 μm.

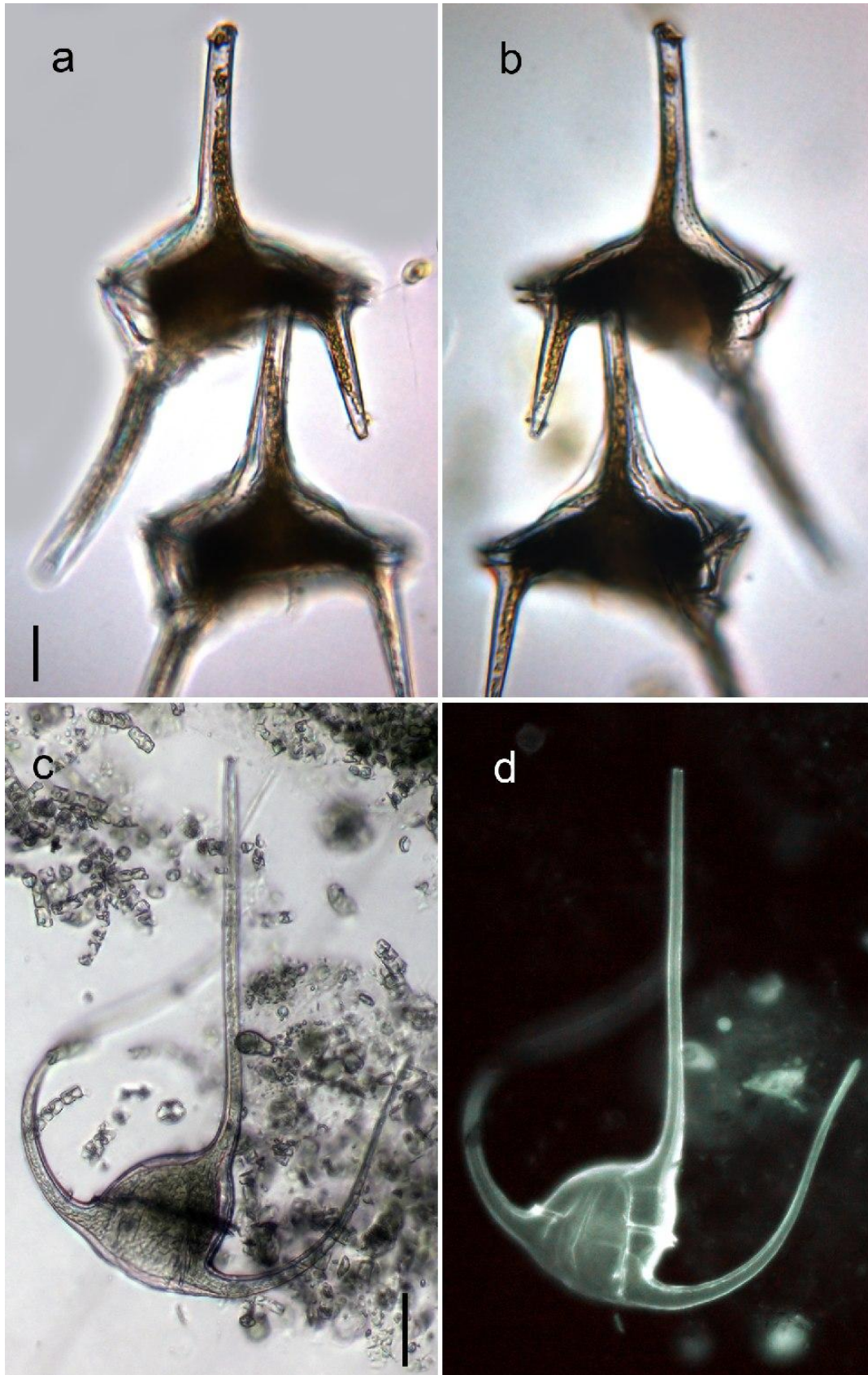


Plate A84. *Ceratium candelabrum* (a, b); *Ceratium contortum* (c, d).
a, b – LM, BF; c – PhC, BF; d – LM, epifluorescence. Scale bars: a, b – 20 μm ; c, d – 50 μm .

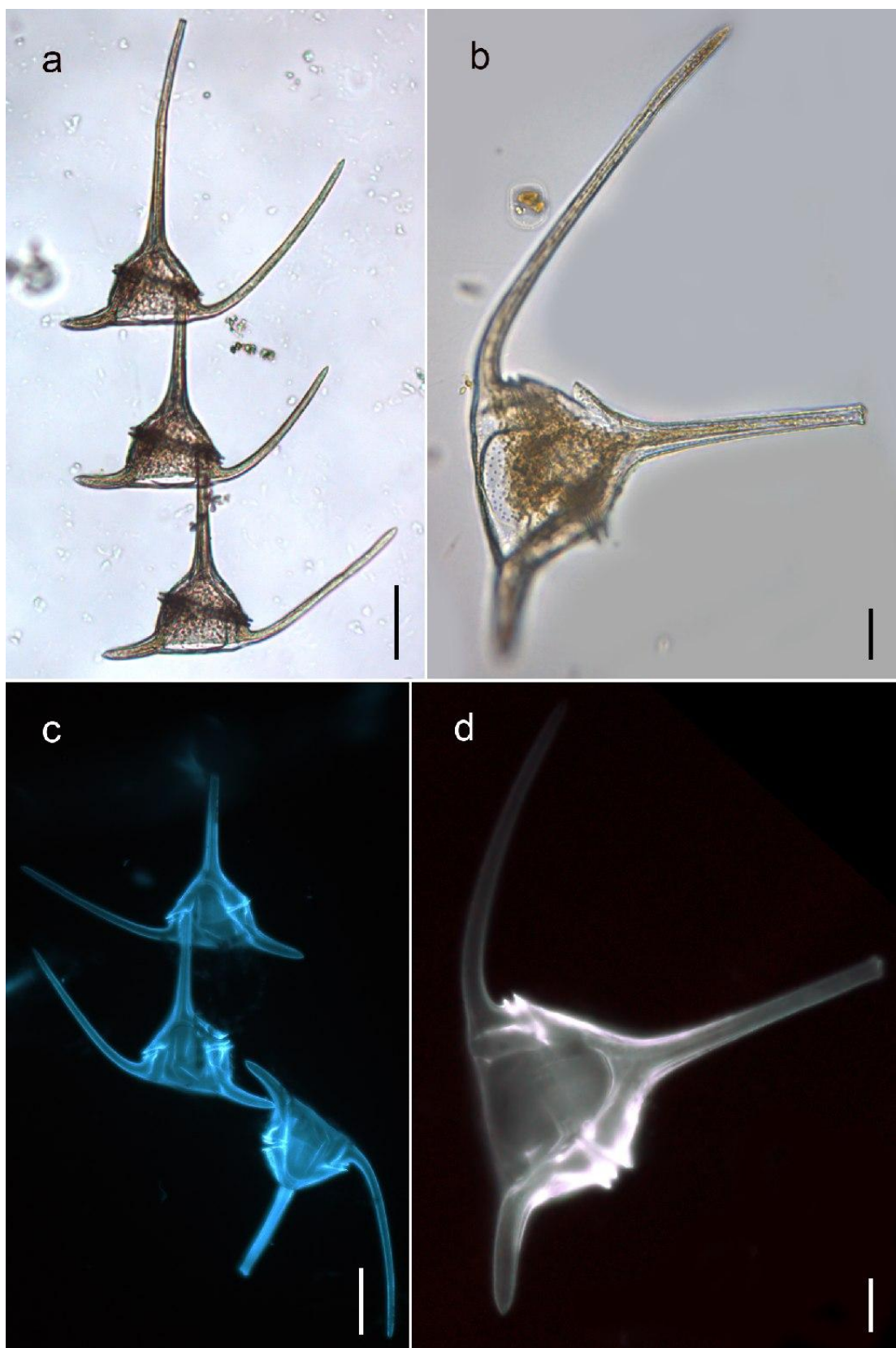


Plate A85. *Ceratium dens* (a-d).

a, b – LM, BF; c, d – LM, epifluorescence. Scale bars: a, c – 50 μm ; b, d – 20 μm .

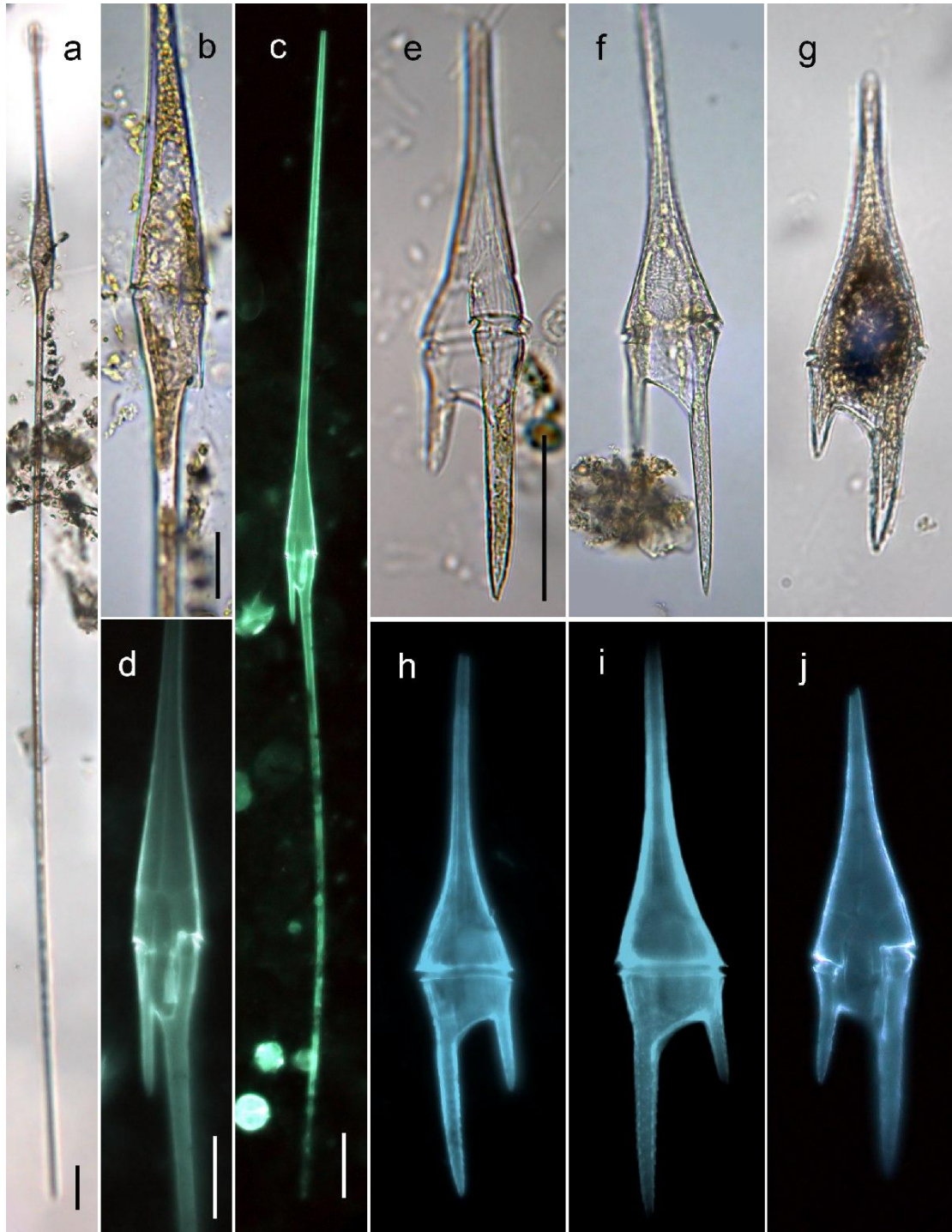


Plate A86. *Ceratium extensum* (a, b); *Ceratium strictum* (c, d); *Ceratium furca* (e-j).
 a, b, e-g – LM, BF; c, d, h-j – LM, epifluorescence. Scale bars: a, c – 50 μm ; b, d-j – 20 μm .

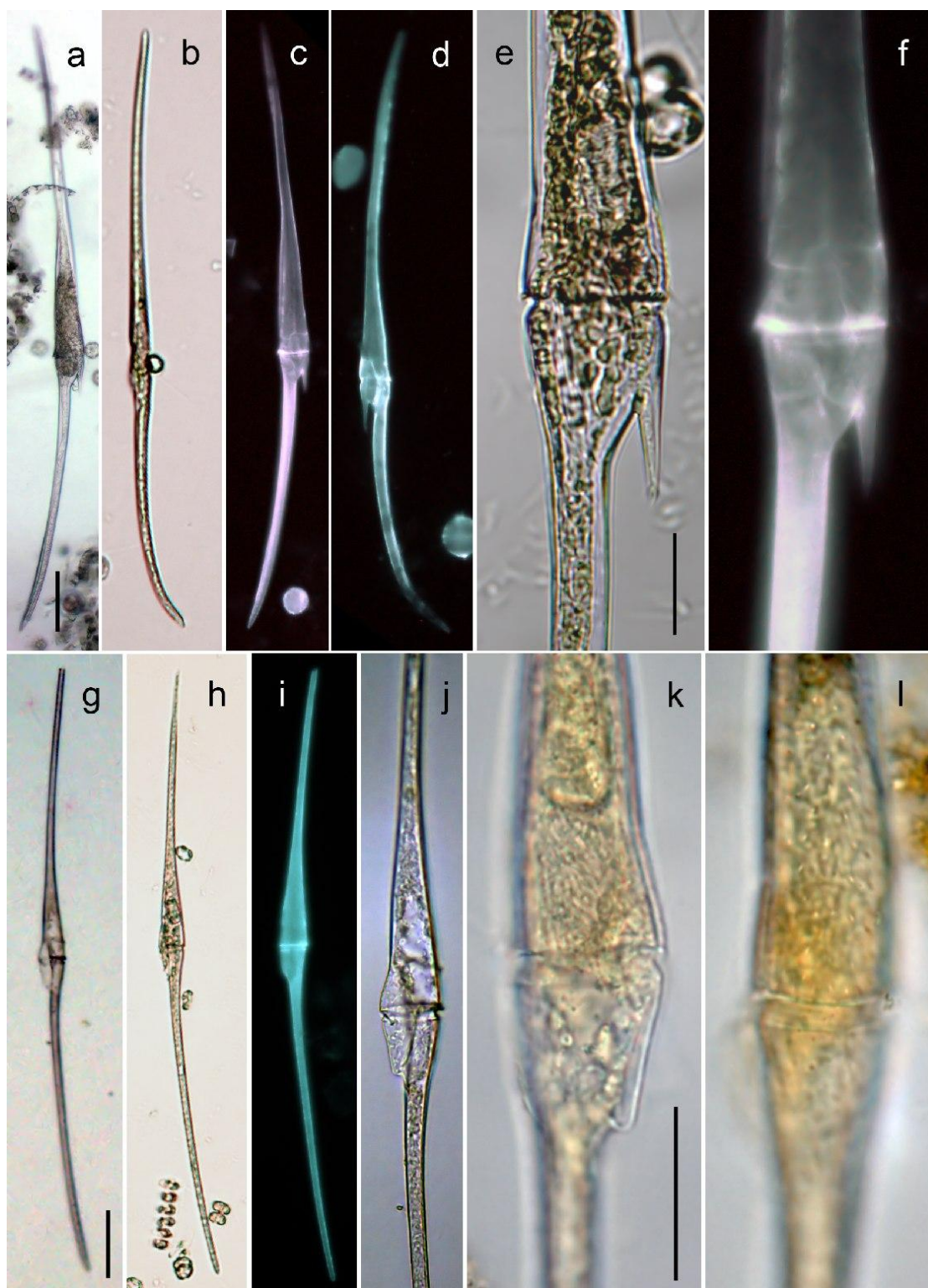


Plate A87. *Ceratium falcatum* (a-f); *Ceratium fusus* (g-l).
 b, e, h, j-l – LM, BF; a, g – PhC, BF; c, d, f, i – LM, epifluorescence. Scale bars: a, g – 50 µm; e, f, k, l – 20 µm.

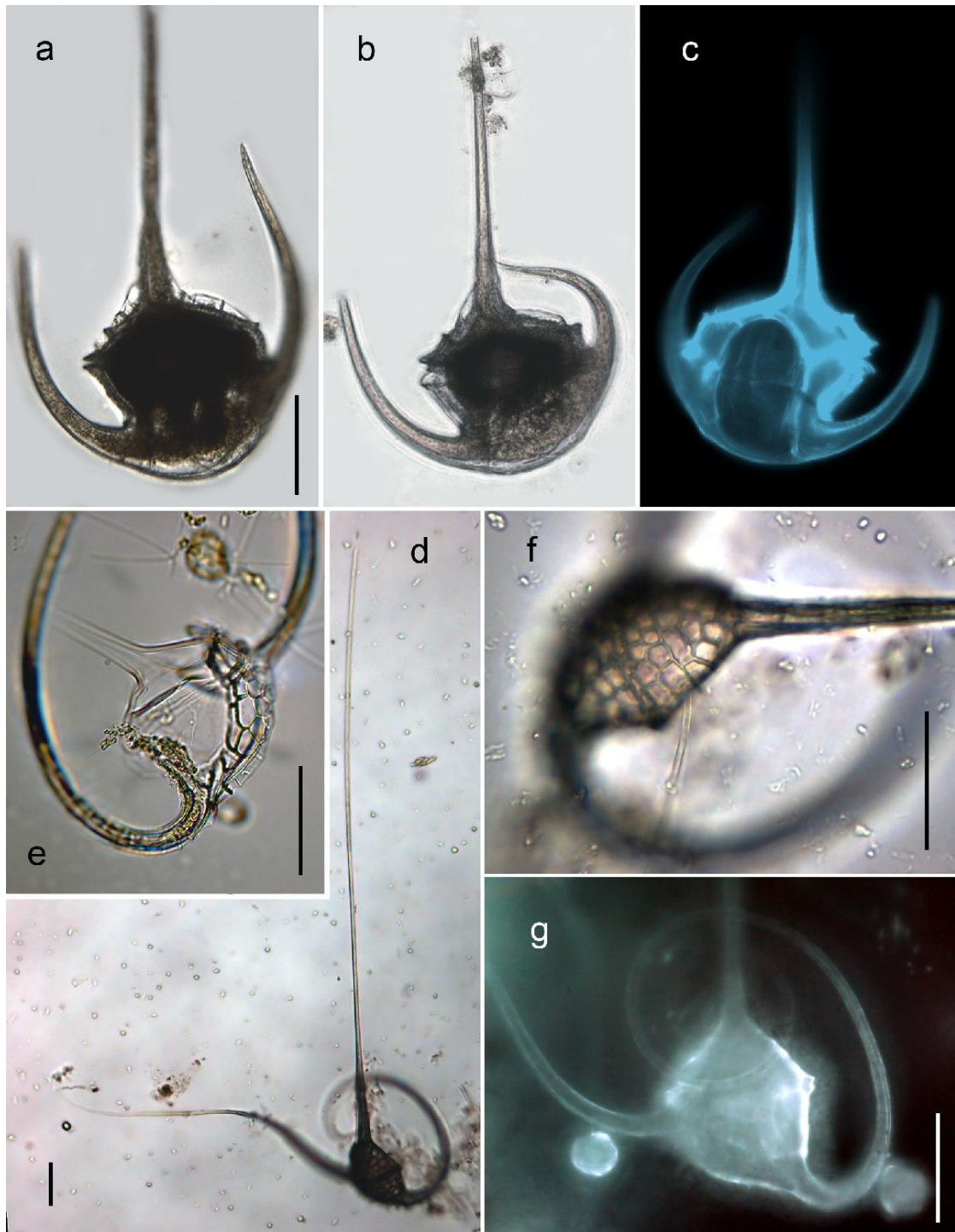


Plate A88. *Ceratium gibberum* (a-c); *Ceratium hexacanthum* (e-g).
a, b, e, f – LM, BF; d – PhC, BF; c, g – LM, epifluorescence. Scale bars – 50 μm.



Plate A89. *Ceratium horridum* (a-c); *Ceratium karstenii* (d-f).
a, c, d-f – LM, BF; b – LM, epifluorescence. Scale bars: a, b, d-f – 50 µm; c – 20 µm.

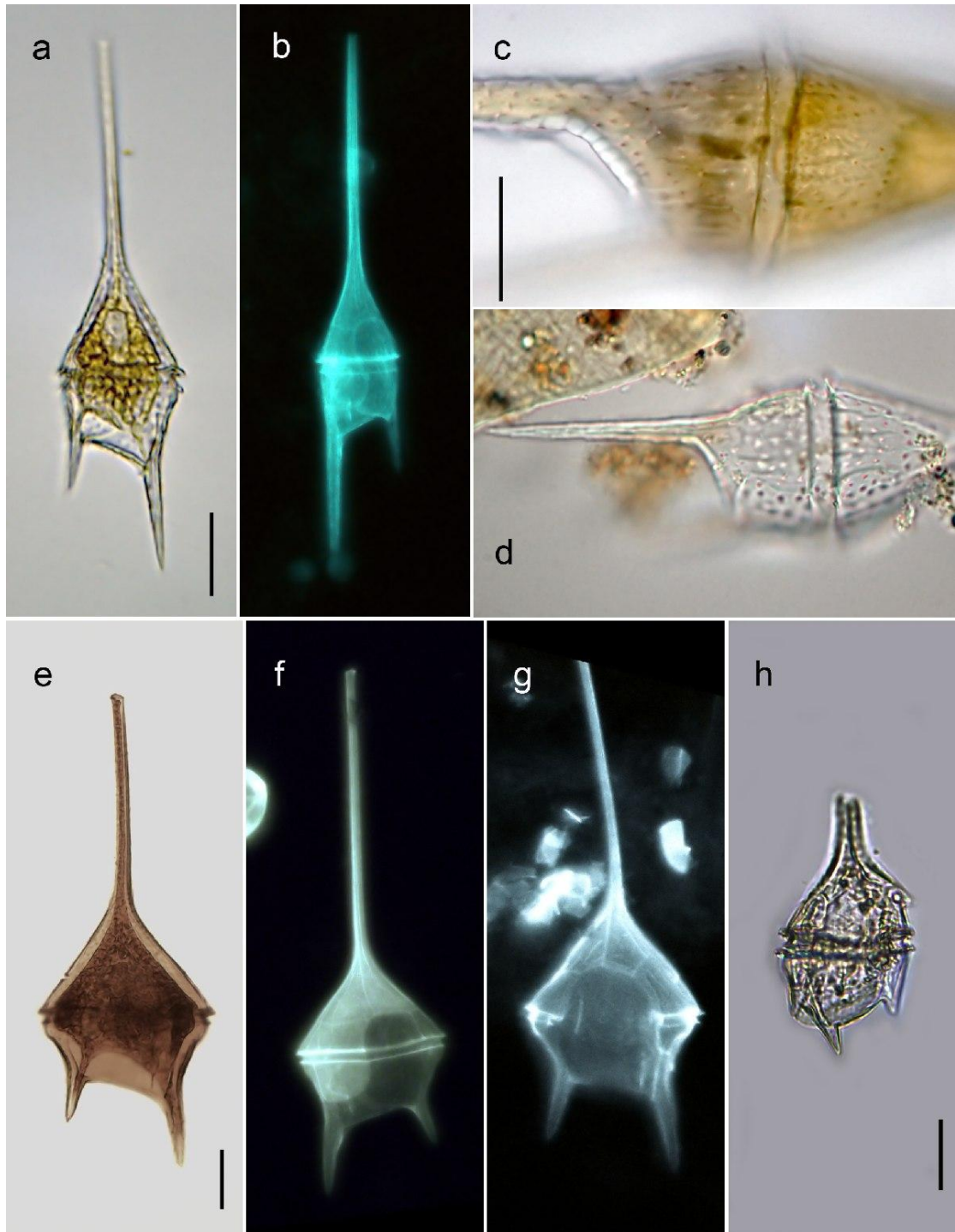


Plate A90. *Ceratium kofoidi* (a-d); *Ceratium pentagonum* (e-g); *Ceratium minutum* (h).
a, c-e, h – LM, BF; b, f, g – LM, epifluorescence. Scale bars – 20 μ m.

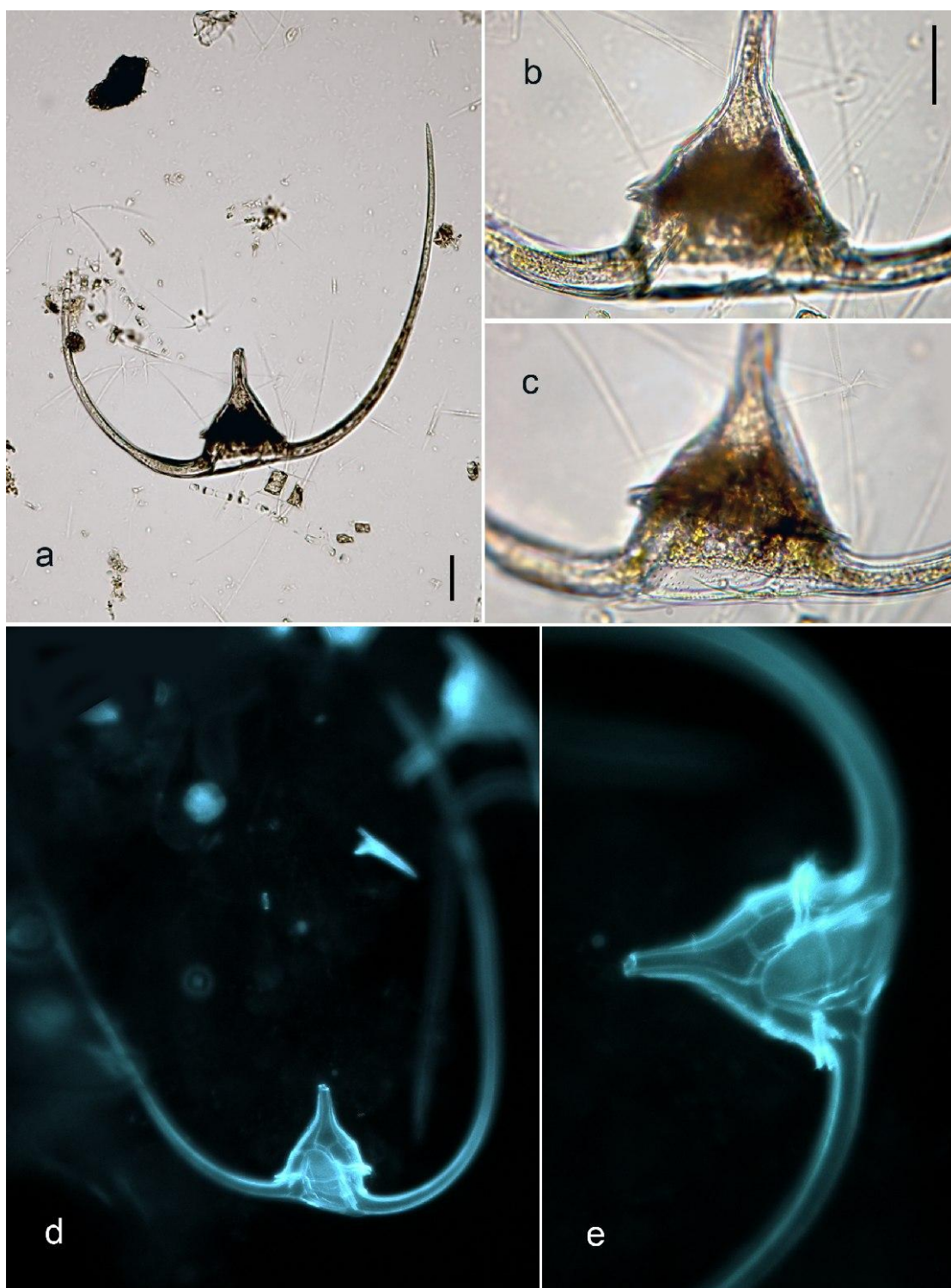


Plate A91. *Ceratium lunula* (a-e).
a-c – LM, BF; d, e – LM, epifluorescence. Scale bars – 50 μm.

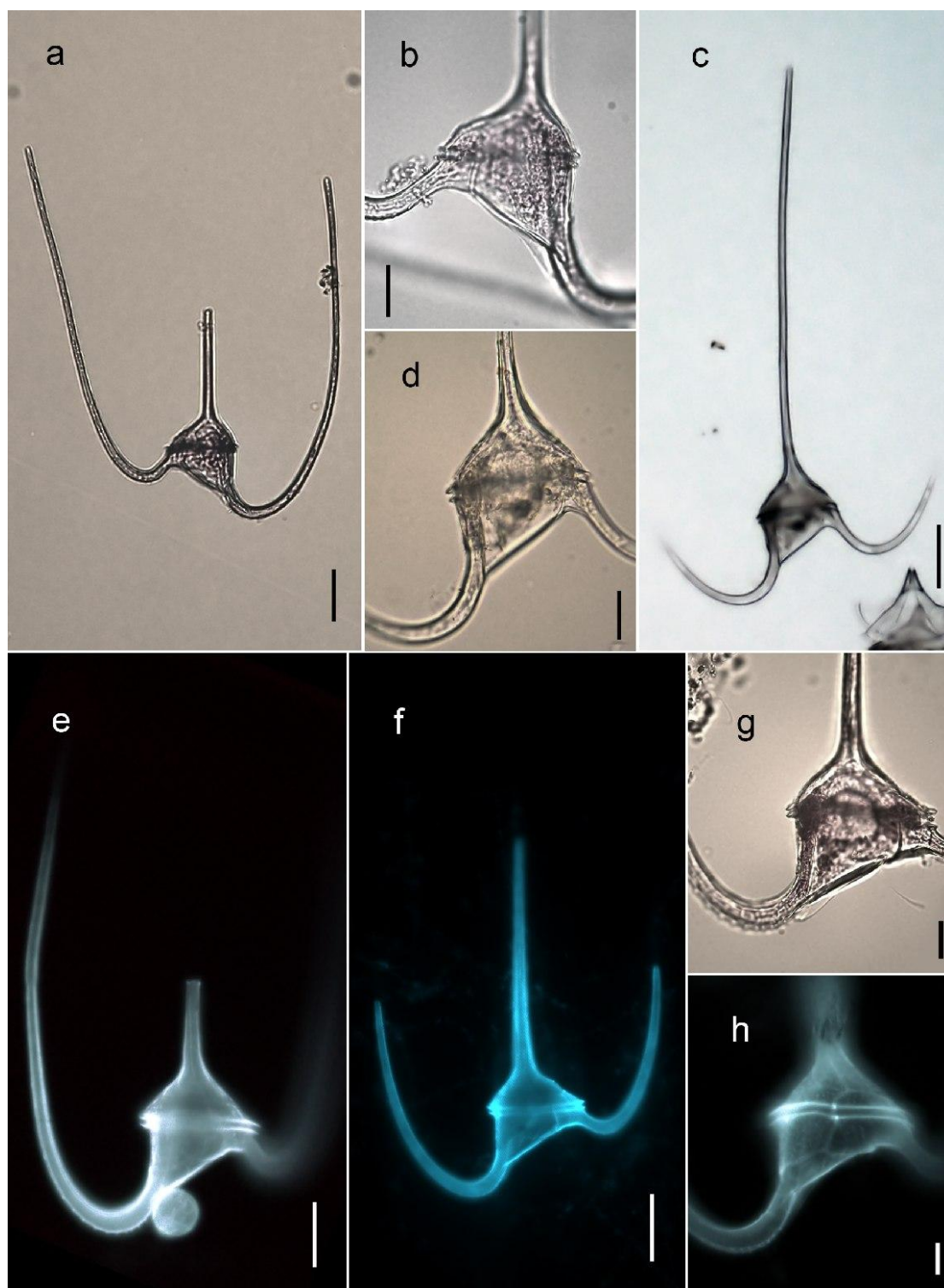


Plate A92. *Ceratium macroceros* var. *macroceros* (a, b, e-h); *Ceratium macroceros* var. *gallicum* (c, d).

a, b, d, g – LM, BF; c – PhC, BF; e, f, h – LM, epifluorescence. Scale bars: a, c, e, f – 50 µm; b, d, g, h – 20 µm.

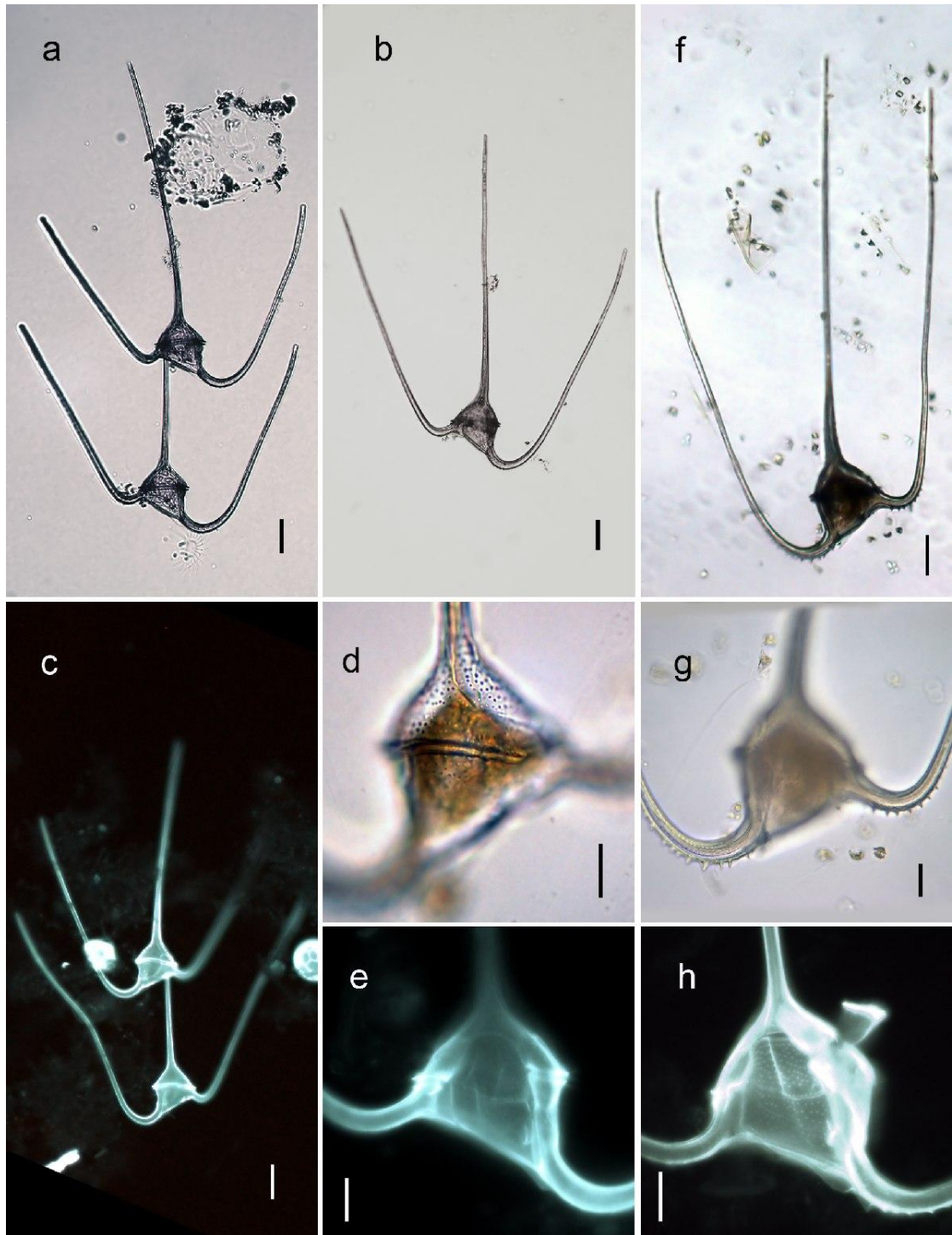


Plate A93. *Ceratium massiliense* var. *massiliense* (a-e, h); *Ceratium massiliense* var. *armatum* (f, g).
a, b, d, g – LM, BF; f – PhC, BF; c, e, h – LM, epifluorescence. Scale bars: a-c, f – 50 μm ; d, e, g, h – 20 μm .

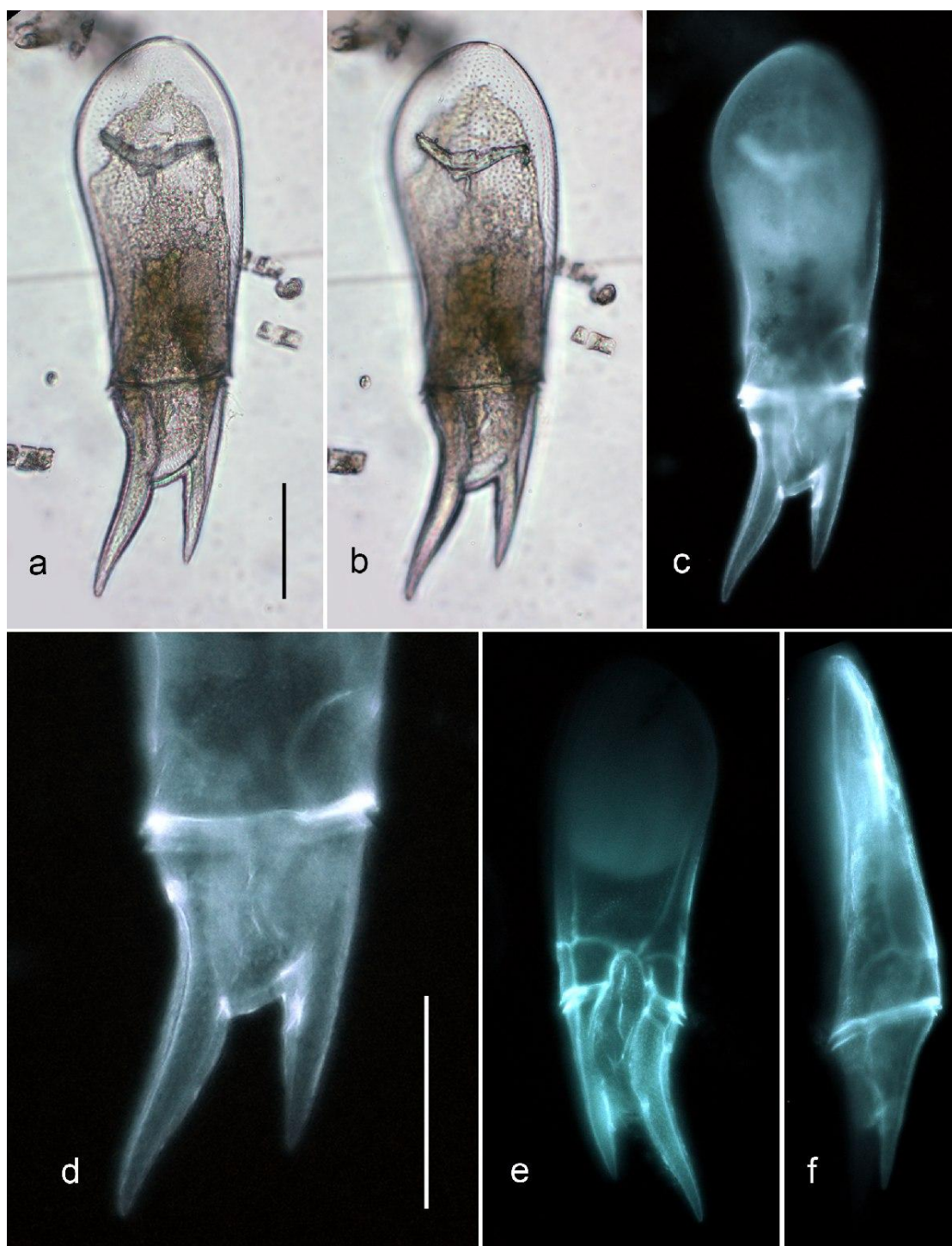


Plate A94. *Ceratium praelongum* (a-f).
 a, b – PhC, BF; c-f – LM, epifluorescence. Scale bars – 50 μm.

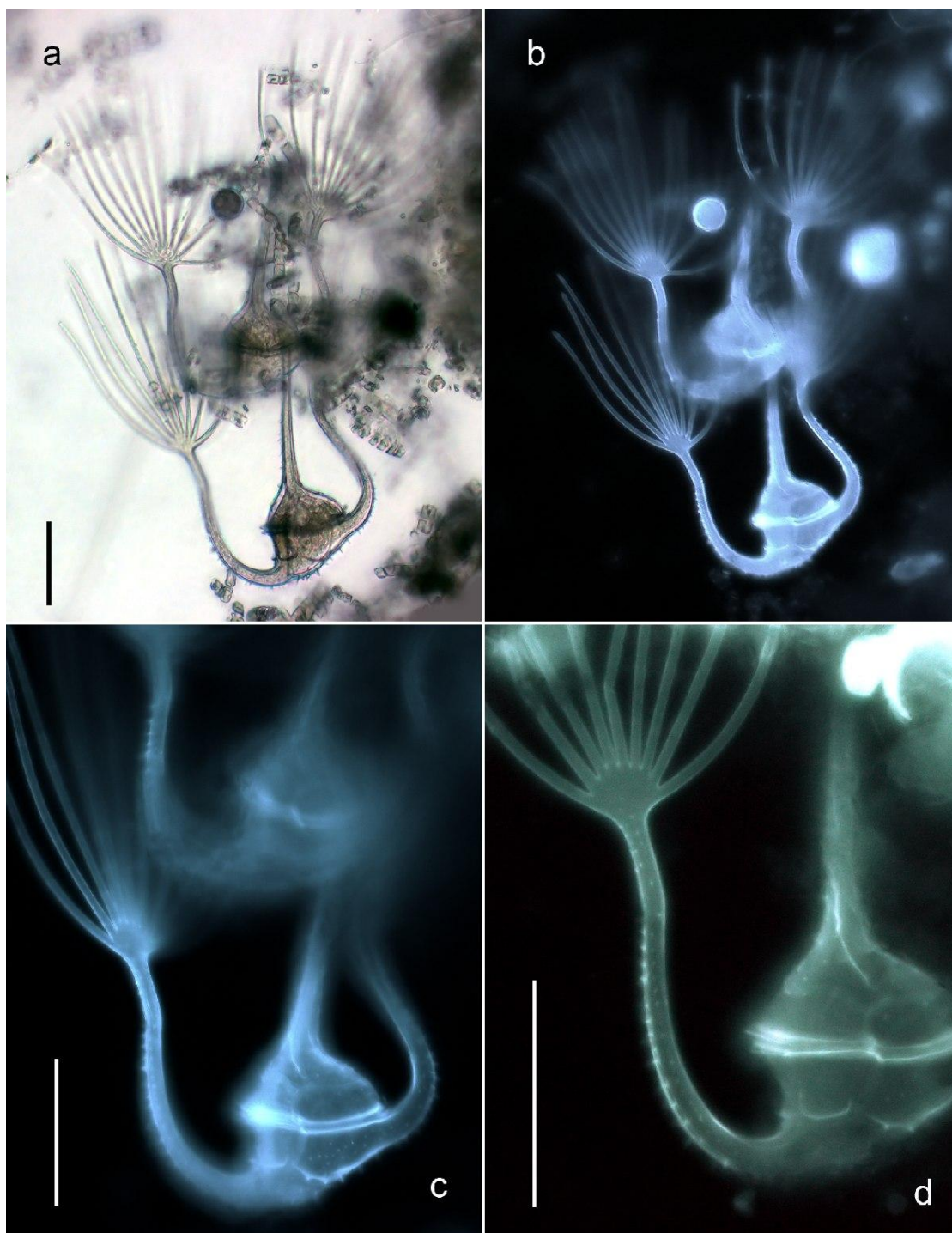


Plate A95. *Ceratium ranipes* (a-d).
a – PhC, BF; b-d – LM, epifluorescence. Scale bars – 50 μm.

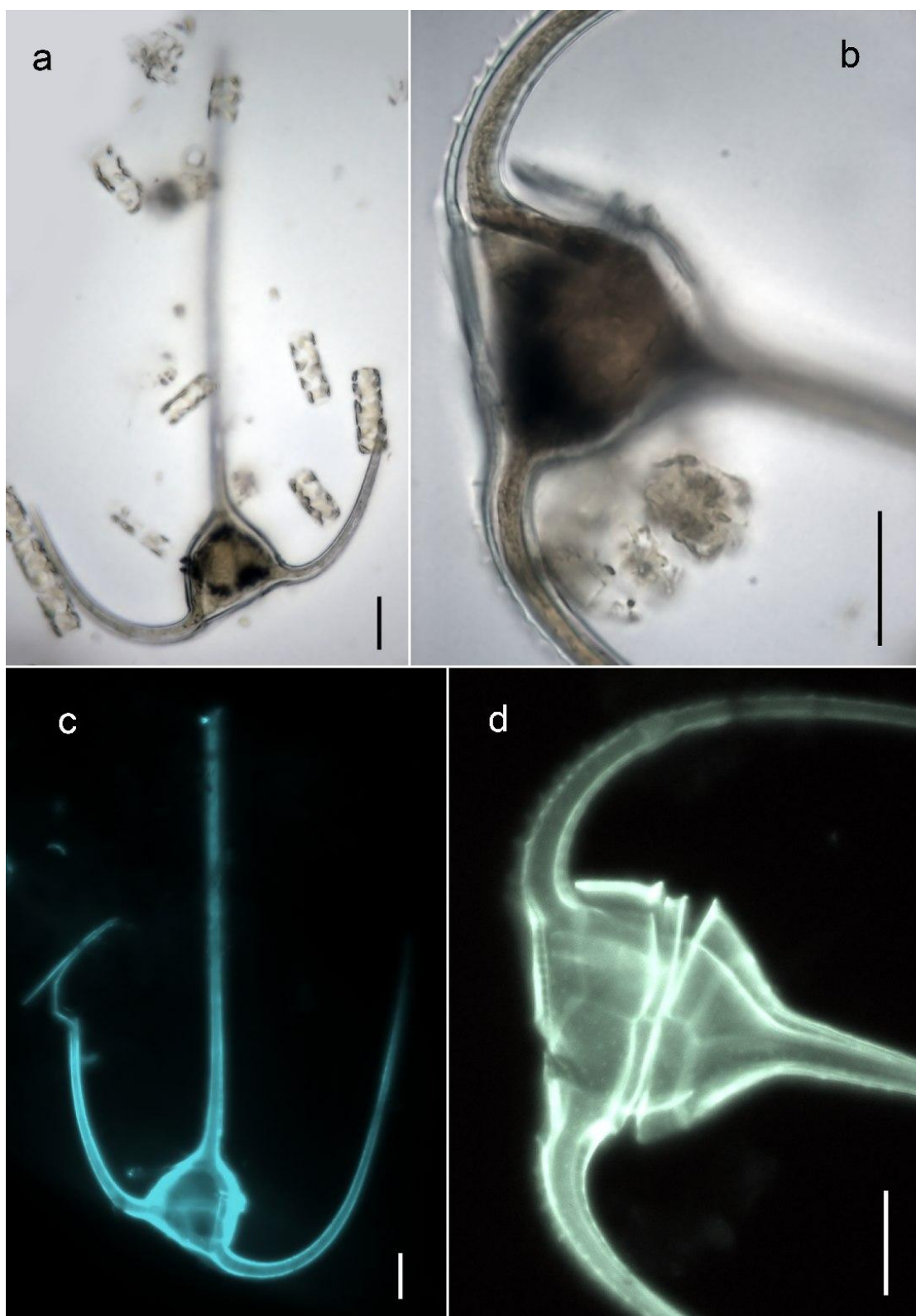


Plate A96. *Ceratium tenue* var. *buceros* (a-d).
 a, b – LM, BF; c, d – LM, epifluorescence. Scale bars – 20 μ m.

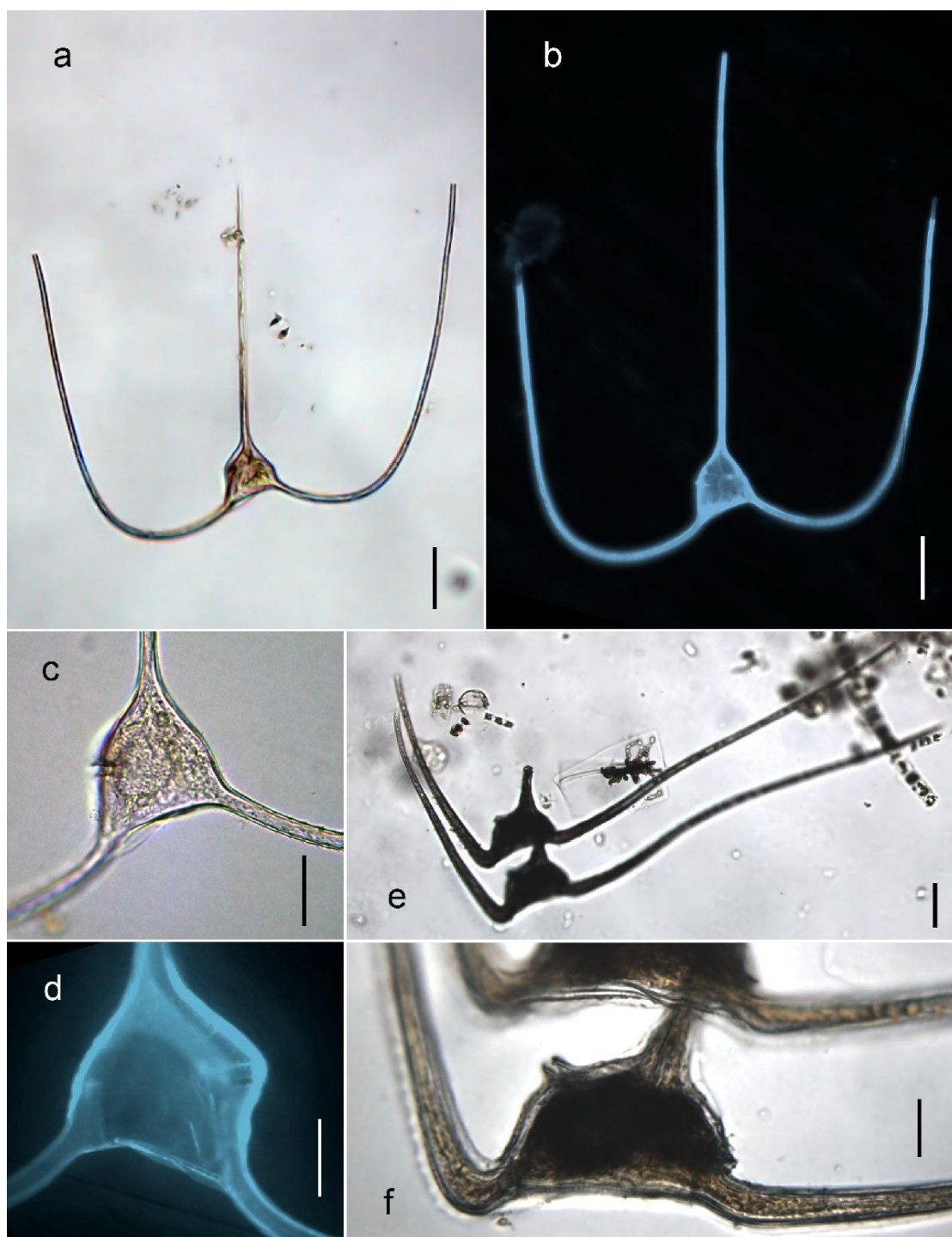


Plate A97. *Ceratium trichoceros* (a-d); *Ceratium vultur* var. *sumatranum* (e, f).
a, c – LM, BF; e, f – PhC, BF; b, d – LM, epifluorescence. Scale bars: a, b, e – 50 μ m; c, d, f – 20 μ m.

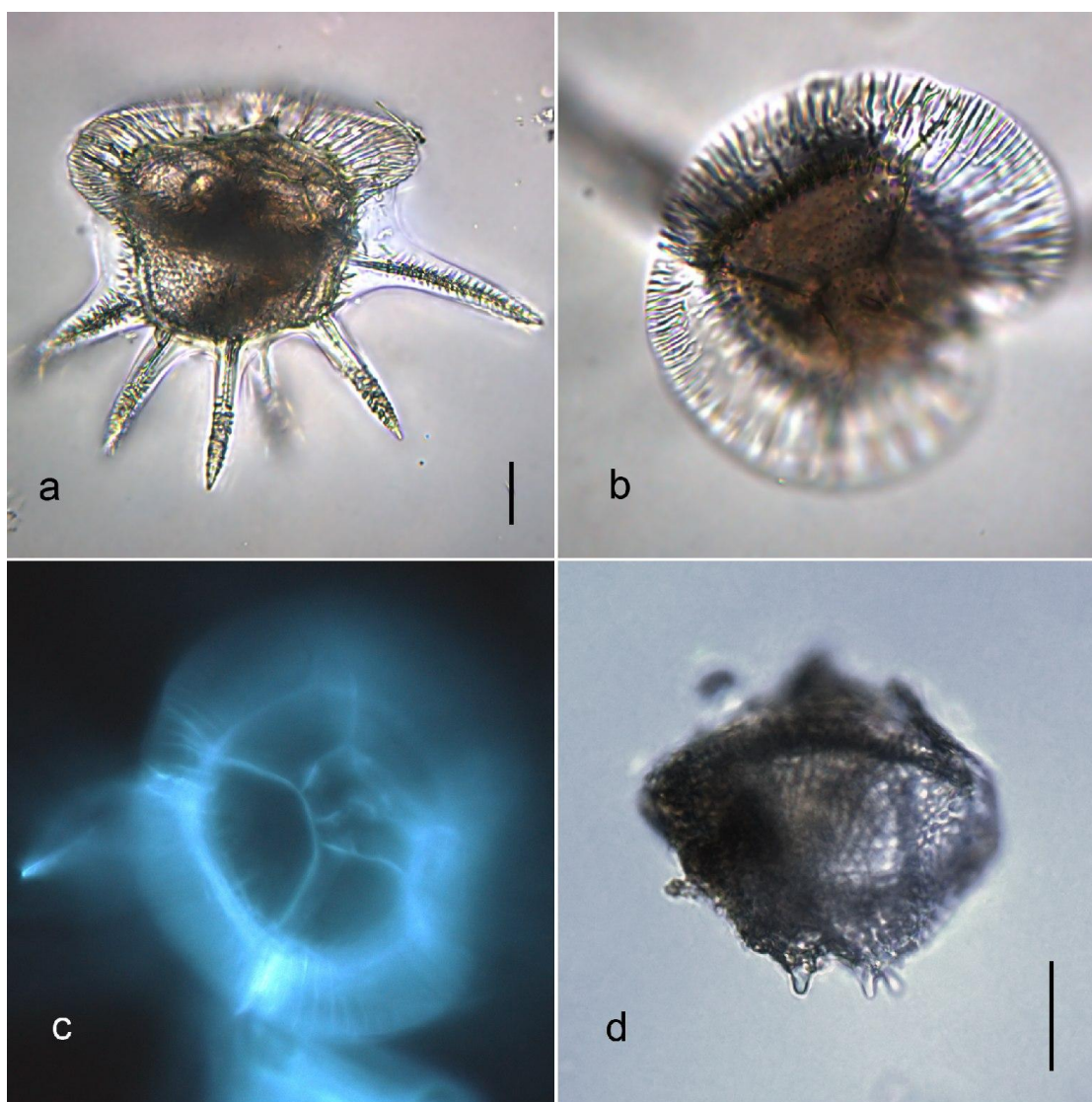


Plate A98. *Ceratocorys horrida* (a-c); *Ceratocorys armata* (d).
a, b, d – LM, BF; c – LM, epifluorescence. Scale bars – 20 μm.

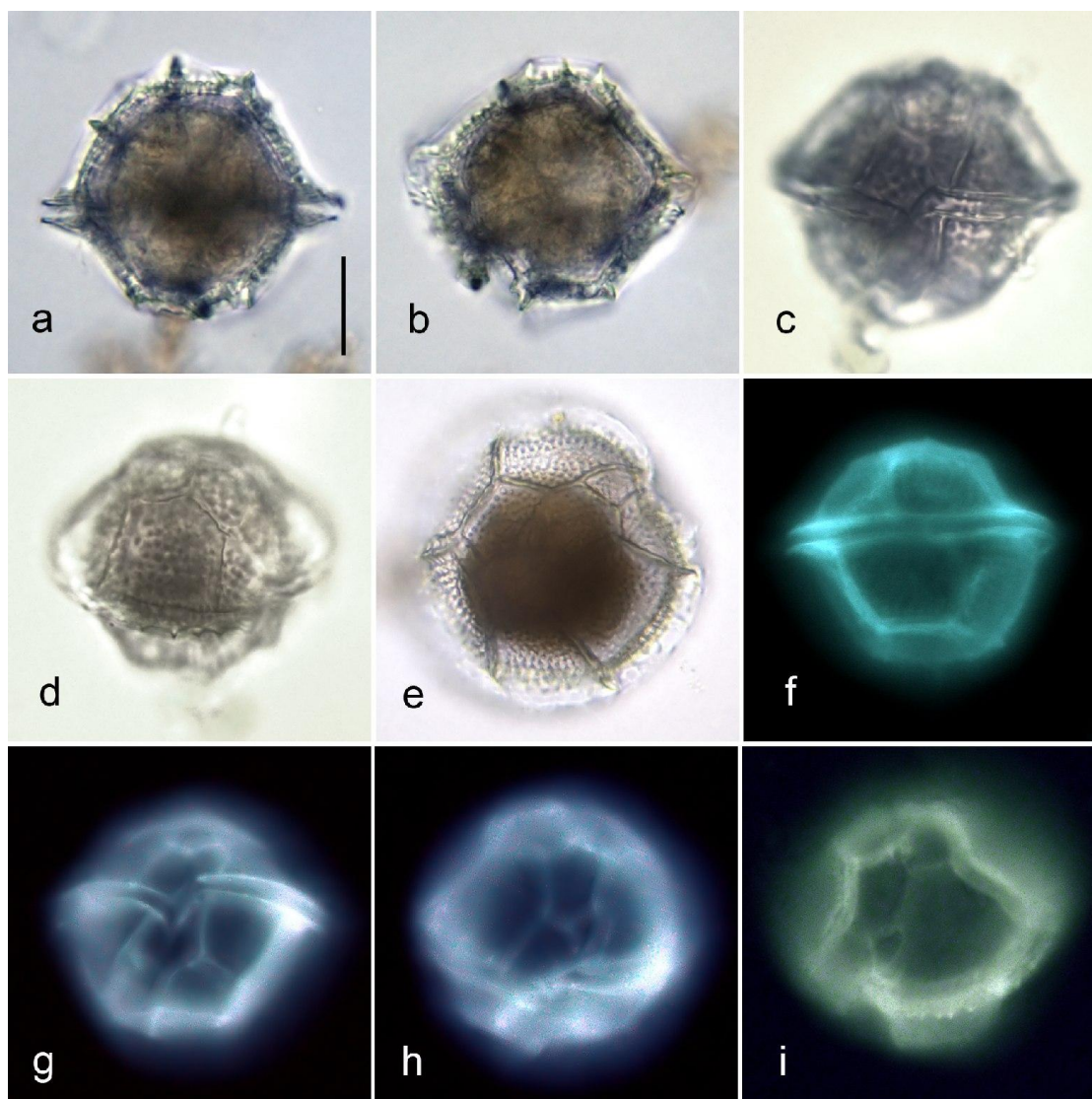


Plate A99. *Goniodoma polyedricum* (a-i).

a, b, e – LM, BF; c, d – PhC, BF; f-i – LM, epifluorescence. Scale bar – 20 μ m.

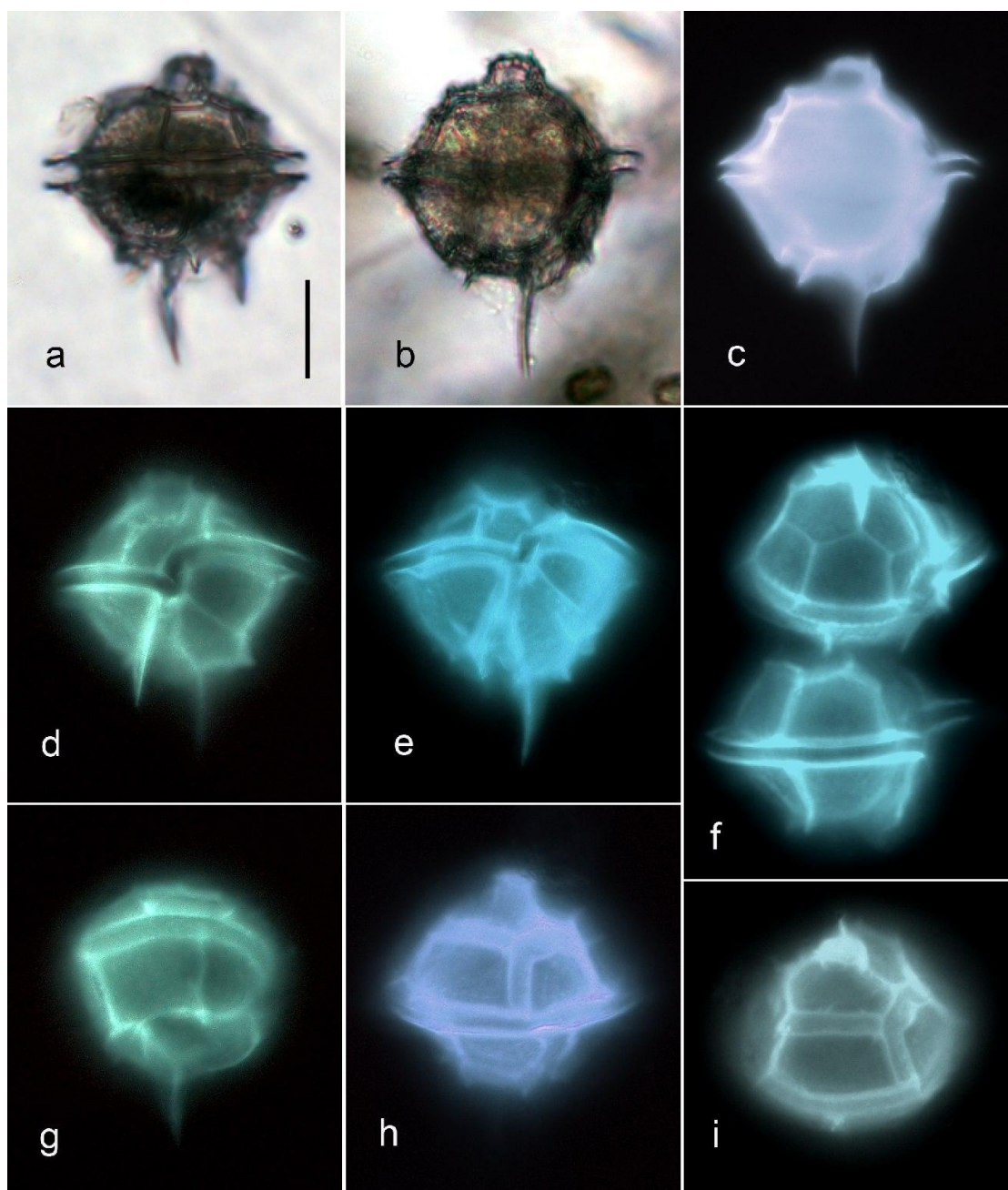


Plate A100. *Pyrodinium bahamense* var. *bahamense* (a-e, g, h); *Pyrodinium bahamense* var. *compressum* (f, i).

a, b – PhC, BF; c-i – LM, epifluorescence. Scale bar – 20 μ m.

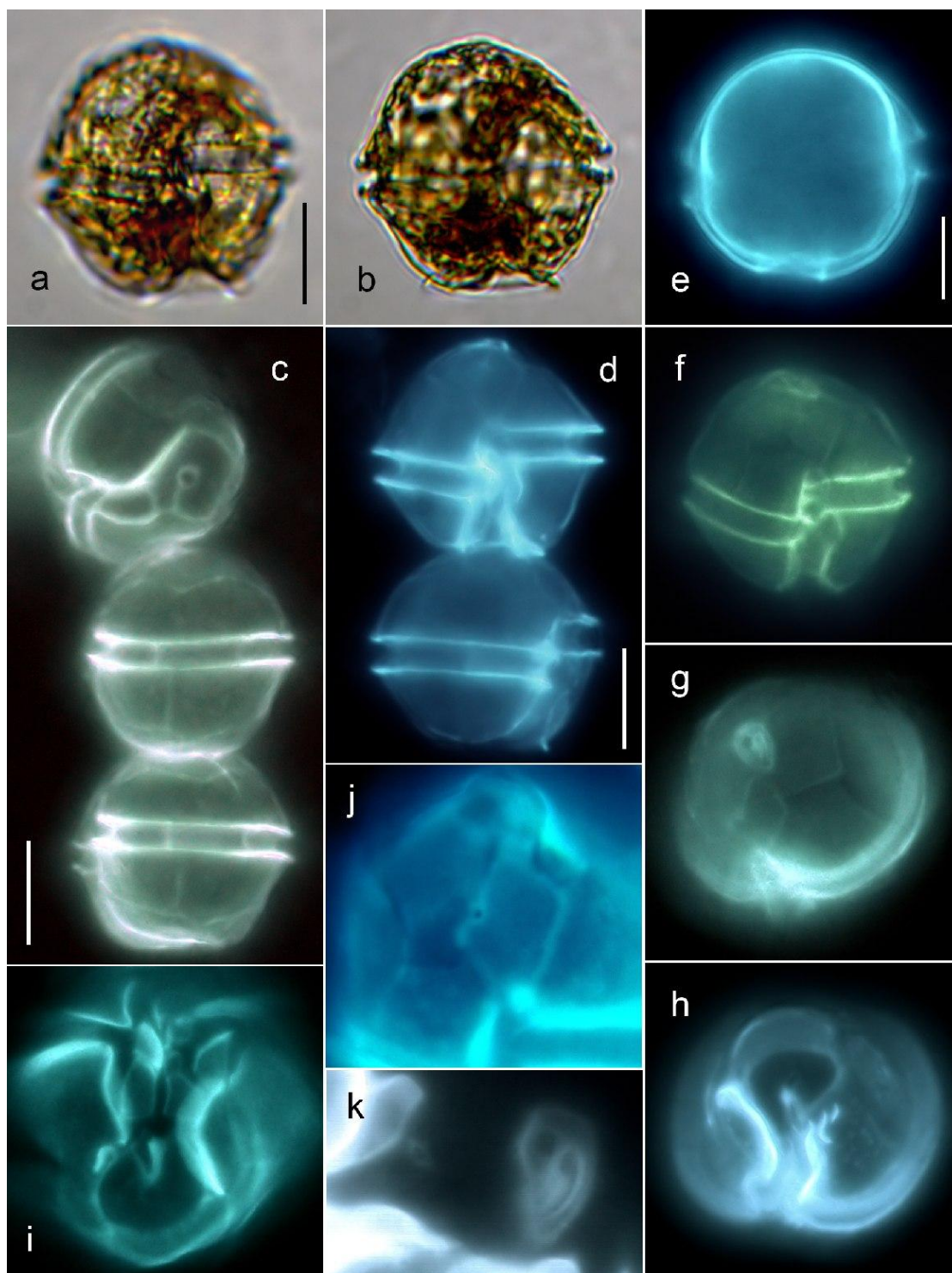


Plate A101. *Alexandrium tamiyavanichii* (a-k).
 a, b – LM, BF; c-k – LM, epifluorescence. Scale bars – 20 μm.

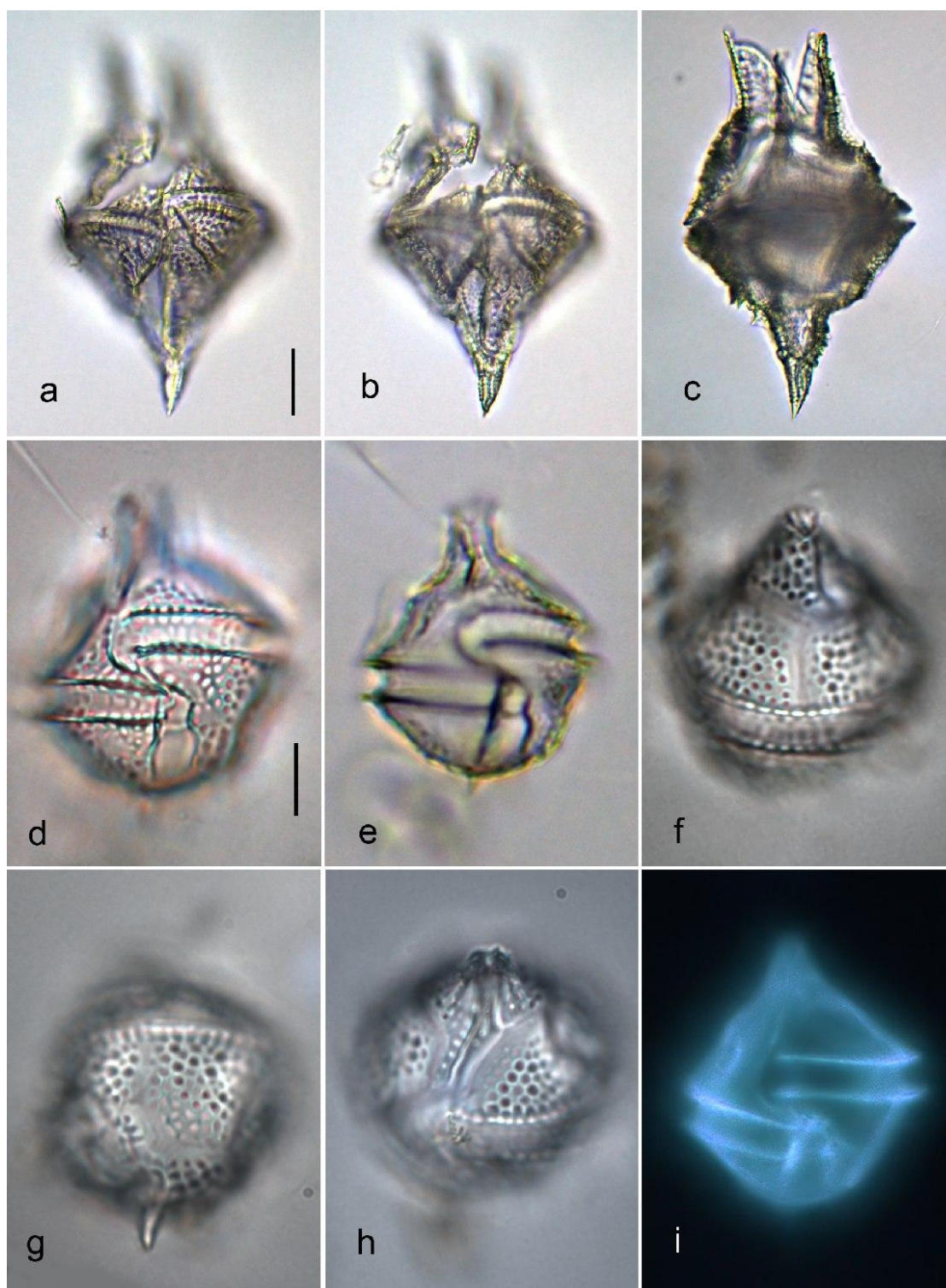


Plate A102. *Gonyaulax birostris* (a-c); *Gonyaulax spinifera* (d-i).
 a-h – LM, BF; i – LM, epifluorescence. Scale bars: a-c – 20 μm ; d-i – 10 μm .

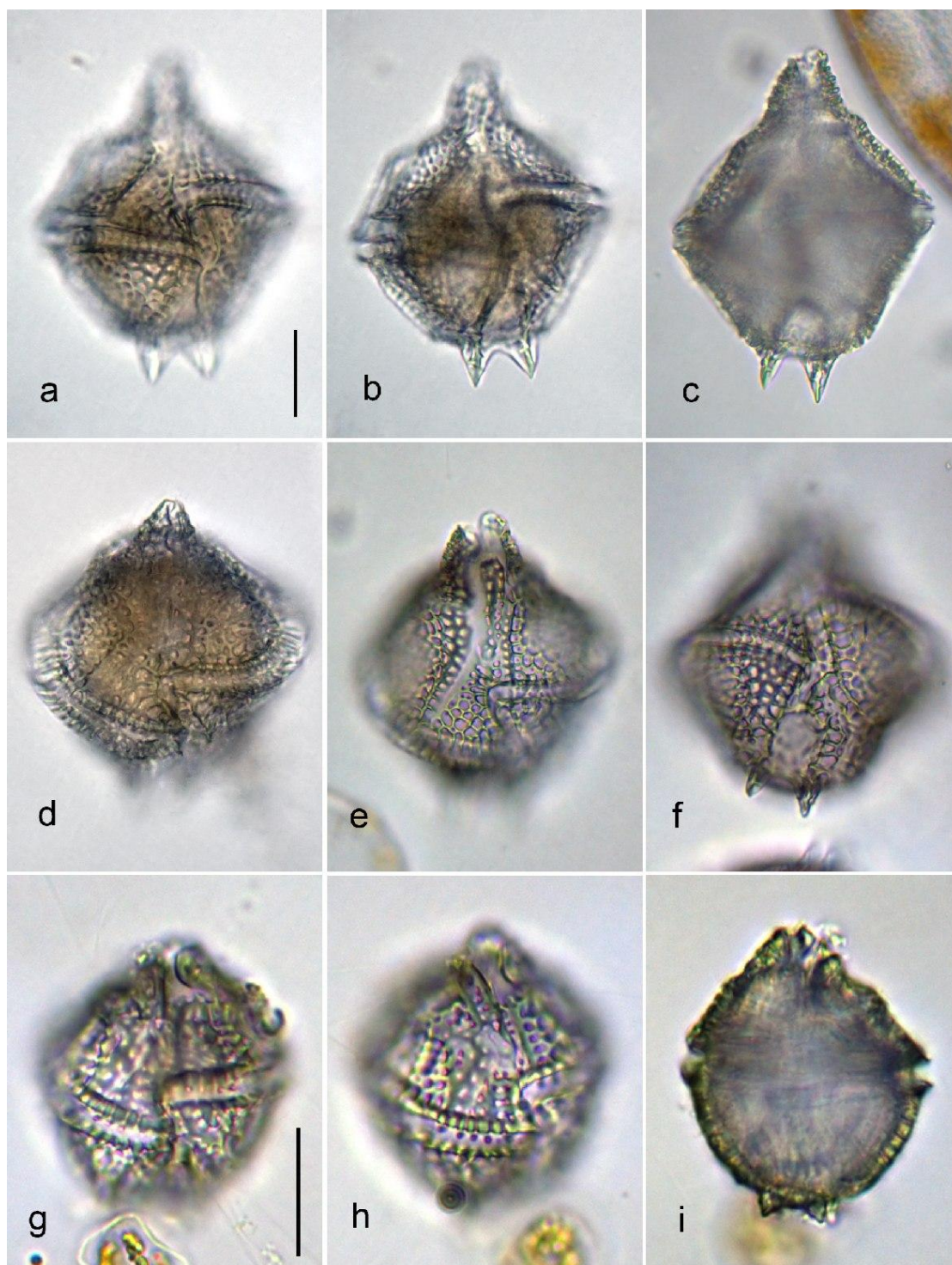


Plate A103. *Gonyaulax digitale* (a-f); *Gonyaulax scrippsae* (g-i).
a-i – LM, BF. Scale bars – 20 μm .

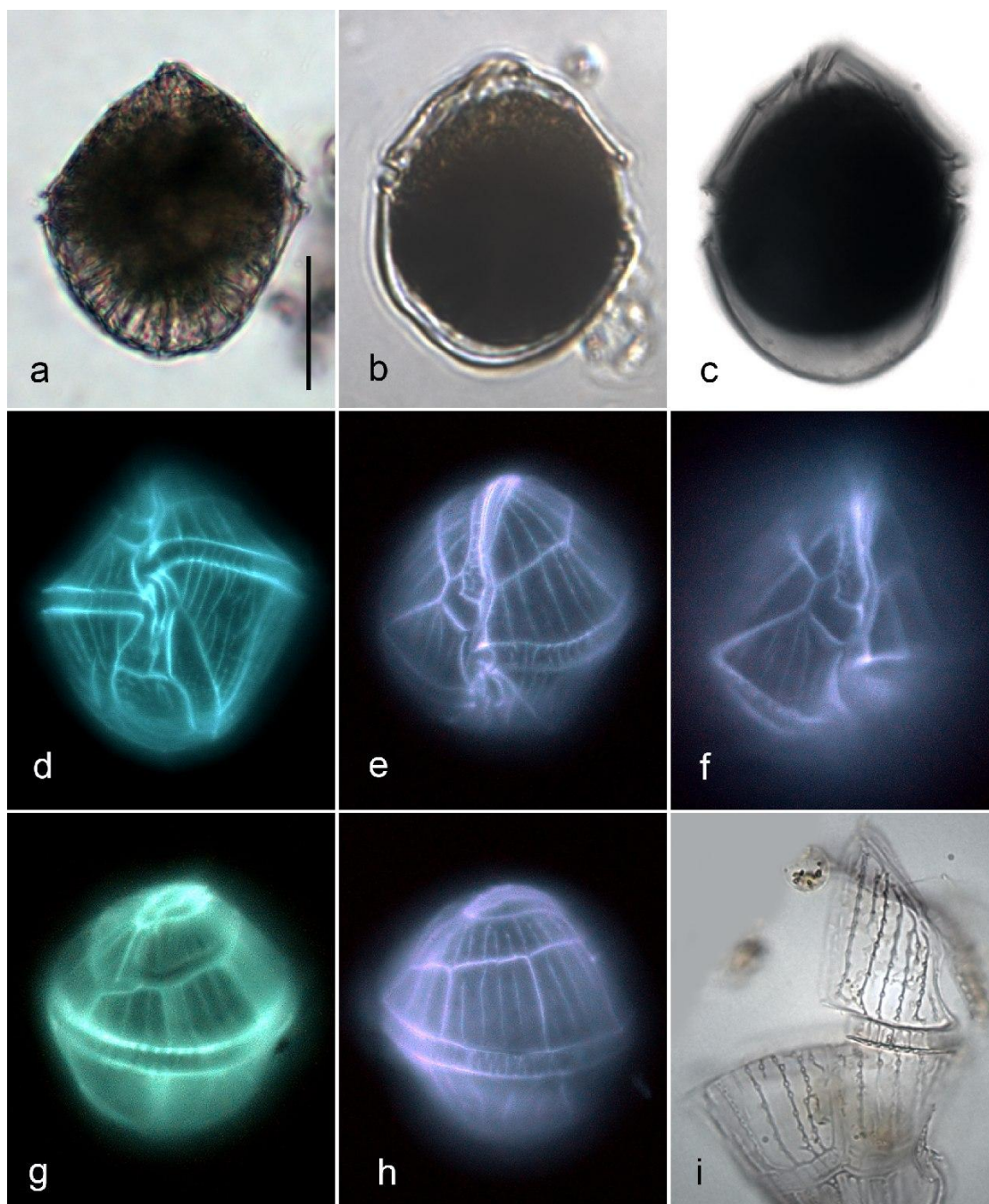


Plate A104. *Gonyaulax fragilis* (a-i).

a-c – PhC, BF; i – LM, BF; d-h – LM, epifluorescence. Scale bar – 30 μm .

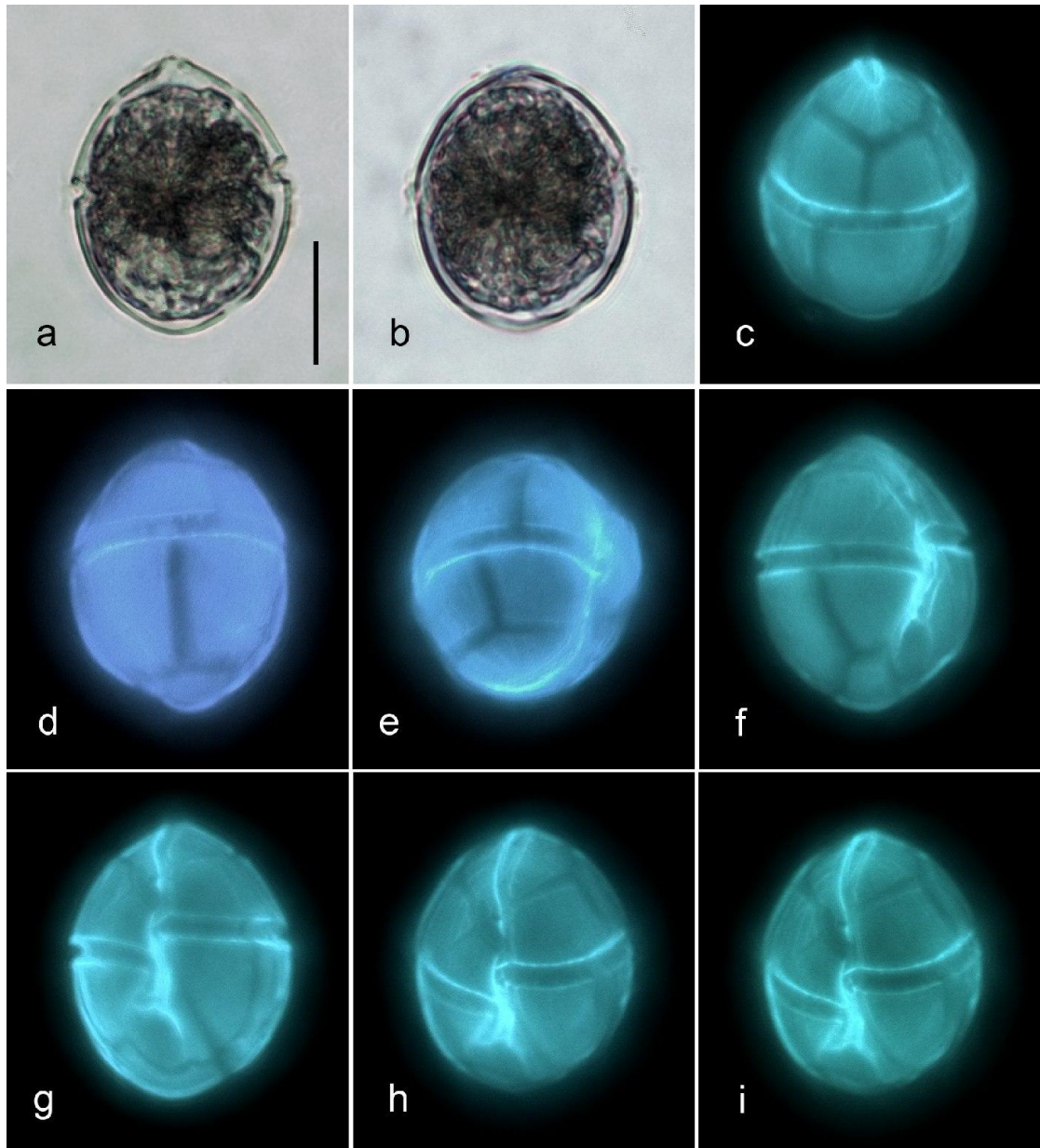


Plate A105. *Gonyaulax hyalina* (a-i).
 a, b – PhC, BF; c-i – LM, epifluorescence. Scale bar – 20 μm .

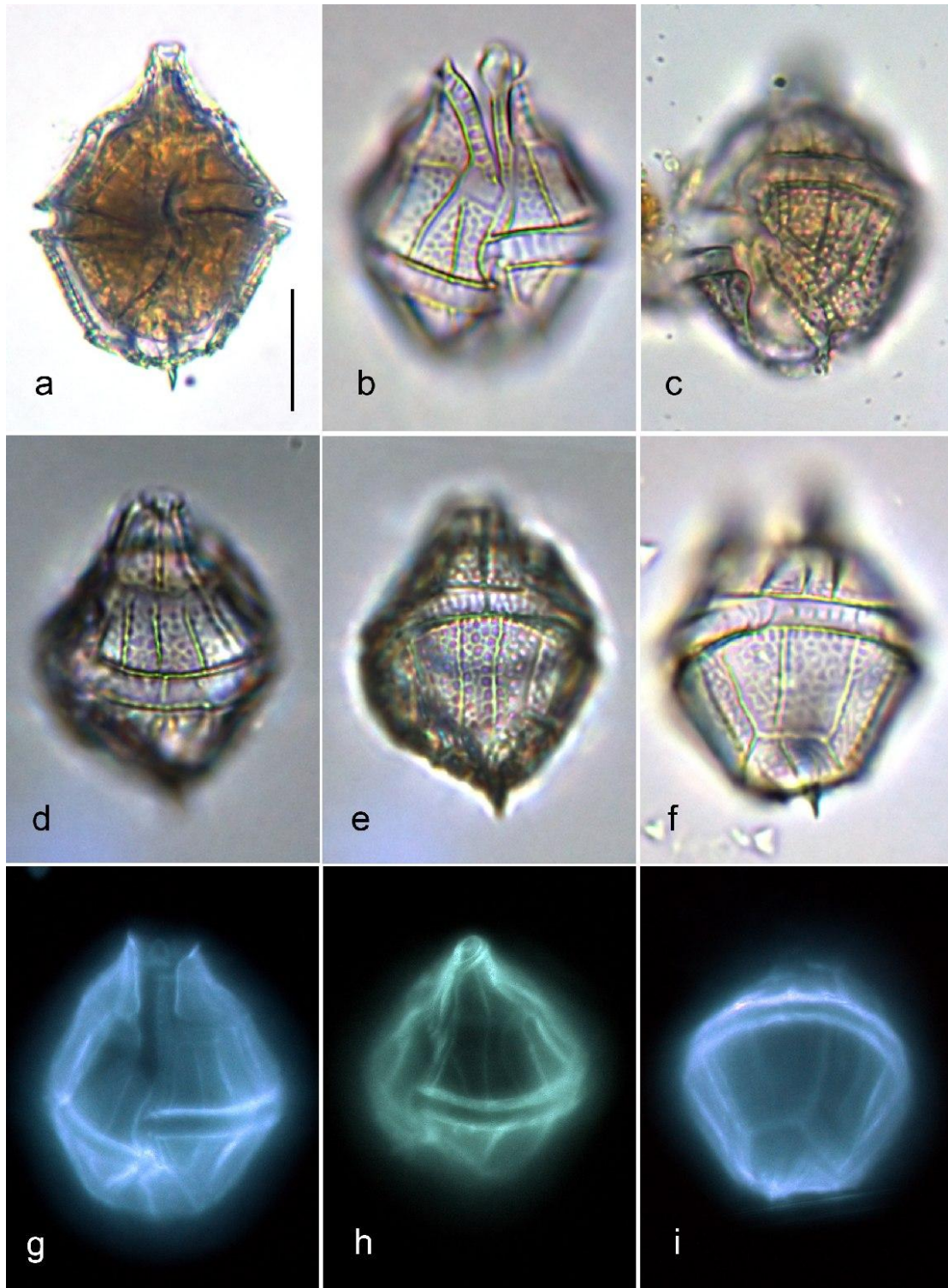


Plate A106. *Gonyaulax polygramma* (a-i).
a-f – LM, BF; g-i – LM, epifluorescence. Scale bar – 20 μm .

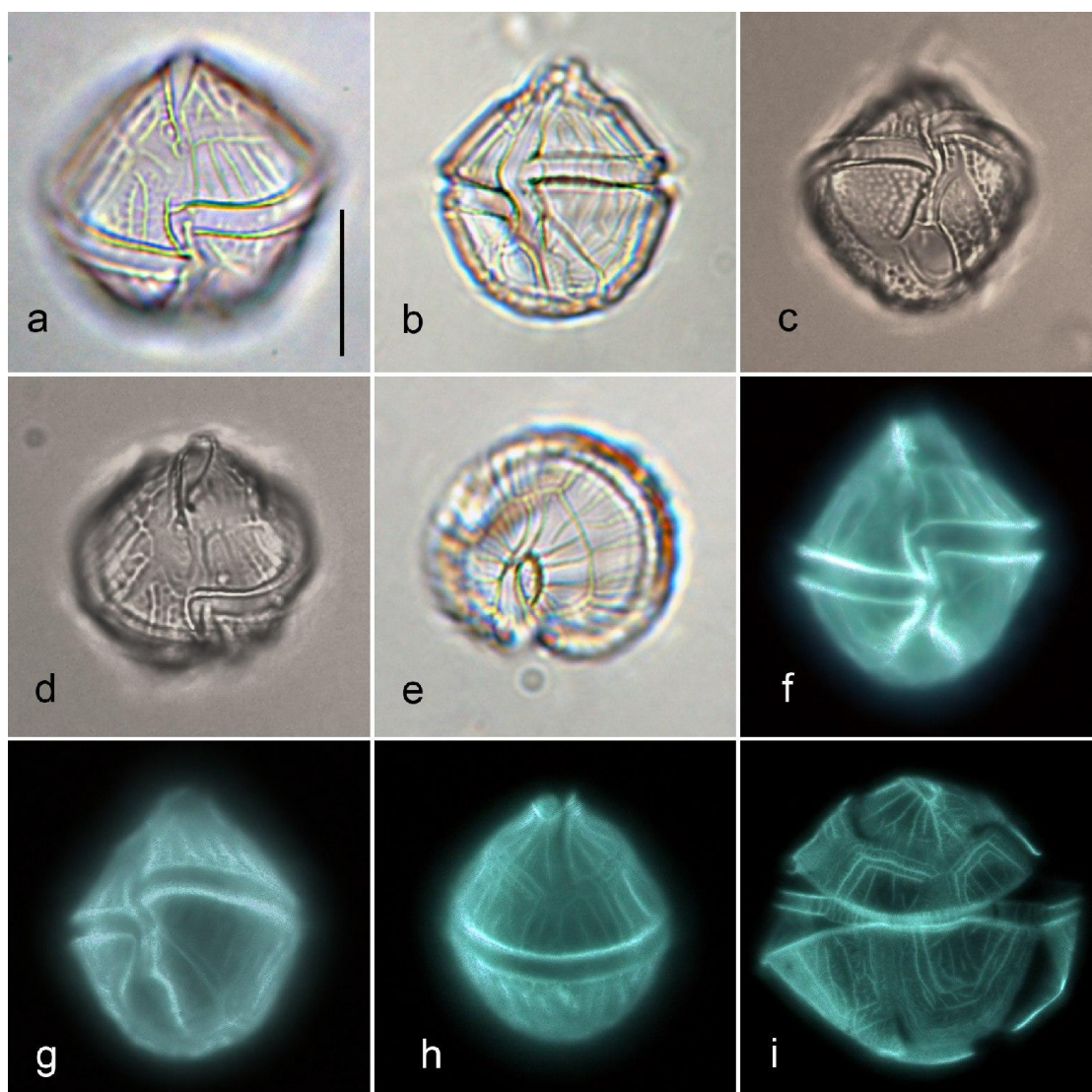


Plate A107. *Gonyaulax turbinei* (a-i).
 a-e – LM, BF; f-i – LM, epifluorescence. Scale bar – 20 μm .

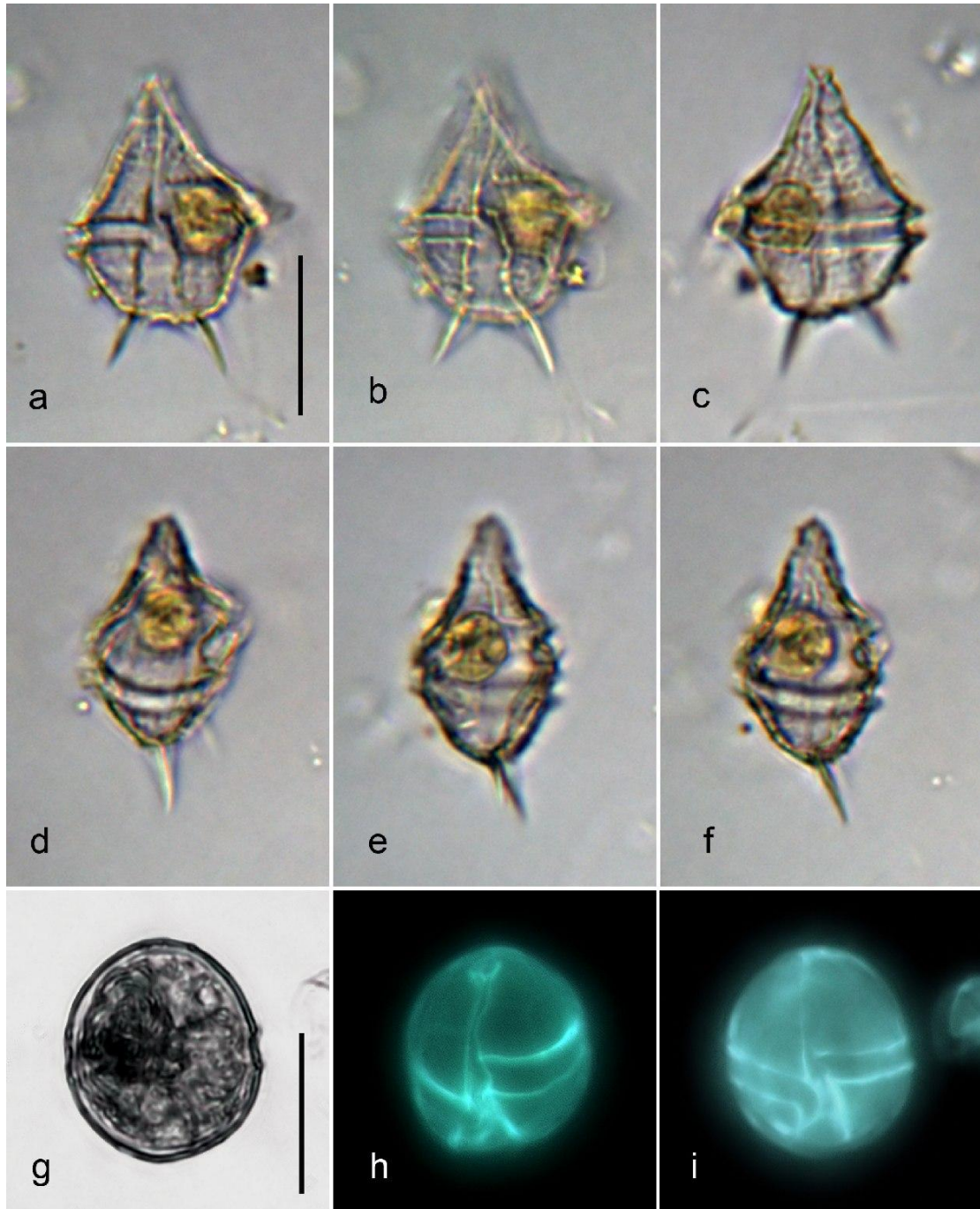


Plate A108. *Gonyaulax verior* (a-f); *Gonyaulax sp. 1* (g-i).
 a-f – LM, BF; g – PhC, BF; h, i – LM, epifluorescence. Scale bars – 20 μ m.

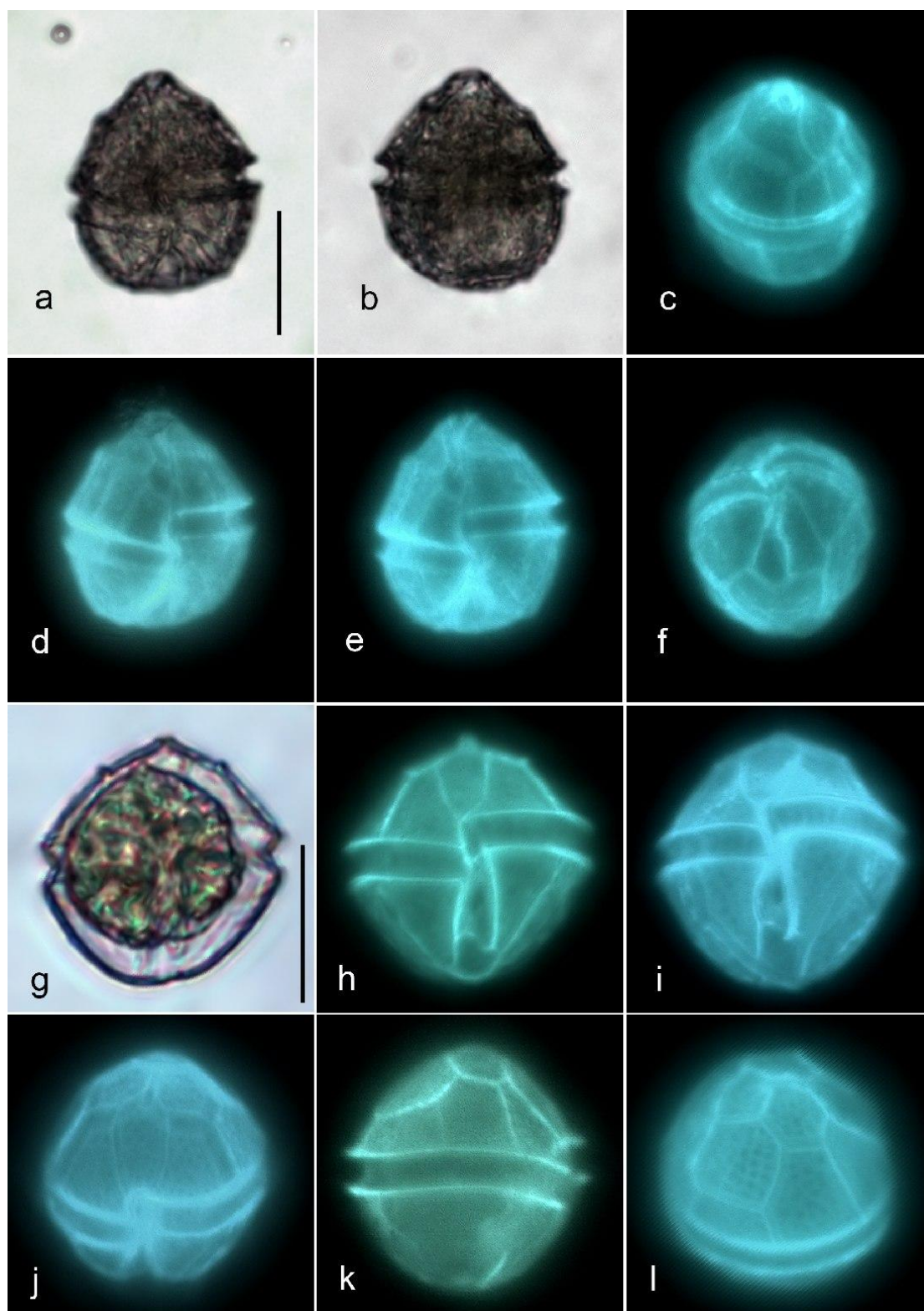


Plate A109. *Gonyaulax* sp. 2 (a-f); *Lingulodinium polyedrum* (g-l).
a, b, g – PhC, BF; c-f, h-l – LM, epifluorescence. Scale bars – 20 μm.

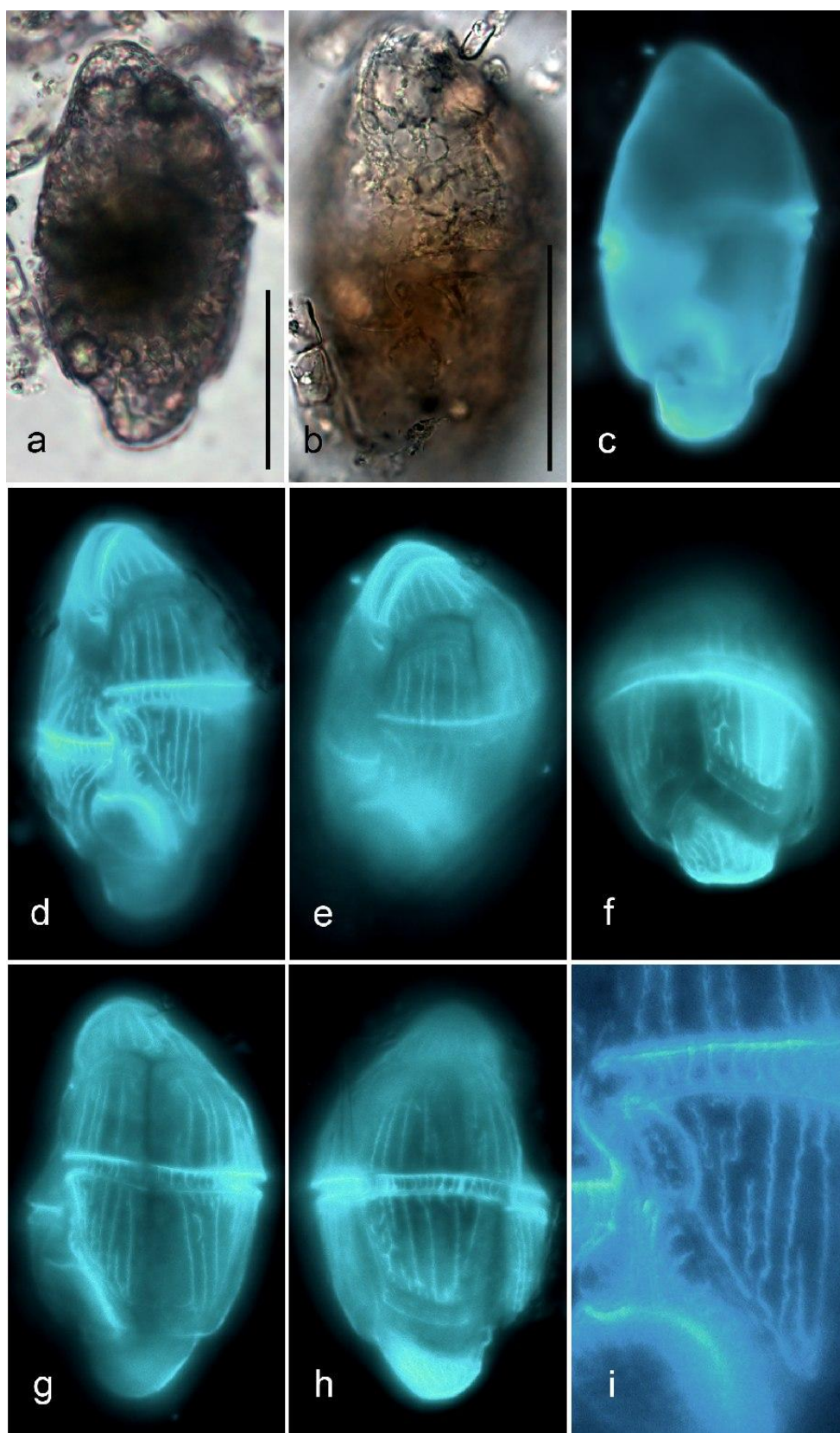


Plate A110. *Gonyaulax* sp. 3 (a-i).
a, b – LM, BF; c-i – LM, epifluorescence. Scale bars – 50 μ m.

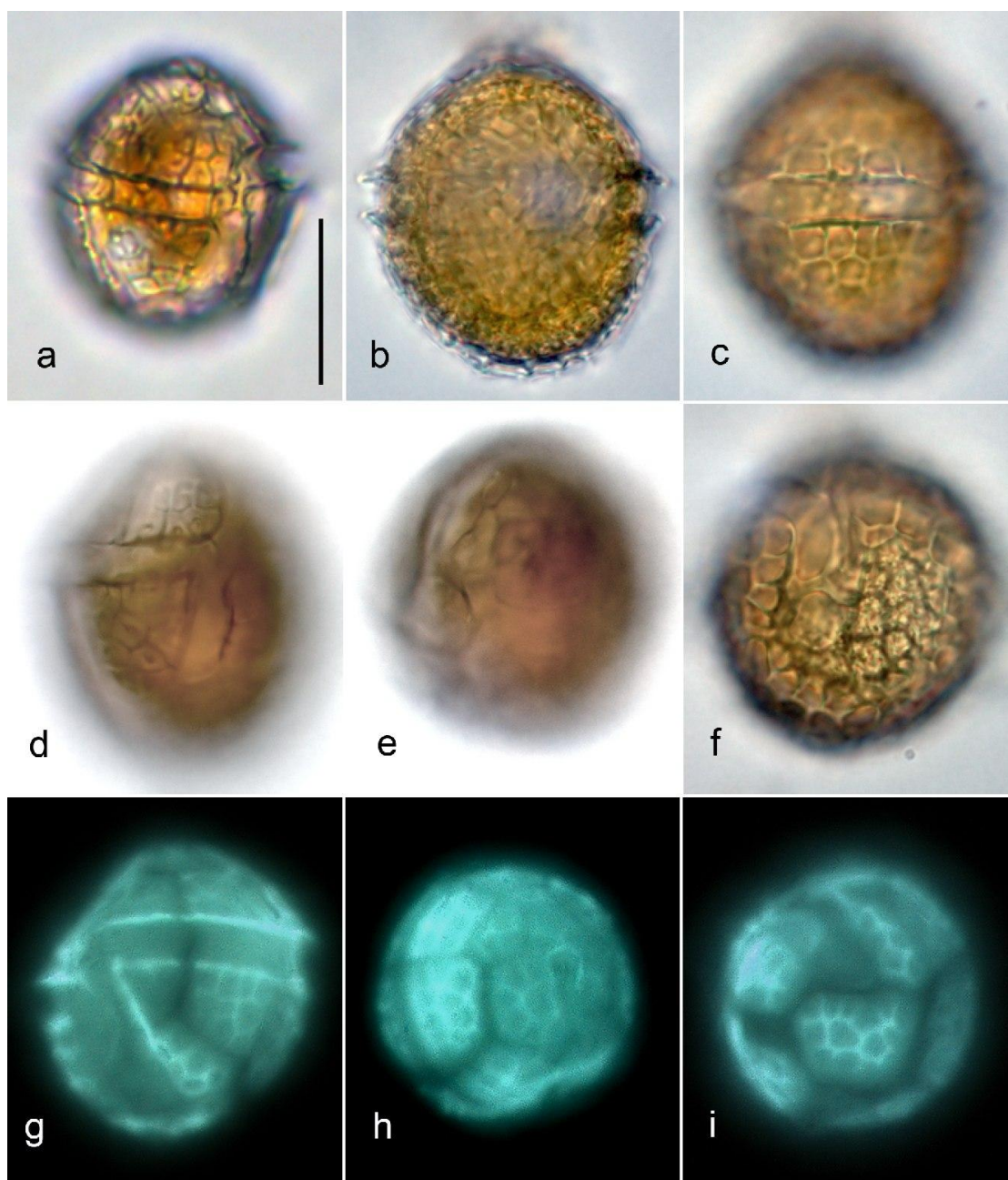


Plate A111. *Protoceratium reticulatum* (a-i).
 a-f – LM, BF; g-i – LM, epifluorescence. Scale bar – 20 μm .

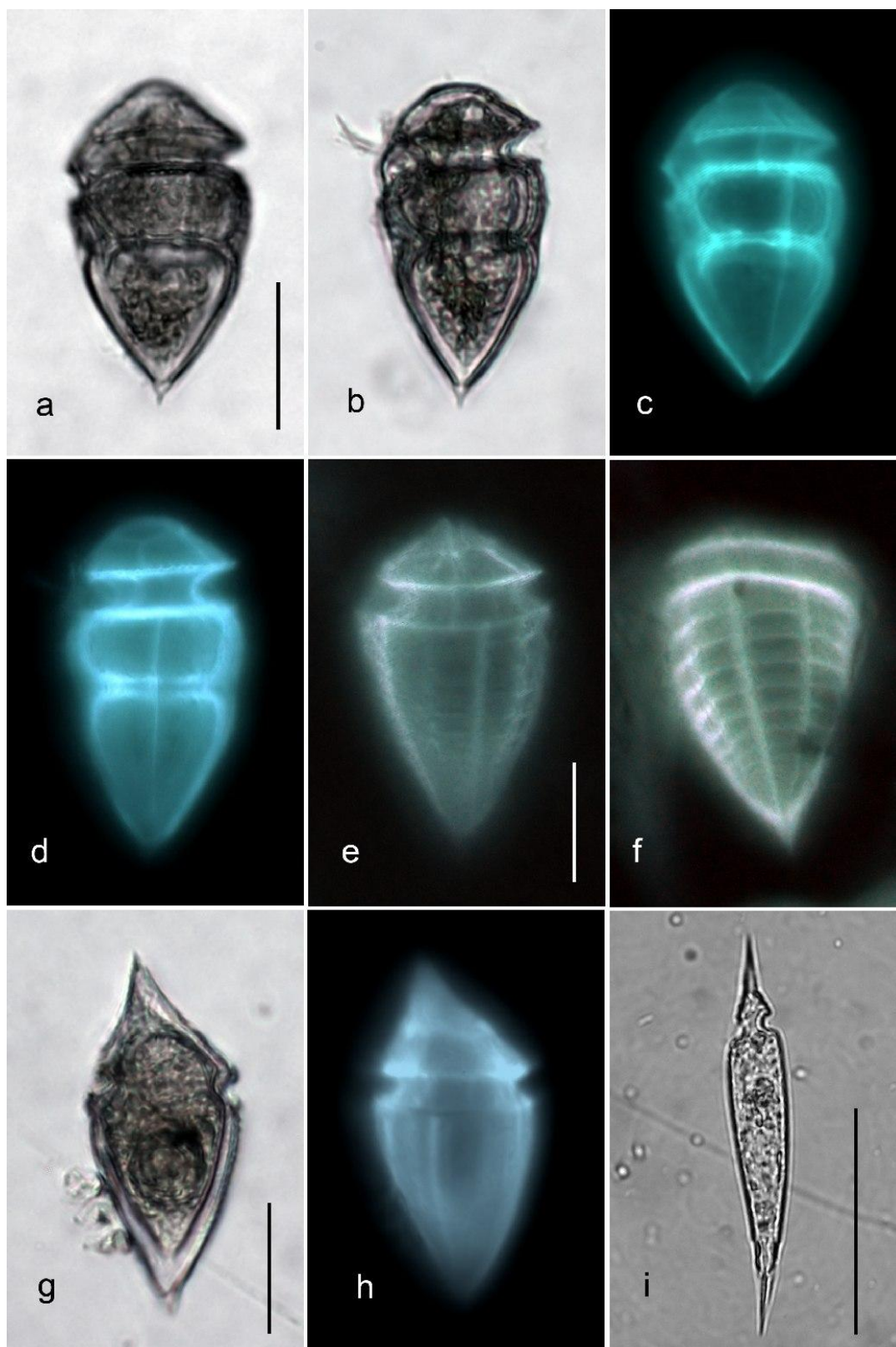


Plate A112. *Corythodinium constrictum* (a-d); *Corythodinium tessellatum* (e, f); *Corythodinium diploconus* (g, h); *Oxytoxum scolopax* (i).
a, b, g, i – PhC, BF; c-f, h – LM, epifluorescence. Scale bars: a-h – 20 μ m; i – 40 μ m.

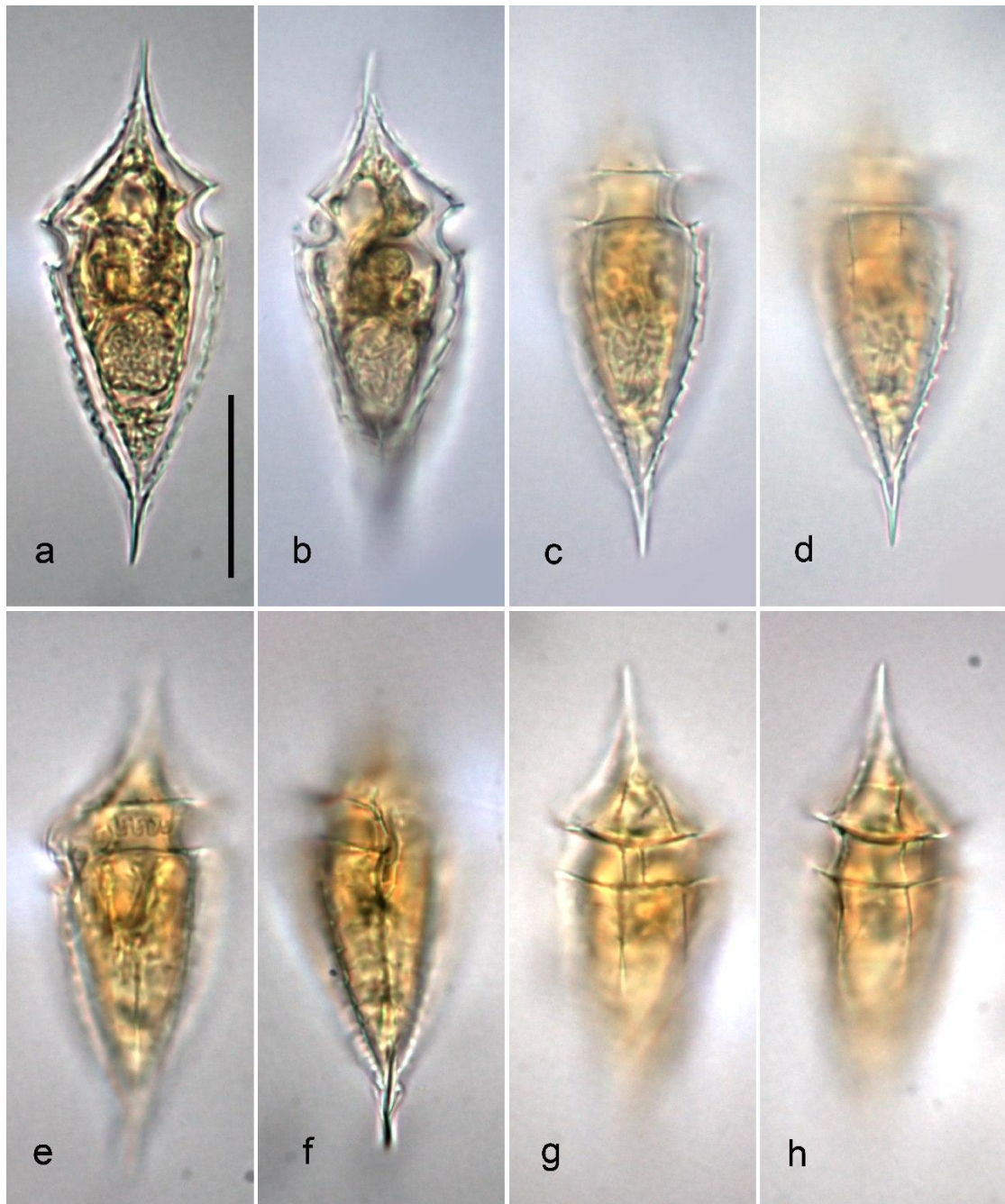


Plate A113. *Corythodinium* sp. (a-h).
a-h – LM, BF. Scale bar – 20 μ m.

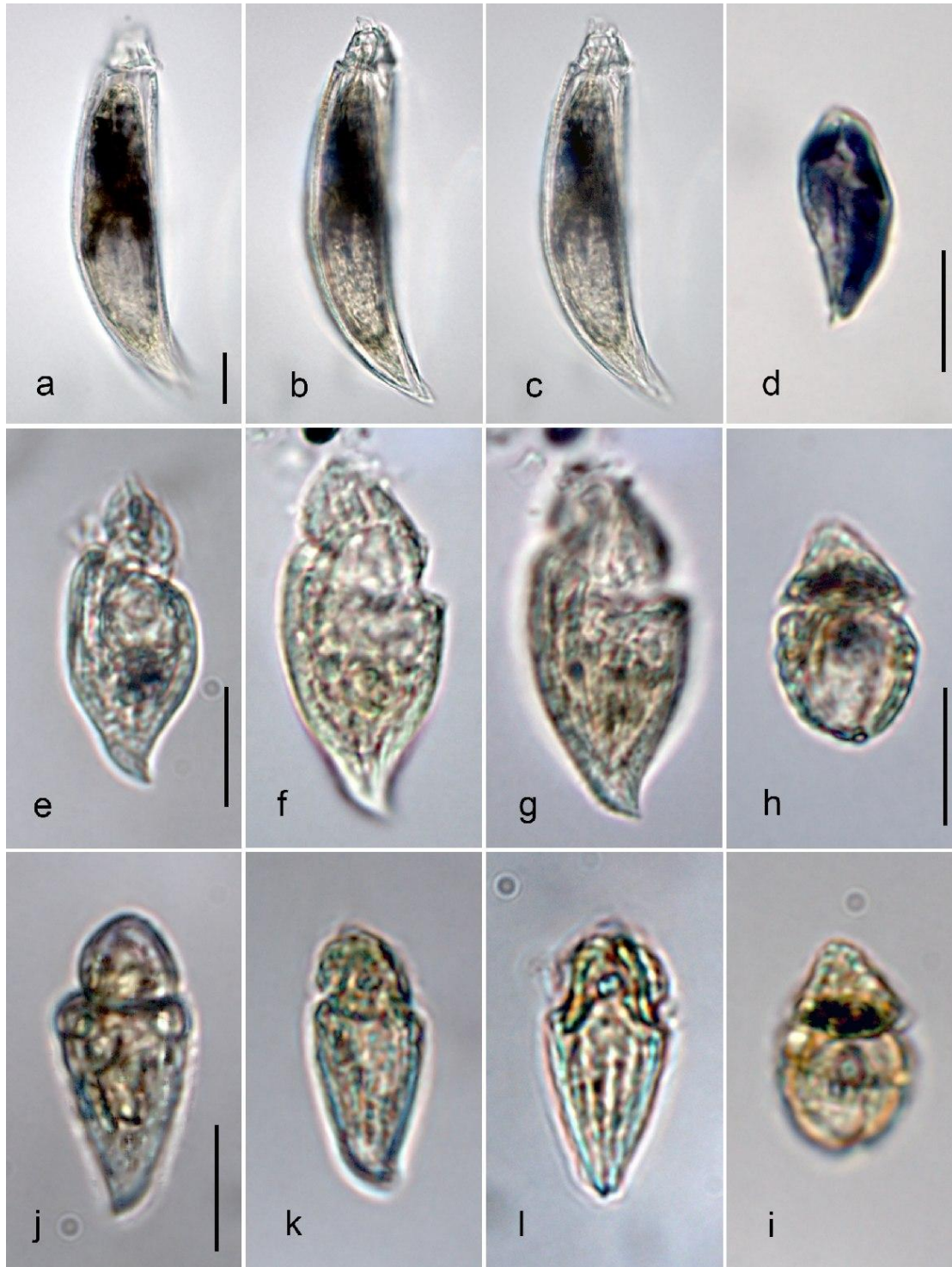


Plate A114. *Oxytoxum curvatum* (a-c); *Oxytoxum sp. 1* (d); *Oxytoxum variabile* (e-g); *Oxytoxum sp. 2* (h, i); *Oxytoxum sp. 3* (j-l).
a-l – LM, BF. Scale bars – 10 µm.

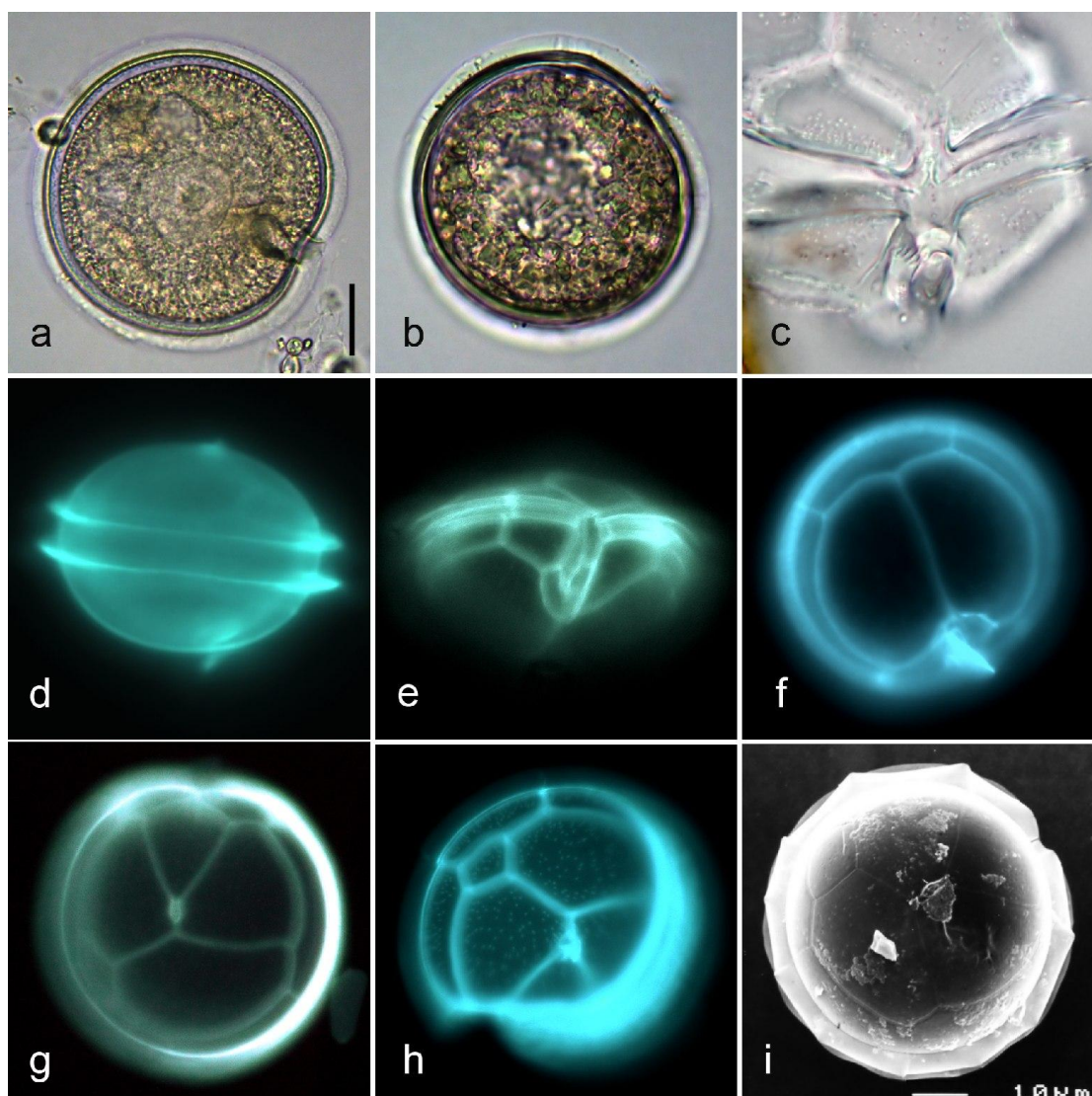


Plate A115. *Diplopelta bomba* (a-i).

a-c – LM, BF; d-h – LM, epifluorescence; i – SEM. Scale bars: a-h – 20 µm; i – 10 µm.

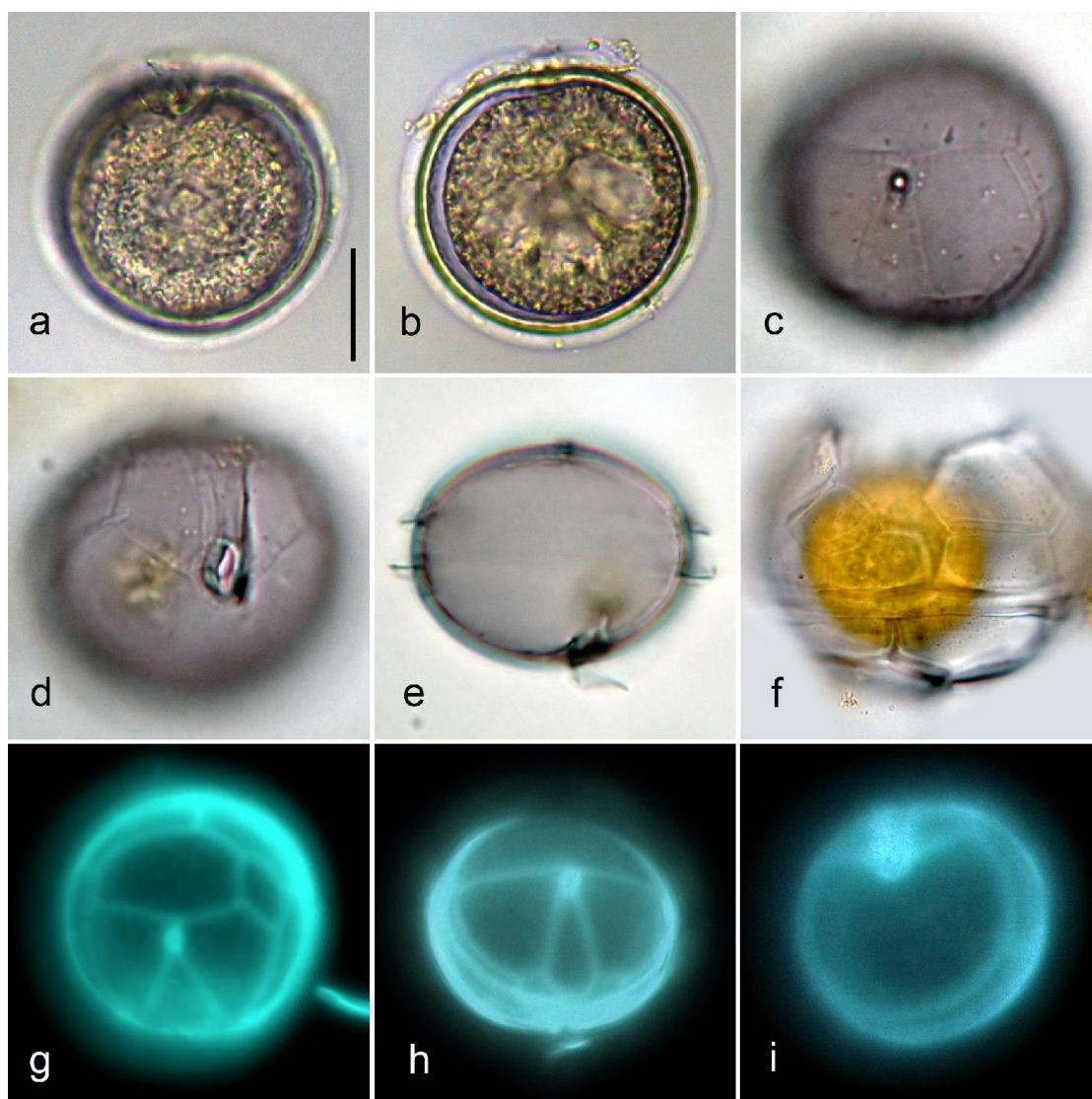


Plate A116. *Preperidinium meunieri* (a-i).
 a-f – LM, BF; g-i – LM, epifluorescence. Scale bar – 20 μ m.

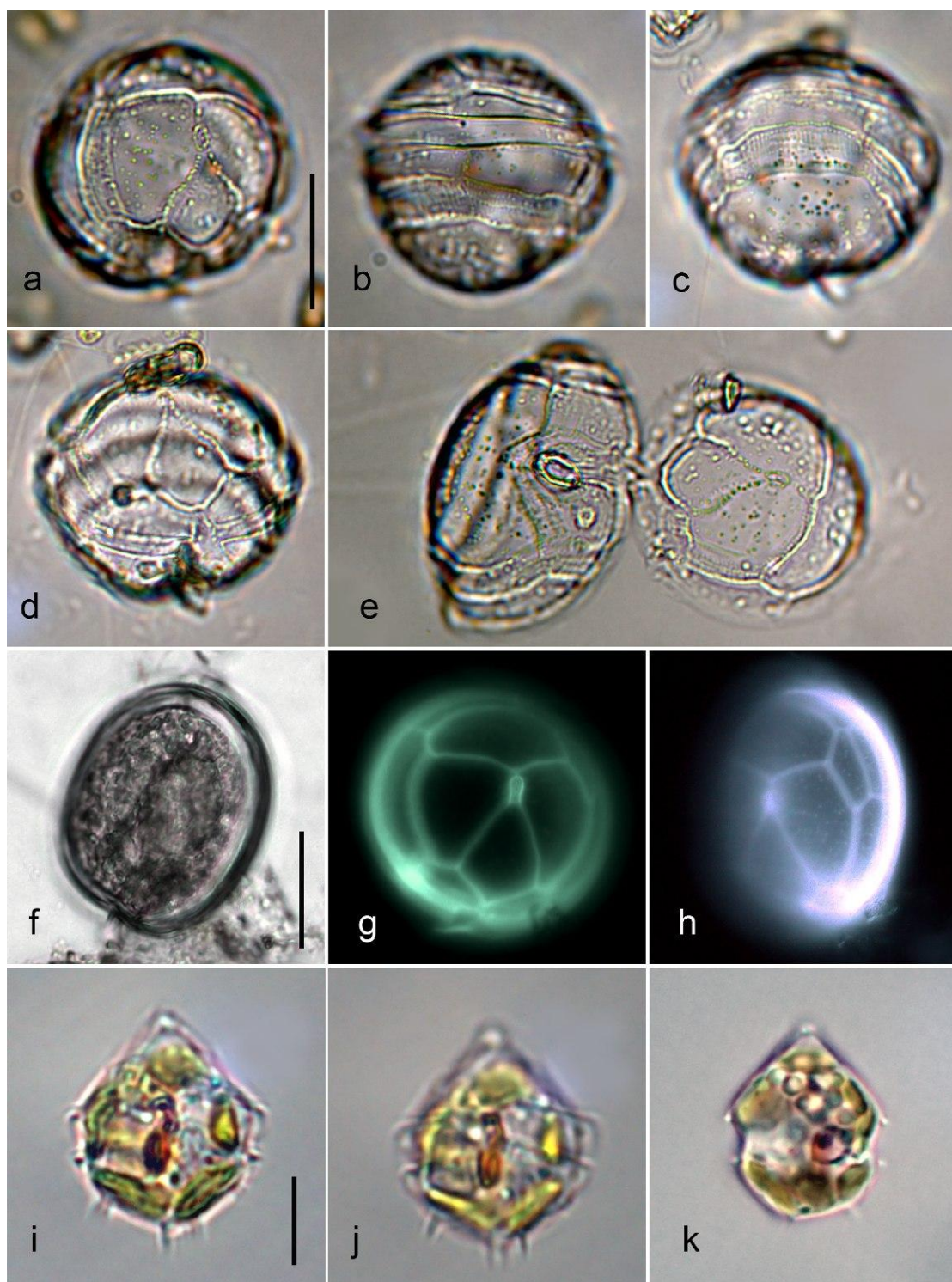


Plate A117. *Diplopsalis lenticula* (a-e); *Diplopelta steinii* (f-h); *Peridinium quinquecorne* (i-k).
 a-e, i-k – LM, BF; f – PhC, BF; g, h – LM, epifluorescence. Scale bars: a-h – 20 μm ; i-k – 10 μm .

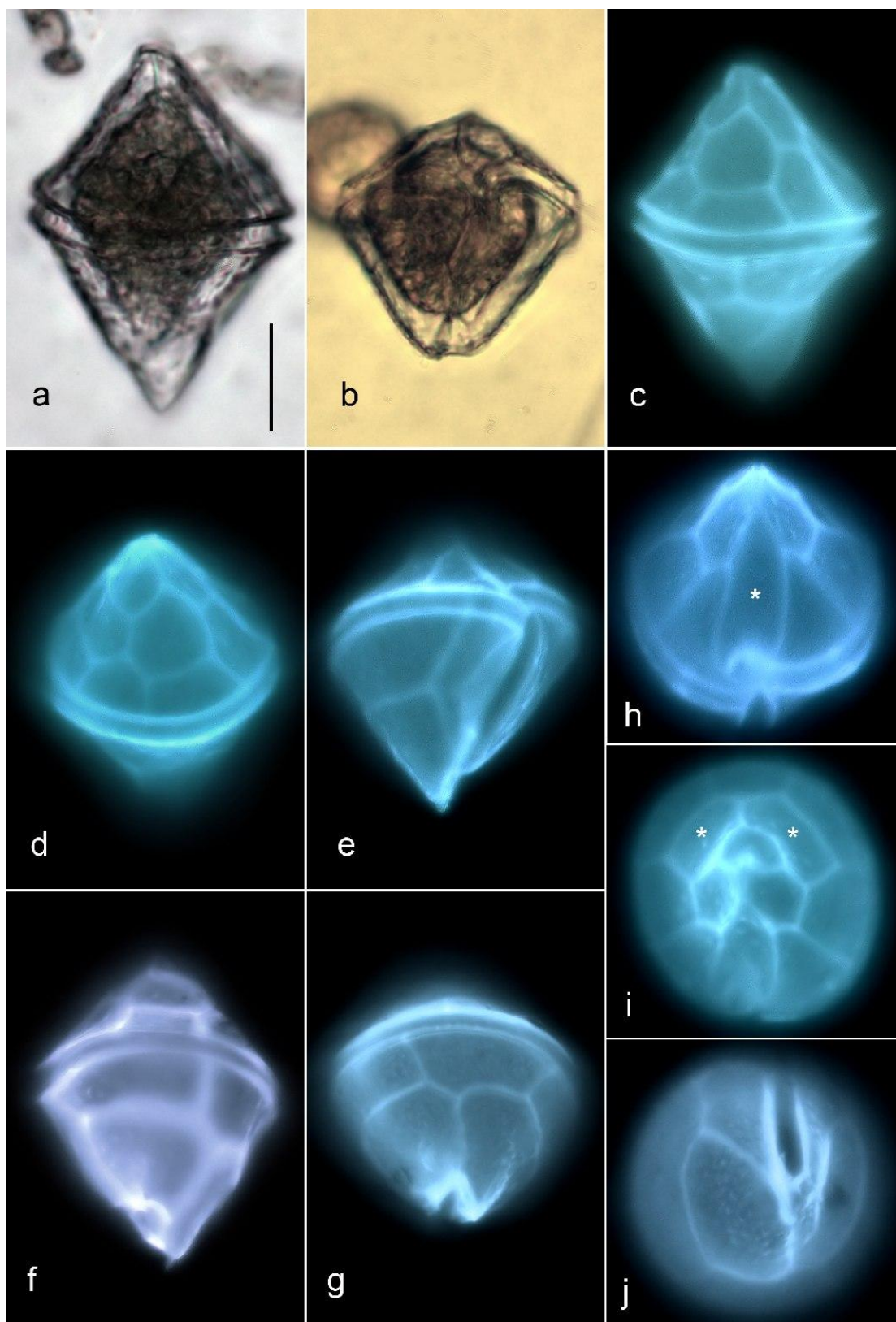


Plate A118. *Protoperidinium abei* (a-j).

h – plate 1' is indicated by asterisk; i – plates 1a and 2a are indicated by asterisks.

a, b – PhC, BF; c-j – LM, epifluorescence. Scale bar – 20 μ m.

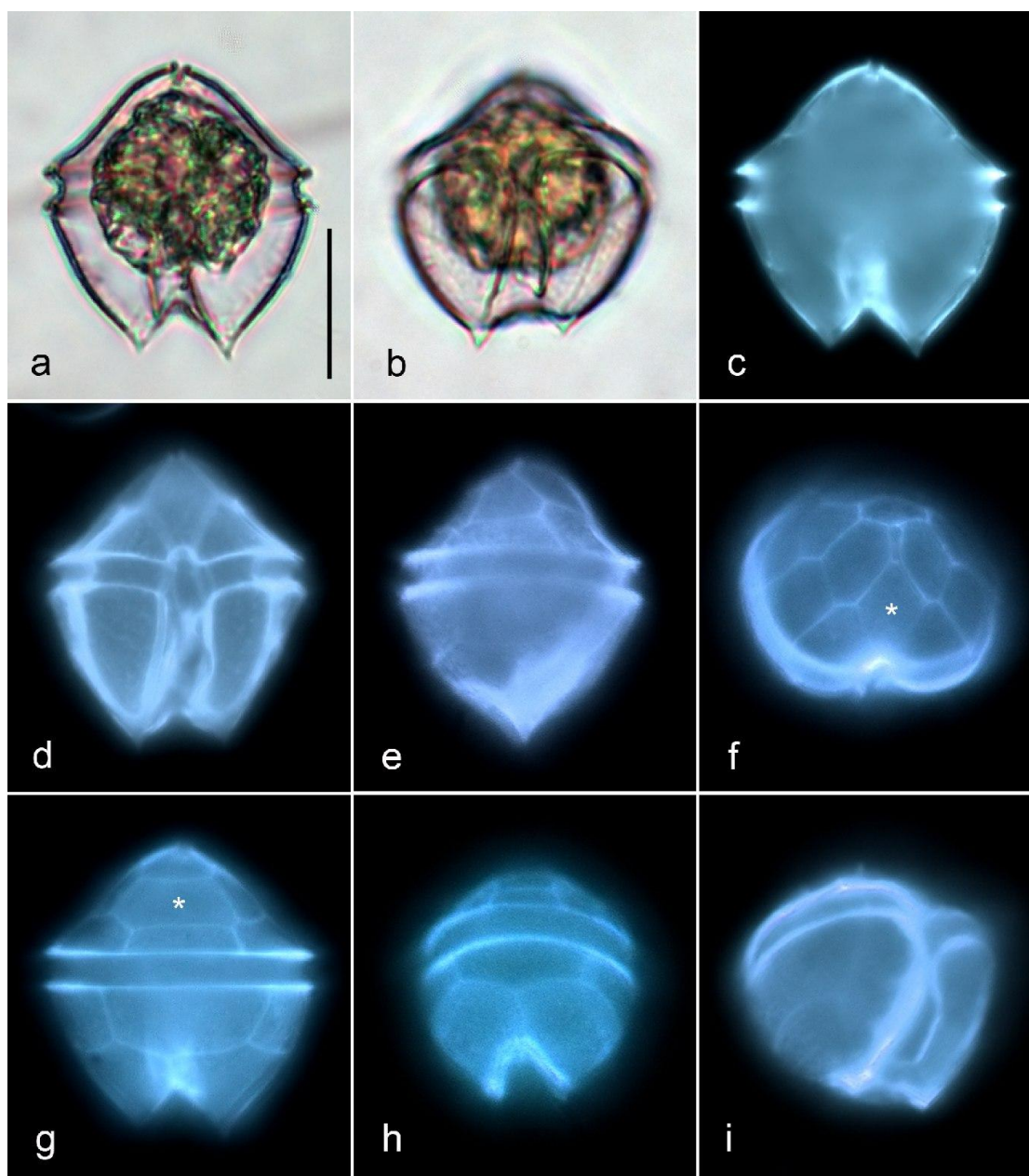


Plate A119. *Protoperidinium* cf. *achromaticum* (a-i).

f – plate 1' is indicated by asterisk; g – plate 2a is indicated by asterisk.

a, b – PhC, BF; c-i – LM, epifluorescence. Scale bar – 20 μ m.

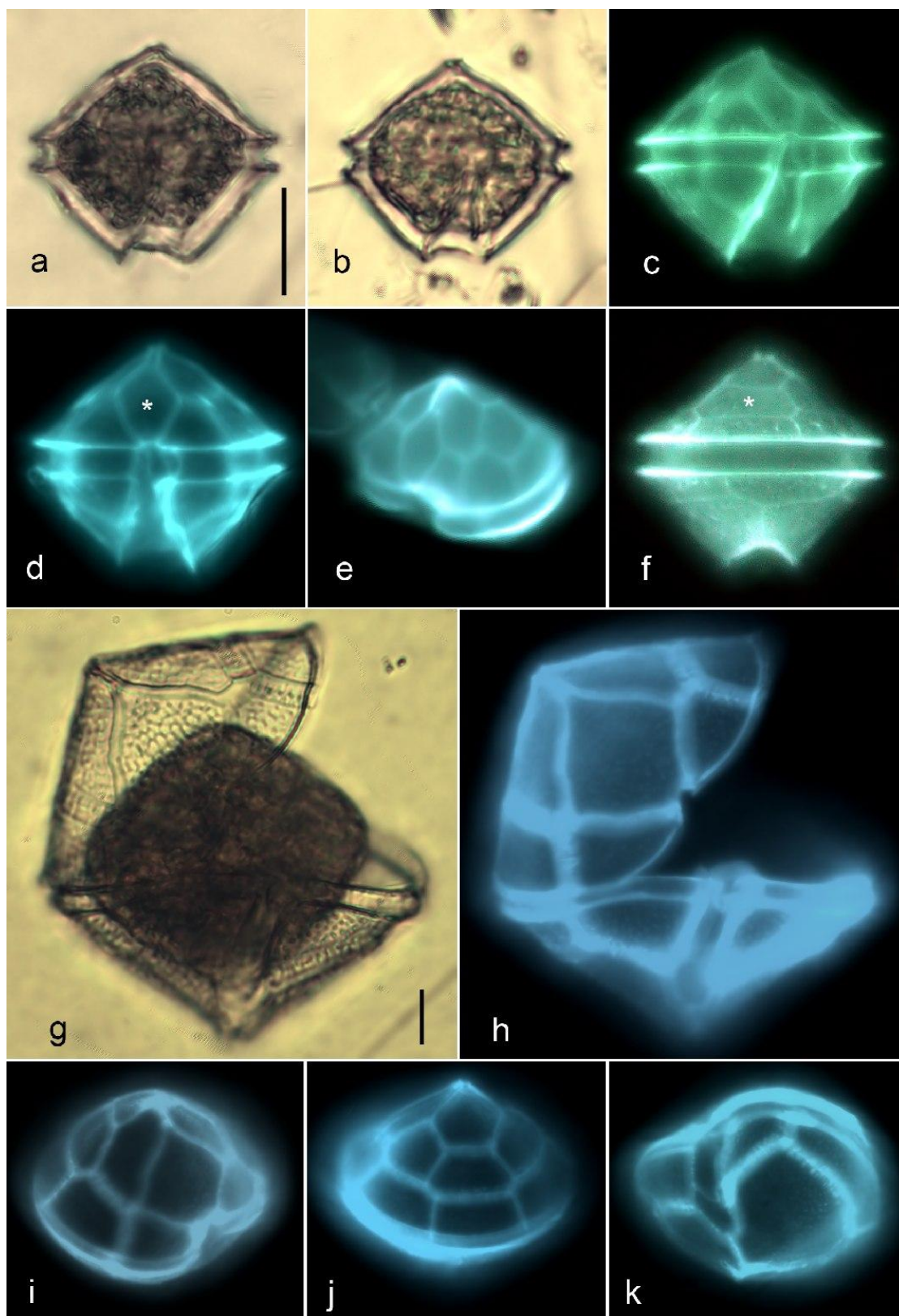


Plate A120. *Protoperidinium* sp. 1 (a-f); *Protoperidinium biconicum* (g-k).
d – plate 1' is indicated by asterisk; f – plate 2a is indicated by asterisk.
a, b, g – PhC, BF; c-f, h-k – LM, epifluorescence. Scale bars – 20 μm.

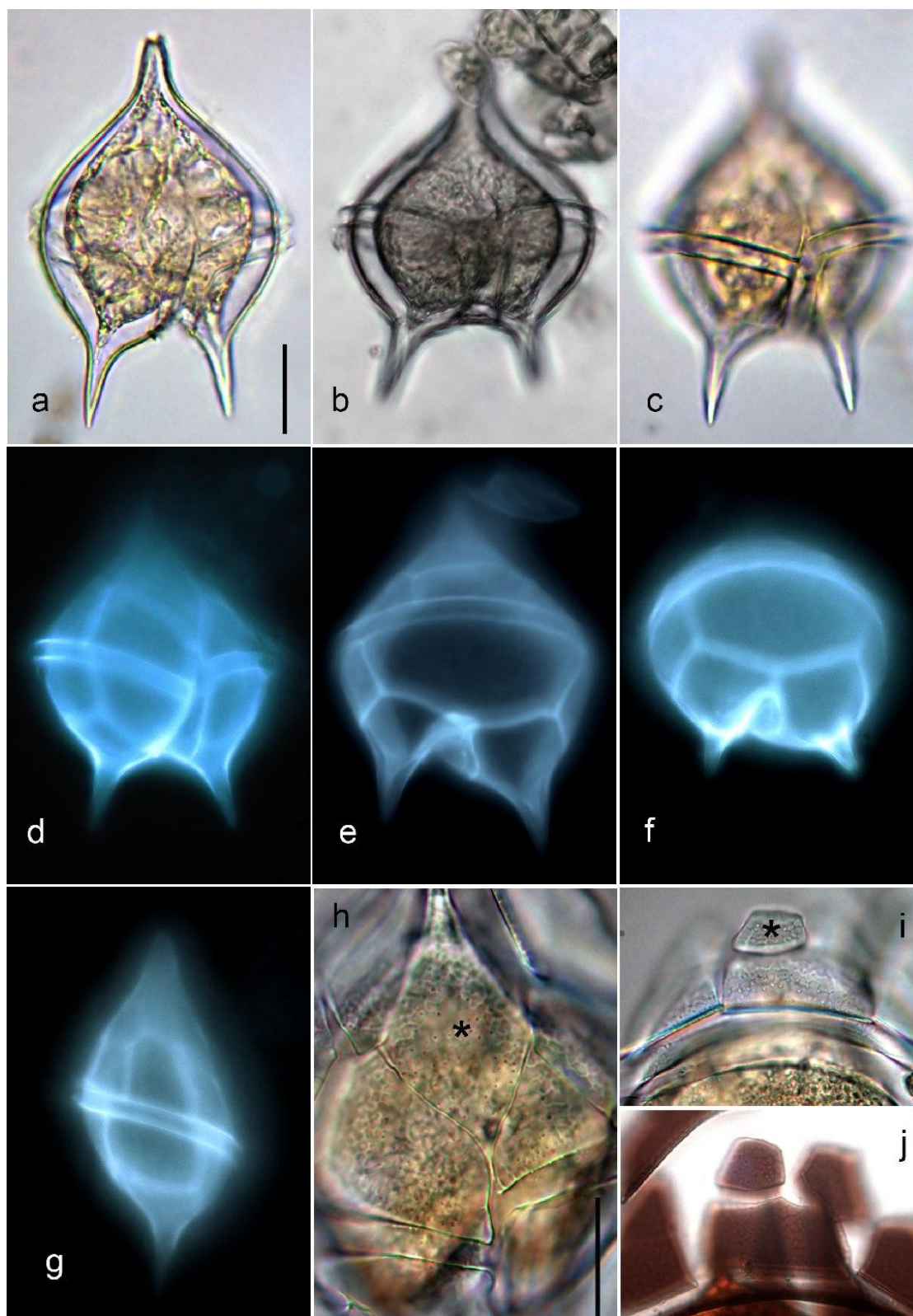


Plate A121. *Protoperidinium claudicans* (a-j).

h – plate 1' is indicated by asterisk; i – plate 2a is indicated by asterisk.

a, c, h-j – LM, BF; b – PhC, BF; d-g – LM, epifluorescence. Scale bars – 20 μ m.

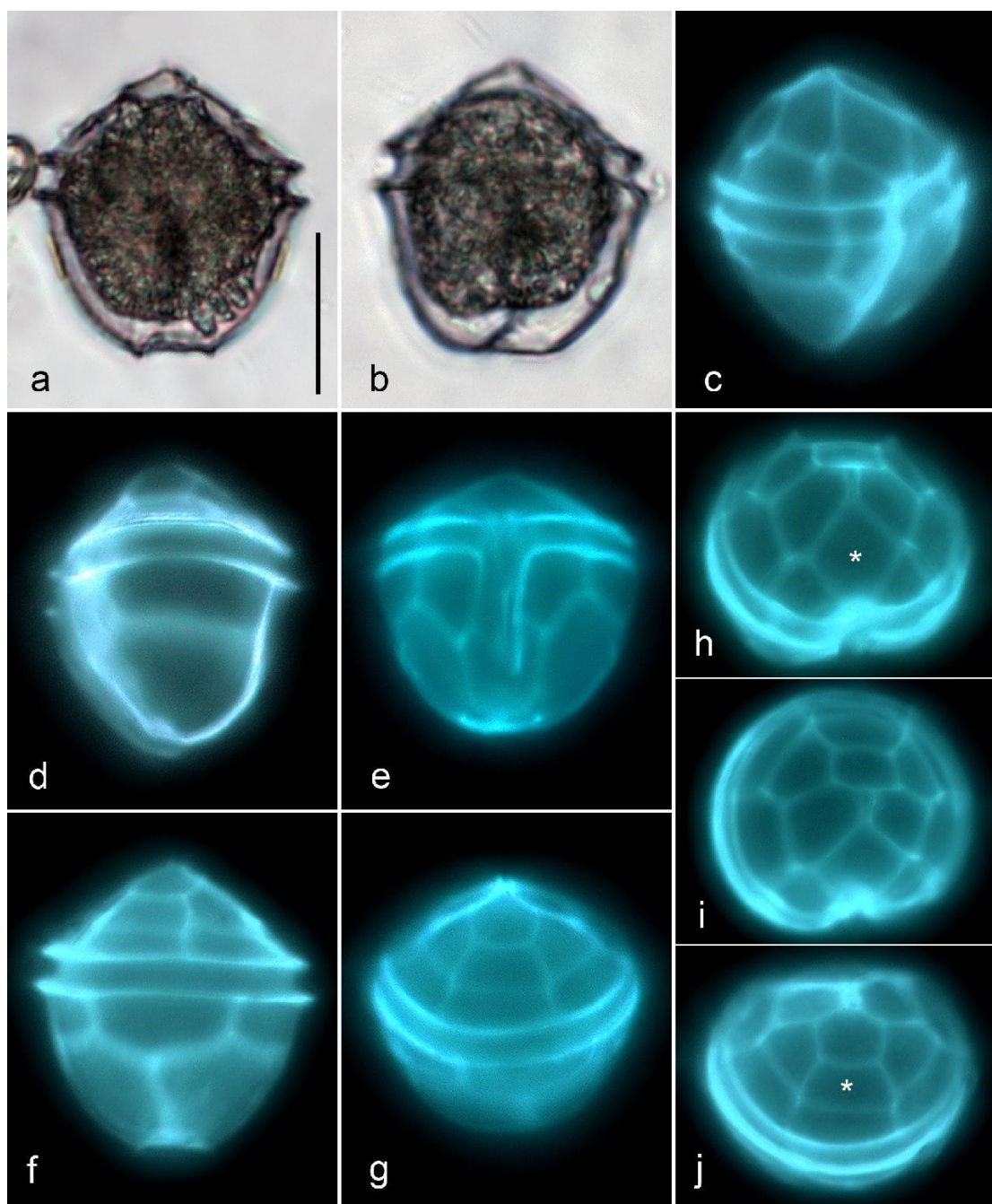


Plate A122. *Protoperidinium conicoides* (a-j).
h – plate 1' is indicated by asterisk; j – plate 2a is indicated by asterisk.
a, b – PhC, BF; c-j – LM, epifluorescence. Scale bar – 20 μ m.

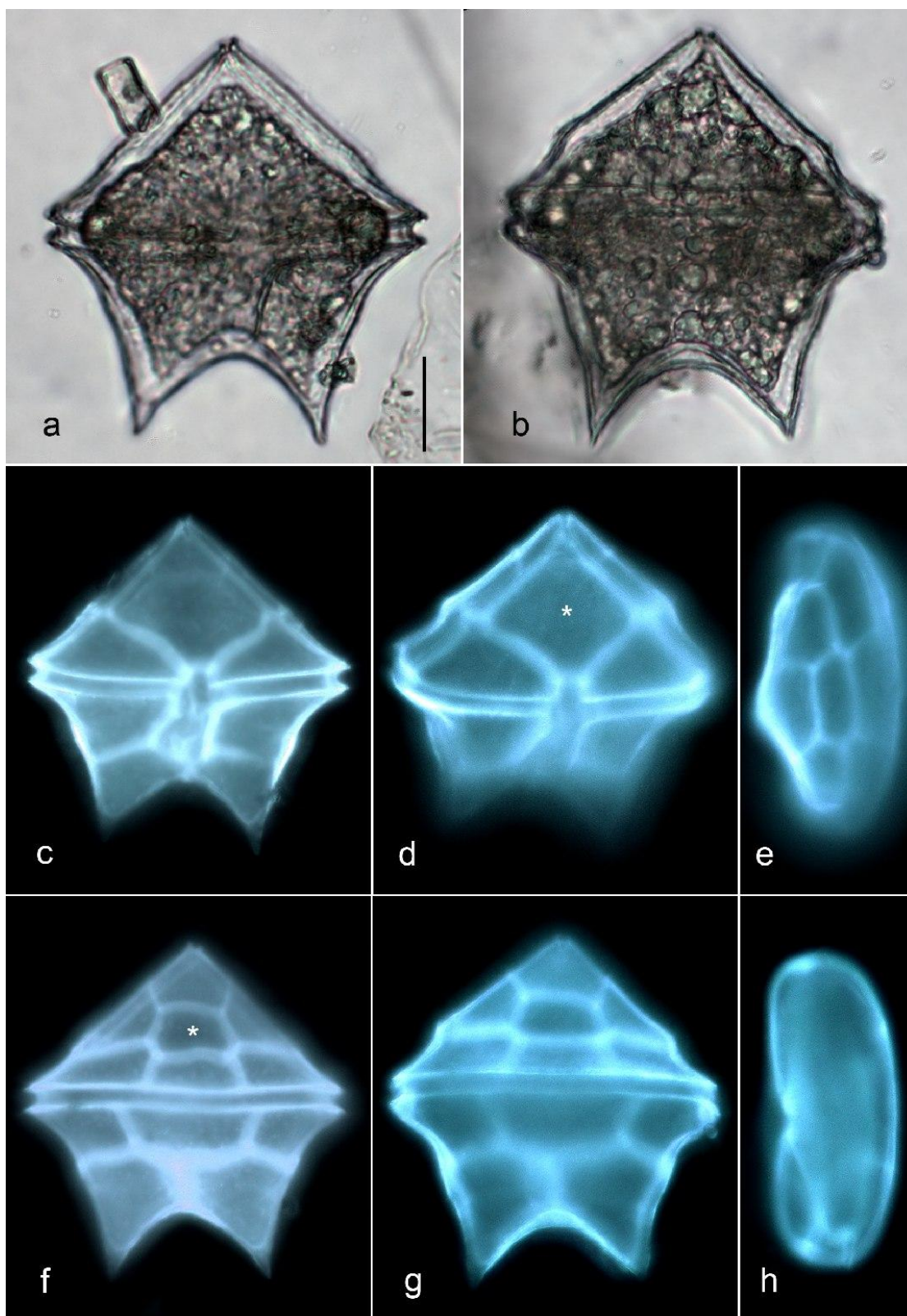


Plate A123. *Protoperidinium conicum* var. *conicum* (a-h).
d – plate 1' is indicated by asterisk; f – plate 2a is indicated by asterisk.
a, b – PhC, BF; c-h – LM, epifluorescence. Scale bar – 20 μ m.

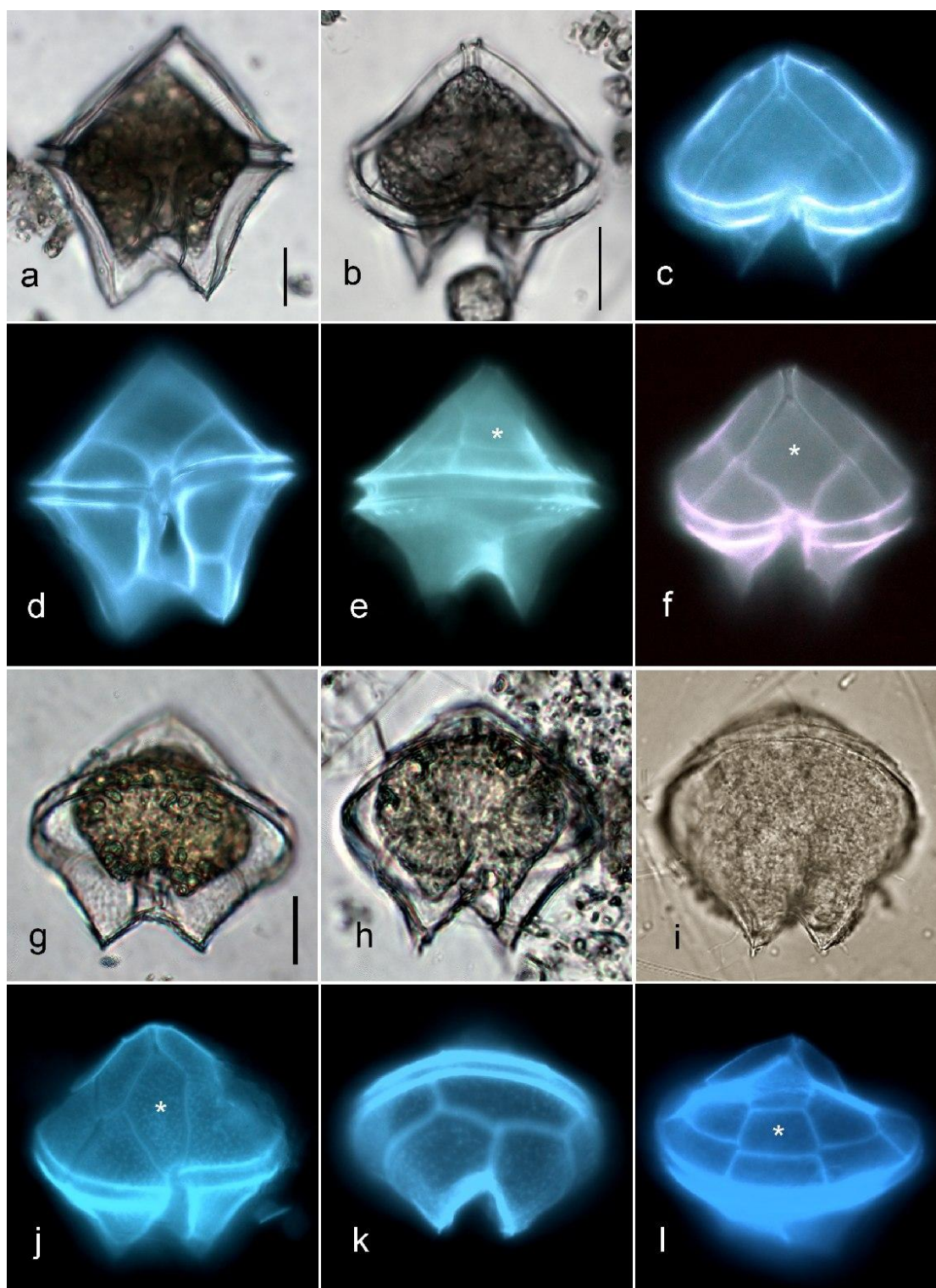


Plate A124. *Protoperidinium conicum* var. *quardafuianum* (a, d); *Protoperidinium conicum* var. *concavum* (b, c, e, f); *Protoperidinium leonis* (g-l).

f, j – plates 1' are indicated by asterisks; e, l – plates 2a are indicated by asterisks.

a, b, g-i – PhC, BF; c-f, j-l – LM, epifluorescence. Scale bars – 20 μ m.

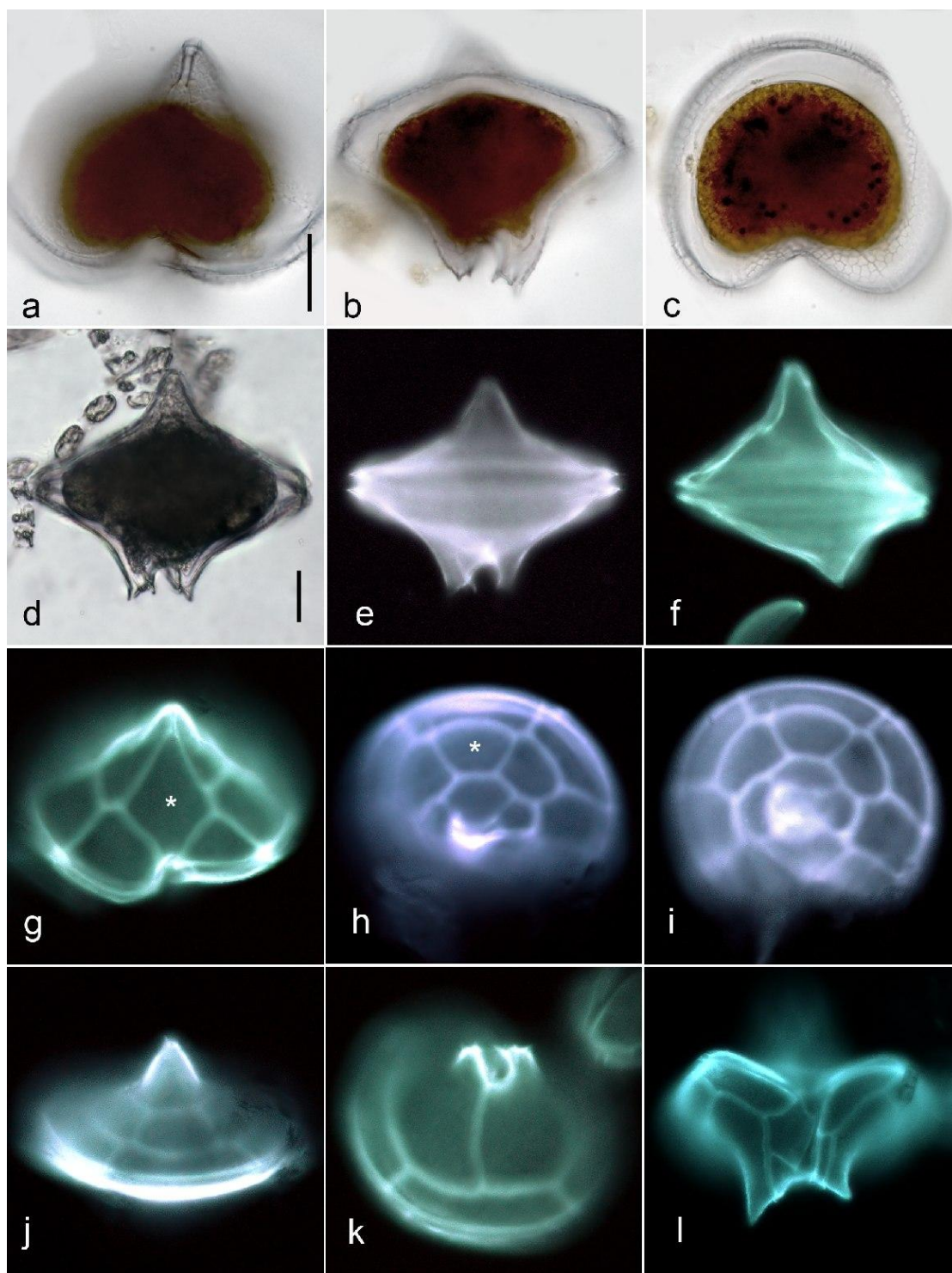


Plate A125. *Protoperidinium curtipes* (a-l).

g – plate 1' is indicated by asterisk; h – plate 2a is indicated by asterisk.

a-c – LM, BF; d – PhC, BF; e-l – LM, epifluorescence. Scale bars – 20 μm .

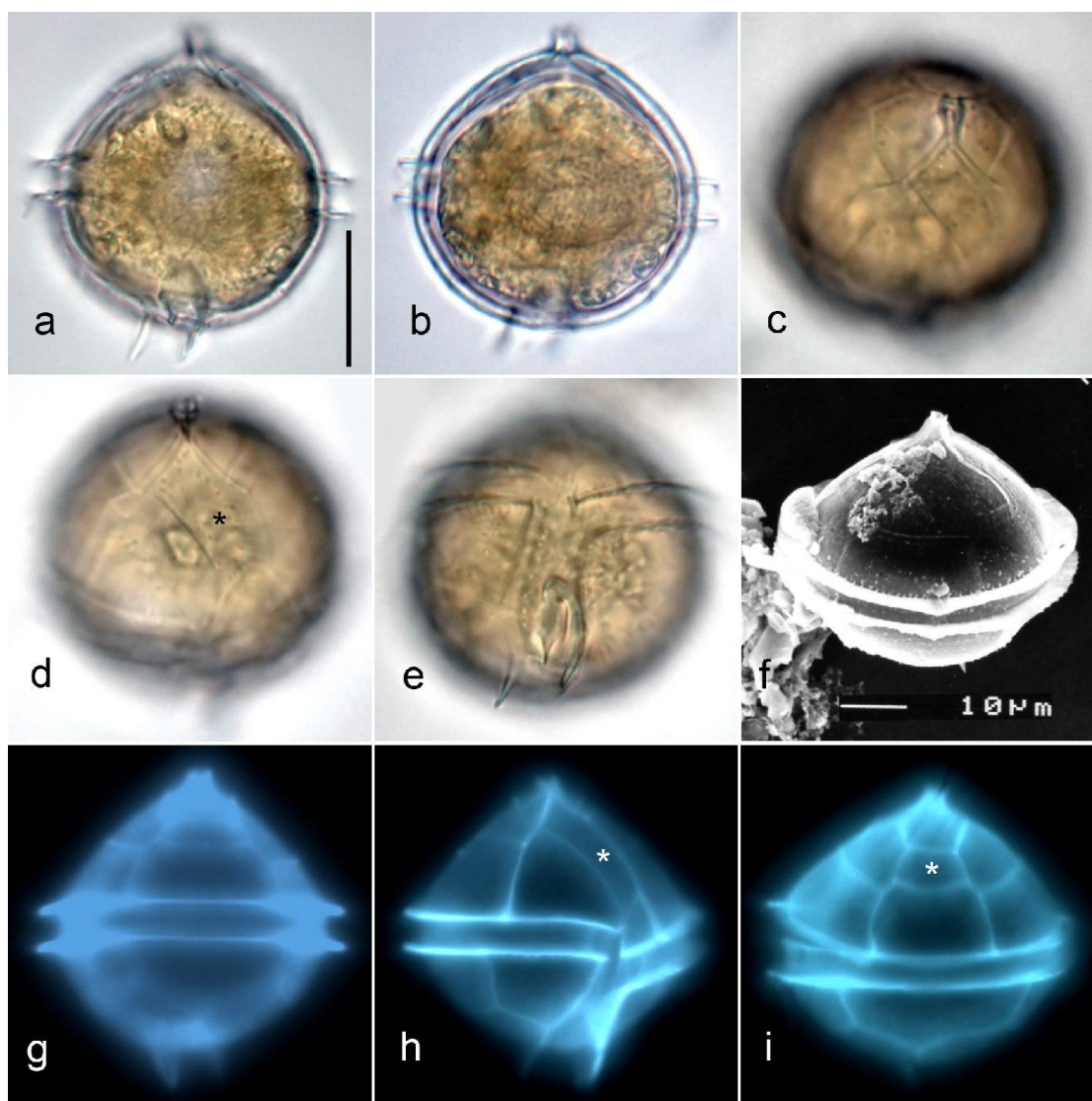


Plate A126. *Protoperidinium curvipes* (a-i).

h – plate 1' is indicated by asterisk; i – plate 2a is indicated by asterisk.

a-e – LM, BF; f – SEM; g-i – LM, epifluorescence. Scale bars: a-e, g-i – 20 μm; f – 10 μm.

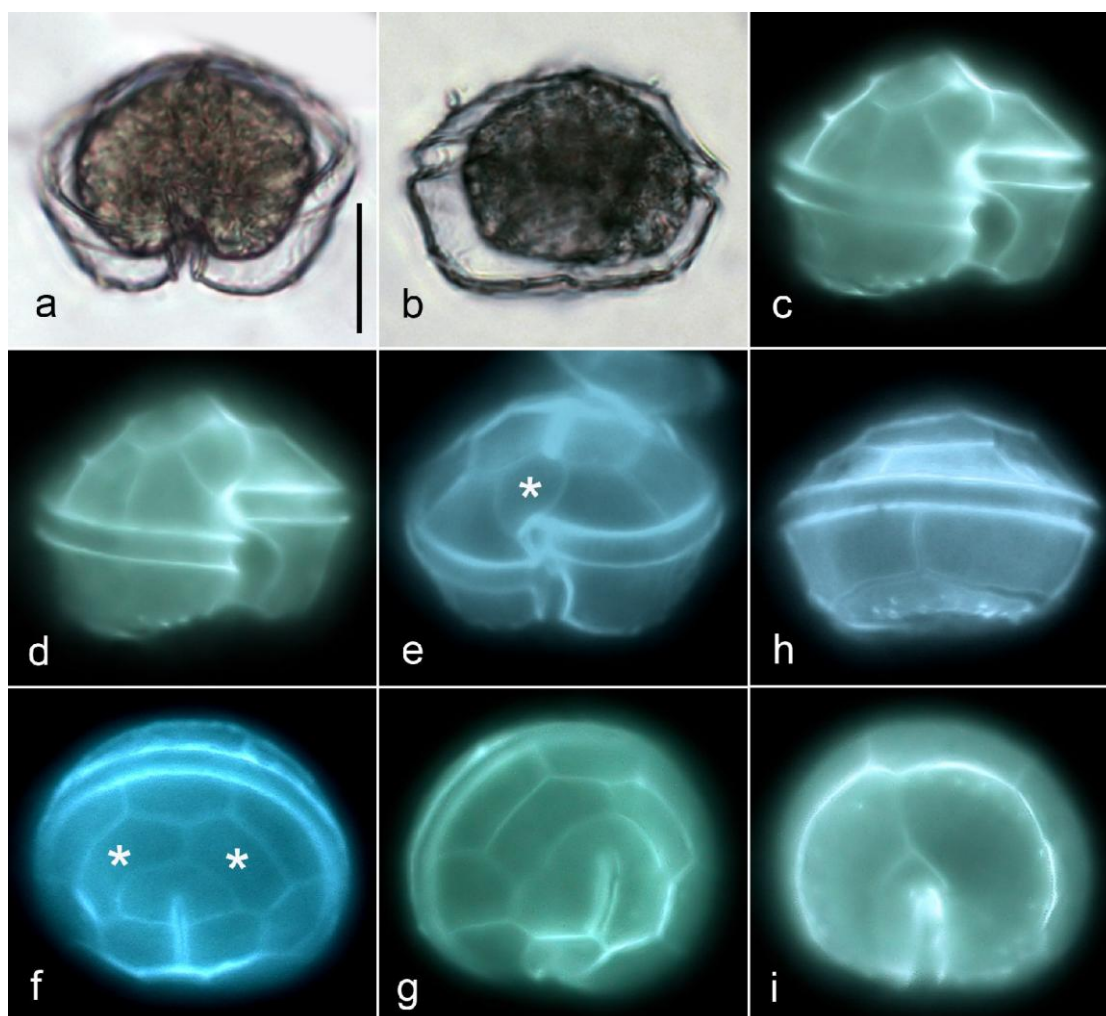


Plate A127. *Protoperidinium denticulatum* (a-i).

e – plate 1' is indicated by asterisk; f – plates 1a and 2a are indicated by asterisks.

a, b – PhC, BF; c-i – LM, epifluorescence. Scale bar – 20 μm .

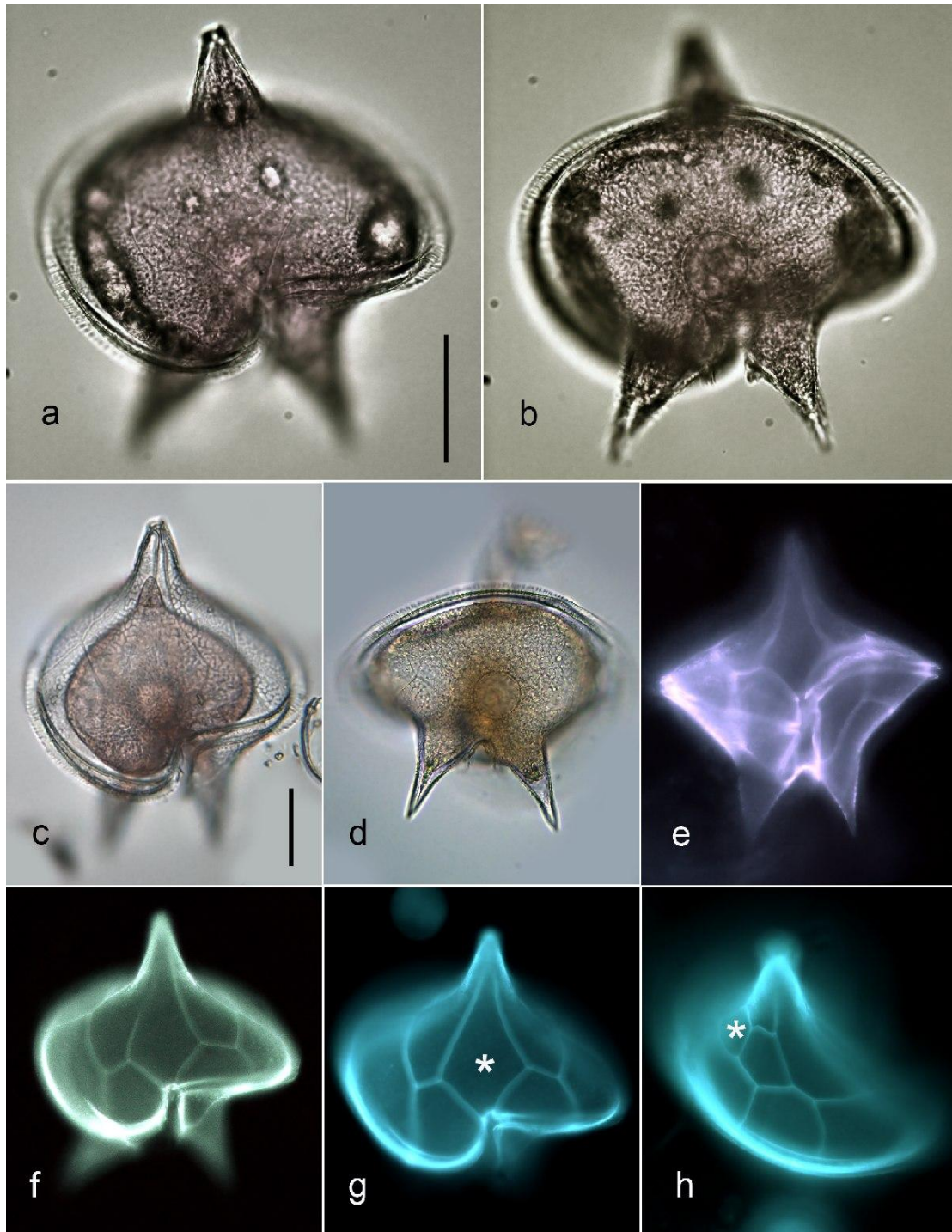


Plate A128. *Protoperidinium depressum* (a-h).
g – plate 1' is indicated by asterisk; h – plate 2a is indicated by asterisk.
a-d – LM, BF; e-h – LM, epifluorescence. Scale bars – 50 μm.

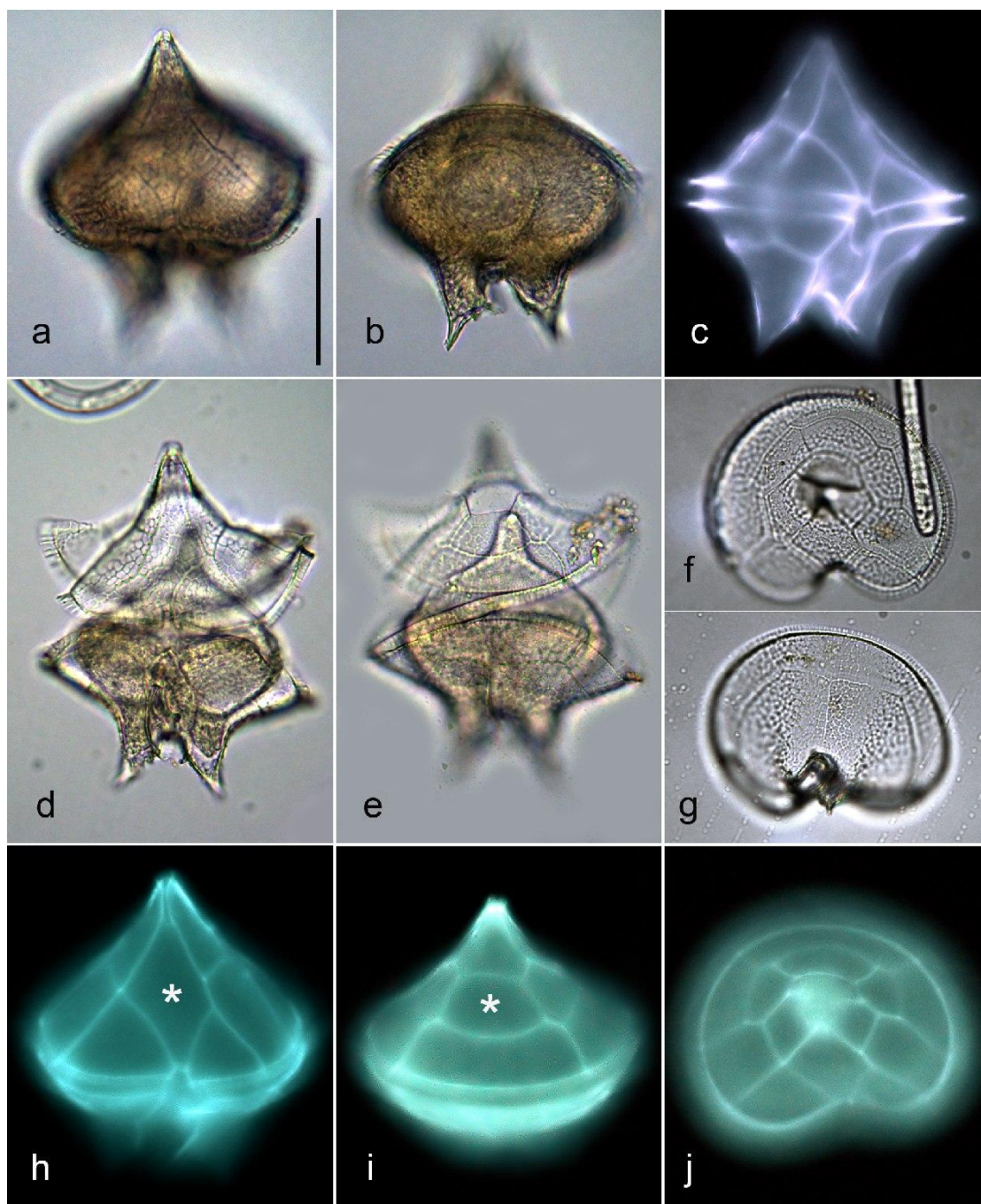


Plate A129. *Protoperidinium divergens* (a-j).

h – plate 1' is indicated by asterisk; i – plate 2a is indicated by asterisk.

a, b, d-g – LM, BF; c, h-j – LM, epifluorescence. Scale bar – 40 μ m.

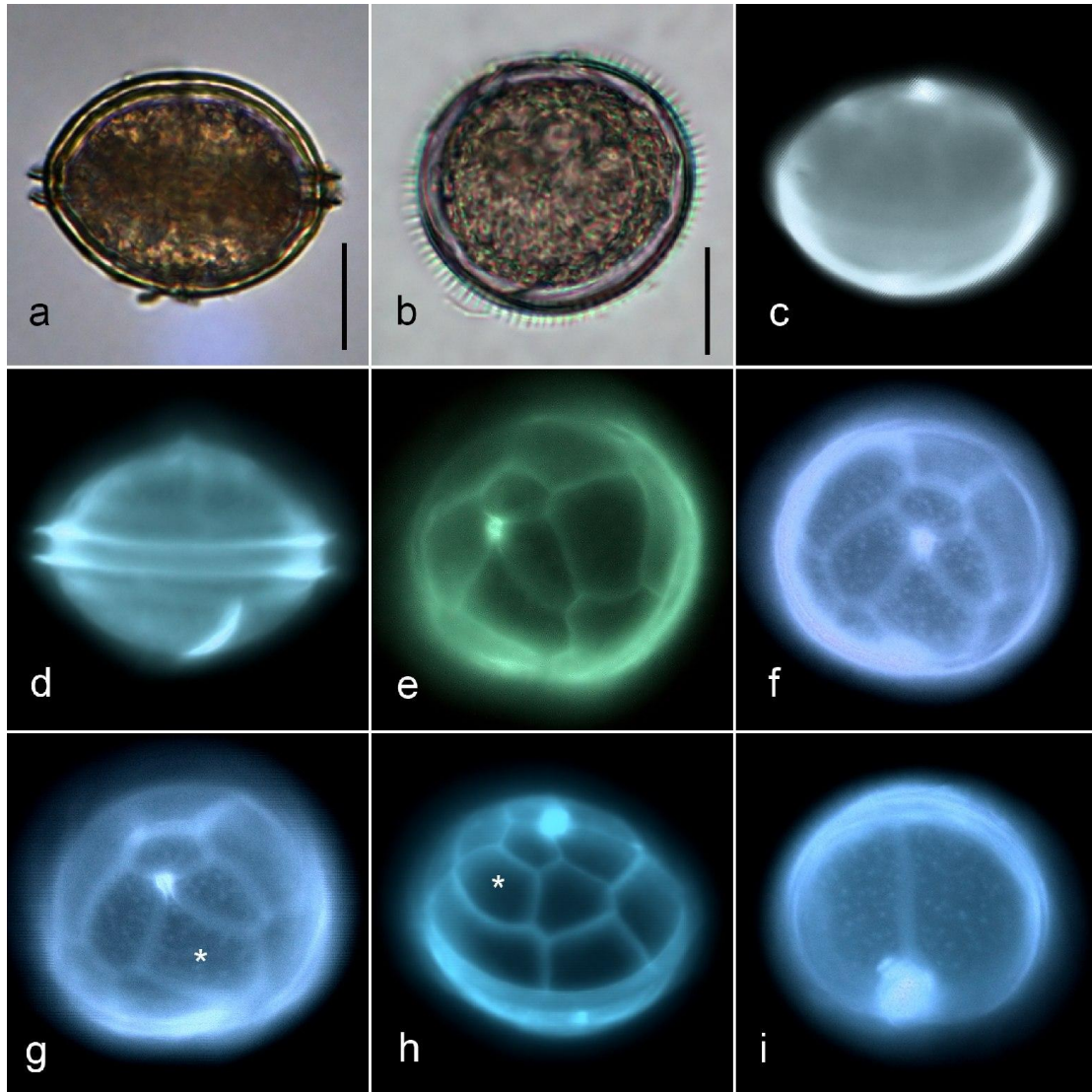


Plate A130. *Protoperidinium globulus* (a-i).

g – plate 1' is indicated by asterisk; h – plate 2a is indicated by asterisk.

a, b – LM, BF; c-i – LM, epifluorescence. Scale bars – 20 μ m.

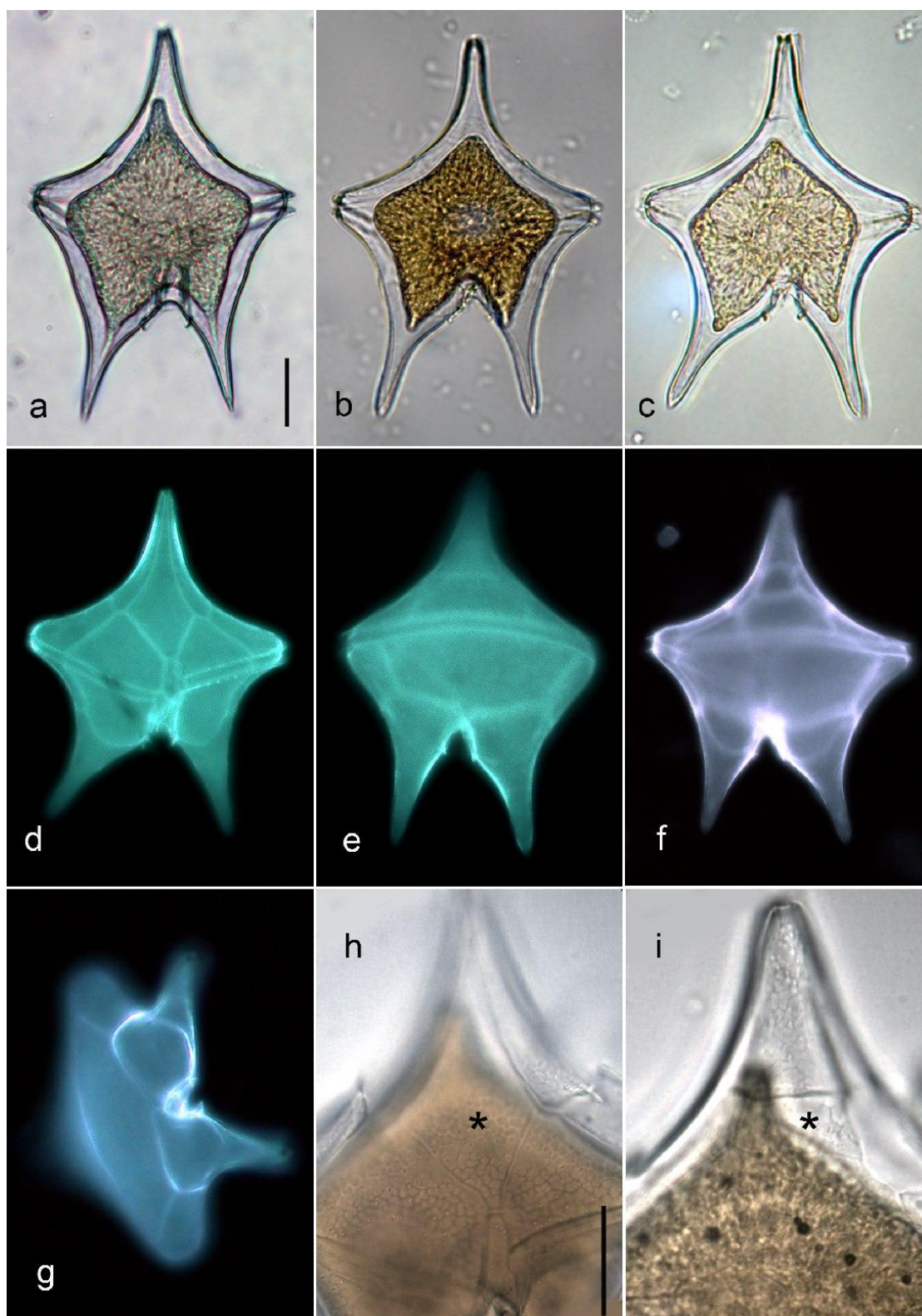


Plate A131. *Protoperidinium venustum* (a-i).

h – plate 1' is indicated by asterisk; i – plate 2a is indicated by asterisk.

a – PhC, BF; b, c, h, i – LM, BF; d-g – LM, epifluorescence. Scale bar – 20 μ m.

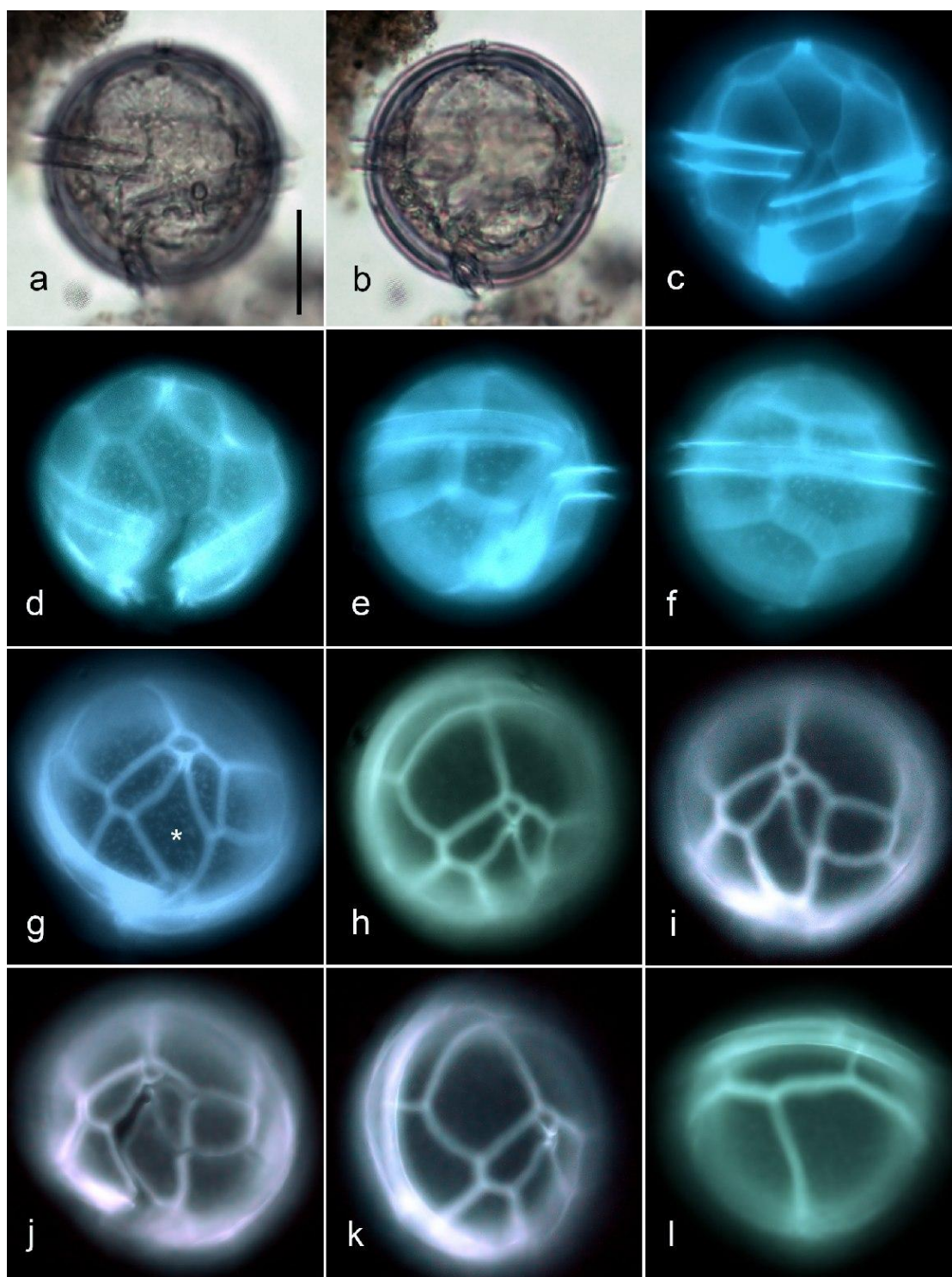


Plate A132. *Protoperidinium hamatum* (a-l).

g – plate 1' is indicated by asterisk.

a, b – PhC, BF; c-l – LM, epifluorescence. Scale bar – 20 μm .

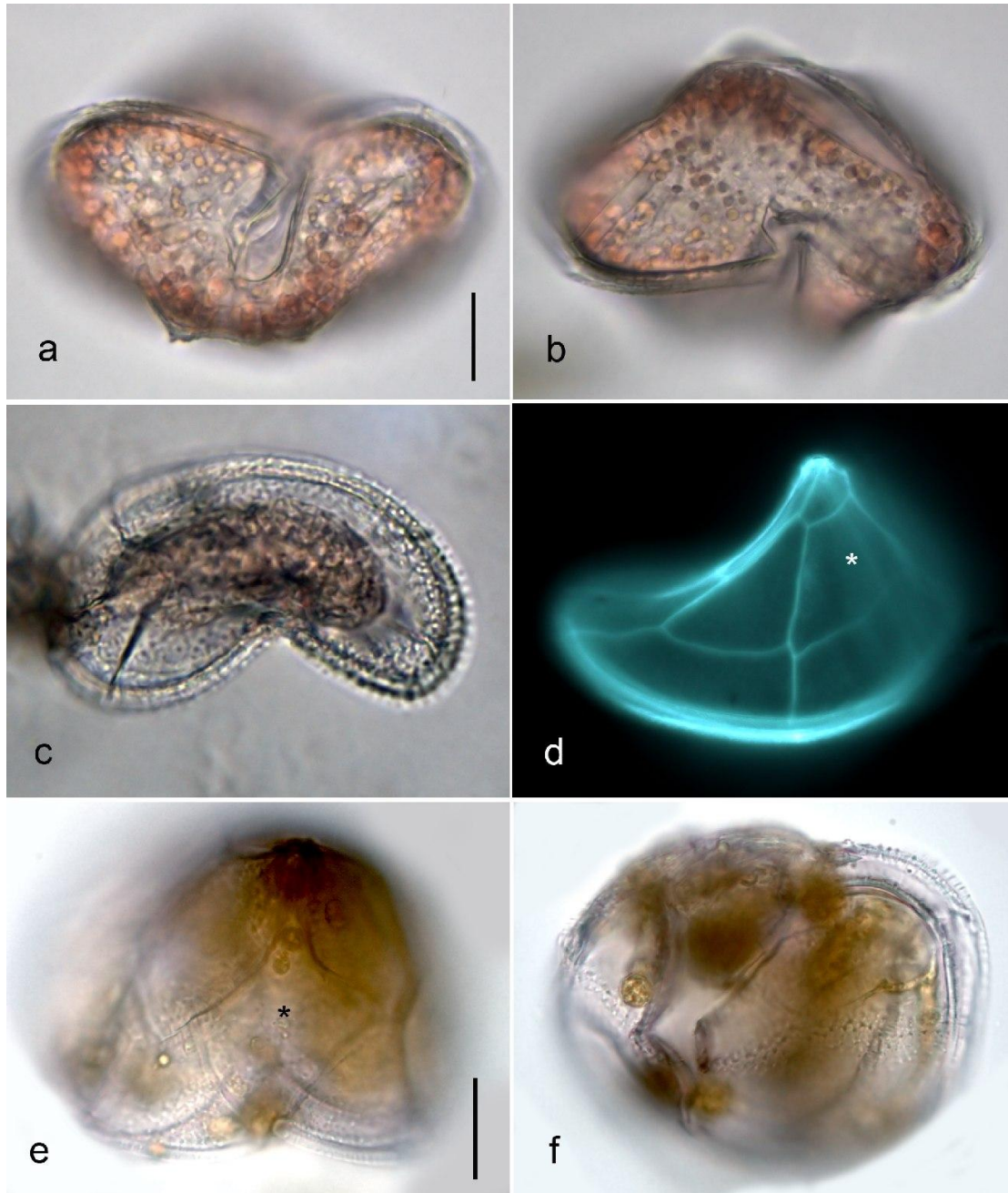


Plate A133. *Protoperidinium pentagonum* (a-d); *Protoperidinium latissimum* (e, f).
e – plate 1' is indicated by asterisk; d – plate 2a is indicated by asterisk.
a-c, e, f – LM, BF; d – LM, epifluorescence. Scale bars – 20 μm .

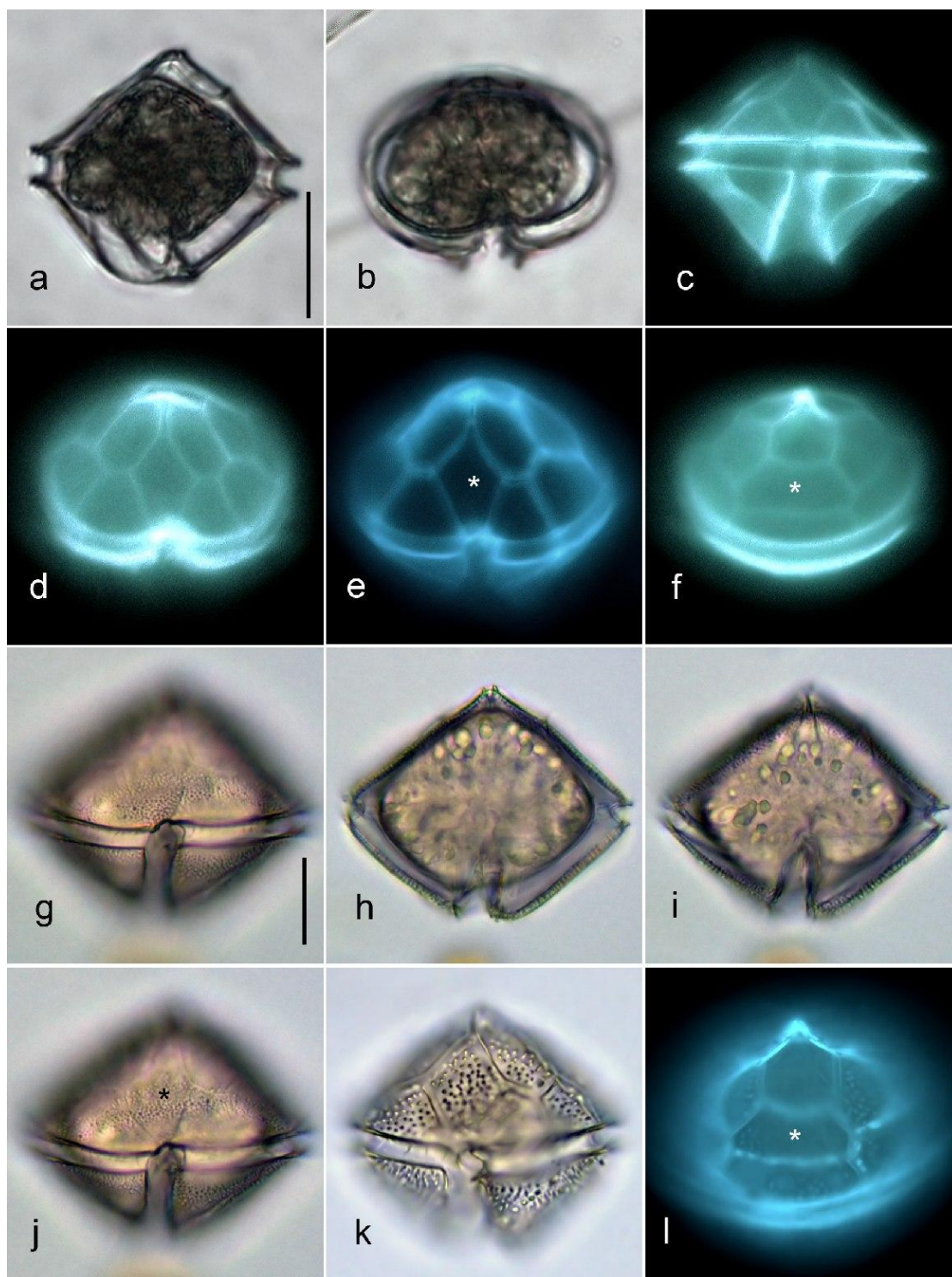


Plate A134. *Protoperidinium subinerme* (a-f); *Protoperidinium marielebourae* (g-l).
e, j – plates 1' are indicated by asterisks; f, l – plates 2a are indicated by asterisks.
a, b – PhC, BF; g-k – LM, BF; c-f, l – LM, epifluorescence. Scale bars – 20 μ m.

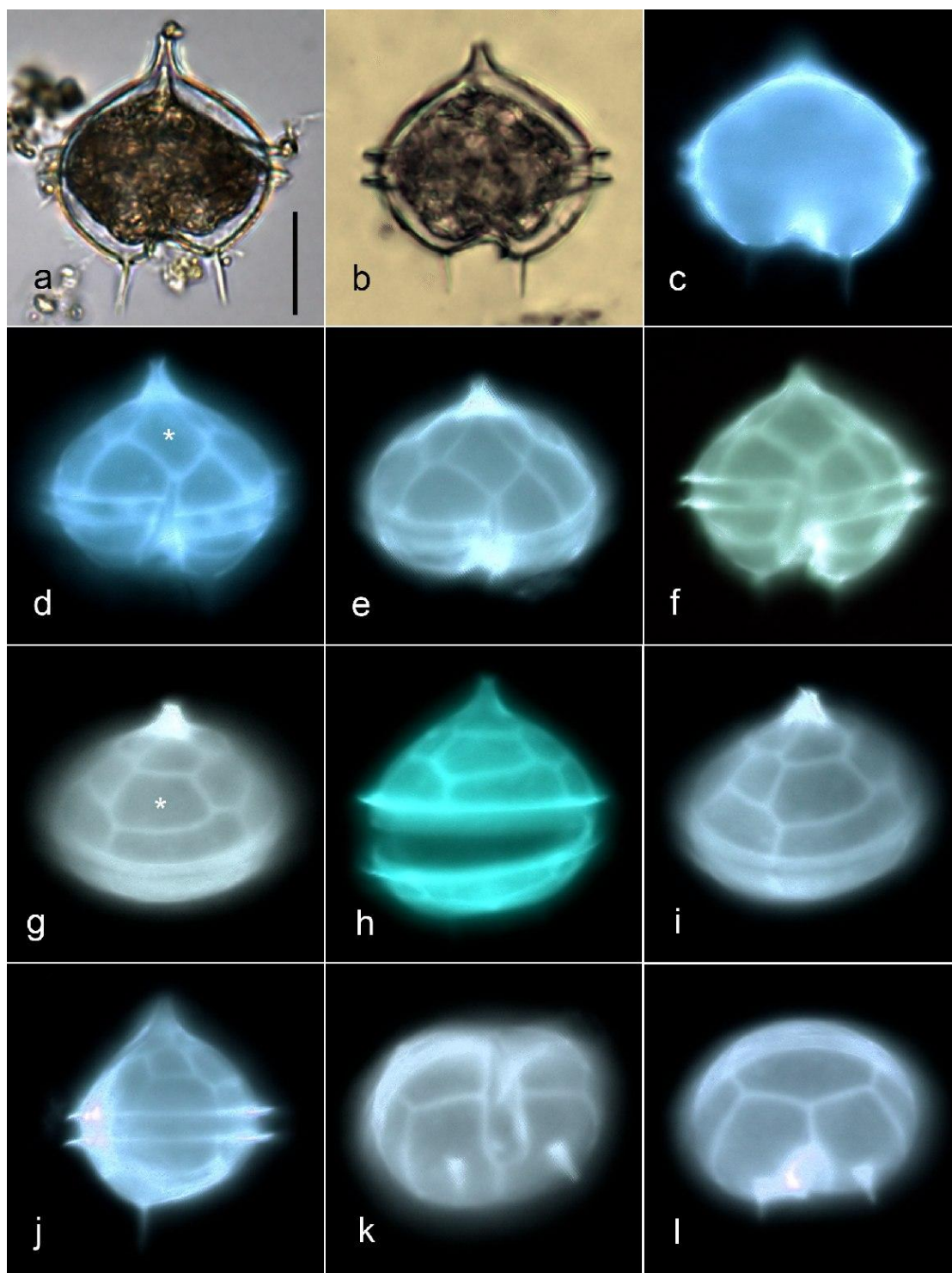


Plate A135. *Protoperidinium mite* (a-l).

d – plate 1' is indicated by asterisk; g – plate 2a is indicated by asterisk.

a – PhC, BF; c-l – LM, epifluorescence. Scale bar – 20 μ m.

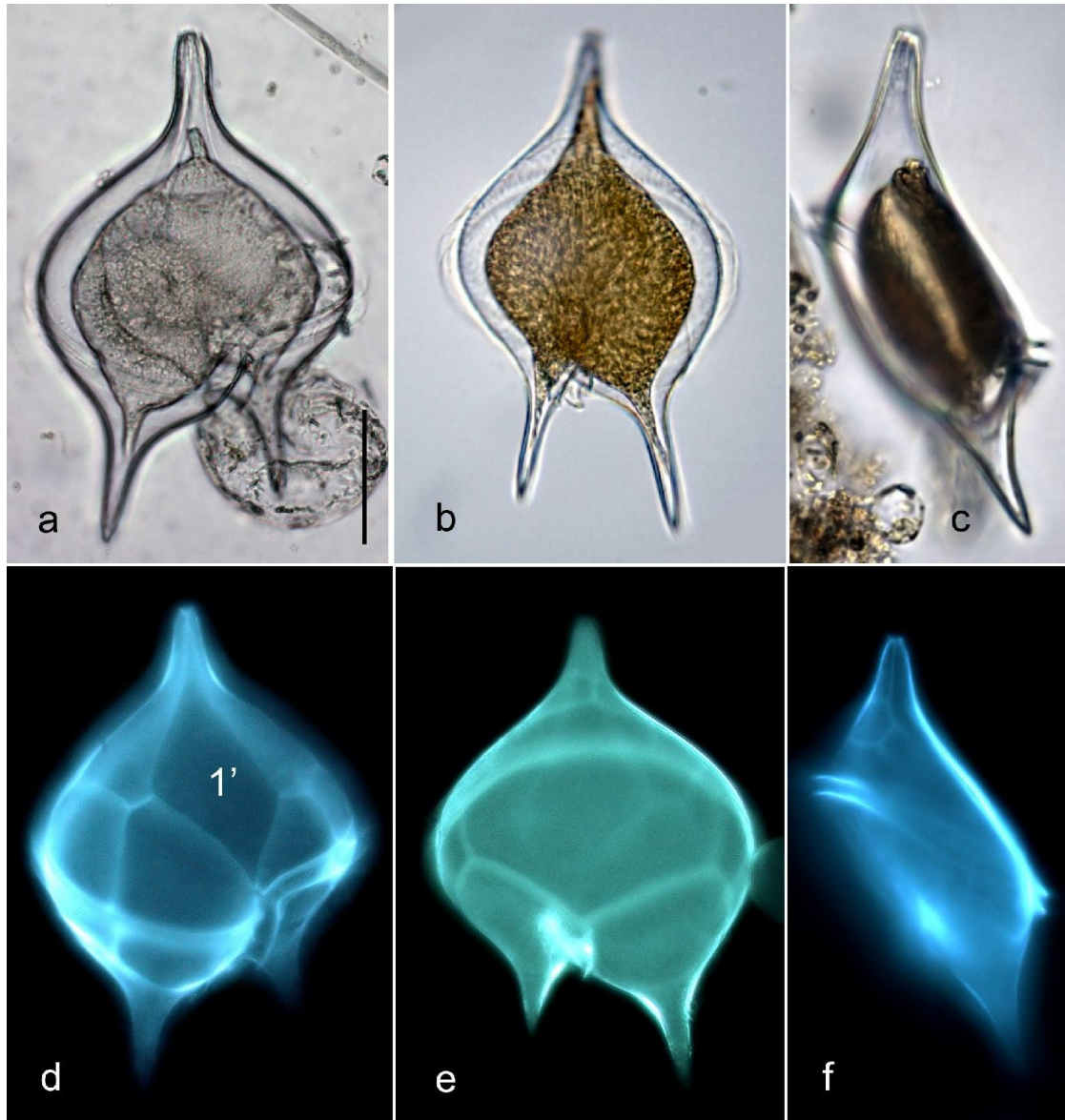


Plate A136. *Protoperidinium murrayi* (a-f).

a – PhC, BF; b, c – LM, BF; d-f – LM, epifluorescence. Scale bar – 50 μm .

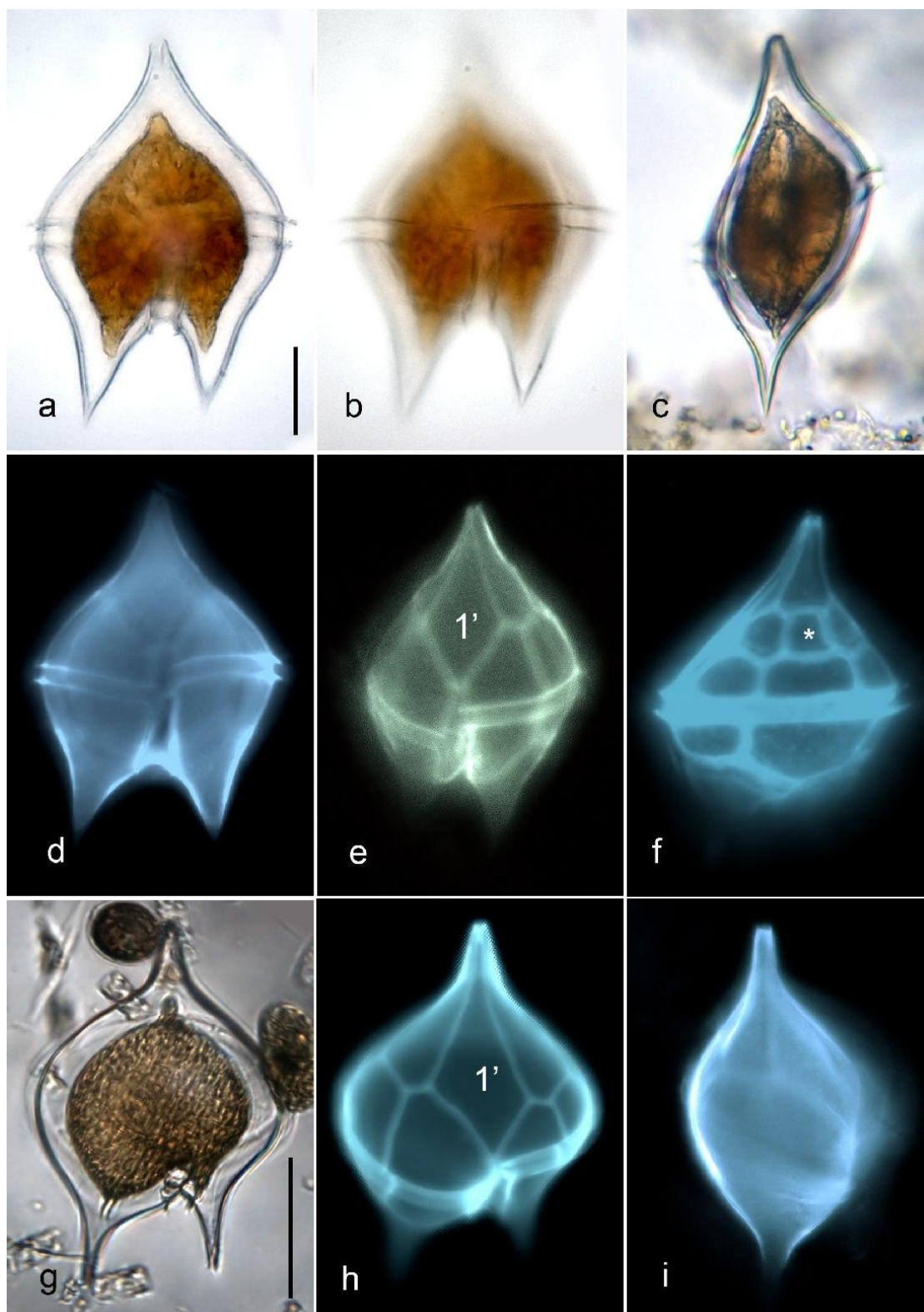


Plate A137. *Protoperidinium oblongum* (a-f); *Protoperidinium oceanicum* (g-i).
 f – plate 2a is indicated by asterisk.
 a-c, g – LM, BF; d-f, h, i – LM, epifluorescence. Scale bars: a-f – 20 μ m; g-i – 50 μ m.

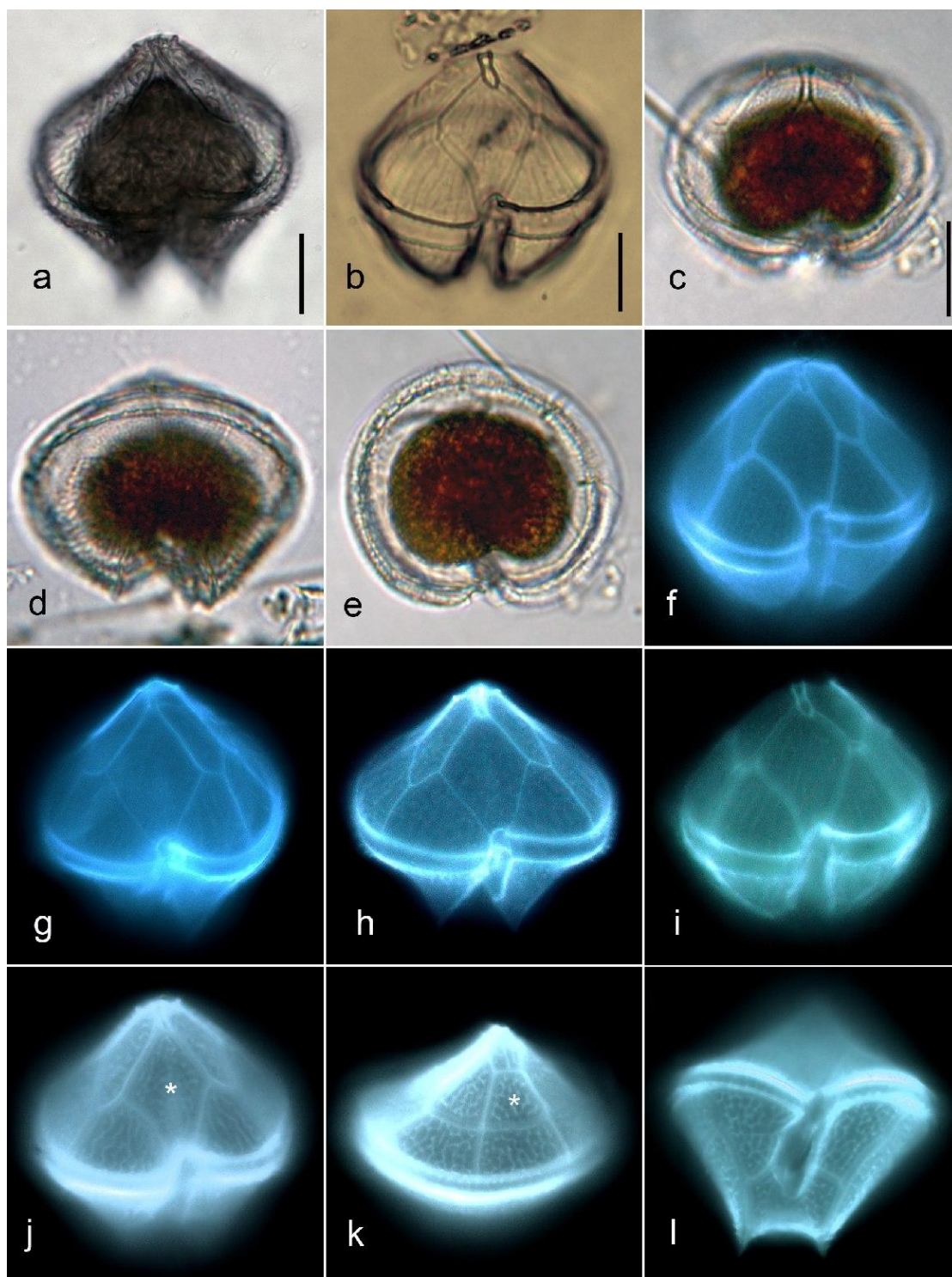


Plate A138. *Protoperidinium obtusum* (a-l).

j – plate 1' is indicated by asterisk; k – plate 2a is indicated by asterisk.

a, b – PhC, BF; c-e – LM, BF; f-l – LM, epifluorescence. Scale bars – 20 μ m.

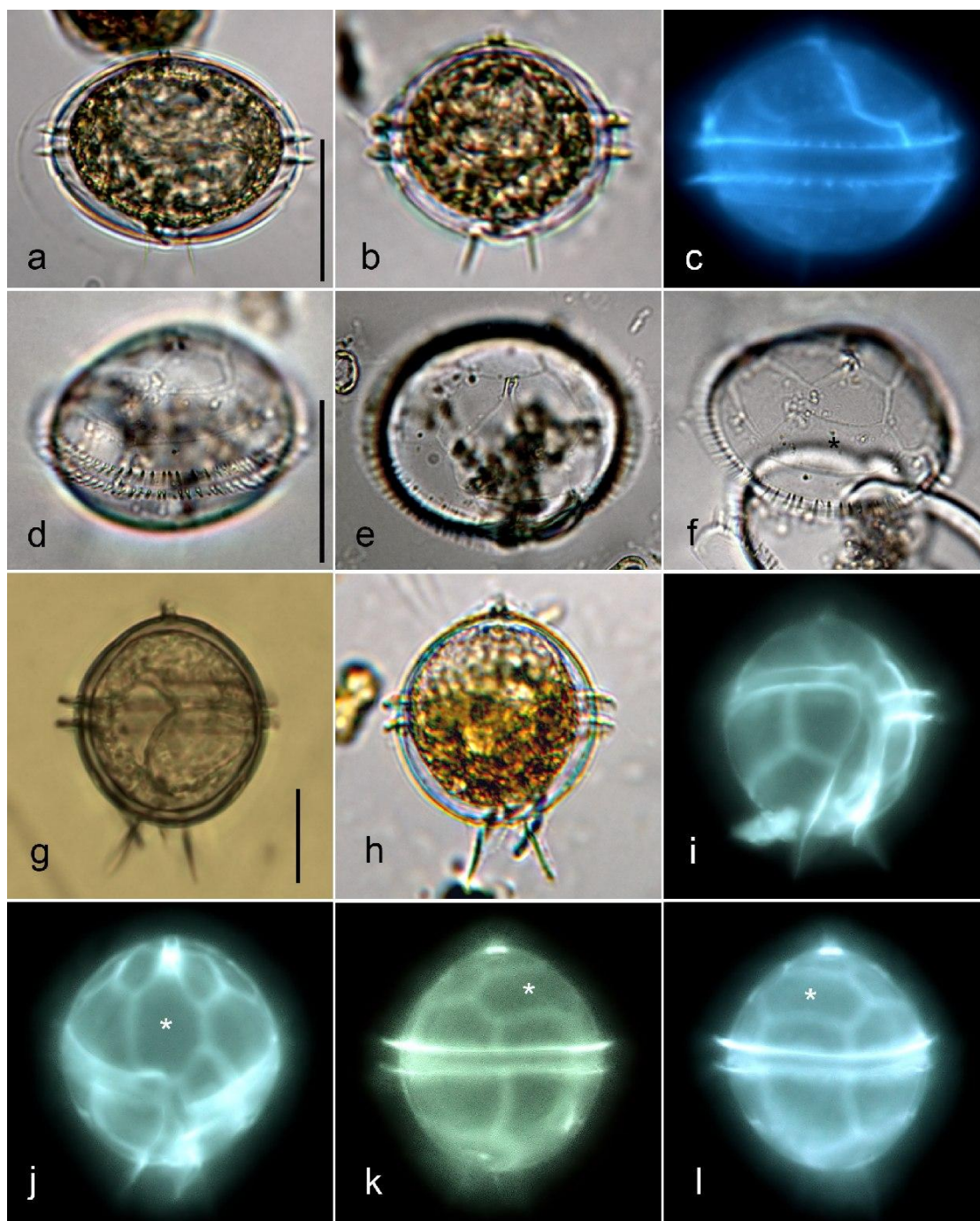


Plate A139. *Protoperidinium ovatum* (a-f); *Protoperidinium ovum* (g-l).
 j – plate 1' is indicated by asterisk; k, l – plates 2a are indicated by asterisks.
 a, b, d-f, h – LM, BF; g – PhC, BF; c, i-l – LM, epifluorescence. Scale bars – 20 μ m.

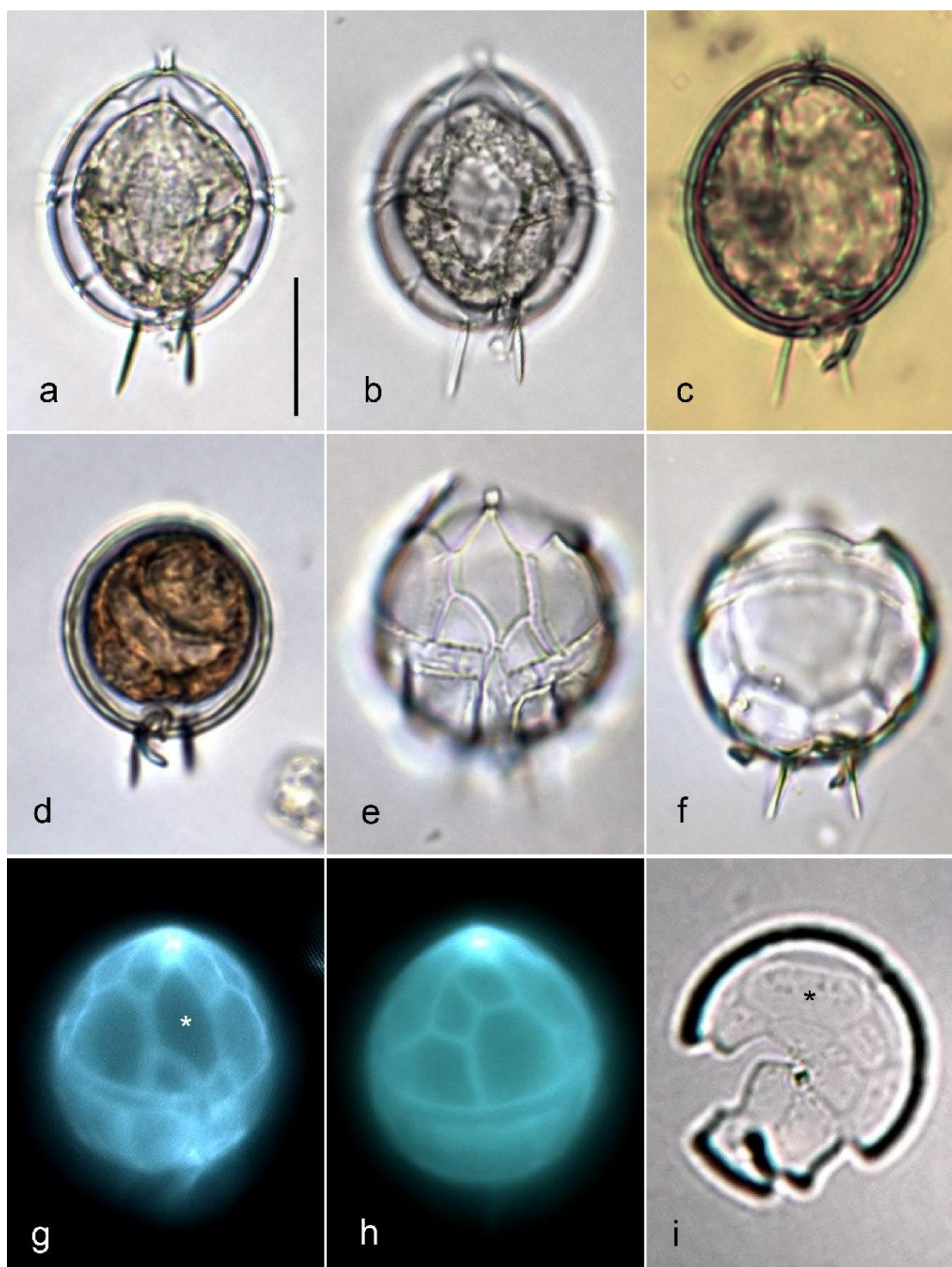


Plate A140. *Protoperidinium ovum* (a-i).

g – plate 1' is indicated by asterisk; i – plate 2a is indicated by asterisk.

a, b, e, f, i – LM, BF; c, d – PhC, BF; g, h – LM, epifluorescence. Scale bar – 20 μ m.

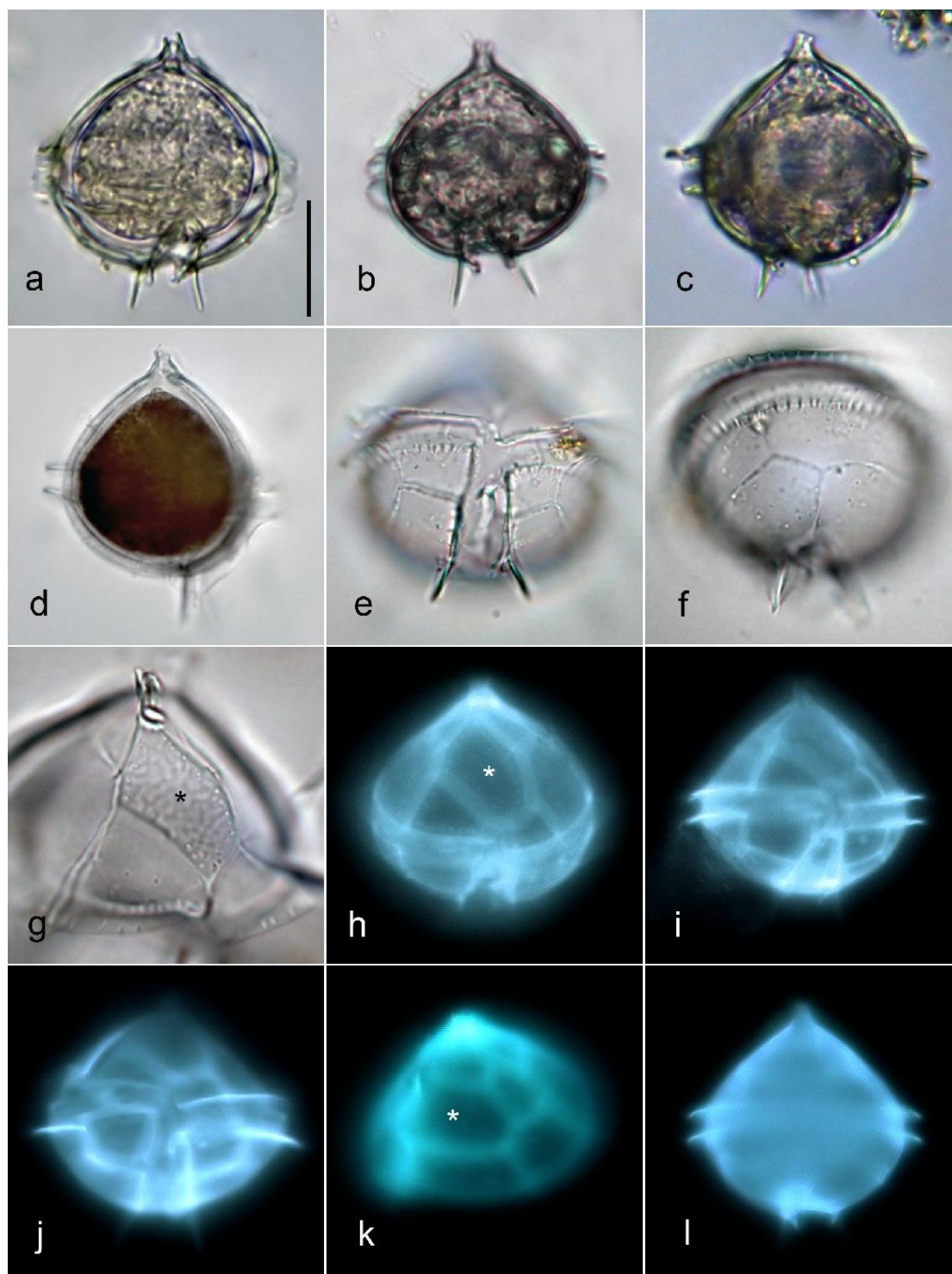


Plate A141. *Protoperidinium pellucidum* (a-l).

h – plate 1' is indicated by asterisk; k – plate 2a is indicated by asterisk.

a-g – LM, BF; h-l – LM, epifluorescence. Scale bar – 20 μ m.

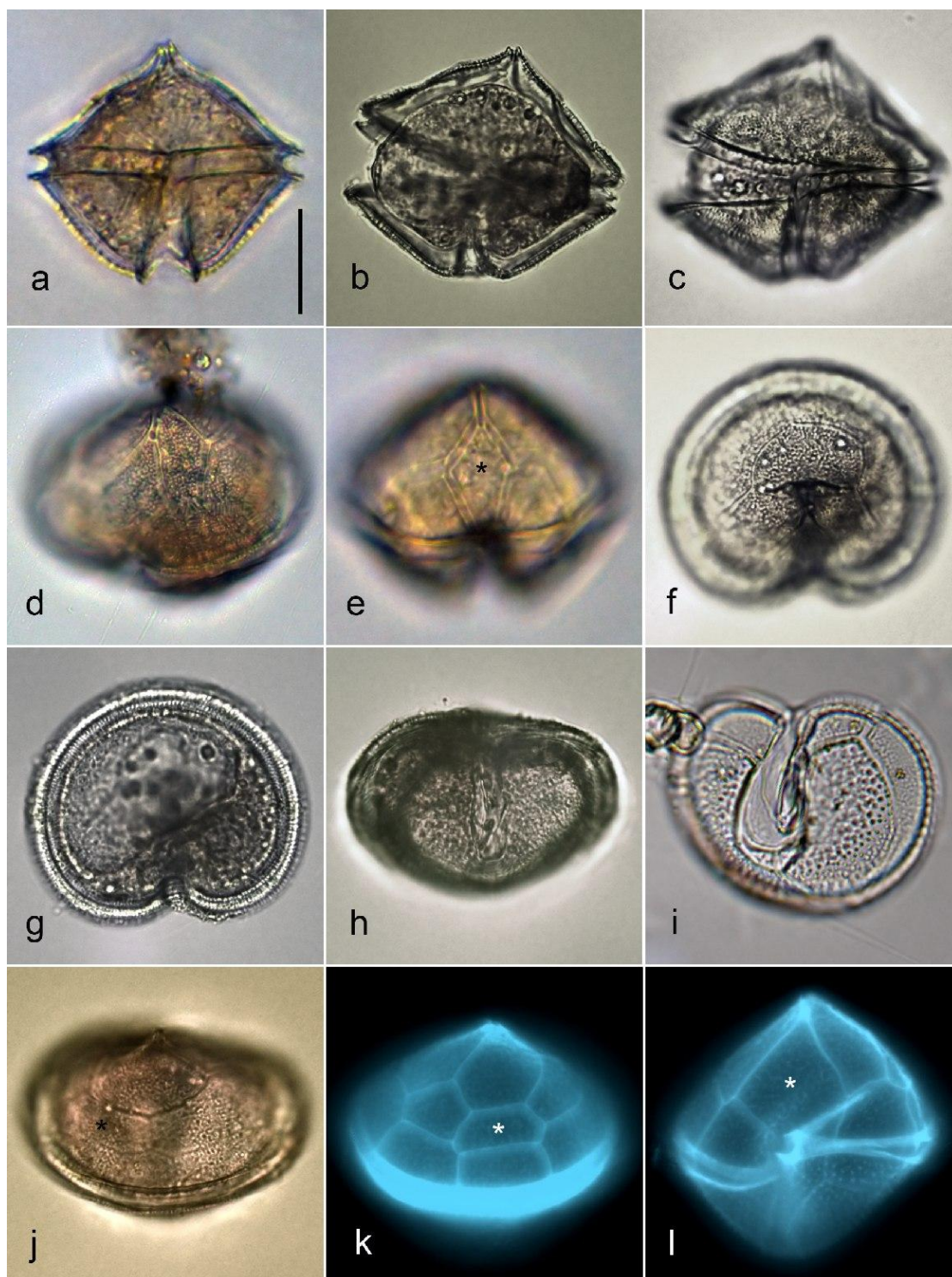


Plate A142. *Protoperidinium punctulatum* (a-l).

k – plate 1' is indicated by asterisk; l – plate 2a is indicated by asterisk.

a-j – LM, BF; k, l – LM, epifluorescence. Scale bar – 20 μ m.

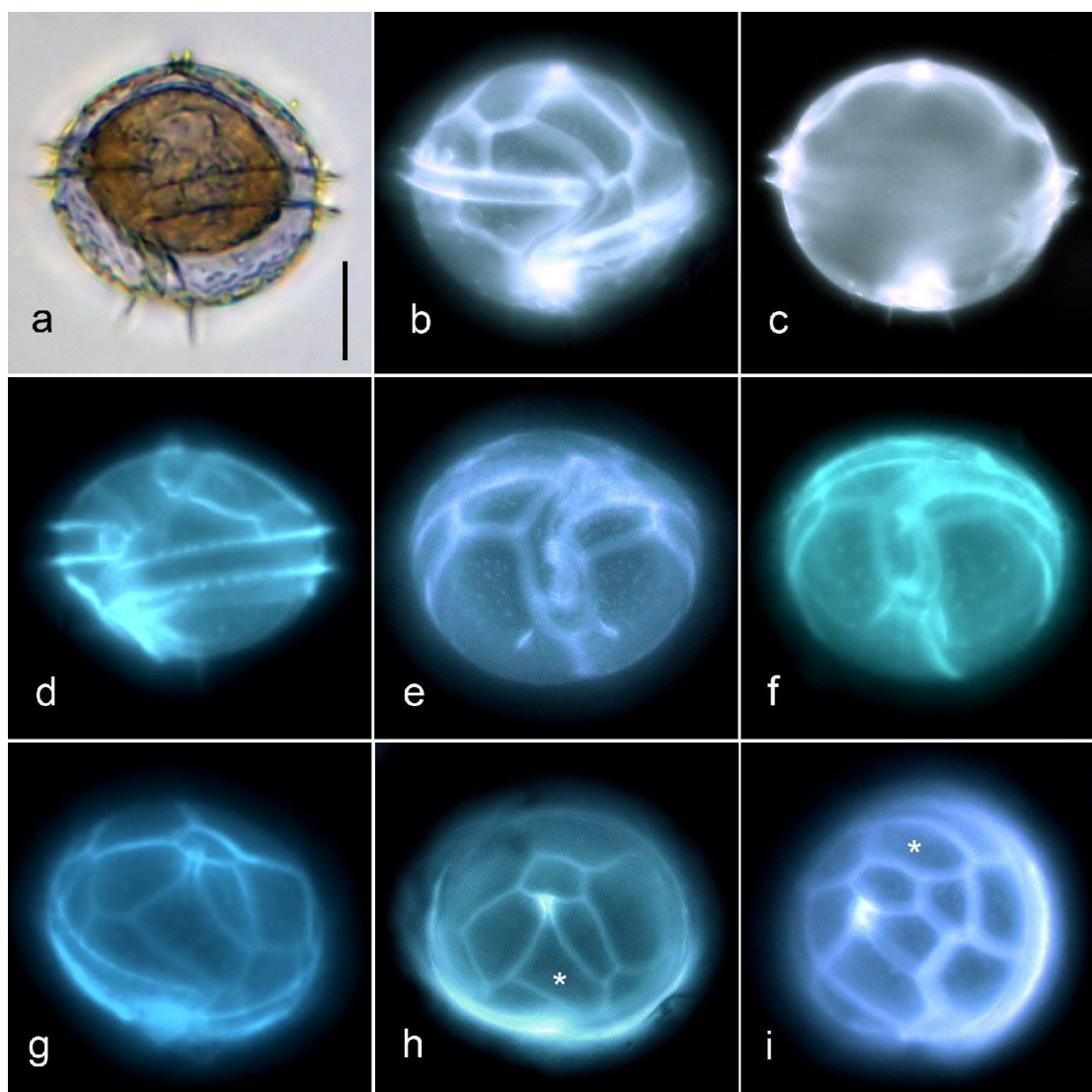


Plate A143. *Protoperidinium quarnerense* (a-i).

h – plate 1' is indicated by asterisk; i – plate 2a is indicated by asterisk.

a – LM, BF; b-i – LM, epifluorescence. Scale bar – 20 μm .

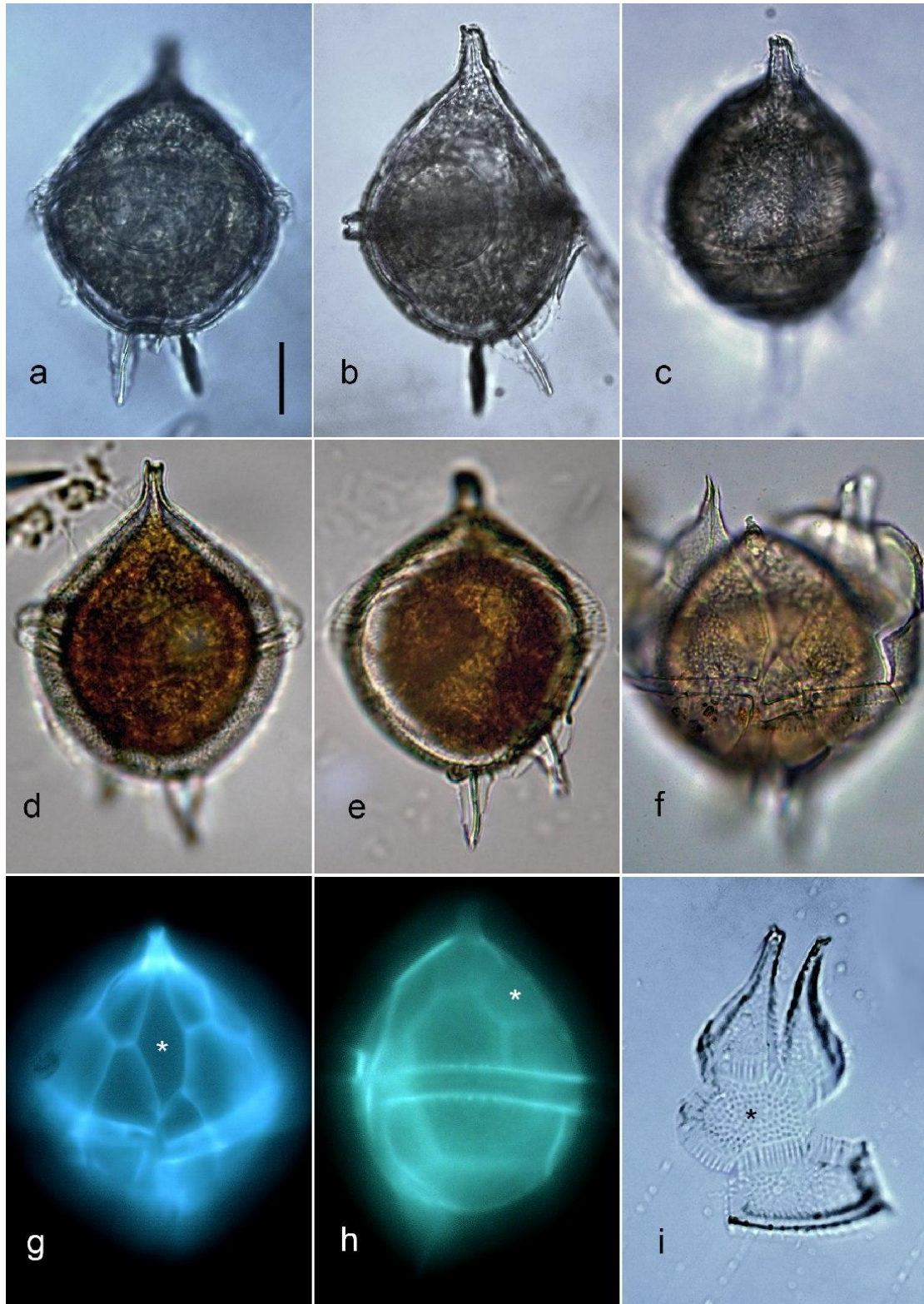


Plate A144. *Protoperidinium steinii* (a-i).

g – plate 1' is indicated by asterisk; h, i – plates 2a are indicated by asterisks.
a-c – PhC, BF; d-f, i – LM, BF; g, h – LM, epifluorescence. Scale bar – 20 μm .

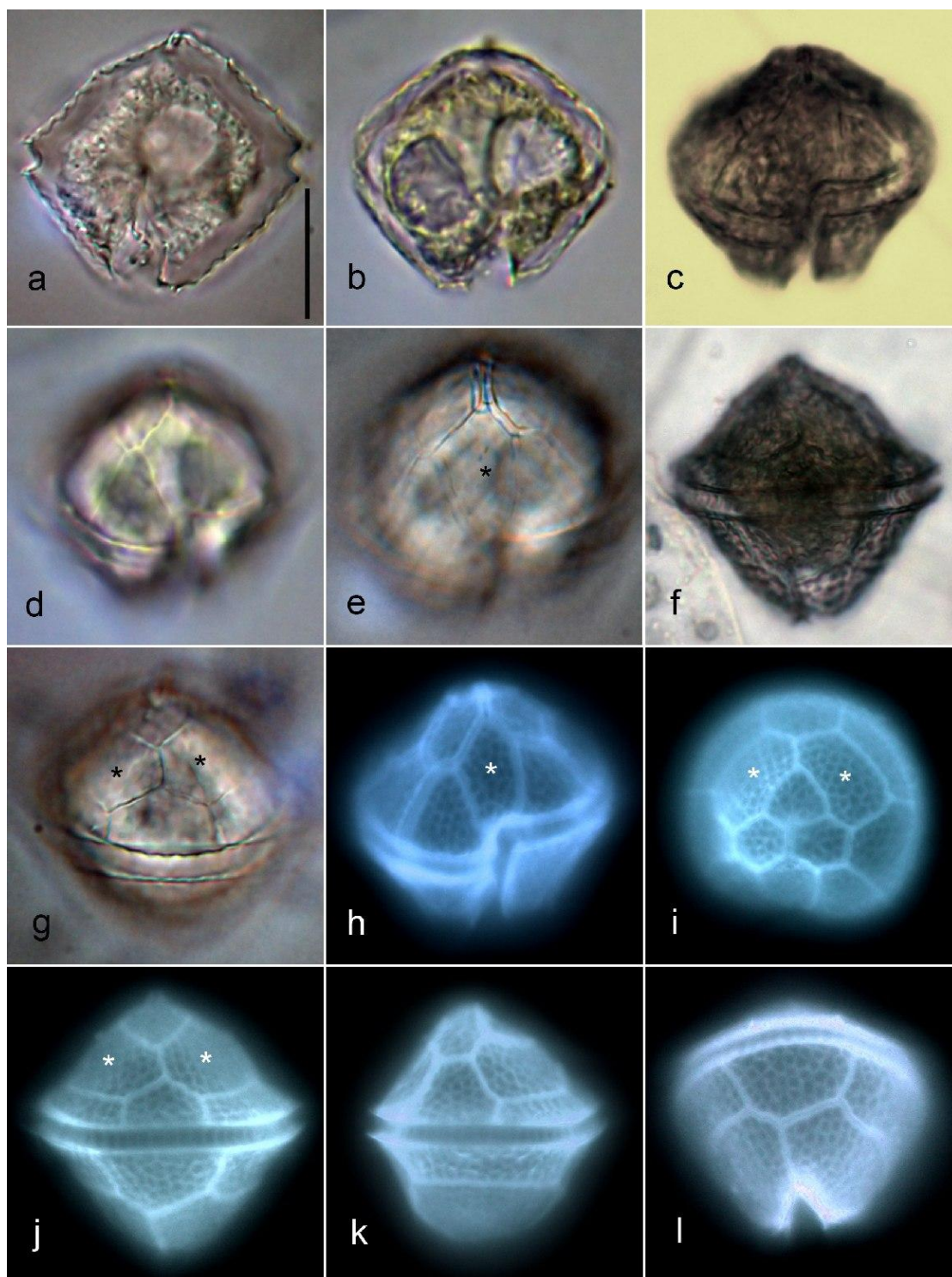


Plate A145. *Protoperidinium thorianum* (a-l).

h – plate 1' is indicated by asterisk; i, j – plates 1a and 2a are indicated by asterisks.
a, b, d, e, g – LM, BF; c, f – PhC, BF; h-l – LM, epifluorescence. Scale bar – 20 μ m.

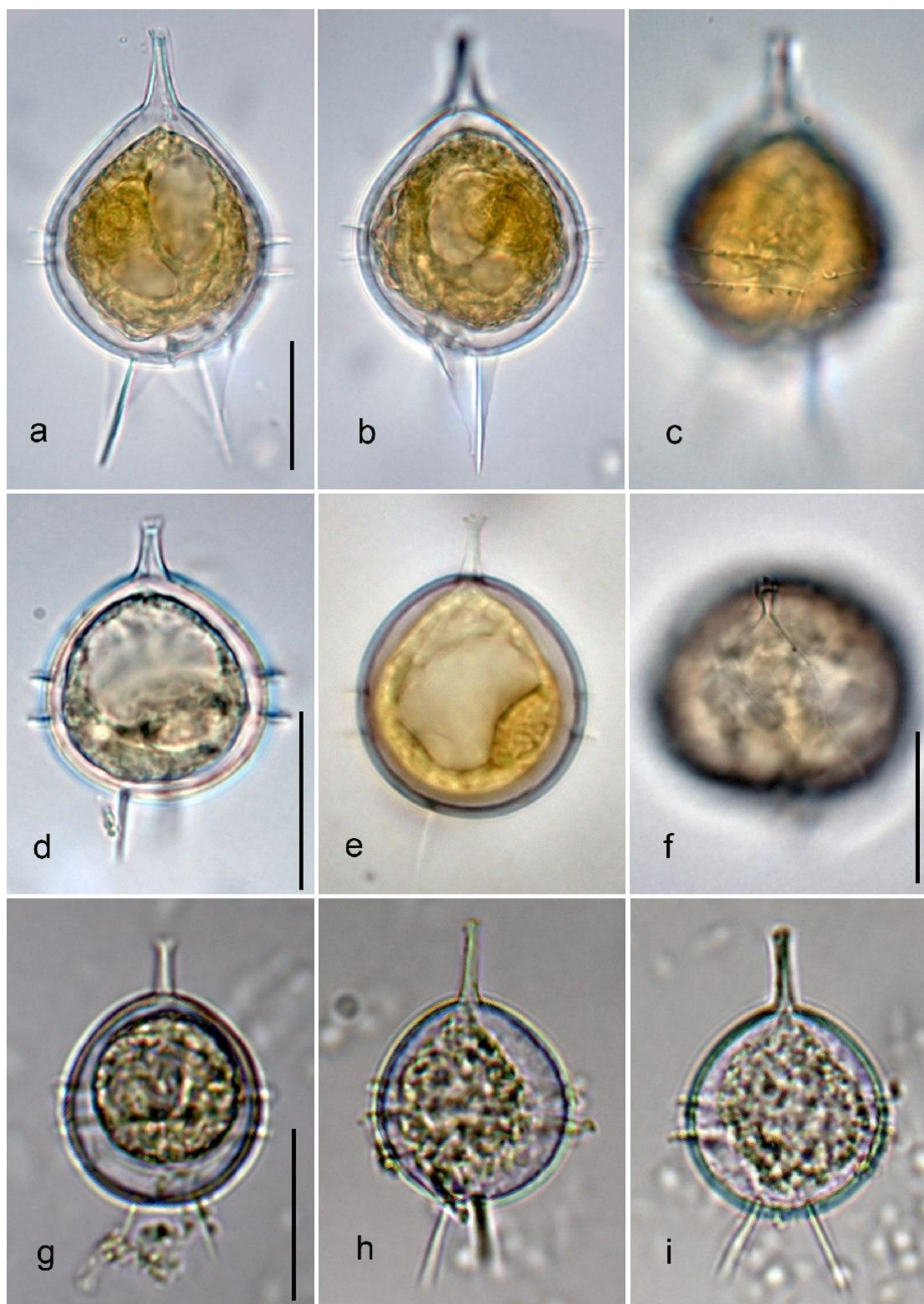


Plate A146. *Protoperidinium* sp. 2 (a-c); *Protoperidinium* sp. 3 (d-i).
a-i – LM, BF. Scale bars – 20 μm.

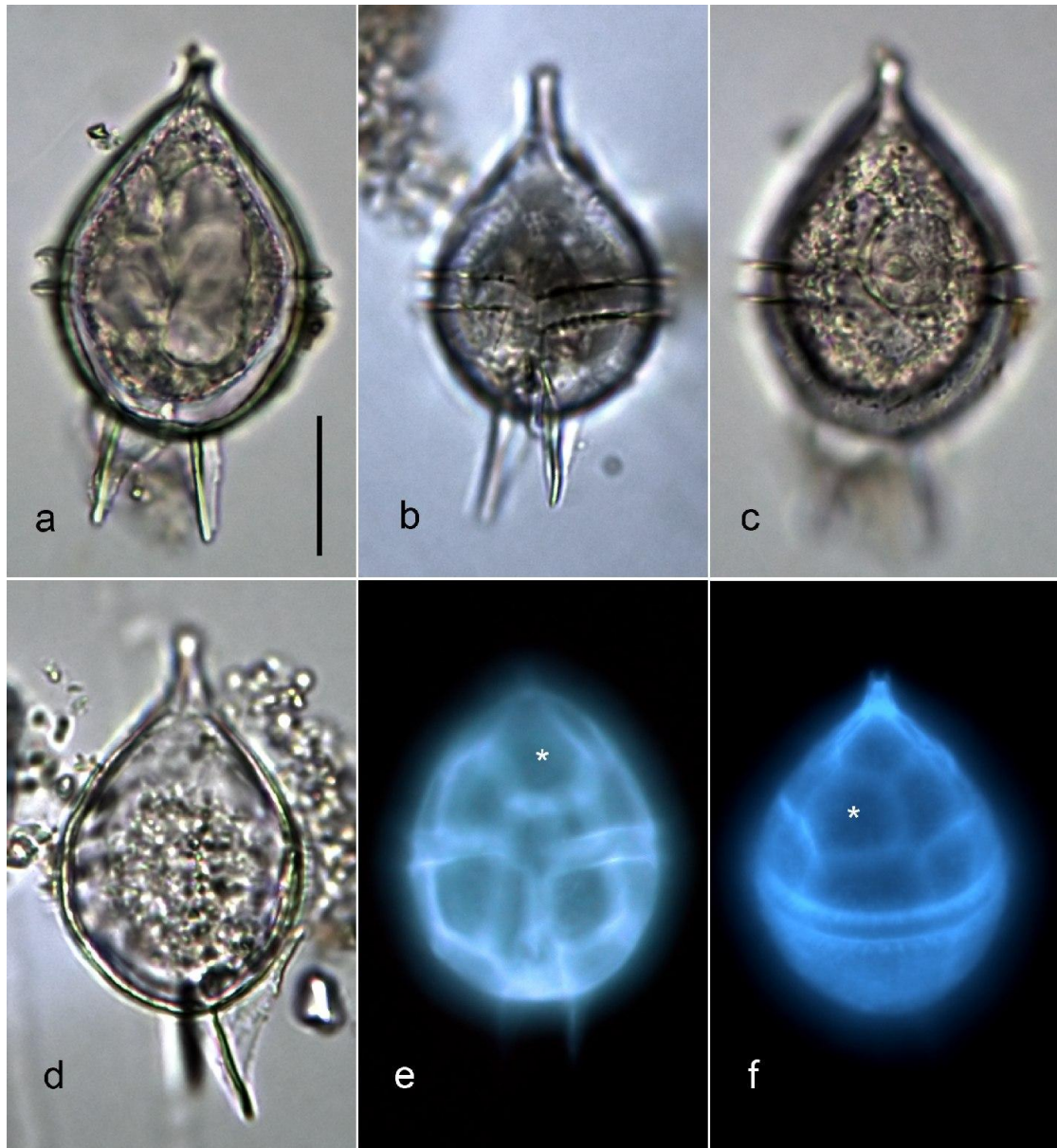


Plate A147. *Protoperidinium* sp. 4 (a-f).

e – plate 1' is indicated by asterisk; f – plate 2a is indicated by asterisk.
 a-d – LM, BF; e, f – LM, epifluorescence. Scale bar – 20 μ m.

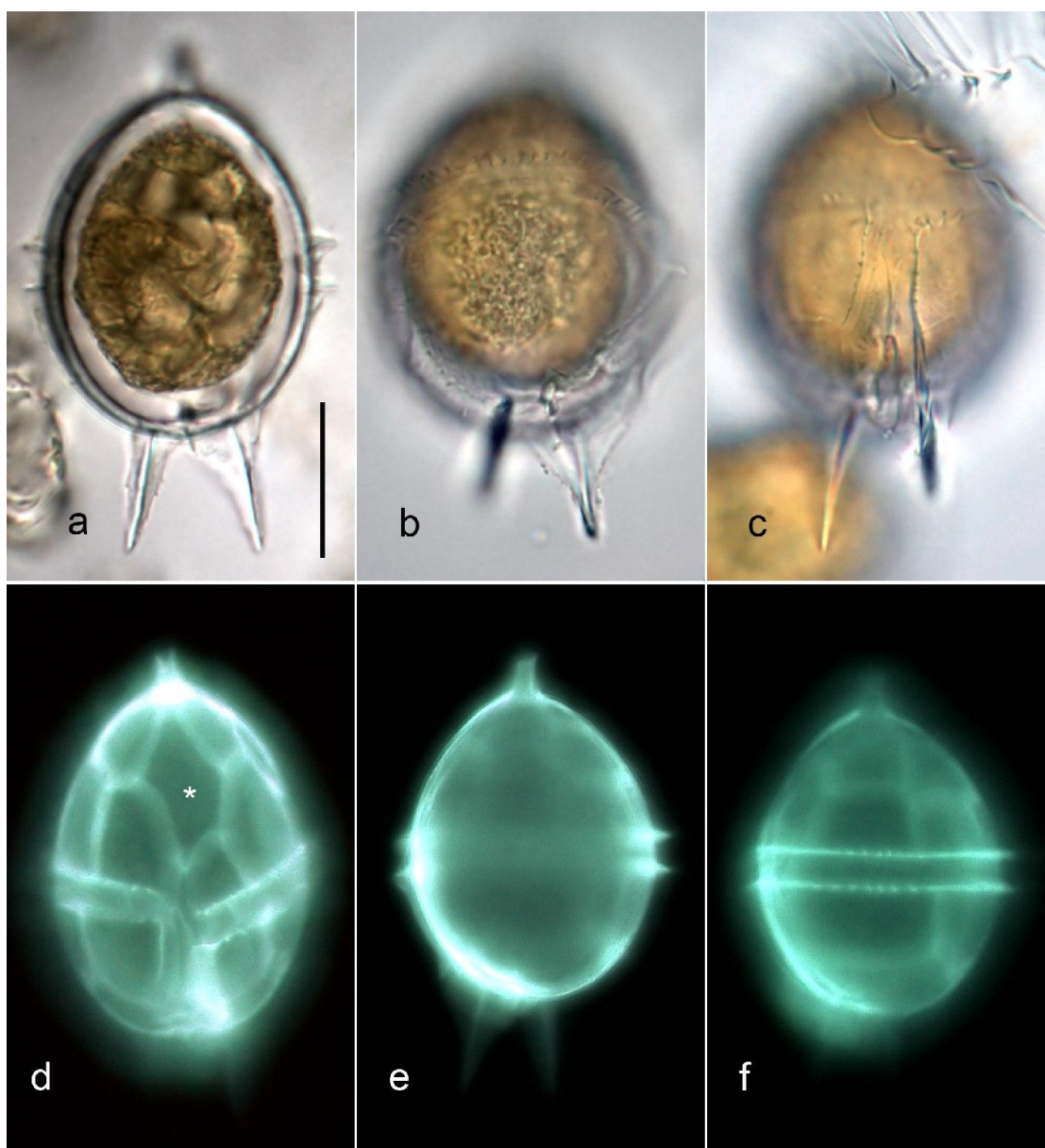


Plate A148. *Protoperidinium* sp. 4 (a-f).

d – plate 1' is indicated by asterisk.

a-c – LM, BF; d-f – LM, epifluorescence. Scale bar – 20 μ m.

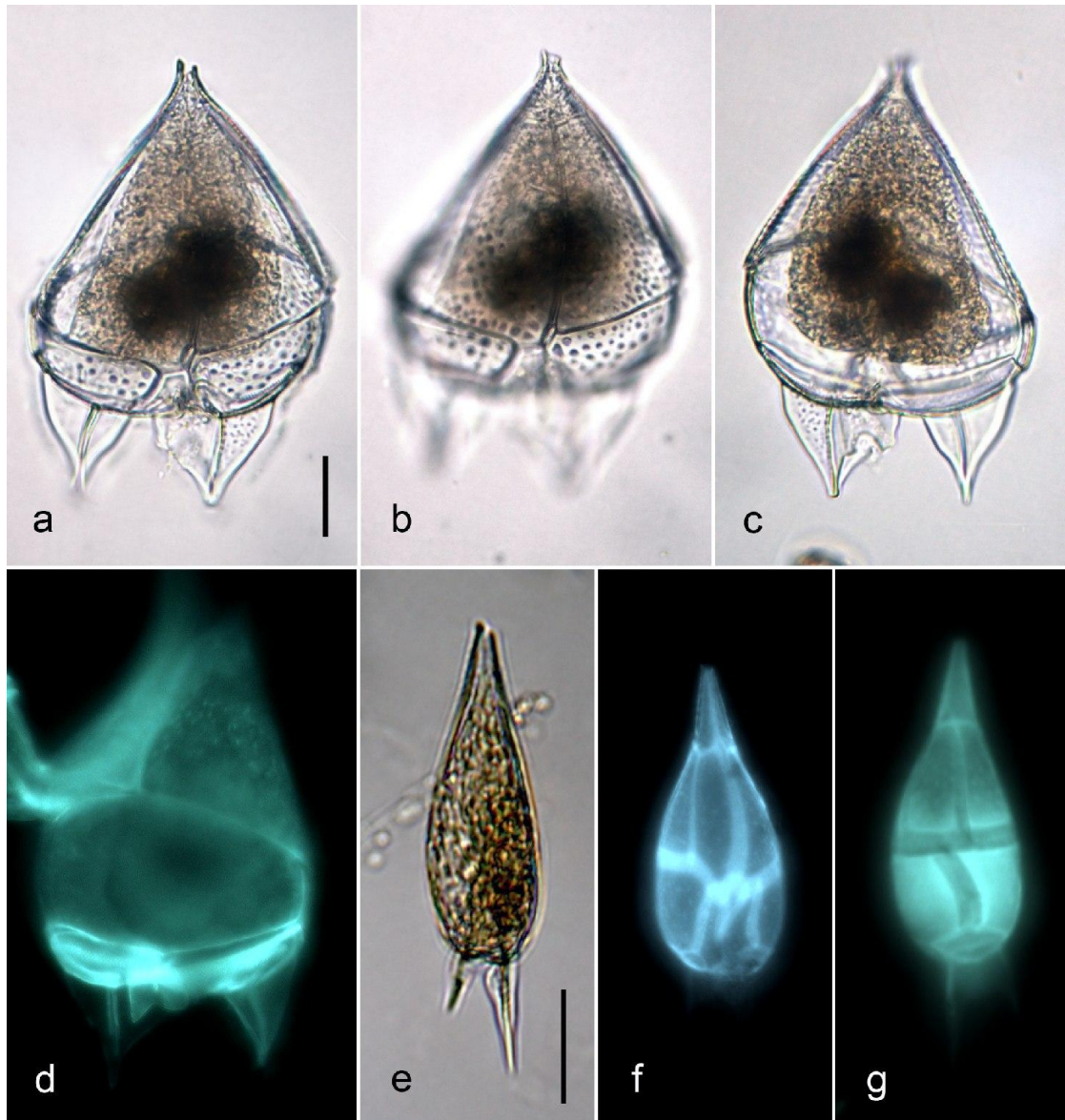


Plate A149. *Podalampas bipes* (a-d); *Podalampas palmipes* (e-g).
a-c, e – LM, BF; d, f, g – LM, epifluorescence. Scale bars – 20 μm.

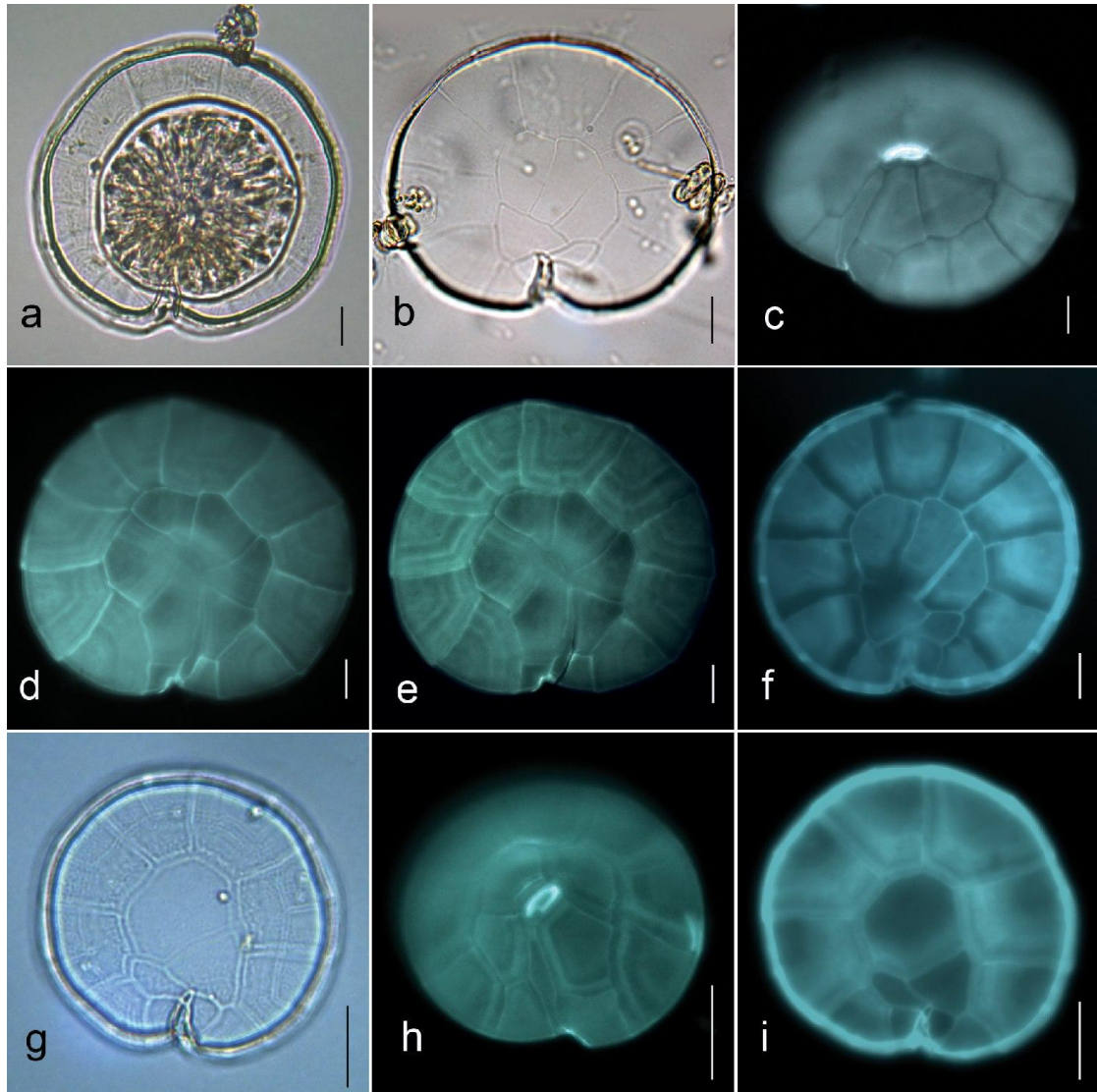


Plate A150. *Pyrophacus steinii* (a-f); *Pyrophacus horologicum* (g-i).
a, b, g – LM, BF; c-f, h, i – LM, epifluorescence. Scale bars – 20 μm .

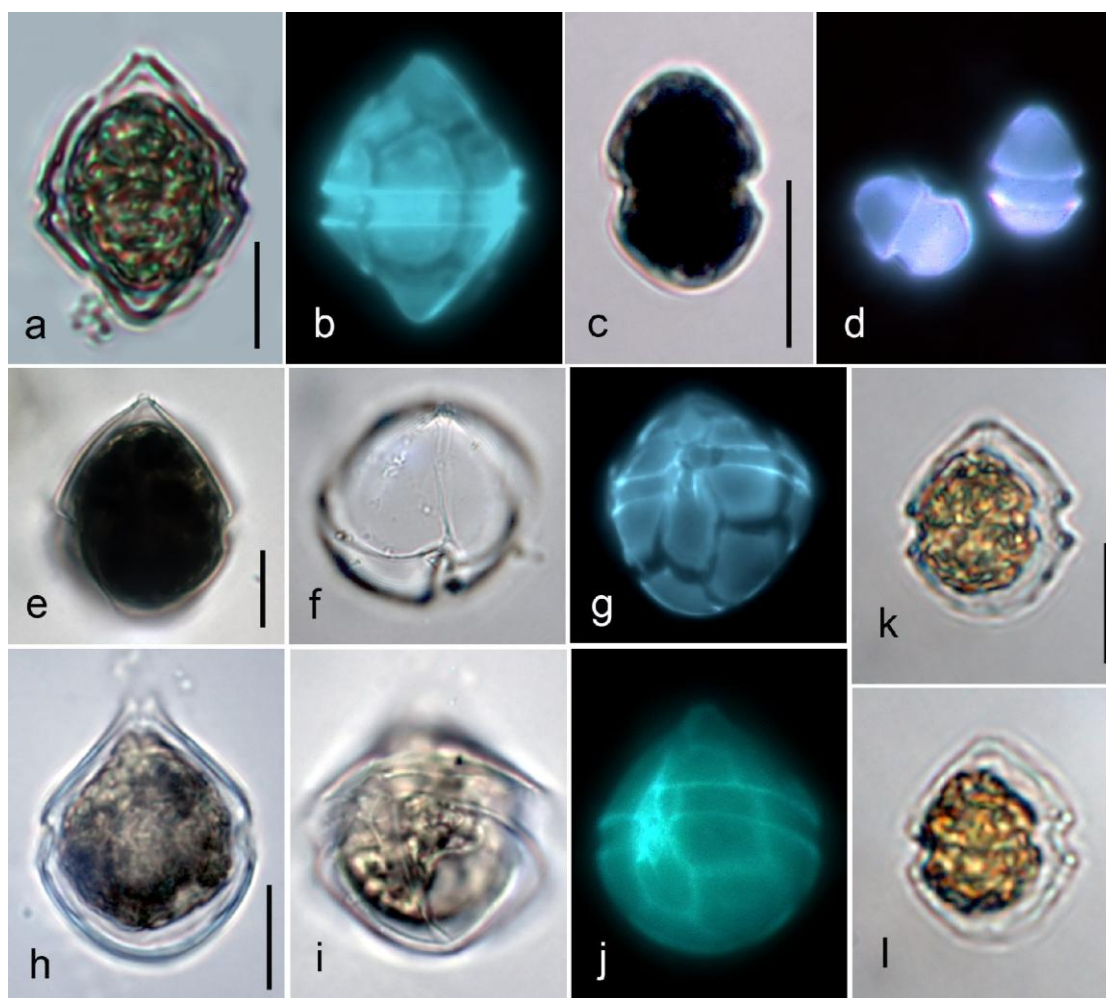


Plate A151. *Heterocapsa triquetra* (a, b); *Heterocapsa* sp. (c, d); *Scrippsiella trochoidea* (e-g); *Scrippsiella* sp. 1 (h-j); *Scrippsiella* sp. 2 (k, l).
 a, c – PhC, BF; e, f, h, i, k, l – LM, BF; b, d, g, j – LM, epifluorescence. Scale bars – 10 μ m.

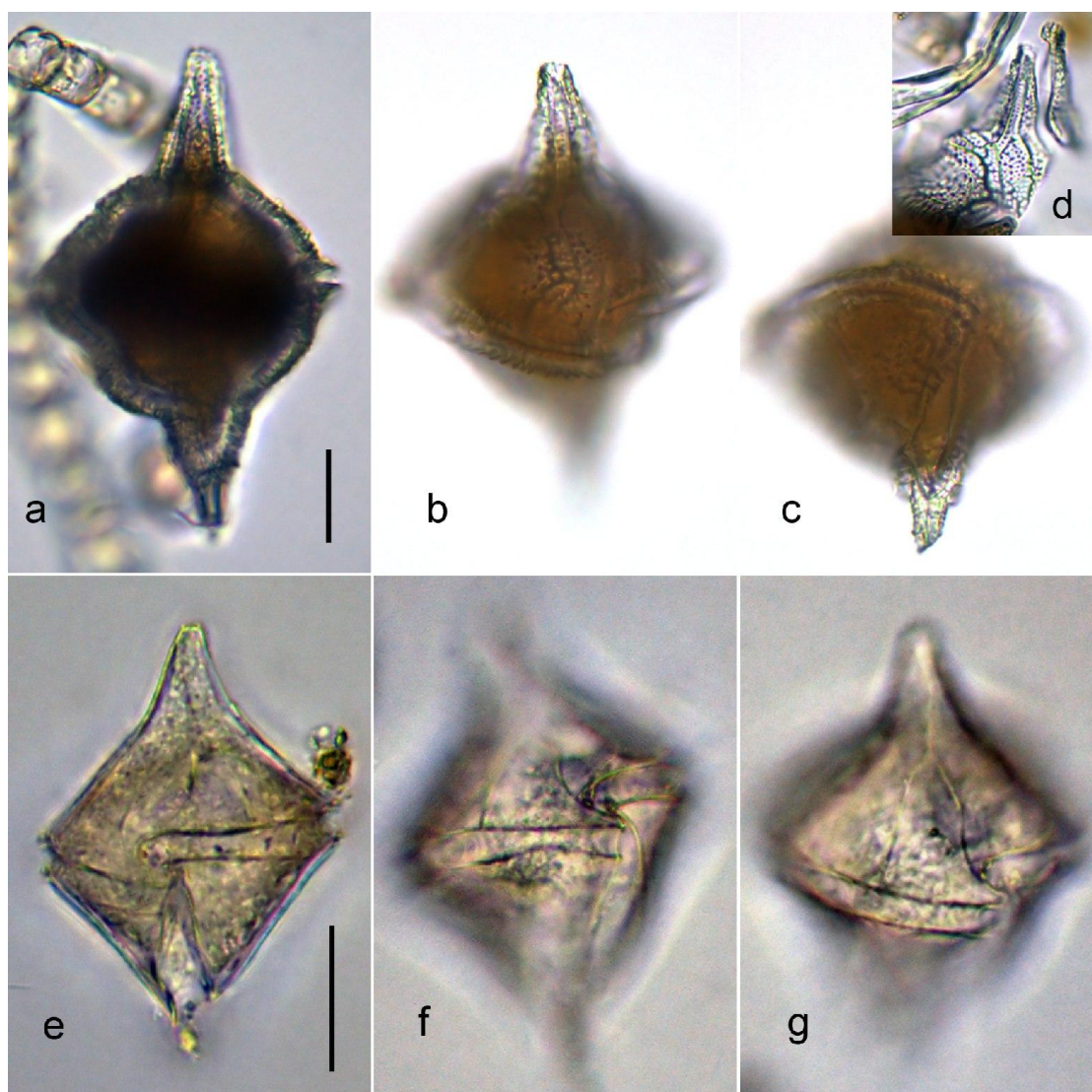


Plate A152. *Spiraulax jolliffei* (a-d); *Spiraulax sp.* (e-g).
a-g – LM, BF. Scale bars – 20 μ m.

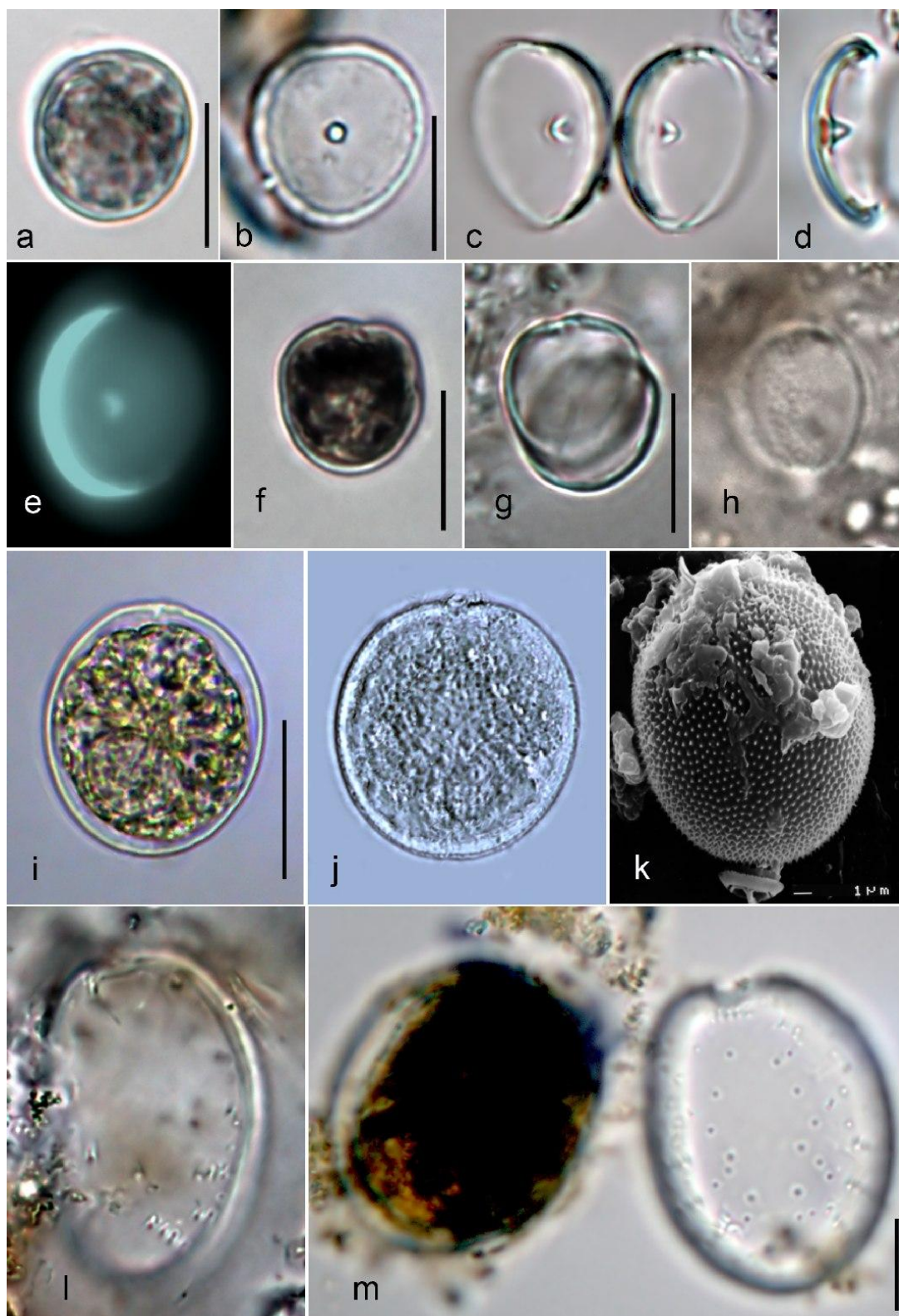


Plate A153. *Mesoporos perforatus* (a-e); *Prorocentrum minimum* (f-h); *Prorocentrum balticum* (i-k); *Prorocentrum rhathymum* (l, m).

a-d, f-g – PhC, BF; i, j, l, m – LM, BF; e – LM, epifluorescence; k – SEM. Scale bars: a-j, l, m – 10 μ m; k – 1 μ m.

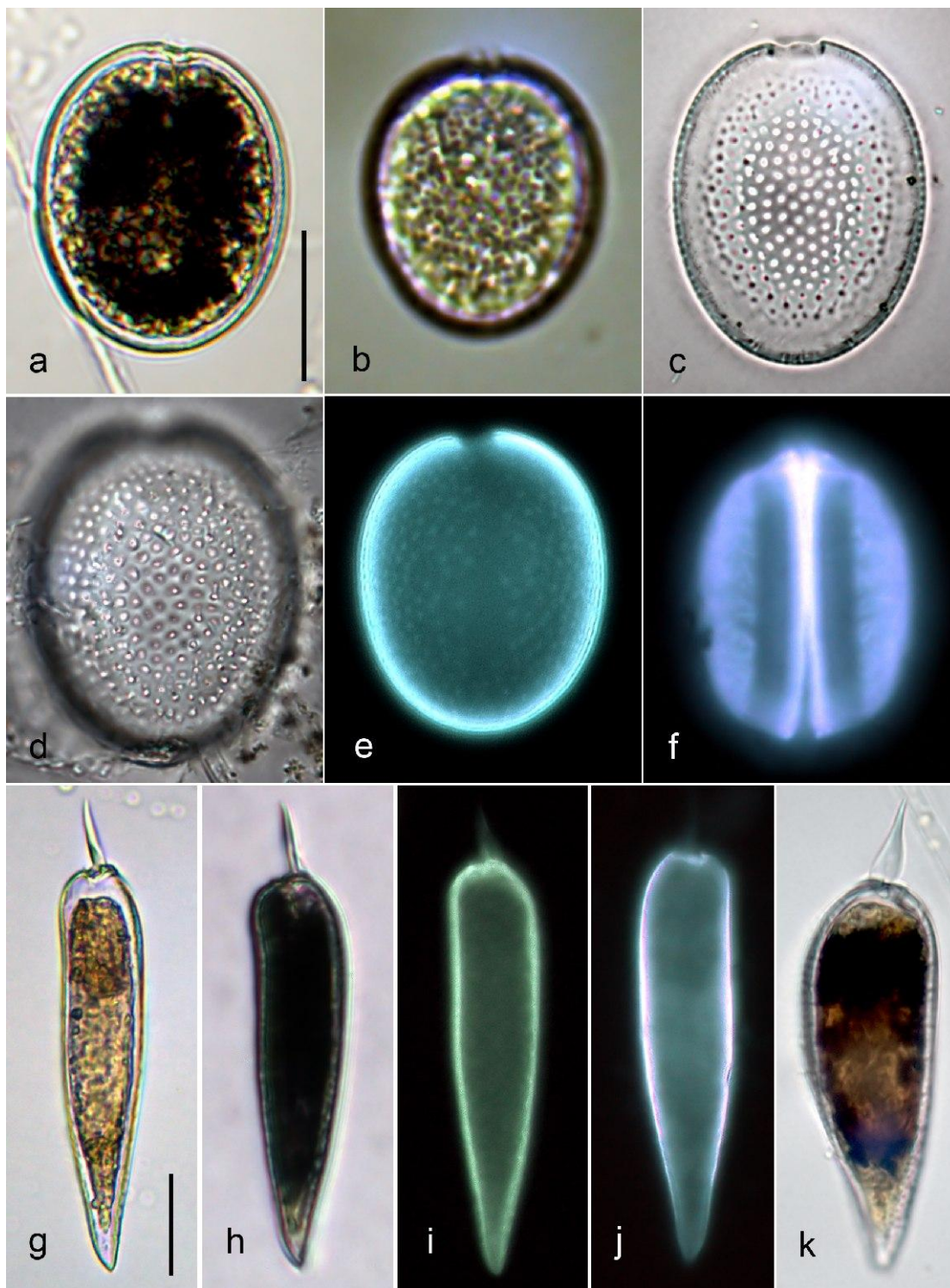


Plate A154. *Prorocentrum compressum* (a-f); *Prorocentrum sigmoides* (g-j); *Prorocentrum gracile* (k).

a, g, k – LM, BF; b-d, h – PhC, BF; e, f, i, j – LM, epifluorescence. Scale bars – 20 μ m.

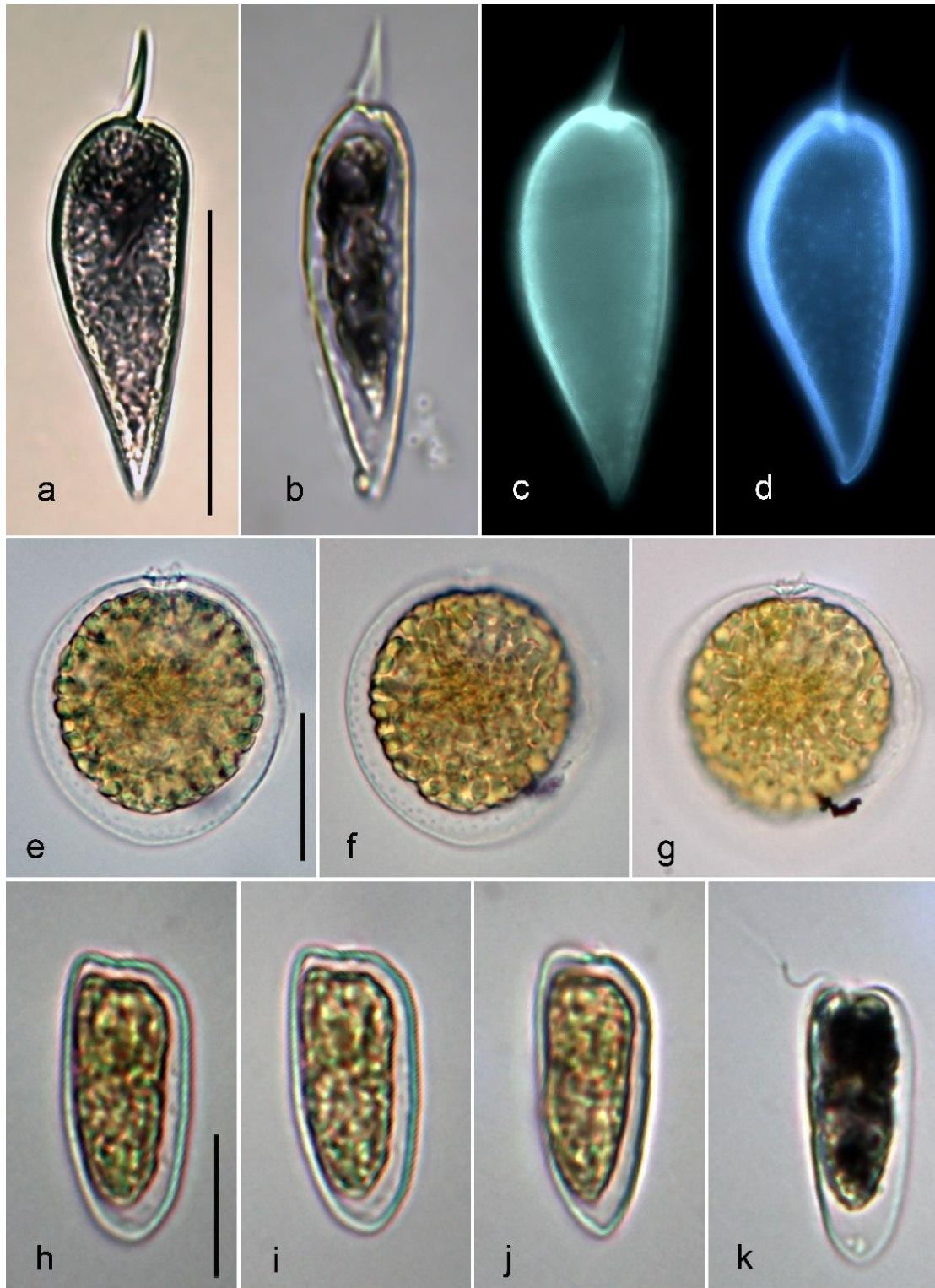


Plate A155. *Prorocentrum gracile* (a-d); *Prorocentrum sp.* (e-g); *Prorocentrum dentatum* (h-k).

a, b, e-j – LM, BF; k – PhC, BF; c, d – LM, epifluorescence. Scale bars: a-g – 20 μ m; h-k – 10 μ m.

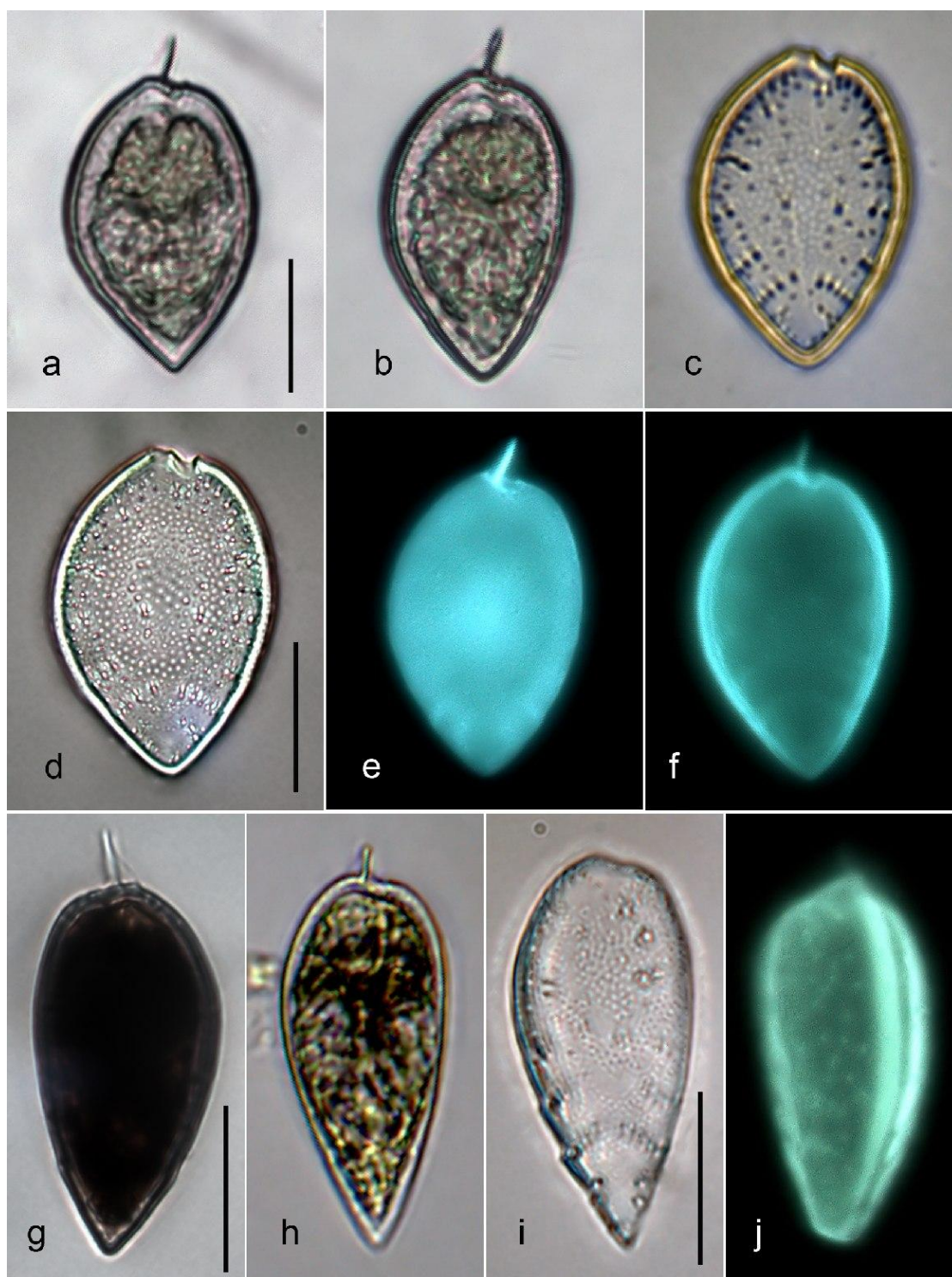


Plate A156. *Prorocentrum micans* (a-f); *Prorocentrum gracile* (g-j).
 a-c – PhC, BF; d – PhC, DF; g-i – LM, BF; e, f, j – LM, epifluorescence. Scale bars – 20 μm.

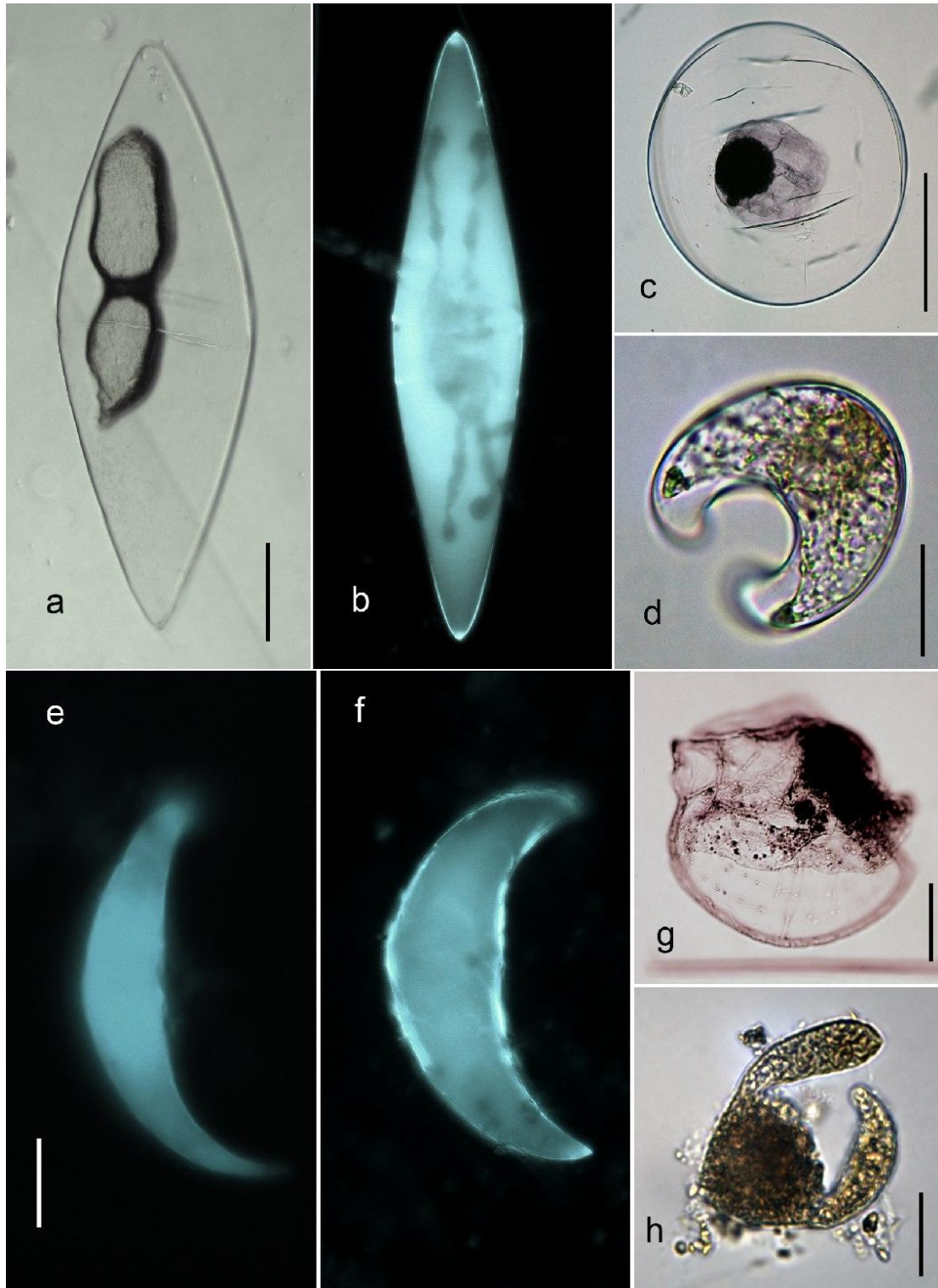


Plate A157. *Pyrocystis fusiformis* (a, b); *Pyrocystis noctiluca* (c); *Pyrocystis obtusa* (d); *Dissodinium pseudolunula* (e, f); *Kofoidinium velleloides* (g); *Gyrodinium falcatum* (h).
a, c, d, g, h – LM, BF; b, e, f – LM, epifluorescence. Scale bars: a-c – 50 µm; d-h – 20 µm.

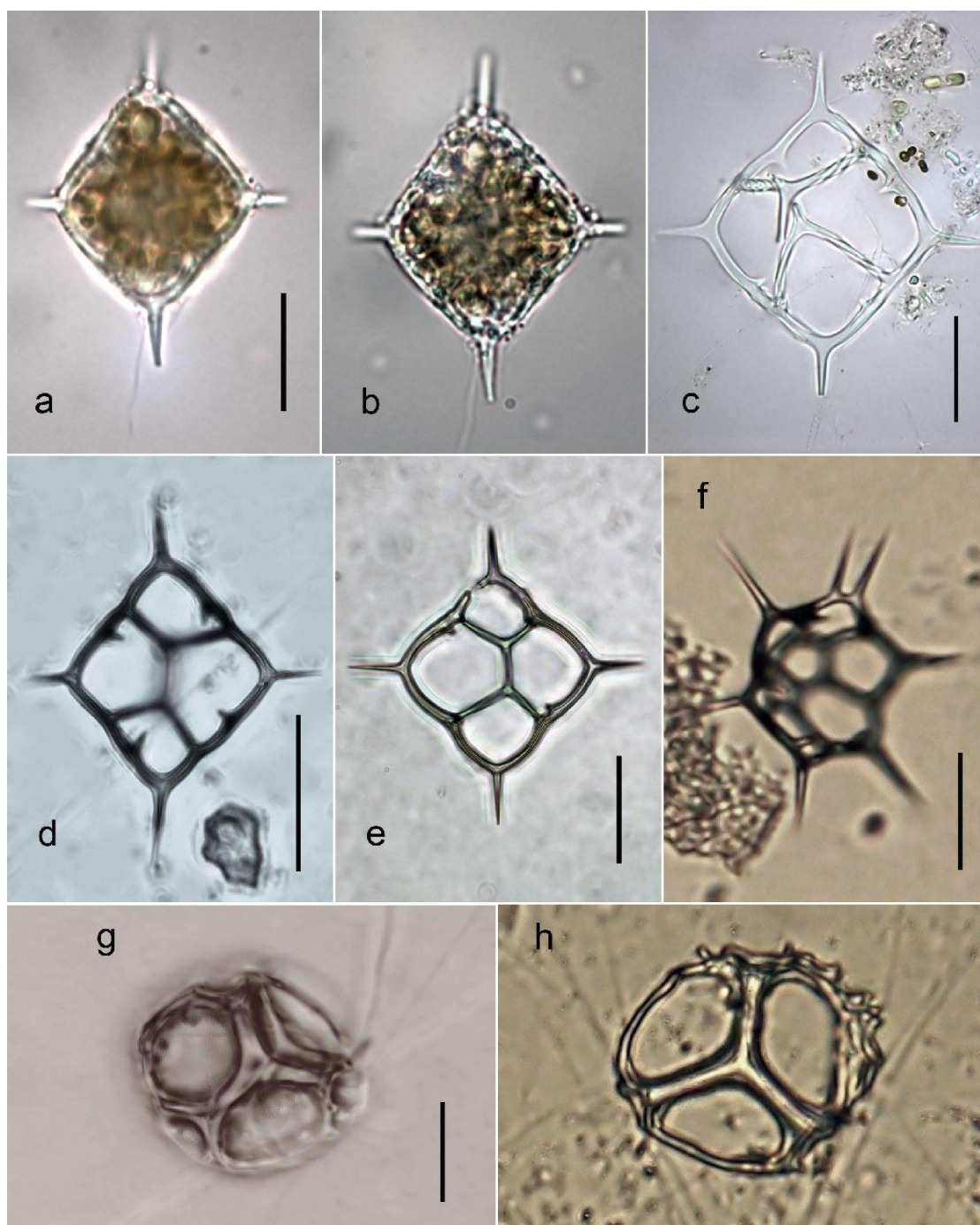


Plate A158. *Dictyocha fibula* (a-e); *Dictyocha speculum* (f); *Ebria tripartita* (g, h).
a-c, f, h – LM, BF; d, e, g – PhC, BF. Scale bars – 20 μm.

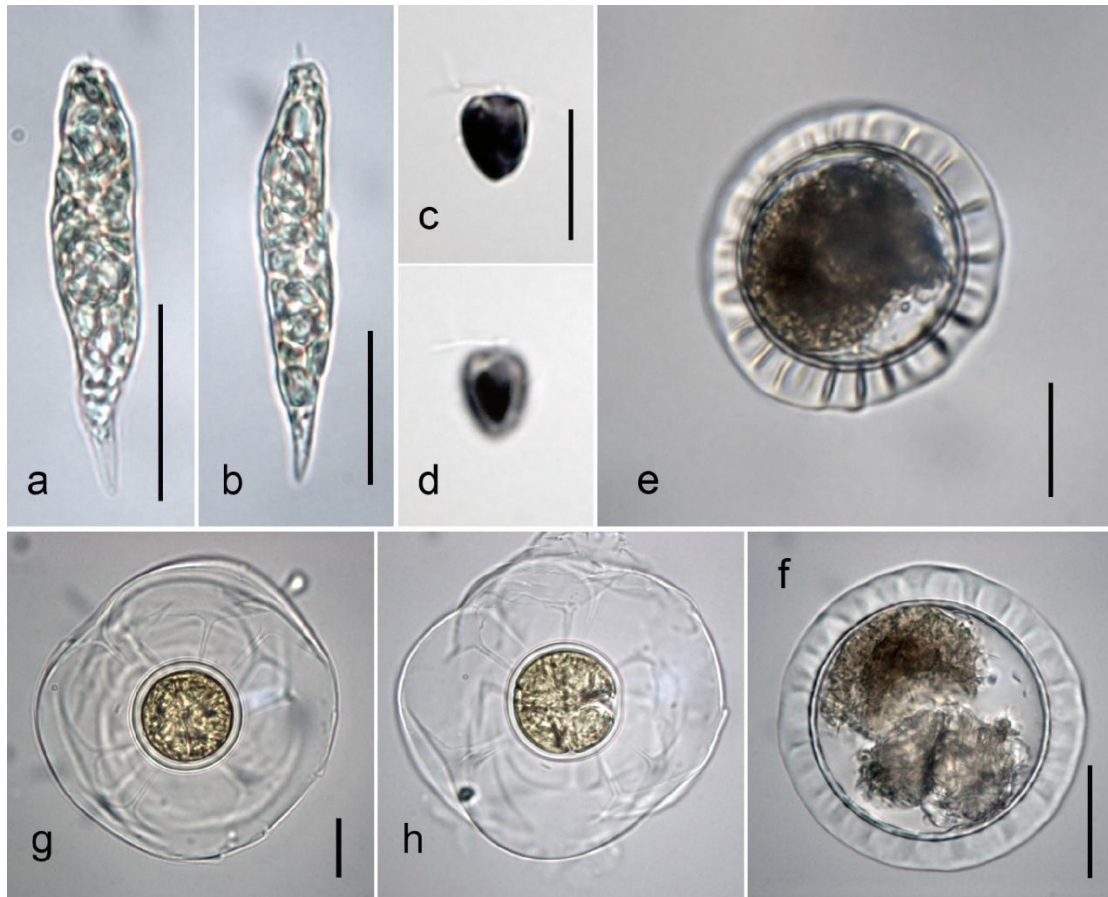


Plate A159. *Eutreptiella* sp. (a, b); *Pyramimonas* sp. (c, d); *Pterosperma undulatum* (e, f); *Pterosperma* sp. (g, h).
a-f – LM, BF. Scale bars: a, b, e-h – 20 μ m; c, d – 10 μ m.