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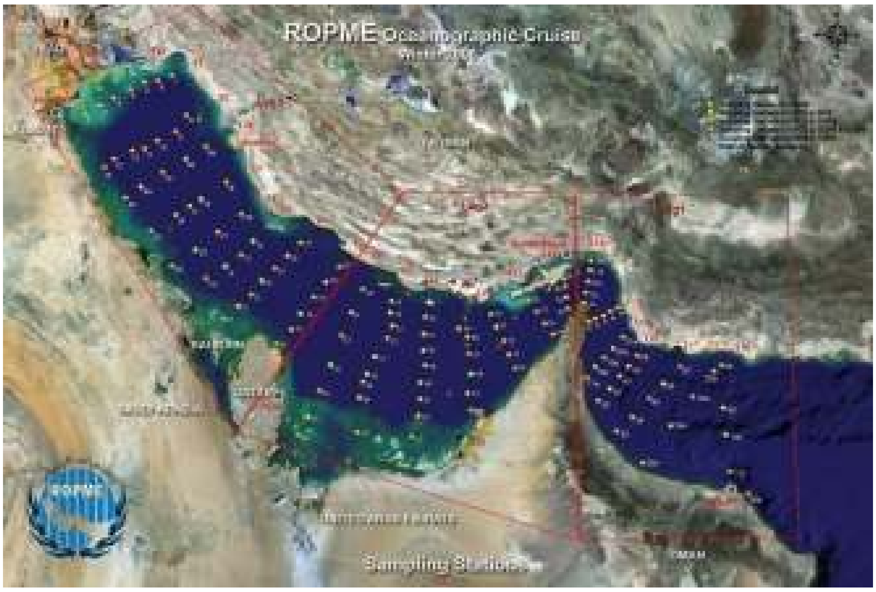
ROPME Oceanographic Cruise - Winter 2006



Technical Report Series

Technical Report : No. 5

Phytoplankton in the ROPME Sea Area

December 2010

ROPME Oceanographic Cruise - Winter 2006
Technical Report Series:

1. Physical oceanography
2. Contaminants in Marine Sediments
3. Nutrients
4. Chlorophyll
5. Phytoplankton
6. Zooplankton
7. Ichthyoplankton
8. Meiobenthos
9. Macrobenthos

Disclaimer

This Report has been prepared by Kuwait Institute for Scientific Research, as the principal Investigator on 'Phytoplankton' under a contract with ROPME. The report is being separately subjected to peer review and linking with other relevant data and information, in order to develop an integrated understanding of the ROPME Sea Area. Meanwhile, in order to bestow the benefit of viewing the results in their preliminary form and promote a general level of understanding of the marine environment of the Region, notwithstanding the possible delay by peer review, this document is being brought out as part of a special Technical Report Series in the very form in which it was submitted by the Principal Investigator. Owing to this reason, ROPME shall not accept responsibility on the accuracy of data or interpretations contained in this Report.

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Preface:

In recognition of the importance of the oceanographic Cruises in ROPME Sea Area to understand the state of the marine environment, ROPME Council has assign high priority to the scientific Cruises. In pursuance of the Council Decision CM12/7, ROPME had the responsibility 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 provision 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 11 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 collected samples 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 from the Cruise among Regional scientific community towards a better understanding of the marine environment in the RSA and to enable higher marine research, ROPME Secretariat decided on the publication of the results in a series of Technical Reports as follows:

1. Physical oceanography
2. Contaminants in Marine Sediments
3. Nutrients
4. Chlorophyll
5. Phytoplankton
6. Zooplankton
7. Ichthyoplankton
8. Meiobenthos
9. Macrobenthos

The present Technical Report is devoted to the phytoplankton in the RSA. The analyses of phytoplankton samples and reporting have been conducted by Dr. Faiza Y. Al-Yamani of Kuwait Institute for Scientific Research, as the principal Investigator on 'Phytoplankton' under a contract with ROPME.

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1. Introduction

Phytoplankton 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, plankton algae respond quickly to environmental changes and thus are a valuable indicator of water quality. The term 'phytoplankton' encompasses all taxonomic micro-algal 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 Kuwait's waters of the 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). Additionally, two 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 passed 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 our ability to forecast the events and to reduce the harmful effects and their economic impact (Faust and Gulledge, 2000; Larsen and Nguyen, 2004).

The ecology and taxonomy of phytoplankton in the ROPME Sea Area (RSA) has been studied during the past few decades (e.g., Enomoto, 1971; Al-Kaisi, 1976; Jacob *et al*., 1979, Al-Yamani *et al*., 1997; Subba Rao *et al*., 1999); however, only very limited detailed taxonomical studies have been done on marine phytoplankton of the RSA as a whole. Information about distribution of some phytoplankton species occurring in the Kuwait's waters has been published by Enomoto (1971), Al-Yamani *et al*. (2004), and Al-Kandari *et al*. (2008). 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 Qatari waters have been published by Dorgham and Muftah in 1986. Species composition of phytoplankton in Shatt Al-Arab River (Iraq) has been revised by Al-Saboonchi and Al-Saad (1988). There are only few studies on the benthic diatom flora of the RSA (Hendey, 1970; Basson and Mohammed, 1989). The valuable review of phytoplankton diversity has been performed by Subba Rao and Al-Yamani (1998), which was based on limited available data regarding phytoplankton from the different parts of the RSA. Assessment of the phytoplankton diversity of the RSA has been reported by Jacob and Al-Muzaini in 1990 and the latest estimation of phytoplankton diversity in Kuwait's waters has been published recently by Al-Yamani *at al.* (2004) and by Al-Kandari *et al*. (2008).

Available published information regarding 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 investigation of phytoplankton communities in different parts of the RSA is a very important current task.

The present study is focused on the detailed examination of phytoplankton species diversity and spatial distribution in the ROPME Sea Area based on the samples, which were collected during the ROPME Oceanographic Cruise conducted during the winter season of 2006.

2. Material and Methods

Phytoplankton samples were collected during ROPME's winter cruise from February to March 2006 in the ROPME Sea Area (RSA). The cruise covered the inner RSA and the Sea of Oman. The cruise was divided into three legs and to 23 transects. The position of the stations from which phytoplankton samples collected and sampling route are illustrated in Fig. 1 and 2. The dates and time of collection, depth of sampling and maximum depth for each station as well as coordinates of stations are included in Table 1.

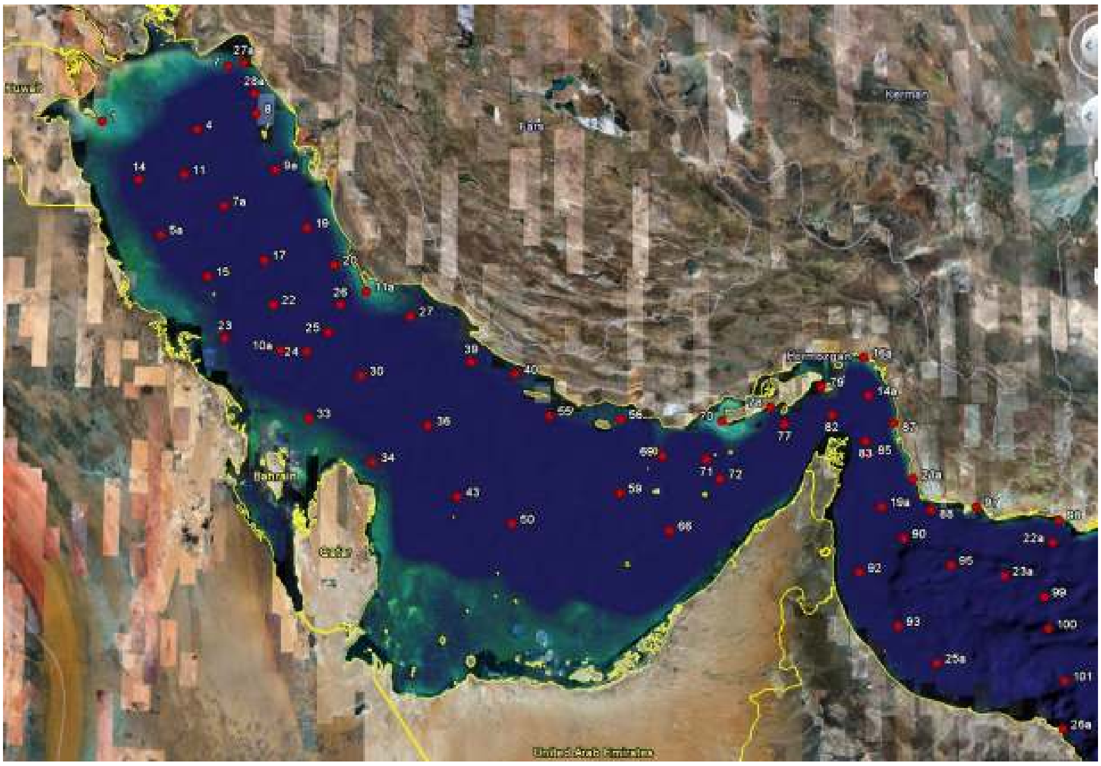

Fig. 1. Phytoplankton sampling stations during winter 2006 cruise.

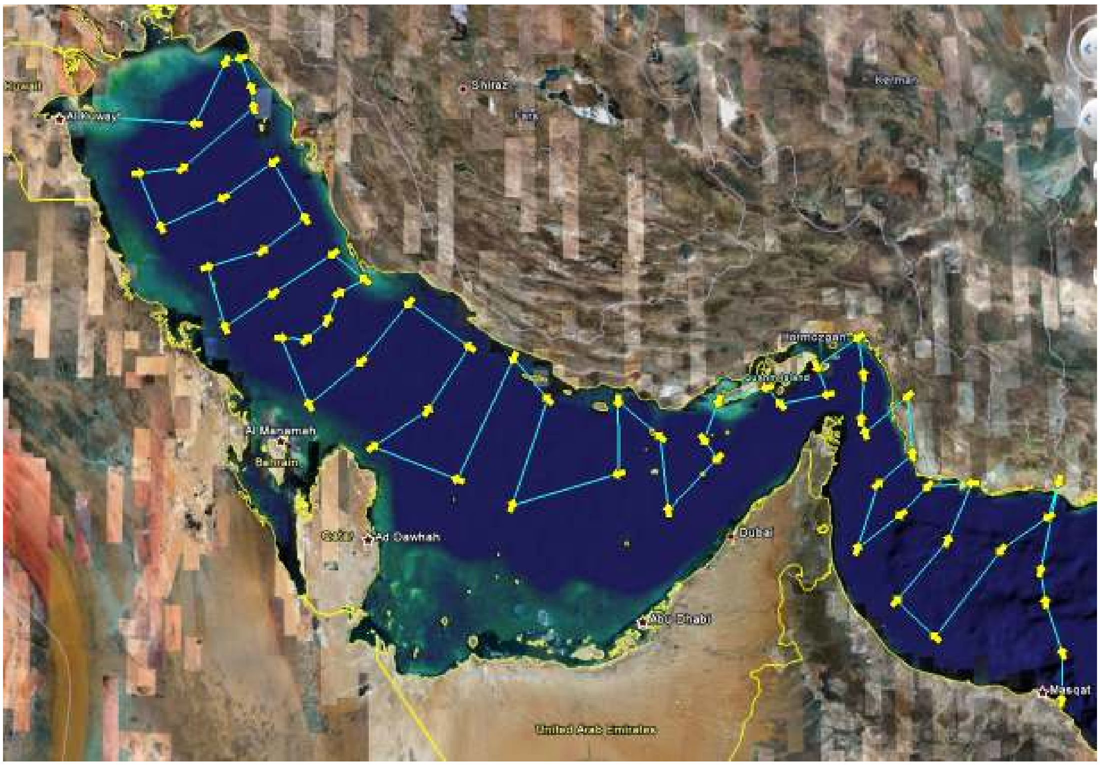

Fig. 2. Sampling route for the ROPME oceanographic cruise during the winter of 2006.

Table 1. Sampling Stations Details for the RSA

Transect	Station	Coordinates		Date	Time	Depth (m)	Sampling Depth (m)			Sampling Method	
		Latitude	Longitude				Surface	Middle	Bottom	Niskin Bottle	Oblique Net Tow
18	**26a**	23º31'000"	58º46'100"	3-Feb-2006	08:07	53	3	25	45	+	
	101	23º52'420"	58º36'791"	3-Feb-2006	12:32	450	3	50	100	+	
	100	24º23'404"	58º35'244"	3-Feb-2006	16:27	2700	3	50	100	+	
	99	24º46'136"	58º35'100"	3-Feb-2006	19:07	1700	3	50	100	+	
	98	25º26'801"	58º36'914"	3-Feb-2006	07:25	50	3	25	45	+	
17a	**22a**	25º18'070"	58º28'909"	4-Feb-2006	09:38	200	3	50	100	+	
	23a	24º58'210"	58º06'300"	4-Feb-2006	12:17	1000	3	50	100	+	
	25a	24º05'505"	57º13'813"	4-Feb-2006	19:28	55	3	25	100	+	
17	**93**	24º33'147"	56º50'739"	5-Feb-2006	07:17	67	3	25	45	+	
	95	24º59'595"	57º24'758"	5-Feb-2006	12:39	1039	3	50	100	+	
	97	25º38'200"	57º54'000"	5-Feb-2006	18:05	54	3	25	45	+	
16	**88**	25º40'043"	57º24'048"	5-Feb-2006	07:16	65	3	25	45	+	
	90	25º20'310"	56º58'530"	6-Feb-2006	11:13	300	3	50	100	+	
	92	25º01'340"	56º37'080"	6-Feb-2006	15:38	183	3	45	90	+	
15a	**19a**	25º37'386"	56º45'487"	6-Feb-2006	20:44	110	3	48	96	+	
	21a	25º53'400"	57º11'300"	6-Feb-2006	07:24	57	3	24	47	+	
15	**87**	26º18'900"	57º01'800"	7-Feb-2006	11:53	26	3	11	22	+	
	85	26º13'000"	56º46'000"	8-Feb-2006	07:51	104	3	32	65	+	
	83	26º08'763"	56º31'767"	8-Feb-2006	13:16	95	3	42	85	+	+
14a	**14a**	26º43'066"	56º34'862"	8-Feb-2006	21:58	64	3	24	47	+	+
	16a	27º01'400"	56º39'300"	9-Feb-2006	11:19	30	3	11	22	+	+
14	**79**	26º51'046"	56º10'378"	13-Feb-2006	08:08	45	3	16	32	+	+
	82	26º23'771"	56º13'583"	13-Feb-2006	14:21	90	4	40	80	+	+

Table 1. Contd.

Transect	Station	Coordinates		Date	Time	Depth (m)	Sampling Depth (m)			Sampling Method	
		Latitude	Longitude				Surface	Middle	Bottom	Niskin Bottle	Oblique Net Tow
13	**77**	26º20'671"	55º43'561"	13-Feb-2006	08:08	61	4	26	52	+	+
	78	26º28'769"	55º36'474"	14-Feb-2006	10:37	45	4	19	40	+	+
12	**70**	26º32'104"	54º57'957"	14-Feb-2006	14:17	44	4	19	40	+	
	71	26º12'000"	55º03'000"	14-Feb-2006	16:58	83	4	36	72	+	
	72	25º57'254"	55º10'080"	14-Feb-2006	18:50	72	4	29	59	+	+
11	**66**	25º31'090"	54º37'156"	15-Feb-2006	16:27	42	3	16	34	+	+
	69	26º08'382"	54º27'506"	15-Feb-2006	22:05	75	3	29	64	+	+
10	**56**	26º20'905"	53º55'864"	21-Feb-2006	07:01	93	3	41	82	+	+
	59	25º39'885"	53º53'944"	21-Feb-2006	12:49	42	3	16	36	+	+
9	**50**	25º35'092"	52º58'225"	22-Feb-2006	07:46	39	4	16	32	+	+
	55	26º36'057"	53º24'057"	22-Feb-2006	16:35	86	3	39	79	+	+
8	**40**	26º47'800"	52º57'400"	22-Feb-2006	06:41	86	3	36	74	+	+
	43	25º43'513"	52º23'170"	23-Feb-2006	14:34	33	3	11	25	+	+
7	**34**	26º02'500"	51º31'200"	27-Feb-2006	07:49	14	2	7	11	+	+
	36	26º28'190"	51º54'900"	28-Feb-2006	13:32	52	3	22	45	+	+
	39	27º07'000"	52º34'100"	28-Feb-2006	06:00	77	3	32	66	+	+
6	**27**	27º29'200"	51º57'0"	1-Mar-2006	10:53	54	3	25	50	+	+
	30	26º57'100"	51º18'500"	1-Mar-2006	17:17	71	3	31	63	+	+
	33	26º21'800"	50º45'500"	1-Mar-2006	06:39	14	2	7	11	+	+
5	**10a**	26º59'800"	50º23'700"	2-Mar-2006	16:35	26	3	11	22	+	+
	24	27º10'100"	50º43'500"	2-Mar-2006	06:45	65	3	29	58	+	+
	25	27º18'290"	50º58'400"	3-Mar-2006	09:08	67	3	29	58	+	+
	26	27º30'497"	51º11'060"	3-Mar-2006	12:45	73	3	29	58	+	+
	11a	27º43'179"	51º27'088"	3-Mar-2006	15:10	17	2	7	11	+	+

Table 1. Contd.

Transect	Station	Coordinates		Date	Time	Depth (m)	Sampling Depth (m)			Sampling Method	
		Latitude	Longitude				Surface	Middle	Bottom	Niskin Bottle	Oblique Net Tow
4	**20**	27º54'410"	50º59'518"	4-Mar-2006	06:32	63	3	25	50	+	+
	22	27º23'887"	50º13'952"	4-Mar-2006	12:19	57	3	25	51	+	+
	23	27º09'561"	49º52'363"	4-Mar-2006	15:38	43	3	17	35	+	+
3	**15**	27º39'842"	49º30'928"	4-Mar-2006	06:32	21	3	6	11	+	+
	17	28º01'115"	50º07'896"	5-Mar-2006	12:39	60	3	24	49	+	+
	19	28º21'033"	50º44'312"	5-Mar-2006	17:24	57	3	21	42	+	+
2a	**9a**	28º51'200"	50º24'200"	6-Mar-2006	07:12	47	3	24	48	+	+
	7a	28º31'145"	49º49'321"	6-Mar-2006	11:54	54	3	8	16	+	+
	5a	28º08'501"	49º05'508"	6-Mar-2006	17:09	21	3	8	16	+	+
2	**14**	28º33'885"	48º45'702"	6-Mar-2006	06:18	24	3	16	33	+	+
	11	28º49'120"	49º25'120"	7-Mar-2006	11:58	44	3	18	36	+	+
	8	29º17'580"	50º05'490"	7-Mar-2006	06:35	42	3	17	35	+	+
2-1	**28a**	29º38'011"	50º11'008"	8-Mar-2006	09:42	26	3	11	20	+	
	27a	29º56'006"	50º03'006"	8-Mar-2006	11:54	15	3	6	11	+	
1	**7**	29º52'106"	49º52'049"	8-Mar-2006	14:32	13	3	5	10	+	+
	4	29º13'245"	49º26'487"	9-Mar-2006	09:59	41	3	18	35	+	+
	1	29º21'000"	48º29'000"	9-Mar-2006	17:57	13	2	-	10	+	+

The collected samples consisted of 191 one-liter samples collected for quantitative analysis by Niskin bottle from three depth layers (surface, middle and bottom) at each station (sample from the middle layer of Station 1 was not collected by ROPME), and 42 qualitative one-liter samples were collected by oblique net tows (net diameter of 60 cm and mesh size of 20 μm). Sample from Station 7 was not available for analysis because it contained petroleum.

Samples collected by the Niskin bottle were preserved with acidified Lugol solution. Net samples were preserved with unacidified Lugol solution.

2.1 Taxonomical Analysis

Some taxa, in particular the diatoms and some dinoflagellates, cannot be identified to species or even genus level at the magnification used for counting and without special treatments.

Taxonomical analysis of phytoplankton has been conducted based on the 42 one-liter samples, which were collected by oblique net tows. A collection of permanent slides was also prepared from the net samples material. Net samples were collected for qualitative analysis at the same station (excluding Leg 1), where quantitative Niskin bottle samples were collected. 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 investigation of phytoplankton diversity. Some species were examined from the Niskin bottle samples in addition to the above material
.

Examination by light microscopy (LM) is the standard method used in the 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 light microscopy, scanning electron microscopy (SEM) and transmission electron microscopy (TEM).

Light Microscopy: Slides were examined using Leica DM LM microscope and/or Axiovert 200M (Carl Zeiss) microscope with bright field and phase contrast optic with 40× to 100× objectives. Microscopic slides for all specimens from all collected samples were examined microscopically and all identified phytoplankton taxa were recorded and photographed. High quality photomicrographs were taken with Leica DFC 320 or Carl Zeiss Axiocam HRc digital cameras.

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

Permanent Slides 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, could reveal many details, which are important for identification utilizing the light microscope.

A collection of permanent slides was 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, 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.

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

Detailed description of each prepared permanent slide is presented in Annex 1.

Scanning Electron Microscopy: Electron microscopic examination is essential for detailed analysis of the microstructure in some phytoplankton species, especially for small-sized groups. To prepare material for scanning electron microscopy subsamples from net samples 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 and was examined by a scanning electron microscope (SEM).

Estimation of Cell Sizes: Size is an important criterium for the identification of 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.

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 documentation of the different phytoplankton species. A collection of images for each identified phytoplankton taxon was produced based on the original photomicrographs. These images were used also for illustration of the phytoplankton species in the illustrated Atlas or guide.

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 when examining live samples, such as the 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 is 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 can not generally be identified to the species level by LM in 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 electron microscopy. Morphological features of species belonging to genera such as *Chaetoseros, 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 without end setae and damaged state of cells were observed in 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 indicate 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*, *Psedo-nitzscha, Thalassiosira, Trichodesmium,* and the small-sized *Protoperidinium* species were identified up to the genus level, while the naked flagellates were enumerated as a group.

2.2 Quantitative Analysis

A total of 191 quantitative one-liter samples were collected by the Niskin bottle from three depth layers (surface, middle and bottom) at each station. These samples were used for the estimation of phytoplankton density (abundance). The procedure for quantitative analysis involved recording the taxa observed and the number of algal objects (cells) for each taxon, in a known area of the counting chamber.

The Utermöhl method (sedimentation method) was used for quantitative analysis of the Niskin bottle sample (Utermohl, 1958). After full sedimentation for a period of four to eight weeks, samples were concentrated by carefully siphoning off the top water layer without disturbing the sedimented algae (using rubber hose with curved end) from 1000 ml down to 160-180 ml.

The concentrated sample was then well shaken and an aliquot of 25 ml of the sample was placed in the standard Utermöhl settling counting chamber. After sedimentation during a 24 h period in a well-covered dark desiccator, the area of the settling chamber was examined with a Leica DMIL inverted microscope at 200× to 400× magnification. For phytoplankton enumeration, the appropriate area of the chamber was scanned, depending on the abundance of each species.

Two alternative strategies were used for enumeration of phytoplankton taxa: (I) 20-40 randomly-selected viewing fields were examination at 400× magnification for very abundant phytoplankton species; and (II) the complete chamber area were scanned at 200× magnification for most species.

Number of cells per 1 liter (density) was calculated according to formula (1) or (2). The concentration of each individual taxon was calculated by formula (1) for the first counting strategy and by formula (2) for the second counting strategy:

$$(1),\qquad Abundance(cell/L) = n \cdot \frac{\frac{\pi \cdot D_{chamber}^2}{4}}{\frac{\pi \cdot D_{field}^2}{4} \cdot 20} \cdot \frac{V_{sample}}{V_{chamber}}$$

where n – number of cells in 20 (40) fields of viewer, $D_{chamber}$ – diameter of Utermöhl chamber, D_{field} – diameter of field of viewer; V_{sample} – volume of sample; $V_{chamber}$ – volume of Utermöhl chamber (25 ml).

$$(2),\qquad Abundance(cell/L) = n \cdot \frac{V_{sample}}{V_{chamber}}$$

where n – number of cells in Utermöhl chamber; V_{sample} – volume of sample after concentration; $V_{chamber}$ – examined volume of Utermöhl chamber (25 ml).

The taxa were counted depending on the results of previous taxonomical analysis. In general, to ensure that analyses were based on as much unique ecological information as possible, the lowest taxonomic resolution possible was used for assignments (e.g., genus or species). Most microalgae were identified to the species level mainly based on Schiller (1937), Cupp (1943), Steidinger and Williams (1970), Taylor (1976), Dodge (1982), Dowidar (1983), Hustedt (1985), Sournia (1986), Ricard (1987), Balech (1988), Round *et al*. (1990), Tomas (1997), Konovalova (1998) and Witkowski et al. (2000). When precise species identification was difficult, the similar taxa were grouped into categories such as "*Gymnodinium*-like group", "*Chaetoceros* spp.", "*Protoperidinium globulus* group". For example, some very similar species from the genus *Protoperidinium* were grouped, as an example, the pair of similar species *Protoperidinium oblongum* and *Protoperidinium claudicans* was enumerated together, because they could not be distinguished without examination of plates 1' and 2a. The quantitative data regarding colonial the prymnesiophyte *Phaeocystis* sp. are not reliable, because abundance estimation of this species based on fixed samples cannot be recalculated correctly due to its colonial nature. Cells of this species form gelatinous colonies with various sizes, often up to a few centimeters in diameter. When such large colonies or their fragments were found in the counting chamber, only presence of this species in the sample was recorded, because accurate enumeration of *Phaeocystis* sp. cells was not possible. Therefore, information about *Phaeocystis* sp. was used only in the taxonomical part of this report, but for its density estimates, it was excluded from all other sections.

Single cells were enumerated for most species including taxa with chain forms, while filament numbers were enumerated for *Trichodesmium* sp.

2.3 Statistical Analysis

All data were computerized and analyzed statistically using MS Excel 2000, SigmaPlot 2001, Systat v. 7.0, Primer v. 6.1.9 and BioDiversity Pro v. 2 software.

Statistical analysis was based on the matrix of all data collected during the cruise at 64 stations (191 samples collected by Niskin bottle). A total of 324 phytoplankton taxa were identified. Phytoplankton species identified from the plankton net samples and from the produced permanent slides were used for the generation of a complete check list of species. The data and information from the net samples were excluded from calculations, since data from the net samples are of qualitative nature.

Similarities and differences within the phytoplankton communities were analyzed through the classical taxonomic approach (including examination and comparison of list of species, taxonomic ratios, abundance, occurrence, diversity index, distribution patterns) as well as by cluster analysis. Cluster analysis was based on the similarity matrices of all data collected at 64 stations (samples from surface, middle and bottom layers were summarized) and 324 identified phytoplankton taxa. Similarity among samples was determined using the Bray-Curtis similarity measure or Spearman correlation coefficient. Hierarchical clustering (complete linkage) was applied to the similarity matrices to select groups of stations/species.

To estimate phytoplankton diversity, Margalef's index (species richness), Shannon's index (species diversity), Pielou's index (community evenness) as well as occurrence index (β-diversity) were used. Diversity index was calculated by means of Primer 6.1.9 for Windows (Plymouth Routines In Multivariate Ecological Research).

For the analysis of similarity between species compositions Jaccard (I_J) index of association was used. This index was chosen as the most adequate in the field regarding the maximum values of absolute similarity, because the high sensitiveness of tests is necessary in case of insignificant changes of absolute similarity among very similar species compositions for better estimation of their interrelationships.

Correlation analysis (Pearson linear correlation method) was performed to estimate relationships between phytoplankton and environmental factors. Spatial distribution counter plots were created by Surfer 8 using kriging extrapolated method.

3. Results and Discussion

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 flagellum, large and evident nucleus), silicoflagellates (with external silica skeleton), naked flagellates (heterogeneous group which comprises 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 below 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 **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 phyllum (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 from the preserved samples, which were collected during the ROPME Oceanographic cruise for Winter 2006.

PROKARYOTA – lacking a nucleus enveloped by a membrane

Division **CYANOPHYTA**
Chlorophyll-*a*, c-phycocyanin, 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 derivates) 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 diversity level for each class of phytoplankton represented as the number of taxa recorded from the RSA is presented in Table 2.

Table 2. Diversity of the Main Phytoplankton Groups Recorded from the RSA during Winter 2006

Class	Diversity
Cyanophyceae	2
Cryptophyceae	1
Dinophyceae	184
Psymnesiophyceae	1
Dictyochophyceae	2
Bacillariophyceae	141
Euglenophyceae	1
Prasinophyceae	4
Ebriidea	1
Total phytoplankton diversity	**337**

The phytoplankton community in the ROPME Sea Areas during winter 2006 was very diverse with 337 taxa identified, representing nine classes.

Dinoflagellates (Dinophyceae) contained the greatest number of taxa with 184 identified, followed by diatoms (Bacillariophyceae) - 141 taxa, Prasinophyceae (four taxa), Cyanophyceae and Dictyochophyceae classes are with two taxa each, and Cryptophyceae, Prymnesiophyceae, Euglenophyceae and Ebriidae classes all with only one taxon each.

A complete list of the identified phytoplankton taxa, which were recorded from the quantitative analysis of the Niskin bottle samples, and from the qualitative examination of plankton net samples and permanent slides is presented in Annex 2. The list of taxa is arranged according to the common taxonomical systems for each class (Annex 2).

Figure 4 displays the contribution of each microalgal group out of the total phytoplankton diversity.

Dinoflagellates and diatoms were the most diverse groups. The diversity within each of them was analyzed in detail below.

The highest diversity of dinoflagellates was contributed by both unarmored (44 taxa) and armored (140 taxa) species from 45 genera (Table 3).

Protoperidinium genus showed the highest species diversity (35 taxa), followed by the *Ceratium* genus (28 taxa), *Gymnodinium* (>15 taxa), *Gonyaulax* (12 taxa), *Dinophysis* (11 taxa), *Prorocentrum* (9 taxa) and *Oxytoxum* (8 taxa). The diversity within other genera was not significant. Maximum diversity was recorded in armored dinoflagellates. The species diversity within the small-sized unarmored dinoflagellates (such as *Gymnodinium*-like group) was not adequately estimated since the results were based on preserved material.

The high diversity of diatoms (141 species) was contributed by both centric (86 taxa) and pennate (55 taxa) species (Table 4). The diatom assemblage was dominated by centric species. The largest species diversity associated with centric diatoms from the genus *Chaetoceros* (15 taxa), the *Rhizosolenia* group (12 taxa), which included seven species from *Rhizosolenia* genus and five species from the morphologically close genera *Neocalyptrella, Proboscia* and *Pseudosolenia*, and genus the *Coscinodiscus* (8 taxa) as well as with the pennate diatoms from the *Nitzschia* group (15 taxa), which included seven species from the *Nitzschia* genus and eight species from the morphologically close genera of *Bacillaria*, *Cymatonitzschia*, *Cylindrotheca*, *Psammodictyon* and *Pseudo-nitzschia*.

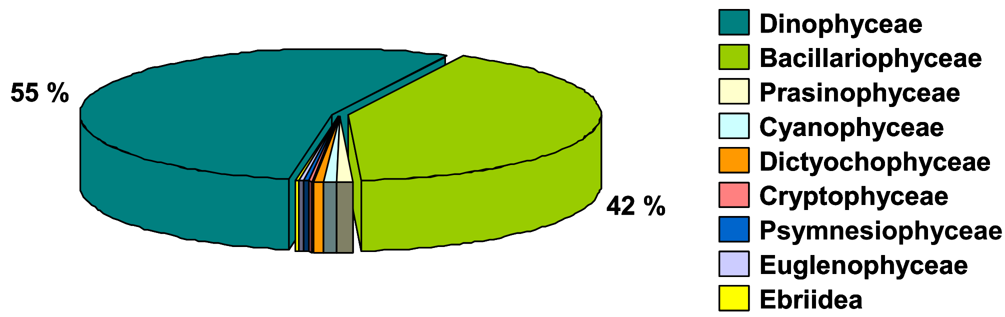

Fig. 3. Contribution of the different groups as percentage of the total phytoplankton diversity.

Table 3. Taxonomical Structure and Diversity within the Class Dinophyceae

Dinophyceae			
Genus	**Number of Taxa**	***Genus***	**Number of Taxa**
Achradina	1	*Kofoidinium*	1
Actiniscus	1	*Lingulodinium*	1
Akashiwo	1	*Mesoporos*	1
Alexandrium	1	*Noctiluca*	1
Amphisolenia	2	*Ornithocercus*	4
Balechina	1	*Oxytoxum*	8
Ceratium	28	*Peridinium*	2
Ceratocorys	2	*Podalampas*	2
Cochlodinium	3	*Polykrikos*	1
Corythodinium	2	*Pronoctiluca*	2
Dicroerisma	1	*Prorocentrum*	9
Dinophysis	11	*Protoceratium*	1
Diplopelta	3	*Protoperidinium*	35
Diplopsalis	1	*Pyrocystis*	5
Dissodinium	1	*Pyrodinium*	1
Goniodoma	1	*Pyrophacus*	2
Gonyaulax	12	*Scrippsiella*	2
Gymnodinium	>15	*Sinophysis*	1
Gyrodinium	5	*Spiraulax*	2
Heterocapsa	3	*Torodinium*	2
Histioneis	2	*Triposolenia*	1
Karenia	1	*Warnowia*	1
Katodinium	1	**Total**	**184**

Table 4. Taxonomical Structure and Diversity within the Class Bacillariophyceae

Bacillariophyceae			
Centric		**Pennate**	
Genus	**Number of Taxa**	***Genus***	**Number of Taxa**
Actinocyclus	3	*Amphora*	>5
Actinoptychus	1	*Bacillaria*	2
Asteromphalus	2	*Caloneis*	1
Bacteriastrum	3	*Campilodiscus*	1
Bellerochea	1	*Cylindrotheca*	1
Biddulphia	2	*Cymatonitzschia*	1
Cerataulina	2	*Cymatosira*	1
Chaetoceros	15	*Diploneis*	2
Climacodium	1	*Enthomoneis*	2
Corethron	2	*Ephemera*	1
Coscinodiscus	8	*Gomphonema*	1
Cyclotella	2	*Gyrosigma*	2
Dactyliosolen	1	*Haslea*	1
Detonula	1	*Mastoneis*	1
Ditylum	1	*Meuniera*	1
Eucampia	2	*Licmophora*	1
Guinardia	3	*Lyrella*	1
Hemiaulus	3	*Navicula*	>2
Lauderia	1	*Nitzschia*	7
Leptocylindrus	3	*Petrodictyon*	1
Lithodesmium	1	*Petroneis*	1
Neocalyptrella	1	*Plagiotropis*	3
Odontella	3	*Pleurosigma*	>4
Palmeria	1	*Psammodictyon*	1
Paralia	1	*Pseudo-nitzschia*	3
Planktoniella	1	*Surirella*	1
Podosira	1	*Synedra*	2
Proboscia	3	*Thalassionema*	1
Pseudosolenia	1	*Thalassiothrix*	2
Rhizosolenia	7	*Trachyneis*	2
Skeletonema	1		
Stellarima	1		
Stephanopyxis	1		
Streptotheca	2		
Thalassiosira	3		
Triceratium	1		
Total	**86**		**55**

Significant densities of pennate diatoms, especially large and small benthic diatoms from periphytone, epipelon and epipsammon associations (genus *Pleurosigma*, *Gyrosigma*, *Diploneis*, *Surirella*, *Campilodiscus*, *Trachyneis*, *Nitzschia*, *Enthomoneis*, *Plagiotropis*, *Caloneis*, *Lyrella*, *Petroneis*, *Licmophora*, *Gomphonema*) were recorded. For some of these diatoms (*Pleurosigma* spp., *Surirella fastuosa*, *Trachyneis antillarum, Caloneis liber, Diploneis weissflogii*, and *Plagiotropis lepidoptera*) high abundances at several locations (especially in the coastal zone or in the bottom layer) were observed.

Phytoplankton diversity within the ROPME Sea Area were previously reported by several investigators. Though those studies mainly were limited in space and time, they provide some background information on the RSA phytoplankton diversity and the species/group composition. Some available information regarding phytoplankton diversity from the different parts of RSA is summarized in Table 5.

3.2 Phytoplankton Species of the RSA

The frequency of distribution of species diversity among the different encountered classes is displayed in Fig. 5. Approximately half of phytoplankton species (52% of total species diversity) is characterized by low occurrence level (less than 10% of examined samples).

To estimate the level of species occurrence, 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%); and ***ubiquitous*** (greater than 75%).

Only eight microalgal taxa (2% of total phytoplankton diversity) were observed in more than 75% of examined samples. This group of ubiquitous species includes *Gymnodinium*-like group of small-sized dinoflagellates, which occurred practically at all sampling stations (in 9% of examined samples); medium-sized dinoflagellate *Gyrodinium fusiforme* (94%); naked cryptophytes flagellate *Teleulax* sp. (87%); large-sized diatom *Pleurosigma diverse-striatum* (84%); small-sized dinoflagellate *Oxytoxum variabile* (84%); medium-sized diatom *Thalassionema nitzschioides* (83%); small-sized dinoflagellate *Torodinium robustum* (82%); and medium-sized diatom *Pseudo-nitzschia* cf. *delicatissima* (79%).

Table 5. Comparison of Phytoplankton Diversity Results from Different Areas of the ROPME Sea

Area	Phytoplankton diversity Total (Diatom/Dinoflagellate)	Reference
Shatt Al-Arab River	352 (308/10)	Al-Saboonchi and Al-Saad, 1988 (check list)
Kuwait	178 (155/13)	Al-Kaisi, 1976 (winter cruise)
Qatar	140 (72/40)	
United Arab Emirates	114 (38/43)	
ROPME Sea Area	299 (160/49)	
Kuwait	220 (162/53)	Al-Yamani *et al*., 2004 (interannual surveys)
ROPME Sea Area	223 (134/86)	Jacob and Al-Muzaini, 1990 (review)
Qatar	390 (225/152)	Dorgham and Muftah, 1986 (annual survey)
Shatt Al-Arab Estuary	< 116	Subba Rao and Al-Yamani, 1998 (review)
South off Kuwait	148	
Straits of Hormuz + Sea of Oman	527	
inner RSA **+ Straits of Hormuz** + Sea of Oman	**337 (141/184)**	**Present ROPME survey (Winter 2006 Cruise)**

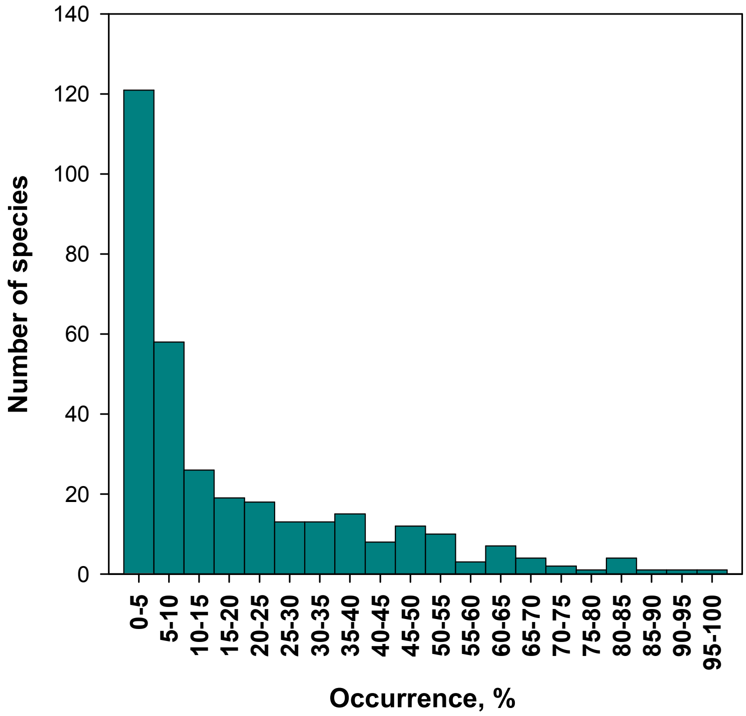

Fig. 4. Distribution of species diversity among the different classes observed from the RSA.

The common species group contains 26 species (8% of total phytoplankton diversity). The majority of the common species are diatoms (18 taxa); in addition,eight dinoflagellate species and one *Dictyocha* species belong to the common species group.

The group of frequent species (18% of total phytoplankton diversity, 60 species) includes 36 diatoms, 22 dinoflagellates, one blue-green alga (*Trichodesmium* sp.) and one euglenophytes (*Eutreptiella* sp.).

Species that demonstrated occasional occurrence (20% of total phytoplankton diversity, 67 species) are members of diatoms (31 species), of dinoflagellates (34 species) as well as one zooflagellate *Ebria tripartita* make up the occasionally observed group.

The group of species with rare occurrence (37% of total phytoplankton diversity, 126 species) includes 50 diatom species, 71 dinoflagellates and five taxa from the classes of Prymnesiophyceae, Prasinophyceae and Dictyochophyceae.

Very rare species (15% of total phytoplankton diversity, 50 species) were registered only in one or two samples, and often only one specimen was observed.

3.3 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). Though 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 the public health risks and the damage caused to the mariculture industry. Therefore, assessment of species composition, occurrence and quantitative distribution of potentially harmful species is a very important part of phytoplankton ecological study. In order to determine potentially harmful species within the RSA, detailed examination of the HAB species in the RSA phytoplankton community was performed here.

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

1. Blooms of species which potentially produce toxins, which 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:

    - (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)

2. Blooms of species which, in most cases are non-toxic 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 (such as *Alexandrium tamarense, Chaetoceros convolutus, Gyrodinium aureolum, Heterosigma akashiwo, Nodularia spumigena*).

3. 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 (*Noctiluca scintillans, Ceratium* spp., *Prorocentrum micans, Heterocapsa triquetra, Skeletonema costatum, Trichodesmium erythraeum, Eutreptiella* spp., *Phaeocystis pouchetii*).

There is no general algal concentration value, which is considered a harmful concentration of cells 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 tumarense* 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 five different classes can be related to 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 6.

Summary of the available published information regarding known potentially harmful algae is included below. This material can be related to Table 6.

Taxon	**Harmful Effect**
Cyanophyceae	
Genus *Trichodesmium*	Bloom-forming marine cyanophyte. To date two species have been reported to be toxigenic, *T. erythraeum* and *T. thiebautii*. Strains can produce neurotoxins and hepatotoxins (Cronberg and Annadotter, 2006).
Bacillariophyceae	
Cerataulina pelagica	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).
Chaetoceros peruvianus	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).
Chaetoceros socialis	Non-toxic bloom-forming species. Harmful effect could be caused by its presence in mucilage colonies (Hallegraeff *et al*., 1995).
Coscinodiscus wailesii	Non-toxic bloom-forming species. In the late 1970's 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).

Table 6. A Checklist of Potentially Harmful Species Recorded in the RSA during the Winter 2006 Cruise.

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 (10^5-10^6 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 abundances; 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.

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:							
Trichodesmium sp.	+ [NT, HT]	38	Frequent	1.1×10^3	55-S	Iran	<1
Pseudonitzschia cf *delicatissima*	+[ASP,BF]	79	Ubiquitous	4.6×10^5	36-M	Qatar	38.1
Pseudo-nitzschia cf *pungens*	+ [ASP]	29	Frequent	4.3×10^4	36-M	Qatar	3.6
Pseudo-nitzschia cf *seriata*	+ [ASP]	3	Rare	2.1×10^4	66-S	UAE	6.9
Alexandrium tamiyavanichii	+ [PSP]	15	Occasional	1.9×10^3	87-S	Iran	1.8
Dinophysis acuminata	+ [DSP]	3	Rare	41	78-M	Iran	<1
Dinophysis caudata	+ [DSP]	27	Frequent	389	92-S	Oman	<1
Dinophysis miles	+ [DSP]	14	Occasional	72	28a-M	Iran	<1
Dinophysis mitra	+ [DSP]	3	Rare	18	11-S	Saudi Arabia	<1
Dinophysis rapa	+ [DSP]	<1	Very rare	12	78-S	Iran	<1
Dinophysis rotundata	+ [DSP]	27	Frequent	53	59-M	Iran	<1

Table 6. Contd.

Gymnodinium catenatum	+ [PSP]	28	Frequent	$1.2{\times}10^3$	55-S	Iran	<1
Karenia brevis	+ [NSP]	9	Rare	$1.0{\times}10^3$	23-M	Saudi Arabia	2.9
Lingulodinium polyedrum	+ [PSP]	<1	Very rare	15	78-S	Iran	<1
Prorocentrum balticum	+?	3	Rare	29	87-S	Iran	<1
Prorocentrum minimum	+? [NT]	21	Occasional	$2.9{\times}10^3$	71-B	Iran	6.9
Prorocentrum rhathymum	+ [DSP?]	9	Rare	280	27a-M	Iran	<1
Protoperidinium curtipes	+? [AZP]	10	Rare	48	8-S	Iran	<1
Protoperidinium divergens	+? [AZP]	28	Frequent	133	5a-B	Iran	<1
Pyrodinium bahamense v. *compressum*	+ [PSP]	3	Rare	105	66-S	UAE	<1
Species potentially causing marine mortality:							
Proboscia alata f. *gracillima*	+	26	Frequent	$5.0{\times}10^3$	11a-S	Iran	3.1
Akashiwo sanguinea	+	<1	Very rare	8	9a-M	Iran	<1
Ceratium furca	+	46	Frequent	$2.1{\times}10^3$	7-S	Iran	1.9
Ceratium fusis	+	54	Common	613	5a-S	Saudi Arabia	1.4
Cochlodinium polykrikoides	+	7	Rare	$1.7{\times}10^3$	50-B	UAE	1.0
Dissodinium pseudolunula	+?	<1	Very rare	13	26a-B	Oman	<1
Gonyaulax polygramma	+	13	Occasional	75	90-S	Oman	<1
Noctiluca scintillans	+	46	Frequent	688	90-S	Oman	<1
Peridinium quinquecorne	+	<1	Very rare	45	28a-S	Iran	<1
Prorocentrum micans	+	47	Frequent	$3.3{\times}10^3$	36-S	Qatar	<1
Protoceratium reticulatum	+	<1	Very rare	34	50-B	UAE	<1
Scrippsiella trochoidea	+	51	Common	$7.5{\times}10^3$	36-S	Qatar	1.4
Phaeocystis sp.	+	4	Rare	62	88-B	Oman	<1
Dictyocha fibula	+	52	Common	667	90-S	Oman	<1
Dictyocha speculum	+	4	Rare	64	8-B	Iran	<1

Table 6. Contd.

Potentially bloom-forming species:							
Bacteriastrum delicatulum	BF	48	Frequent	1.8×10^{5}	88-S	Oman	10.2
Bacteriastrum furcatum	BF	10	Rare	7.8×10^{5}	14a-M	Iran	84.9
Chaetoceros compressus	BF	52	Common	1.5×10^{6}	78-M	Iran	87.1
Chaetoceros curvisetus	BF	37	Frequent	1.2×10^{6}	88-S	Oman	66.1
Chaetoceros lorenzianus	BF	78	Ubiquitous	2.3×10^{5}	27-S	Iran	32.1
Chaetoceros pseudocurvisetus	BF	22	Occasional	1.4×10^{5}	82-B	Iran	41.9
Chaetoceros socialis	+ [BF]	4	Rare	5.8×10^{5}	78-S	Iran	75.6
Chaetoceros tortissimus	BF	34	Frequent	1.6×10^{6}	14a-S	Iran	88.3
Guinardia delicatula	+ [BF]	44	Frequent	2.5×10^{5}	66-M	UAE	65.6
Gymnodinium-like group	BF	95	Ubiquitous	4.7×10^{5}	19a-B	UAE	81.0
Lauderia borealis	BF	67	Common	3.4×10^{5}	97-B	Iran	61.1
Skeletonema costatum	+ [BF]	20	Occasional	3.7×10^{5}	36-M	Qatar	31.0
Teleaulax sp.	BF	87	Ubiquitous	2.2×10^{5}	25-M	Iran	83.1
Leptocylindrus danicus	+ [bf]	70	Common	9.2×10^{4}	9a-B	Iran	49.7
Coscinodiscus wailesii	+ [bf]	5	Rare	16	27a-S	Iran	<1
Guinardia flaccida	+ [bf]	62	Common	8.9×10^{3}	7-B	Iran	6.6
Cerataulina pelagica	+ [bf]	55	Common	5.4×10^{4}	93-S	Oman	14.5
Chaetoceros peruvianus	+ [bf]	32	Frequent	1.4×10^{4}	14-B	Kuwait	9.6
Ceratium trichoceros	+ [bf]	36	Frequent	74	27-M	Iran	<1
Prorocentrum compressum	+ [bf]	30	Frequent	158	14-S	Kuwait	<1
Prorocentrum gracile	+ [bf]	36	Frequent	3.9×10^{3}	36-M	Qatar	<1
Prorocentrum sigmoides	+ [bf]	2	Rare	21	15-B	Saudi Arabia	<1
Prorocentrum triestinum	+ [bf]	19	Occasional	427	50-M	UAE	<1

Guinardia delicatula	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).
Guinardia flaccida	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).
Leptocylindrus danicus	Non-toxic bloom-forming species. Blooms of this species may produce fish kill in mariculture cages (Yan *et al*., source: web-site).
Proboscia alata f. *gracillima*	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 county alone, Gaoyang, 75 tons of fish-kill) (Yan *et al*., source: web-site).
Pseudo-nitzschia delicatissima	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 non-toxic. The identity of the New Zealand strain was determined only with a probe, but not confirmed morphologically (IOC list, 2002).
Pseudo-nitzschia pungens	Species 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 non-toxic, but toxic clones (domoic acid) have been reported from New Zealand and the West Coast of the USA (IOC list, 2002).
Pseudo-nitzschia seriata	Toxic bloom-forming species. Several clones of this species 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).
Skeletonema costatum	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).

Dinophyceae

Akashiwo sanguinea

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.

Alexandrium tamiyavanichii

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.

Ceratium furca

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 blue mussel during a bloom of *Ceratium furca* and *Dinophysis fortii,* resulting in reduction of fish mariculture operations and economic loss (Zhao, 2000).

Ceratium fusis

This species can cause harm to invertebrate larvae by an unknown mechanism (Hallegraeff *et al*., 1995).

Cochlodinium polykrikoides

This 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).

Dinophysis acuminata

It 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.

Dinophysis caudata	This species is a producer of okadaic acid, which is a toxin implicated in DSP (IOC list, 2002). Its blooms associated with mass mortality of fish were reported in the Gulf of Thailand and Seto Inland Sea in Japan (Okaichi 1967). Toxicity of the species was found using specimens collected in Philippines waters (Hallegraeff *et al*., 1995).
Dinophysis miles	It is a producer of dinophysistoxin-1 (DTX1), a toxin implicated in DSP (IOC list, 2002). Toxicity of the species has been found using specimens collected in the Philippines waters (Hallegraeff *et al*., 1995).
Dinophysis mitra	It is a confirmed DSP (diarrhetic shellfish poison) toxin-producing species; it produces Dinophysistoxin-1 (DTX 1) and okadiac acid (OA) (Lee *et al*., 1989; Steidinger and Tangen, 1997).
Dinophysis rapa	This species was found to produce okadaic acid (IOC list, 2002).
Dinophysis rotundata	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 were reported to be non-toxic (IOC list, 2002). *D. rotundata* is the first heterotrophic dinoflagellate in which toxin productivity has been confirmed (Lee *et al*., 1989).
Dissodinium pseudolunula	Secondary cysts with dinospores were frequently observed in net hauls from fish farms. Probably parasitic on salmon lice eggs (Throndsen *et al*., 2007).
Gymnodinium catenatum	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).

Gonyaulax polygramma	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).
Karenia brevis	It produces a series of brevetoxins (neurotoxins). Blooms of this 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).
Lingulodinium polyedrum	It is a toxic bloom-forming species. Bruno *et al*. (1990) reported the presence of a paralytic shellfish poison (PSP) toxin, saxitoxin, in water samples taken during a bloom of *L. polyedrum.*
Noctiluca scintillans	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 & Nishio, 1976; Fukuyo *et al*., 1990). Extensive toxic blooms have been reported off the east and west coasts of India, where it has been implicated in the decline of fisheries (Aiyar, 1936; Bhimachar and George, 1950).
Peridinium quinquecorne	This species can cause anoxia and fish kills during blooms with very high cell numbers (Fukuyo *et al*., 1990).
Prorocentrum balticum	Toxicology for this species is unknown, but it is regarded as potentially toxic (Steidinger and Tangen, 1997; Faust *et al*., 1999).

Prorocentrum compressum	It is a bloom-forming species, regarded as potentially toxic. Blooms of this species produce harmless water discolorations (Fukuyo *et al*., 2003).
Prorocentrum gracile	It is a bloom-forming species, regarded as potentially toxic. Blooms of this species produce harmless water discolorations (Fukuyo *et al*., 2003).
Prorocentrum micans	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).
Prorocentrum minimum	It is a toxic species, which caused shellfish poisoning and fish kills (Steidinger and Tangen, 1997). Intraperitoneal injection of methanol extracts are toxic to mice. Ingested cells can cause detrimental effects in molluscs. Some strains excrete substances toxic to *Artemia*-nauplii (IOC list, 2002).
Prorocentrum rhathymum	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).
Prorocentrum sigmoides	It is a non-toxic species, but it is harmful to marine organisms due to oxygen depletion at high cell concentration.
Prorocentrum triestinum	It is a non-toxic species, causing brownish seawater discoloration, as was recorded in the Mediterranean Sea (Zingone *et al*., 2006).
Protoceratium reticulatum	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).

Protoperidinium curtipes *Protoperidinium divergens*	It is a probable toxin producer (azaspiracid, which gives DSP-like symptoms in humans) (Throndsen *et al*., 2007).
Pyrodinium bahamense v. *compressum*	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).
Scrippsiella trochoidea	It is a non-toxic species, but it can cause fish kills in sheltered bays through the generation of anoxic conditions (Hallegraeff, 2002).

Prasinophyceae

Genus *Phaeocystis*	The main effects of *Phaeocystis* are 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 1 million NKr. The toxic compound(s) has not been identified (Hallegraeff *et al*., 1995; IOC list, 2002).

Dictyochophyceae

Dictyocha fibula	It is a non-toxic species, but the spiny skeleton may irritate fish gills when present in high concentration (Hansen *et al*., 2001).
Dictyocha speculum	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).

The potentially harmful algae, which were encountered within the RSA during Winter 2006, are included in Table 6. Areas of high HAB abundance were found mainly in the coastal waters. The highest abundances for potentially harmful phytoplankton are included in Table 6 and plotted on RSA map in Fig. 6.

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*. cf *pungens* occurred in 29% of samples) or even have ubiquitous distribution (*P*. cf *delicatissima*, 79% of samples). In addition, *P*. cf *delicatissima* was rather abundant, especially in 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 alga (cyanophyte) *Trichodesmium* sp. occurred frequently (in 38% of samples).

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. 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 tamarense* 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 brevis* 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 RSA (inner RSA), whereas *K. brevis* was found near 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.

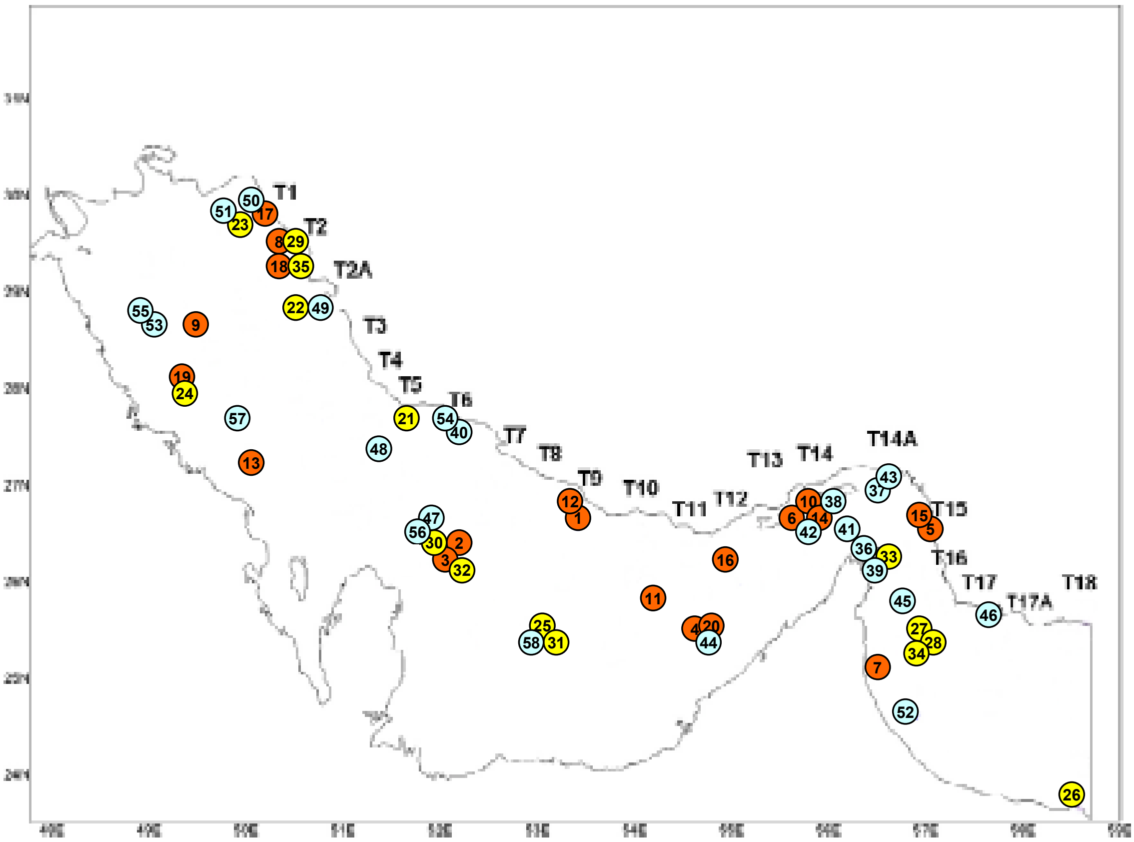

Fig. 5. Distribution of the maximum abundance for the potentially harmful algae species in the RSA during Winter 2006.

Orange circles – potentially toxic species to humans; yellow circles – species potentially causing marine mortality; blue circles – potentially bloom-forming species (refer to Table 6): 1 - *Trichodesmium* sp.; 2 - *Pseudo-nitzschia* cf *delicatissima;* 3 - *Pseudo-nitzschia* cf *pungens;* 4 - *Pseudo-nitzschia* cf *seriata*; 5 - *Alexandrium tamiyavanichii*; 6 - *Dinophysis acuminata*; 7 - *Dinophysis caudata*; 8 - *Dinophysis miles*; 9 - *Dinophysis mitra*; 10 - *Dinophysis rapa*; 11 - *Dinophysis rotundata*; 12 - *Gymnodinium catenatum*; 13 - *Karenia brevis*; 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 fusis*; 25 - *Cochlodinium polykrikoides*; 26 - *Dissodinium pseudolunula*; 27 - *Gonyaulax poligramma*; 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 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 triestinum*.

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 influences 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 of the United Arab Emirates.

Additionally, other potentially harmful algae of non-toxic bloom-forming species were 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 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. Table 6 included information on the bloom-associated harmful effects of *Chaetoceros socialis*, *Guinardia delicatula* and *Skeletonema costatum*.

3.4 Spatial Variability of Phytoplankton in the RSA during Winter 2006

Vertical Distribution of Phytoplankton Diversity. The phytoplankton species diversity for each sampling layer (pooling all stations) and the total diversity for the water column are presented in Table 7 and Fig. 7.

Illustrations show significant similarity between phytoplankton from different sampling levels. The number of enumerated taxa is practically the same from the surface, middle and bottom layers. Ratios of Bacillariophyceae/Dinophyceae are very close to 1 in surface and middle layers, but slightly increased in the bottom layer (1.14) due to presence of some benthic forms to the list of diatom species. Species richness (Margalef Index) slightly increased gradually along with depth. Maximum levels of species diversity (Shannon Index) and community evenness (Pielou's Index) are associated with the surface layer.

Percentage composition of the top-dominant taxa out of the total phytoplankton abundance for each sampling layer is presented in Table 8.

Table 7. Phytoplankton Species Diversity for each Sampling Layer (surface, middle and bottom) and for the Total Diversity for the Water Column based on Combined Diversity for the Three Sampled Layers

Class	Diversity (Number of species)			
	Surface	Middle	Bottom	Total (Pooling Surface, middle and bottom layers)
Bacillariophyceae	127	129	136	153
Dinophyceae	126	129	119	160
Cyanophyceae	2	2	2	2
Cryptophyceae	1	1	1	1
Prymnesiophyceae	0	1	1	1
Dictyochophyceae	2	2	2	2
Euglenophyceae	1	1	1	1
Prasinophyceae	1	3	2	3
Ebriidea	1	1	1	1
Total phytoplankton	261	269	265	324
Species richness (Margalef Index)	15.69	16.44	16.62	18.57
Species diversity (Shannon Index)	3.06	2.86	2.94	3.18
Community evenness (Pielou's Index)	0.55	0.51	0.53	0.55

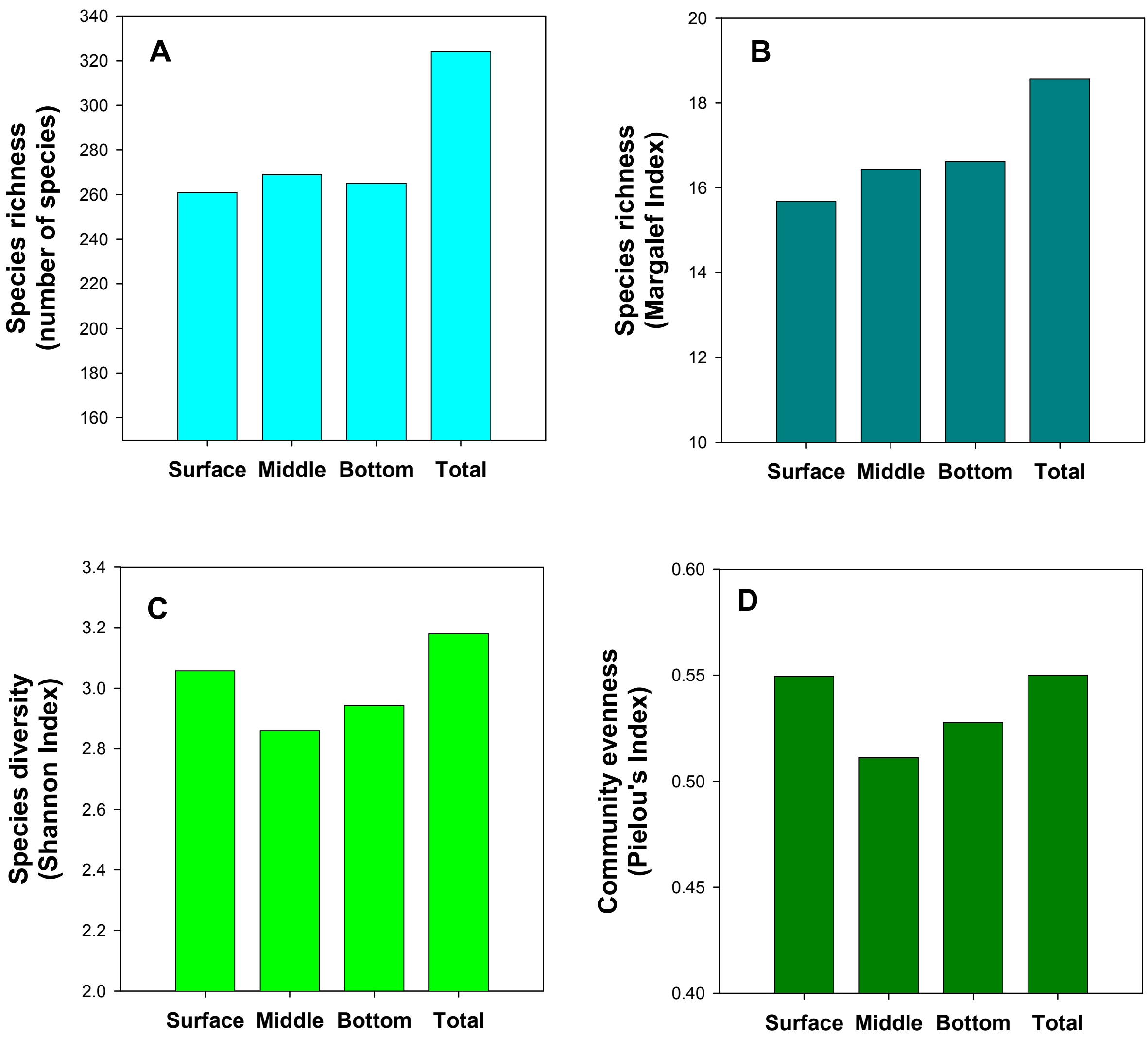

Fig. 6. Vertical distribution and total levels of the main parameters of phytoplankton diversity: species richness (A and B), species diversity (C) and community evenness (D).

Table 8. Percentage Composition of the Top-dominant Taxa out of the Total Phytoplankton Abundance for each Sampling Layer

Surface Layer		Middle Layer		Bottom Layer	
Taxon	**%**	**Taxon**	**%**	**Taxon**	**%**
Chaetoceros curvisetus	19.2	*Gymnodinium*-like group	16.8	*Gymnodinium*-like group	28.0
Chaetoceros tortissimus	12.8	*Chaetoceros compressus*	16.1	*Teleaulax* sp.	13.6
Gymnodinium-like group	9.2	*Bacteriastrum furcatum*	10.0	*Pseudonitzschia delicatissima* group	5.7
Chaetoceros socialis	6.3	*Teleaulax* sp.	9.9	*Lauderia borealis*	5.5
Pseudonitzschia delicatissima group	6.2	*Chaetoceros curvisetus*	9.1	*Chaetoceros pseudocurvisetus*	5.4
Teleaulax sp.	5.5	*Pseudonitzschia delicatissima* group	8.5	*Bacteriastrum delicatulum*	5.3
Chaetoceros lorenzianus	5.5	*Skeletonema costatum*	3.7	*Chaetoceros curvisetus*	4.6
Skeletonema costatum	4.1	*Guinardia delicatula*	3.0	*Leptocylindrus danicus*	4.2
Chaetoceros compressus	4.0	*Nitzschia* sp. 1	2.3	*Skeletonema costatum*	2.4
Bacteriastrum delicatulum	3.2	*Lauderia borealis*	2.2	*Chaetoceros compressus*	2.3
Guinardia delicatula	2.7	*Chaetoceros lorenzianus*	2.1	*Chaetoceros lorenzianus*	2.2
Nitzschia sp. 1	2.3	*Leptocylindrus danicus*	1.9	*Nitzschia* sp. 1	2.2
Chaetoceros pseudocurvisetus	2.0	*Chaetoceros tortissimus*	1.2	*Thalassionema nitzschioides*	1.7
Cerataulina pelagica	1.7	*Oxytoxum variabile*	1.0	*Cerataulina pelagica*	1.4
Lauderia borealis	1.4	*Cerataulina pelagica*	0.9	*Rhizosolenia shrubsolei*	1.3
Bacteriastrum hyalinum	1.4	*Thalassionema nitzschioides*	0.8	*Oxytoxum variabile*	1.1
Leptocylindrus danicus	1.2	*Pseudonitzschia pungens*	0.7	*Torodinium robustum*	0.9
Pseudonitzschia spp.	1.2	*Rhizosolenia shrubsolei*	0.7	*Heterocapsa* sp.1	0.7
Oxytoxum variabile	0.7			*Chaetoceros brevis*	0.7
				Thalassiosira oestrupii	0.5
				Navicula spp.	0.5
				Gyrodinium fusiforme	0.5
				Diploneis weissflogii	0.4

A total of 19 species contributed to a large extent to the phytoplankton abundance in the surface layer. These dominant taxa were composed mainly of chain-forming small- and medium-sized diatoms (16 species: small-sized *Chaetoceros* and *Bacteriastrum* species, *Skeletonema costatum*, *Guinardia delicatula* and *Leptocylindrus danicus*; medium-sized species such as *Lauderia borealis* and *Pseudo-nitzschia* species). The two most dominant species, *Chaetoceros curvicetus* and *Chaetocers tortissimus* contributed together up to 1/3 of the total phytoplankton abundance for the surface layer. The small-sized naked flagellates from the *Gymnodinium*-like group (9.2% of total abundance) and the cryptophycean flagellate *Teleaulax* sp. (5.5%) were observed in quite high concentrations.

A list of the top-dominant taxa from the middle layer contained 18 species and has similar species composition. However, the order of prevalence differs. The top positions are occupied by naked flagellates from *Gymnodinium*-like group (16.8%) and *Chaetoceros compressus* (16.1%).

The community composition of the top-dominant taxa for the bottom layer is more diverse (23 taxa) due to the presence of typically benthic diatoms *Thalassionema nitzschioides*, *Navicula* spp. and *Diploneis weissflogii* in the collected bottom layer samples, and due to the increase in relative abundance for dinoflagellates such as *Oxytoxum variabile*, *Torodinium robustum*, *Heterocapsa* sp. and *Gyrodinium fusiforme*. Diatoms were displaced from the dominant positions by naked flagellates (*Gymnodinium*-like group and *Teleaulax* sp.) that contributed about 41.6% of the total phytoplankton abundance in this layer.

In general, comparison of species composition for the dominant taxa from the different sampled layers revealed significant changes with depth. The role of the combined group of naked flagellates (*Gymnodinium*-like group + cryptophycean flagellate *Teleaulax* sp.) was noticeable moving from surface to bottom layer. In the surface layer, this group contributed only 14.7% of total phytoplankton abundance. Within middle layer their prevalence almost doubled reaching up to 26.7%, and in the bottom layer, this group was in the leading position (41.6%) within the phytoplankton community. The dominant species from the *Chaetoceros* genus displayed an opposite trend. In the surface layer, nine species from the *Chaetoceros* genus contributed together about 54.1% of the total phytoplankton abundance. In the middle layer, the diversity of this group was reduced as well as its contribution, which decreased to five species that contributed 38.5%. For the bottom layer, seven *Chaetoceros* species constituted only 20.3% in total phytoplankton abundance.

There were 12 phytoplankton taxa, which could be found among the dominant species at any depth. These are nine diatoms (*Chaetoceros curvicetus*, *Chaetoceros compressus*, *Chaetoceros lorenzianus*, *Ceratauluna pelagica*, *Lauderia borealis*, *Leptocylindrus danicus*, *Skeletonema costatum*, *Pseudo-nitzschia* cf *delicatissima* and *Nitzschia* sp.1), two naked flagellates (*Gymnodinium*-like group and *Teleaulax* sp.) and a small dinoflagellate *Oxytoxum variabile*.

Spatial Distribution of Phytoplankton Diversity**.** In order to assess the diversity of the phytoplankton community within the RSA, species richness (number of species per sample and Margalef's Index), species diversity (Shannon's Index) and community evenness (Pielou's Index) were calculated for each station from data for the surface, middle and bottom layers (Table 9). Figures 8 and 9 display the spatial variability of the phytoplankton diversity within the studied RSA.

A high diversity level characterized the winter phytoplankton community in the RSA**.** Species richness varied within a wide range from 44 species up to 155 (average number of species per one station was 110.4 ± 21.4); and Margalef's index varied from 5.01 to 11.53 (8.50 ± 1.40). Species richness was relatively evenly distributed throughout the studied area. Localized zones of low or very high species richness are delineated in Fig. 8. Minimal level of species richness was associated with the central part of the inner RSA and with the open waters of Sea of Oman. The highest species richness was observed in the coastal waters of the inner RSA (off the Iranian coast) and near the Strait of Hormuz in the Sea of Oman (Fig. 8).

The observed level of species diversity (Shannon's index) was also quite high (2.05 ± 0.48; ranging from 0.79 to 2.89). Maximum ranks of diversity and community evenness were detected in the northern part of the inner RSA and in the Sea of Oman (Fig. 9).

Species richness was positively correlated with total phytoplankton abundance (Fig. 10 A and B), whereas reverse trends were found in the relationship between phytoplankton abundance and species diversity and evenness (Fig. 10 C and D).

Table 9. Parameters of Phytoplankton Diversity: Species Richness (S – number of species; I_M – Margalef's Index), Community Evenness (I_P – Pielou's Index) and Species Diversity (I_{Sh} – Shannon's Index) for each Sampled Station in the RSA during Winter 2006

Transect	St.#	S	I_M	I_P	I_{Sh}	Transect	St.#	S	I_M	I_P	I_{Sh}
T-18	**26a**	99	7.62	0.43	1.97	**T-9**	**50**	103	7.84	0.37	1.69
	100	68	5.38	0.25	1.04		**55**	95	7.45	0.54	2.44
	101	44	5.42	0.74	2.81	**T-8**	**40**	104	8.03	0.41	1.92
	98	83	7.01	0.53	2.35		**43**	116	9.02	0.40	1.89
	99	52	5.03	0.51	2.01	**T-7**	**34**	108	9.12	0.47	2.18
T-17a	**22a**	120	9.13	0.58	2.76		**36**	113	7.76	0.42	1.98
	23a	116	9.23	0.57	2.69		**39**	120	8.87	0.42	2.02
	25a	129	9.05	0.51	2.45	**T-6**	**27**	152	10.41	0.48	2.43
T-17	**93**	128	9.59	0.60	2.89		**30**	119	9.23	0.36	1.70
	95	103	7.92	0.52	2.41		**33**	115	9.00	0.34	1.60
	97	122	8.60	0.48	2.30	**T-5**	**10a**	100	7.83	0.28	1.27
T-16	**88**	114	7.74	0.42	1.99		**24**	81	6.28	0.29	1.28
	90	155	11.53	0.53	2.68		**25**	67	5.02	0.19	0.79
	92	134	9.74	0.39	1.90		**26**	129	9.70	0.54	2.63
T-15a	**19a**	98	7.18	0.26	1.19		**11a**	108	8.34	0.38	1.76
	21a	105	8.42	0.55	2.57	**T-4**	**20**	120	9.37	0.42	2.03
T-15	**83**	110	8.30	0.33	1.54		**22**	63	5.38	0.42	1.76
	85	109	8.54	0.42	1.98		**23**	105	8.82	0.52	2.41
	87	133	10.32	0.54	2.62	**T-3**	**15**	121	10.17	0.47	2.24
T-14a	**14a**	113	7.54	0.28	1.31		**17**	102	8.63	0.49	2.29
	16a	143	10.28	0.45	2.24		**19**	102	8.11	0.61	2.81
T-14	**79**	111	8.02	0.29	1.36	**T-2a**	**5a**	100	8.31	0.34	1.55
	82	117	8.94	0.48	2.29		**7a**	136	10.62	0.49	2.42
T-13	**77**	102	7.48	0.38	1.75		**9a**	140	10.91	0.50	2.45
	78	145	9.75	0.30	1.47	**T-2**	**8**	131	11.12	0.55	2.67
T-12	**70**	105	8.02	0.48	2.23		**11**	121	9.64	0.45	2.16
	71	96	7.91	0.39	1.79		**14**	128	9.74	0.56	2.69
	72	97	7.81	0.37	1.70	**T-2-1**	**27a**	109	8.58	0.46	2.16
T-11	**66**	133	9.60	0.39	1.89		**28a**	102	7.88	0.35	1.60
	69	110	8.54	0.47	2.20	**T-1**	**1**	114	8.43	0.53	2.49
T-10	**56**	112	8.86	0.38	1.82		**4**	116	9.17	0.46	2.19
	59	105	8.25	0.35	1.65		**7**	113	8.58	0.46	2.16
		S			**I_M**		**I_P**			**I_{Sh}**	
Mean ± STD		110.4 ± 21.4			8.50 ± 1.40		0.44 ± 0.10			2.05 ± 0.48	
Min ÷ Max		44 ÷ 155			5.01 ÷ 11.53		0.19 ÷ 0.74			0.79 ÷ 2.89	

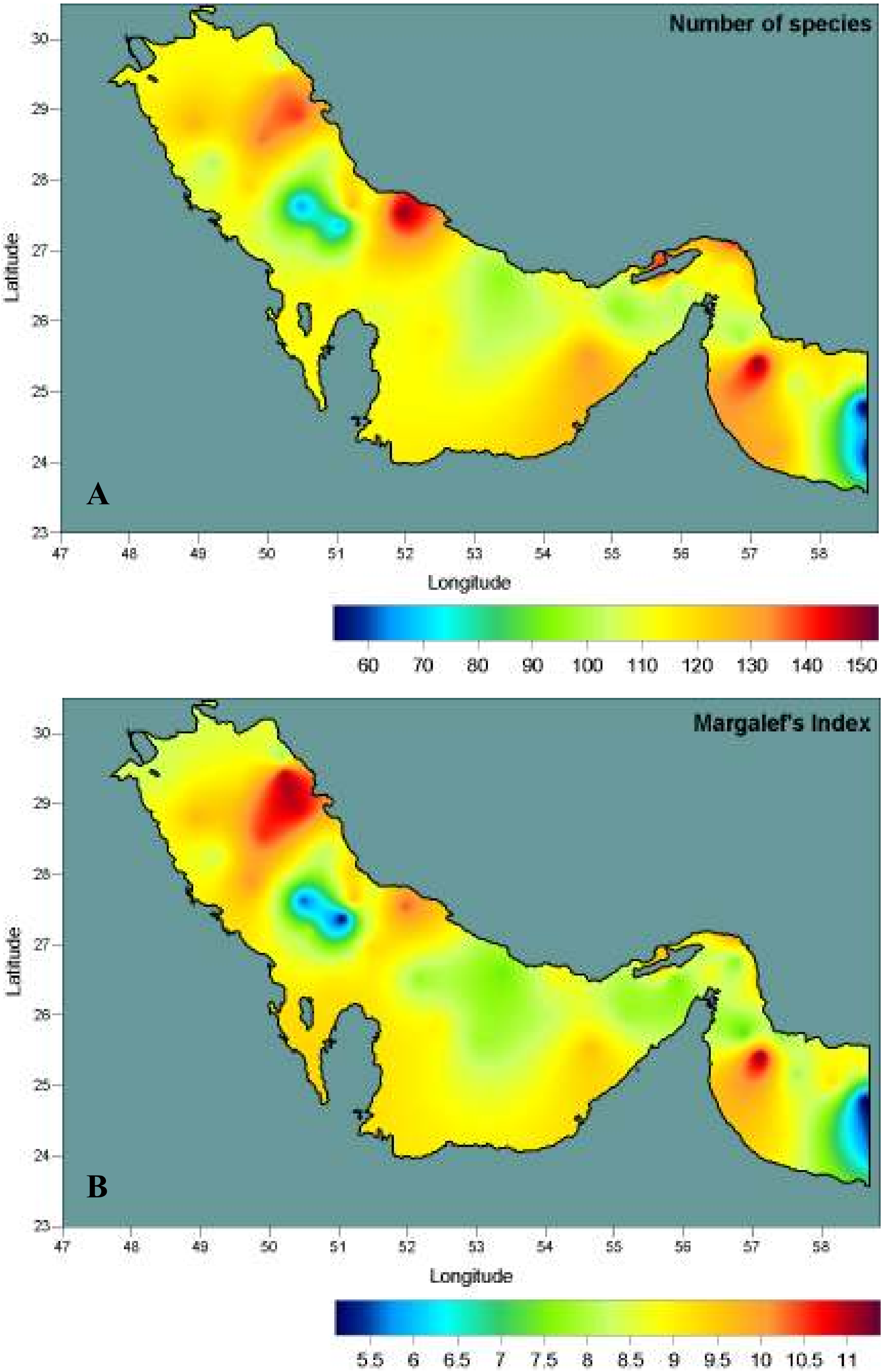

Fig. 7. Spatial distribution of (A) species richness (number of species) and (B) Margalef's Index through the RSA during Winter 2006.

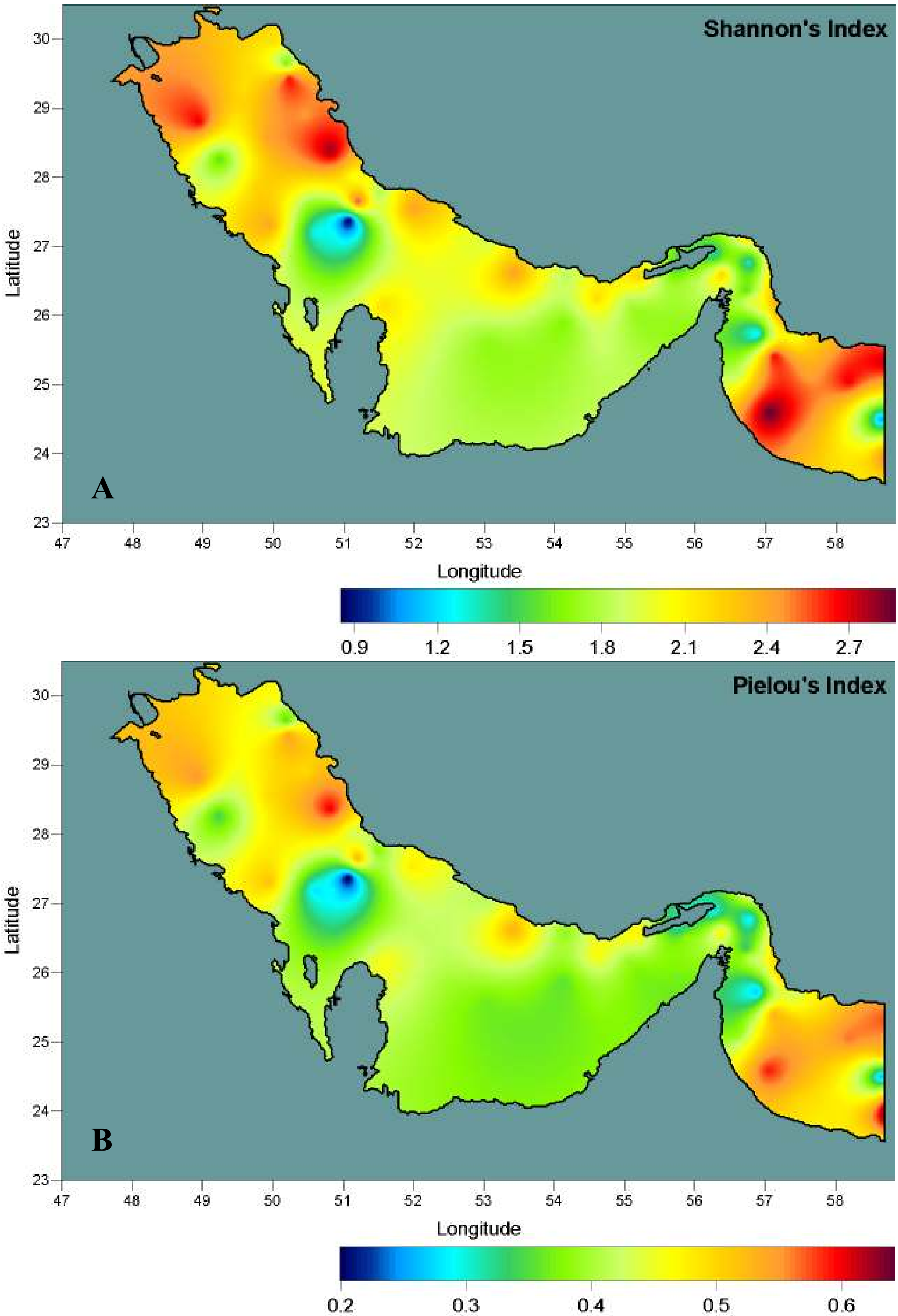

Fig. 8. Spatial distribution of (A) species diversity (Shannon's Index) and (B) community evenness (Pielou's Index) throughout the RSA during Winter 2006.

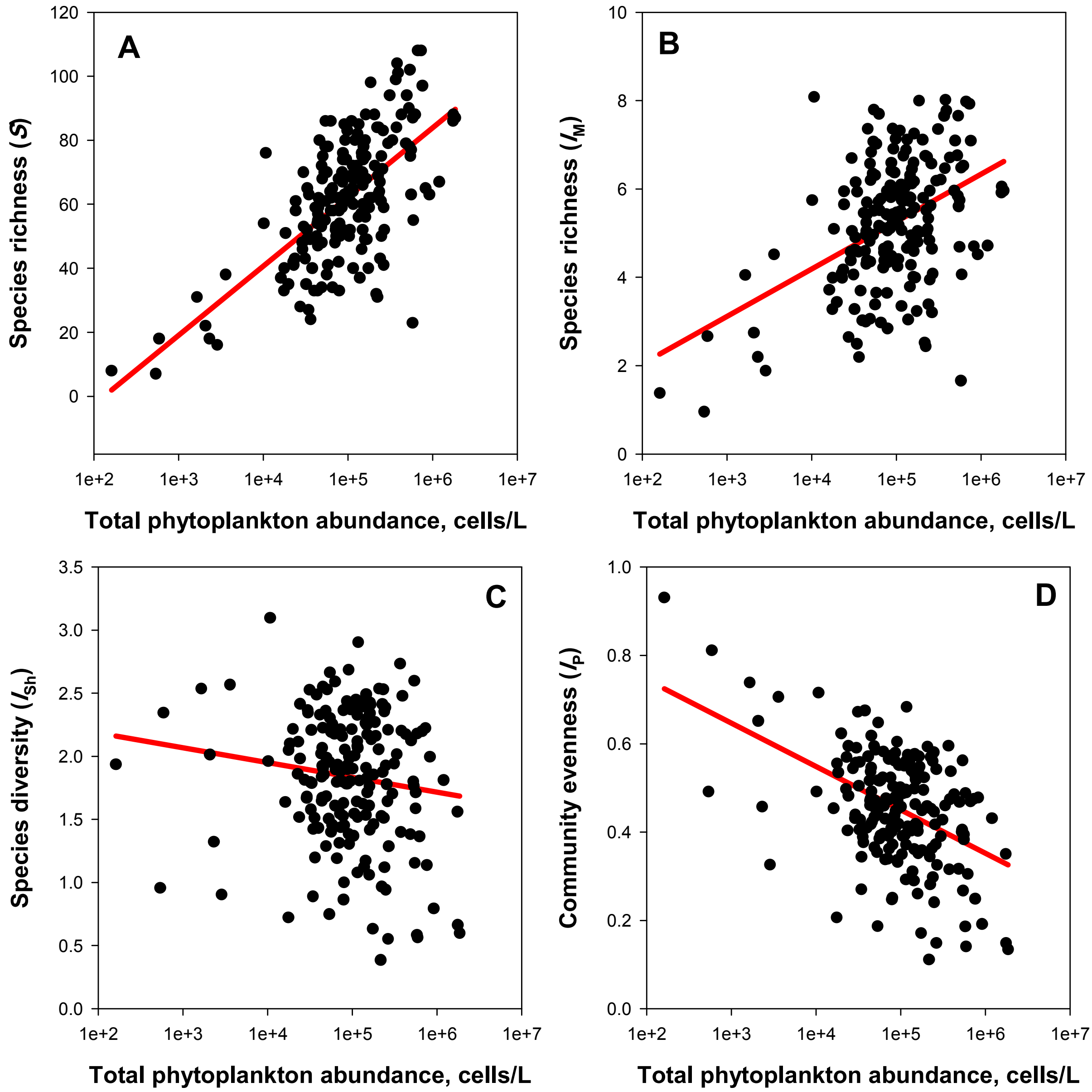

Fig. 9. Correlation between total phytoplankton abundance and parameters of phytoplankton diversity: species richness (number of species per sample – *S* (A) and Margalef's Index – I_M (B)), species diversity (Shannon's Index – I_{Sh} (C)) and community evenness (Pielou's Index – I_P (D)).

3.5 Spatial Pattern of Phytoplankton Community Structure

Analysis of spatial structure of phytoplankton community was performed using hierarchical clusterization (complete linkage agglomeration method) of Jaccard index of association and Spearman correlation coefficient matrices. Results are presented in Figs. 11 and 12.

Results obtained by the above two different similarity matrices are rather similar and provide evidence of the spatial heterogeneity of the phytoplankton community structure within the studied RSA. The dendrogram based on the Spearman correlation similarity between stations was chosen to provide more detailed analysis, because this calculation method takes into account not only information about species composition of the community (presence/absence matrix for Jaccard association index calculation), but in addition, it involves density data for each species.

The results of the cluster analysis revealed significant differences between the samples collected from the inner RSA (ROPME Sea Area) and those from the Sea of Oman. Similarity between phytoplankton from the above sampled areas is lower than 10% (Fig. 12). Within the samples collected in the inner RSA, three different areas could be detected. In general, four different areas were observed within the sampled RSA with reference to the similarity between samples. Sampling points from each cluster are not scattered randomly within the sampled area, but they are mainly grouped within rather clearly outlined areas (Fig. 13 A; sampling points are colored according to the clusters in Fig. 12).

In general, the first outlined area (cluster I, green color) is mainly located in the northern part of the inner RSA and extends along all the Saudi Arabian and Qatari coasts up to the western part of the United Arab Emirates coast. The second area (cluster II, light blue color) occupies the southern part of the inner RSA (off the Iranian Coast) up to the Strait of Hormuz. The third area (cluster III, red color) is located in the northern part of the inner RSA from Kuwait's waters to the Iranian coast and extends up to the central part of the inner RSA. The fourth area (cluster IV, dark blue color) is off the Strait of Hormuz and is associated with the Sea of Oman.

Within each of the above outlined area, distinct phytoplankton association can be defined. Distinctions of the community structure of phytoplankton from the different areas are illustrated in Fig. 14 and Table 10. Composition and relative abundance for the six top-dominant species from each outlined area are shown in Fig. 14 A. The cumulative curve of the percentage contribution of each species to the total phytoplankton abundance for each area is shown in Fig. 14 B. Diversity indices for each phytoplankton association are presented in Table 10.

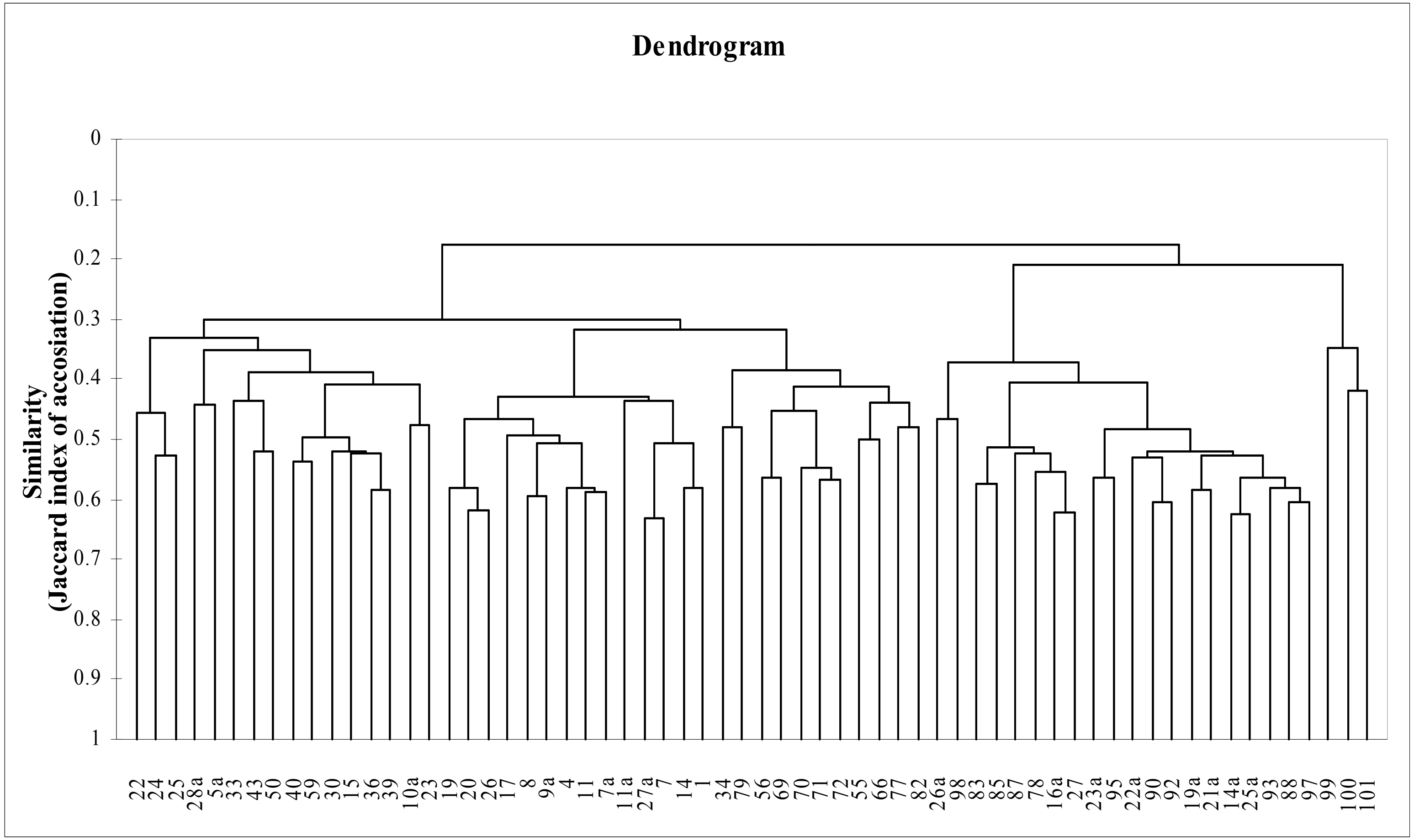

Fig. 10. Dendrogram of the cluster analysis performed based on the Jaccard index of association matrix (64 stations × 324 species; presence/absence matrix).

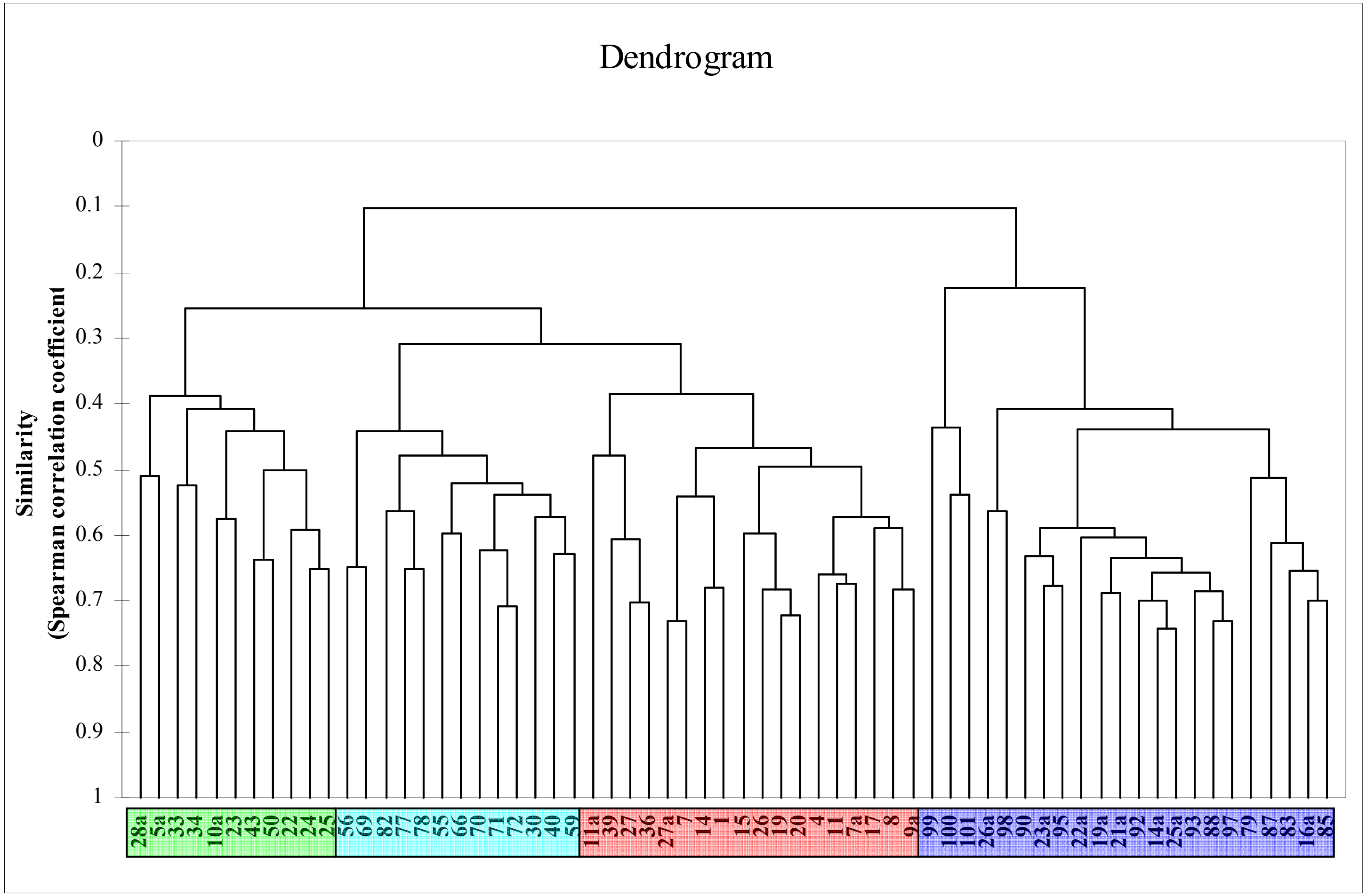

Fig. 11. The dendrogram of the cluster analysis performed based on Spearman correlation coefficient matrix (64 stations × 324 species).

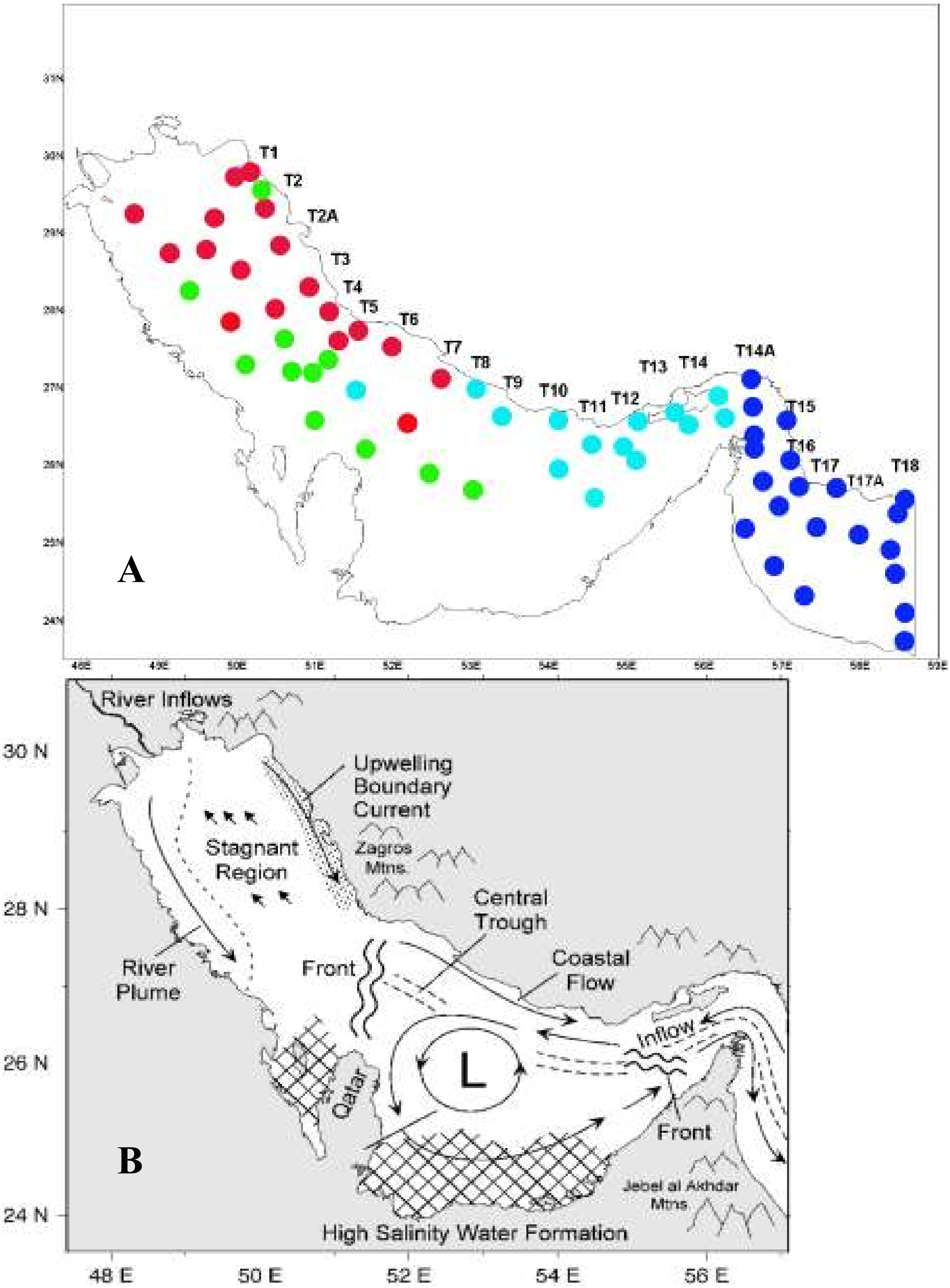

Fig. 12. The sampled area of the ROPME Sea. (A). Spatial distribution of the sampled stations relating to each of the different clusters (color of each point/station corresponds to one of the different clusters shown in Fig. 9. (B). A general diagram of the inner RSA and northern Sea of Oman hydrodynamics: winter circulation pattern (source: Reynolds, 1993).

The phytoplankton community, which is associated with area-I, is the most different community from the other phytoplankton associations due to the very high prevalence of naked flagellates (*Gymnodinium*-like group + *Teleaulax* sp.; comprising more than 80% of total phytoplankton abundance). The high prevalence of naked flagellates explains the significant difference in the shape of the cumulative curve of the percentage contribution of species (Fig. 14 B). Phytoplankton community from this area (area-I) is characterized by comparatively low levels of species diversity and evenness (Table 10).

Phytoplankton associations from the other selected areas have rather similar structure and diversity level; however, significant distinctions in species composition determine the main difference between phytoplankton communities and produce the spatial heterogeneity of the phytoplankton community at the large-scale level (Fig. 14, Table 10).

In the second area, the leading position of the naked flagellates is significantly reduced: *Gymnodinium*-like flagellates (22.5%), *Chaetoceros compressus* (21.2%) and *Chaetoceros socialis* (13.4%) largely contributed to the total phytoplankton abundance in this area. Area-III is characterized by the prevalence of *Pseudo-nitzschia* cf *delicatissima* (18.6%), *Gymnodinium*-like group (14.1%), *Skeletonema costatum* (12.8%) and *Teleaulax* sp. (8.9%). A complex assemblage of dominant species from the Sea of Oman (area-IV) contains *Chaetoceros curvisetus* (26.9%), *Chaetoceros tortissimus* (11.8%), *Gymnodinium*-like flagellates (8.6%) and *Bacteriastrum furcatum* (7.7%).

Analysis of the phytoplankton spatial distribution of the RSA reveals significant macro-scale heterogeneity within the phytoplankton community. Because phytoplankton is a known marker of water masses (Raimont, 1983), the spatial heterogeneity of its structure is most probably related to the general scheme of the RSA hydrodynamics. Two hydrophysical forces mainly determine the general pattern of water masses within the inner RSA – freshwater outflow from the Shatt Al-Arab and Karun rivers in the north and the monsoon-induced inflow from the outer RSA(Arabian Sea) and the Sea of Oman in the southern part of the inner RSA. The combination of these two forces forms the general circulation pattern, which was described by Reynolds (1993) and is represented in Figure 13 B. The description of winter circulation pattern of the inner RSA by Reynolds (1993), can be related to the obtained data from the winter 2006 cruise.

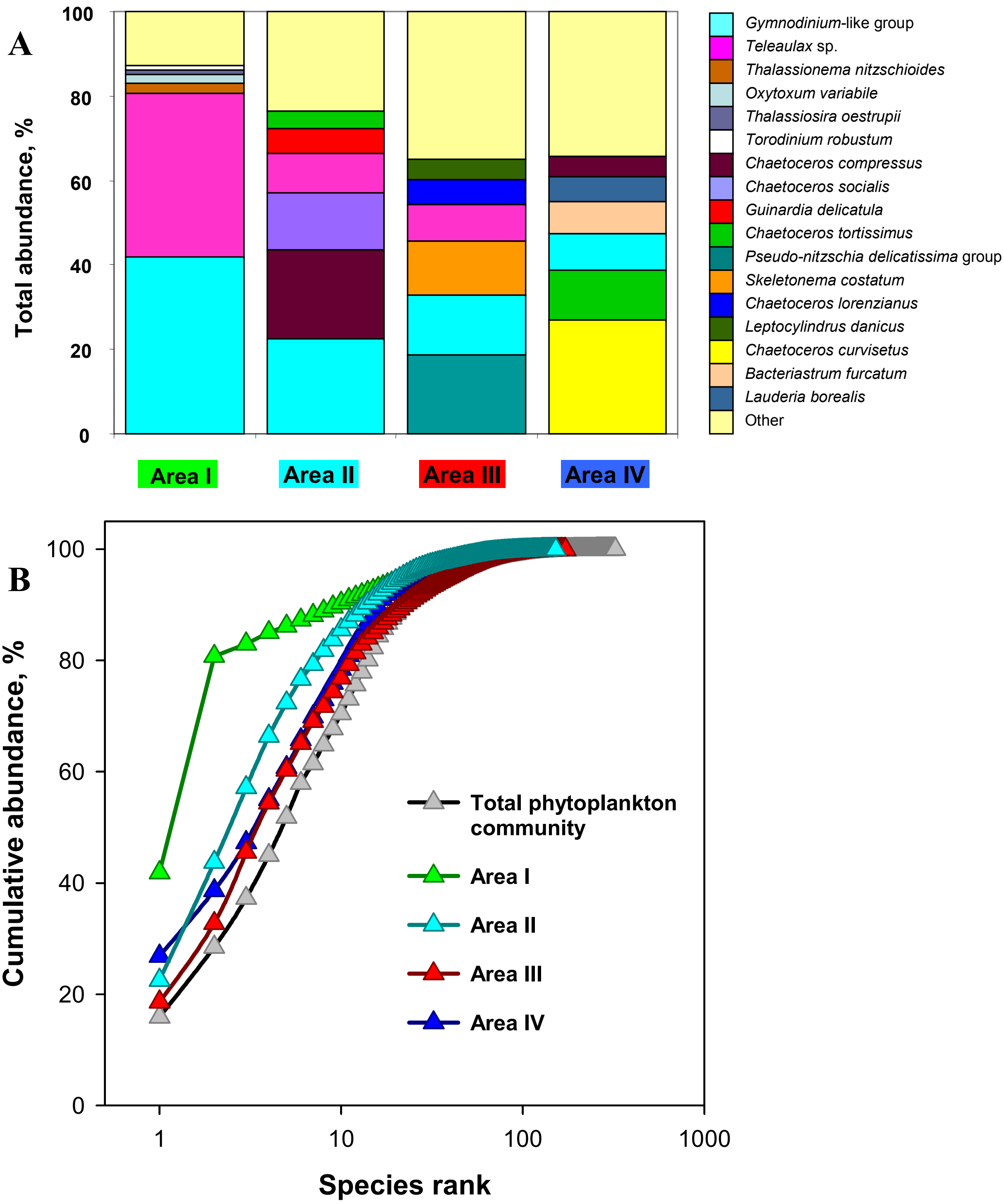

Fig.13. Percentage composition and relative abundance for the top-dominant species from each area. (A)- Species composition for the top-dominant species from each area and their percentage contribution out of the total phytoplankton community; (B)- Cumulative curves of percentage contribution of species to the total phytoplankton abundance for each area.

Table 10. The Diversity Indices for the Phytoplankton Associations from the Different Areas that are Selected by Cluster Analysis (Fig. 12). Ordinal Number and Color of each Area Corresponds to the Clusters in Fig. 12

Index	Area			
	I	II	III	IV
Number of species (*S*)	244	250	263	266
Species richness - Margalef Index, I_M	16.24	15.73	16.31	15.99
Species diversity - Shannon Index, I_{Sh}, log(e)	1.77	2.59	3.02	2.83
Community evenness - Pielou's Index, I_P	0.32	0.47	0.54	0.51

According to Reynolds's scheme, the interaction between the different currents forms two large frontal zones in the central part of the inner RSA and in the southern part near the Strait of Hormuz. Localization of the Hormuz front generally coincides with the boundary between areas III and IV. This front, probably contributes to the significant distinction in the phytoplankton structure between Sea of Oman and the inner RSA. The Sea of Oman is largely affected by the monsoon wind patterns, evident by the Equatorial Counter Current, whereas the inner RSA is relatively unaffected by these wind changes due to topographic shielding.

The winter monsoon over the Sea of Oman, is characterized by a relatively gentle and variable, dry northeast wind, known locally as 'Shamal'. This wind occurs between November and April, leading to modest increases in productivity and a current that flows to the southwest.

The second frontal zone is located in the central part of the inner RSA and divides the area into northern and southern zones. Localization of this front coincides with the boundary between area-II that occupies the southern part of the inner RSA and areas I and III, which are associated with the northwest part of the Area-III generally consists of a large stagnant zone in the northwest part of the inner RSA whereas area-I is partially associated with a downwelling zone on the Saudi coast, which might be influenced by the river plume.

3.6 Composition and Distribution of the Dominant Species in the Phytoplankton Community of the RSA

Among the 337 identified phytoplankton taxa, only 15 species were regarded in the top-dominant positions from the samples collected during the ROPME Winter 2006 cruise. Their relative contribution may be varied within a wide range from 10-15% up to 80-90% of the total phytoplankton abundance. In general, taxonomical composition, degree of prevalence and abundance of dominant species largely determine the main physiological and ecological aspects of the phytoplankton community.

A list of dominant species and areas of their prevalence are shown in Fig. 15. Small-sized *Gymnodinium*-like dinoflagellates were the most frequent and dominant group in the winter RSA phytoplankton. These microalgae dominated mainly within

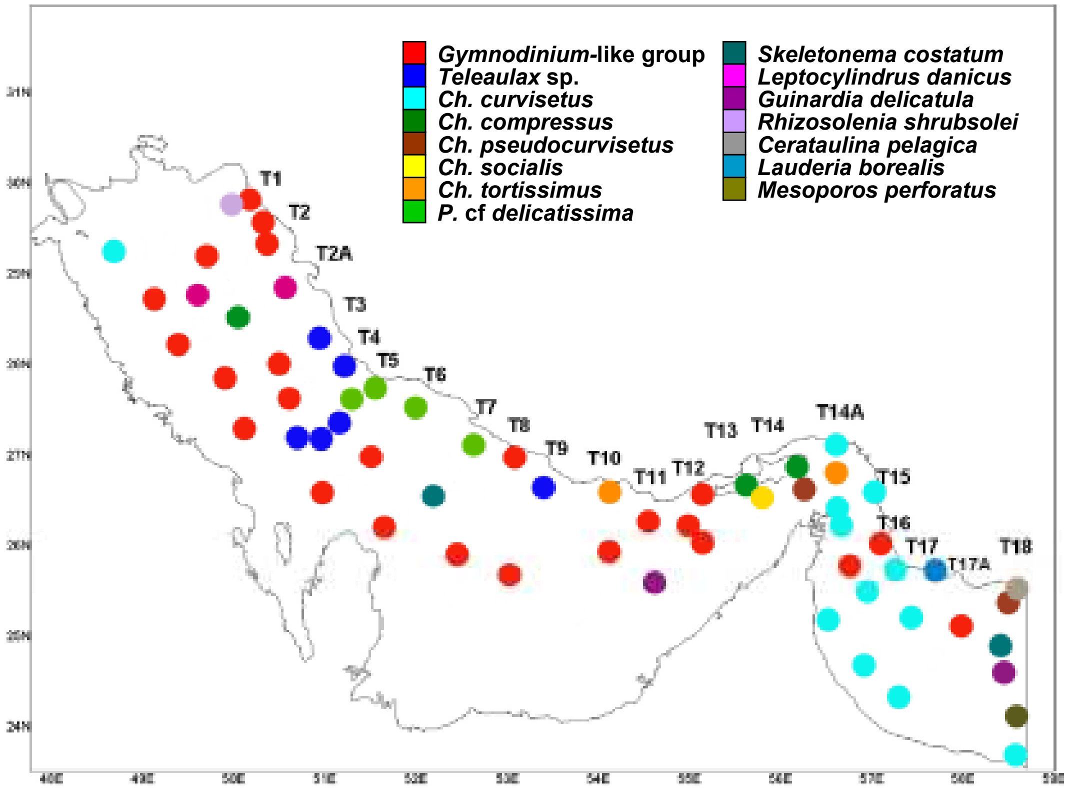

Fig. 14. Distribution of the top-dominant taxa of winter phytoplankton in the RSA indicating the areas of their prevalence.

the inner RSA, especially along the coastal zones of Saudi Arabia, Qatar and UAE. The second group of dominant phytoplankton is comprised of five species from the *Chaetoceros* genus. The most dominant species among this group was *Chaetoceros curvisetus*. The area of *Chaetoceros* prevalence was mainly associated with the Strait of Hormuz and the Sea of Oman. For the other species, the areas of prevalence of the dominant species were more localized. The diatom *Pseudo-nitzschia* cf *delicatissima* bloomed in the central part of the inner RSA off the Iranian coast, whereas a patch of the naked flagellate *Teleaulax* sp. (Cryptophyceae) was observed in close vicinity. Zones of dominance for the rest of the species were randomly scattered within the RSA. Thus, winter phytoplankton abundance in the inner RSA was supported mainly by a significant development of small-sized flagellates (Dinophyceae and Cryptophyceae), whereas small-sized chain-forming diatoms from the *Chaetoceros* genus contributed to a large extent to the phytoplankton community from the Strait of Hormuz and the Sea of Oman.

3.7 Winter Abundance Pattern of RSA Phytoplankton Community

Spatial Variability of Phytoplankton Abundance. Total phytoplankton abundance for the RSA during Winter 2006 varied over a wide range (Fig. 16). Concentration (abundance) of phytoplankton ranged from 162 cells/L up to 1.9×10^6 cells/L (mean = $1.87 \times 10^5 \pm 2.76 \times 10^5$ cells/L). The lowest concentrations of phytoplankton were associated with deeper waters in the Sea of Oman (162-590 cells/L; stations 99, 100 and 101). Moreover, low phytoplankton abundance (less than 10^4 cells/L) was recorded within the waters off the Saudi Arabian coast (stations 5a, 6a, 11, 15, 17, 22, 23), near Qatar (St. 34) and in the southern part of the inner RSA (stations 71, and 72).

In general, the RSA during winter of 2006 was characterized by relatively high phytoplankton abundance (10^4-10^5 cells/L). Highest phytoplankton concentrations (more than 10^6 cells/L) were recorded for the Strait of Hormuz area and also off the Iranian coast. High phytoplankton abundances (concentrations that were close to two million cells per liter) were recorded at St. 88 (1.75×10^6 cells/L), St. 14a (1.86×10^6 cells/L) and St. 78 (1.76×10^6 cells/L). Phytoplankton abundances, that exceeded one million cells per liter (< 1.5×10^6 cells/L), were observed in the central part of the inner

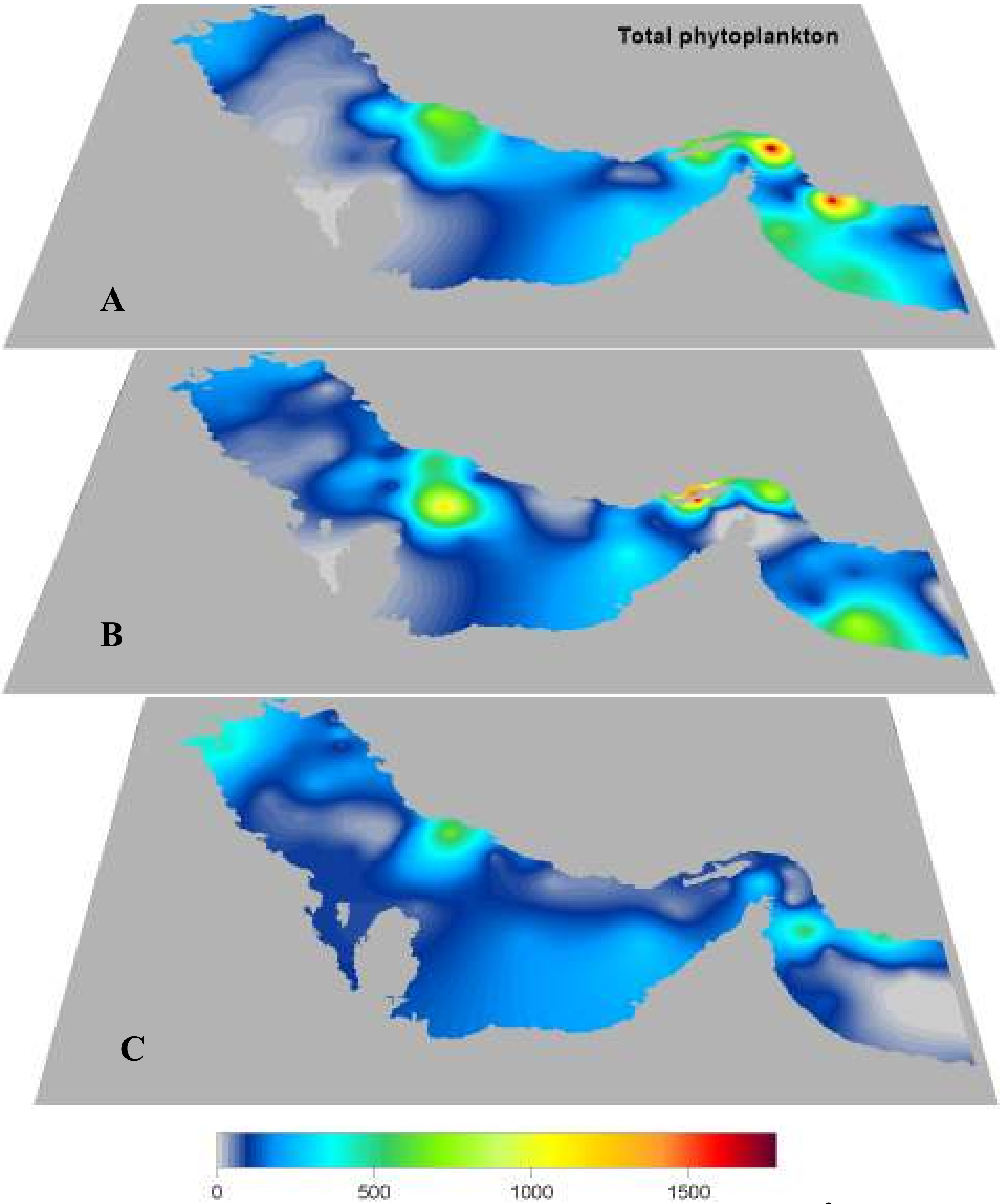

Fig. 15. Spatial distribution of the total phytoplankton abundance (10^3 cells/L) in the RSA for surface (A), middle (B) and bottom (C) sampled layers during winter 2006.

RSA near Qatar (St. 36, 1.2×10^6 cells/L). Significant abundance of phytoplankton (0.5-1 million cells per liter) was observed in the Omani coastal waters (stations 83, 92, and 25a) and off the Iranian coast (stations 97 and 19a) in the Sea of Oman as well as with Iranian coastal zone in the inner RSA (stations 16a, 79, 77, 39 and 27) and in Kuwait's waters (St. 1).

Maximum levels of phytoplankton abundance were supported by mass development of small-sized chain-forming diatoms such as *Chaetoceros tortissimus* (bloomed at St. 14a), *Chaetoceros compressus* (St. 78), *Chaetoceros curvisetus* (St. 88) as well as *Pseudo-nitzschia* cf *delicatissima* and *Skeletonema costatum* (St. 36).

General patterns of total phytoplankton abundance for the surface, middle and bottom sampled layers are presented in Fig. 16 and 17 and in Table 11. Phytoplankton was more abundant in the surface layer (Fig. 13, Table 10). Gradual decrease in mean phytoplankton abundance with depth is shown from 246.8×10^3 to 123.7×10^3 cells/L; thus, there was about twice the reduction in the mean phytoplankton abundance from surface to bottom layers.

Although phytoplankton was more abundant in the surface layer, different patterns of vertical distribution were detected within the studied RSA. All surveyed stations can be classified into three groups according to the presence of maximum phytoplankton abundance. Figure 18 displays the three groupings of stations: stations with high phytoplankton abundance at surface layer, stations with high phytoplankton abundance at middle sampled layer, and stations with high phytoplankton abundance at bottom sampled layer. Maximum phytoplankton abundances were detected in the surface layer within the area that covers mainly Sea of Oman and extends through the Strait of Hormuz and along the Iranian coast in the inner RSA. Higher phytoplankton abundance at the middle and bottom layers was mainly observed within the northern waters of the inner RSA and further off the Qatari coast. The observed pattern is most probably related to at least two different aspects – phytoplankton species composition and sampling strategy. Only the samples collected from the surface layer at the different sampled stations can be comparable, because the surface sampling depth was fixed (2-4 m, Table 1). The depths of the middle and bottom layers depended on the depth of station and varied from 5 to 50 m for the middle layer and from 10 to 100 m for the bottom layer (Table 1). The stations with the high phytoplankton abundance in the surface layer (Sea of Oman, the Strait of Hormuz and off the Iranian Coast) were the deepest sampled stations (mean depth is 310 m) in the RSA during winter 2006. The mean depths of stations with high phytoplankton abundance at the middle and bottom layers were about 91.5 and 49 m, respectively.

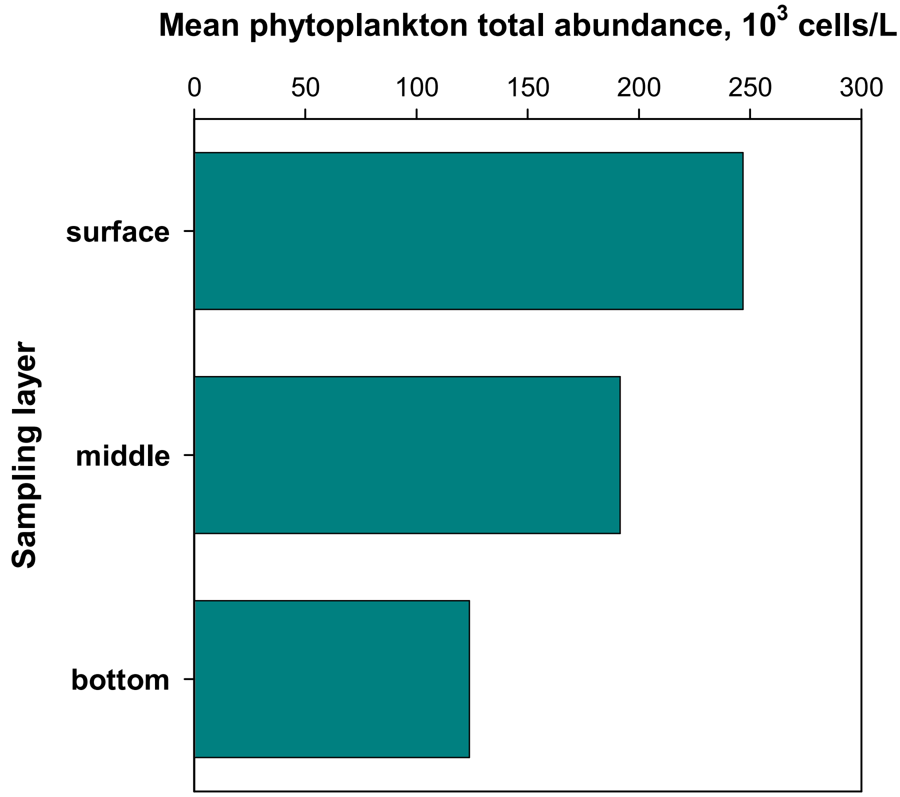

Fig. 16. Vertical distribution of mean phytoplankton abundance.

Table 11. Total Phytoplankton Abundance (mean ± STD) for the Different Sampled Layers

	Total Phytoplankton Abundance, 10^3 cell/L		
	Surface	**Middle**	**Bottom**
Mean ± STD	246.81 ± 343.22	191.64 ± 296.23	123.71 ± 134.83
Min - Max	1.65 - 1861.28	0.59 - 1761.28	0.16 - 669.41

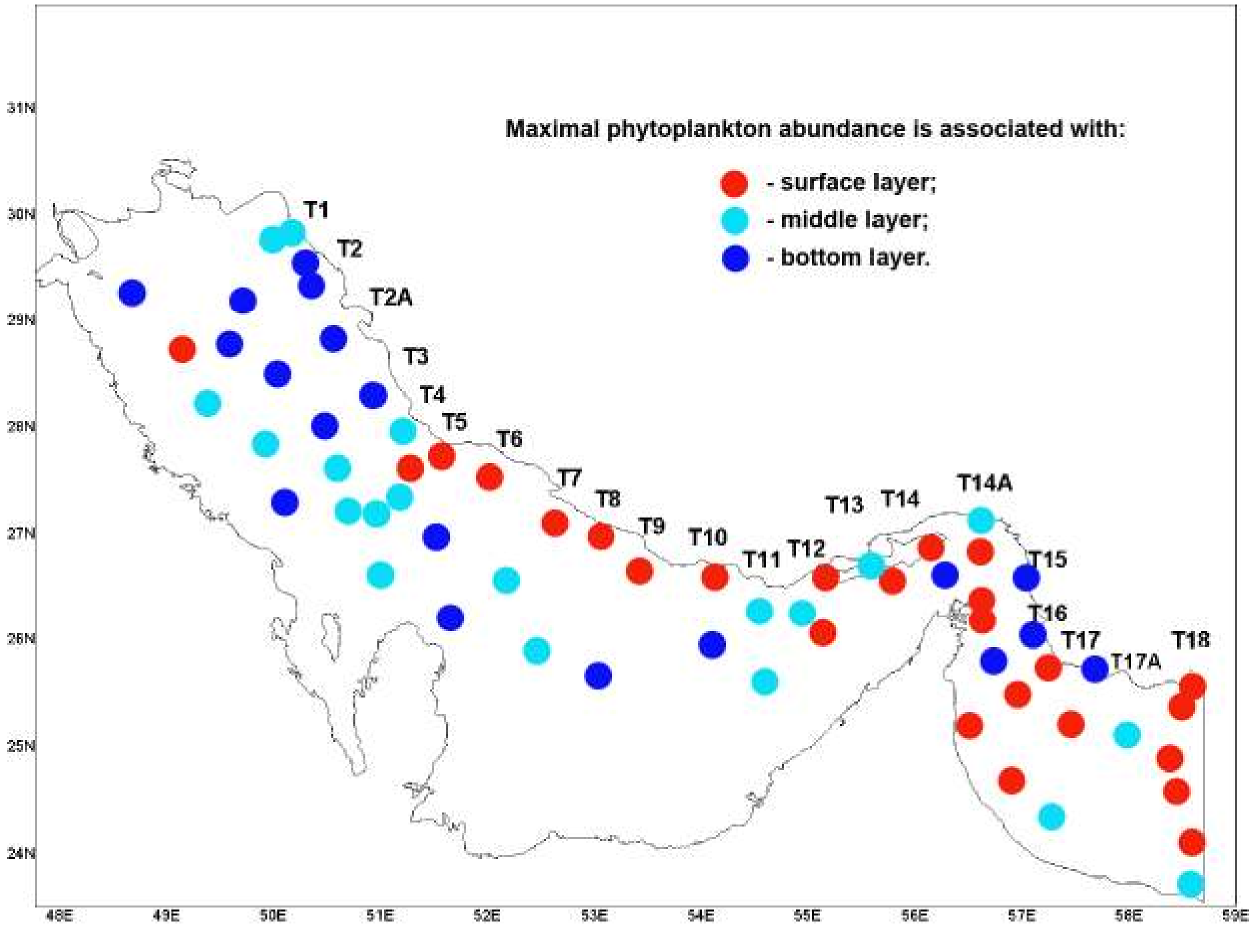

Fig. 17. Distribution of stations with high phytoplankton abundance at the different sampled layers.

The phytoplankton community of the surface layer was largely composed of small-sized diatoms, while the phytoplankton community at the middle and bottom layers was dominated by small-sized flagellates (Figs. 15 and 18). The distinction in the vertical structure of phytoplankton distribution can be attributed to the peculiarity of the different taxonomical groups of the microalgae, e.g., the role of heterotrophic consumption among flagellates is more significant in comparison with diatoms. The autotrophic diatoms were prevalent within the photic layer of the water column, whereas the mixotrophic capability is related to the growth of flagellates in deeper layers.

Spatial Distribution of the Different Phytoplankton Taxa within the RSA: In order to estimate the similarity between spatial distributions of the different phytoplankton taxa, the Spearman correlation coefficients were calculated. The hierarchical cluster analysis was applied to the Spearman correlation matrix (complete linkage agglomeration method). The dendrogram of cluster analysis is shown in Fig. 19. The figure displays that general level of similarity between the spatial distributions of the different phytoplankton taxa was low. All the analyzed phytoplankton taxa were grouped by cluster analysis into four large clusters, however, these groups were selected on a rather low level of similarity; the first cluster was selected at R=0.05, the second cluster at R=-0.02, the third cluster at R=-0.30 and the fourth at R=-0.25. The detected low similarity indicates that the grouped species are distributed independently.

There are a very limited number of taxa that have relatively similar pattern of spatial distribution. Among all analyzed phytoplankton taxa, there were pairs or groups, which showed high similarity (R > 0.6) in their spatial distributions. High correlations were found between spatial distributional patterns of *Leptocylindrus* spp. and *Odontella* spp.; in pairs *Nitzschia* spp. – *Pseudo-nitzschia* spp., *Guinardia-Dactyliosolen* spp. – *Meuniera membranacea*, *Lauderia borealis* – *Rhizosolenia* spp., *Haslea* sp. – *Plagiotropis* spp., *Bellerochia horologicalis* – *Biddulphia* spp., *Ceratium* spp. – *Protoperidinium* spp., *Gymnodinium*-like group – *Teleaulax* sp., *Gyrodinium* spp. – *Oxytoxum* spp.; and in a group *Chaetoceros* spp. – *Eucampia* spp. – *Bacteriatrum* spp.– *Stephanopyxis palmeriana,* and in a group *Surirella fastuosa* – *Campylodiscus* sp. – *Caloneis liber* – *Diploneis* spp. – *Thachyneis* spp. Possible reason for the observed high similarity in the spatial distributions for the species in pairs and in groups is the morphological and/or ecological similarity between these microalgae. For example, similar spatial distribution was detected for species from the morphologically and taxonomically related genera *Nitzschia* and *Pseudo-nitzschia*, *Chaetoceros* and *Bacteriastrum*, *Haslea* and *Plagiotropis*. Moreover, benthic diatoms from different genera (*Surirella*, *Campylodiscus*, *Calones*, *Diploneis*, and *Trachyneis*) were grouped together with high similarity level. Taxonomically related genera *Ceratium* and *Protoperidinium* demonstrated similar spatial distribution, occurring mainly in the northern part of the inner RSA. Small-sized autotrophic naked flagellates from different classes - *Gymnodinium*-like group (Dinophyceae) and *Teleaulax* sp. (Crytophyseae) – were similarly distributed probably due to their similar environmental requirements. This explanation could apply also to the pair *Gyrodinium* spp. – *Oxytoxum* spp.

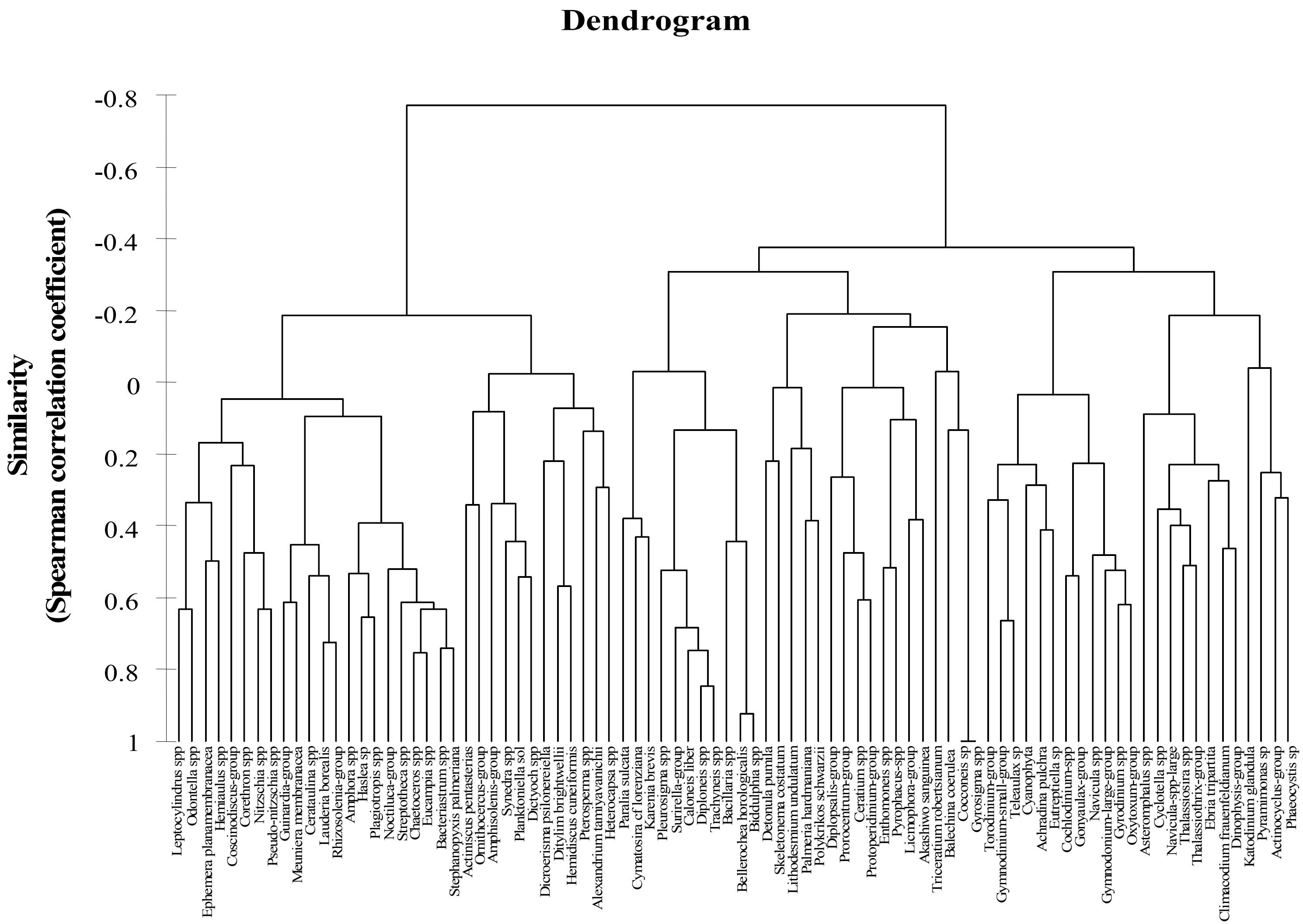

Fig. 18. Dendrogram of the cluster analysis performed based on the Spearman correlation coefficient matrix in order to estimate the similarities between the spatial distributions of the different phytoplankton taxa.

Thus, high level of similarity was detected within very limited number of pairs and groups of phytoplankton taxa, however; in general, independent spatial distribution was observed for most phytoplankton taxa. Very low similarity level (R=-0.78) was found for clusters I and II, which, are grouped forming mainly abundant diatoms and low-abundant dinoflagellates, and clusters III and IV representing mainly abundant dinoflagellates and rare diatoms. This negative correlation indicates that microalgae (diatoms and dinoflagellates) from clusters I-II and III-IV have significant differences in their spatial distributional patterns.

Spatial Distribution of the Main Phytoplankton Taxonomical Groups within the RSA: Spatial distribution for each phytoplankton group from the RSA is illustrated by 3-dimensional plots of abundance for the surface, middle and bottom sampled layers (Figs. 20-57). In addition, mean, minimum and maximum concentrations for each enumerated phytoplankton taxon are included in Annex 3. Information regarding taxon occurrence (%, category, and list of stations where the taxon was present) is included in Annexes 4 and 5. Annex 2 includes a list of all the encountered phytoplankton species in the RSA during winter 2006.

Total Abundance of Diatoms (Bacillariophyceae) - Fig. 20.

Diatoms dominated the phytoplankton community at most of the sampled stations. As the dominant group, diatoms contributed to 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 Kuwait's waters.

Total Abundance of Centric Diatoms - Fig. 21.

Bacillariophyta was composed mostly of centric diatoms. Centric diatoms contributed up to 98% of the total phytoplankton abundance; the highest concentration reached 1.8×10^6 cells/L. The higher abundance of centric diatoms (> 10^6 cells/L) mainly coincided with the distribution pattern of Bacillariophyta.

Total Abundance of *Chaetoceros* spp. - Fig. 22.

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.

Total Abundance of *Bacteriastrum* spp. - Fig. 23.

The genus *Bacteriastrum* is morphologically close to *Chaetoceros,* which are 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.

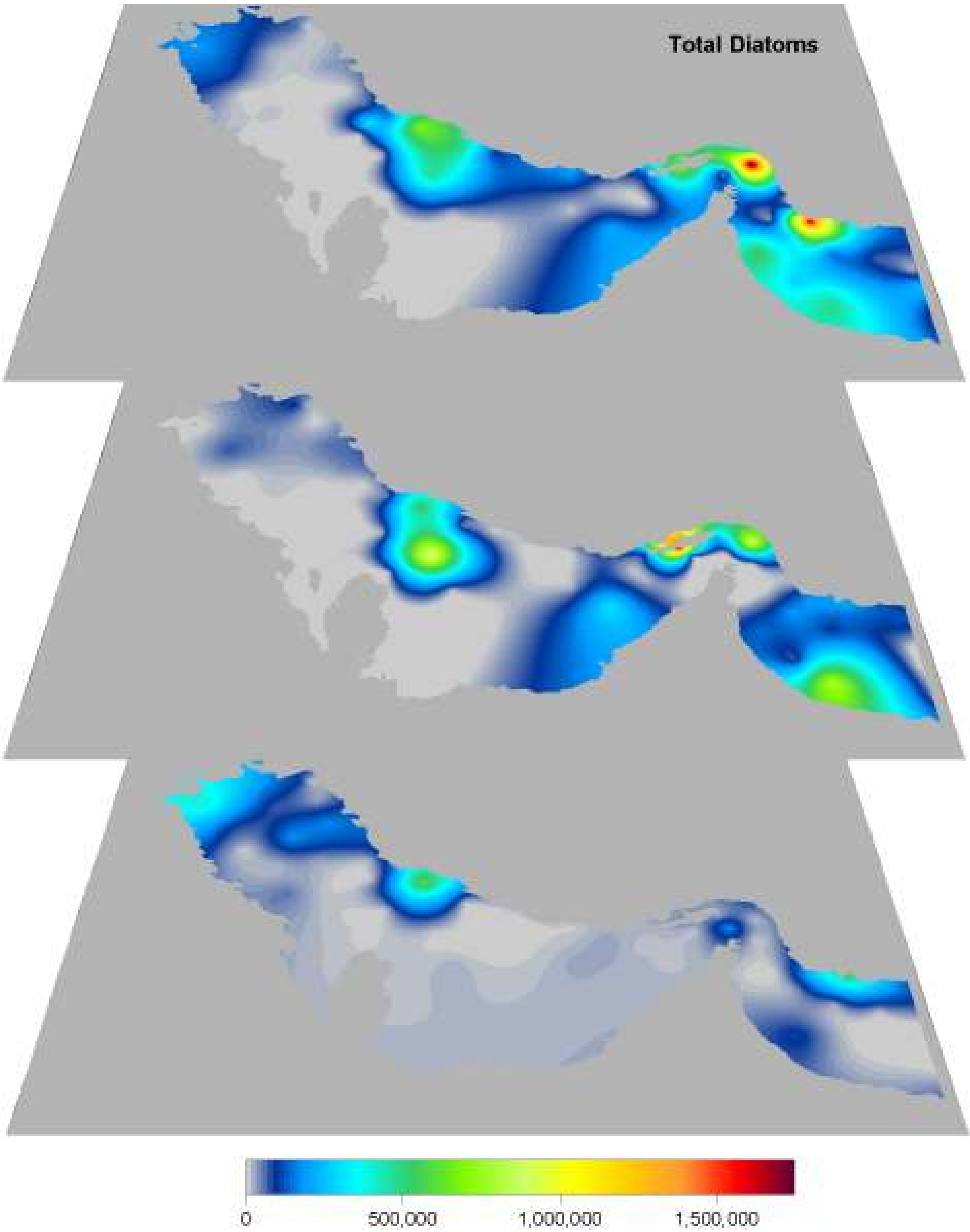

Fig. 19. Interpolated spatial distribution of total abundance (cells/L) of diatoms (Bacillariophyceae) in the ROPME Sea Area during Winter 2006 for the surface (top plot), middle (middle plot), and bottom (low plot) layers.

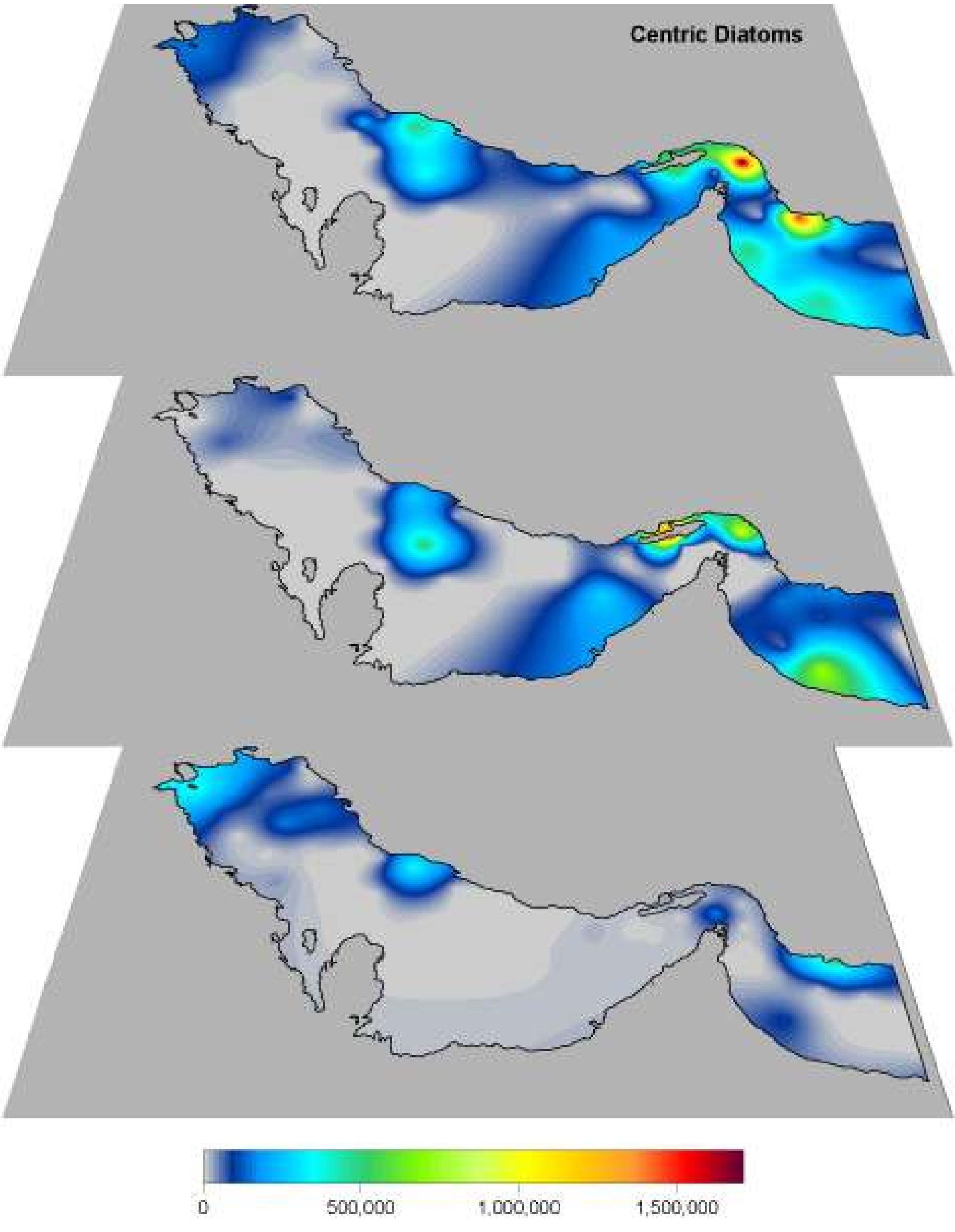

Fig. 20. Interpolated spatial distribution of total abundance (cells/L) of centric diatoms (Bacillariophyceae) in the ROPME Sea Area during Winter 2006 for the surface (top plot), middle (middle plot), and bottom (low plot) layers.

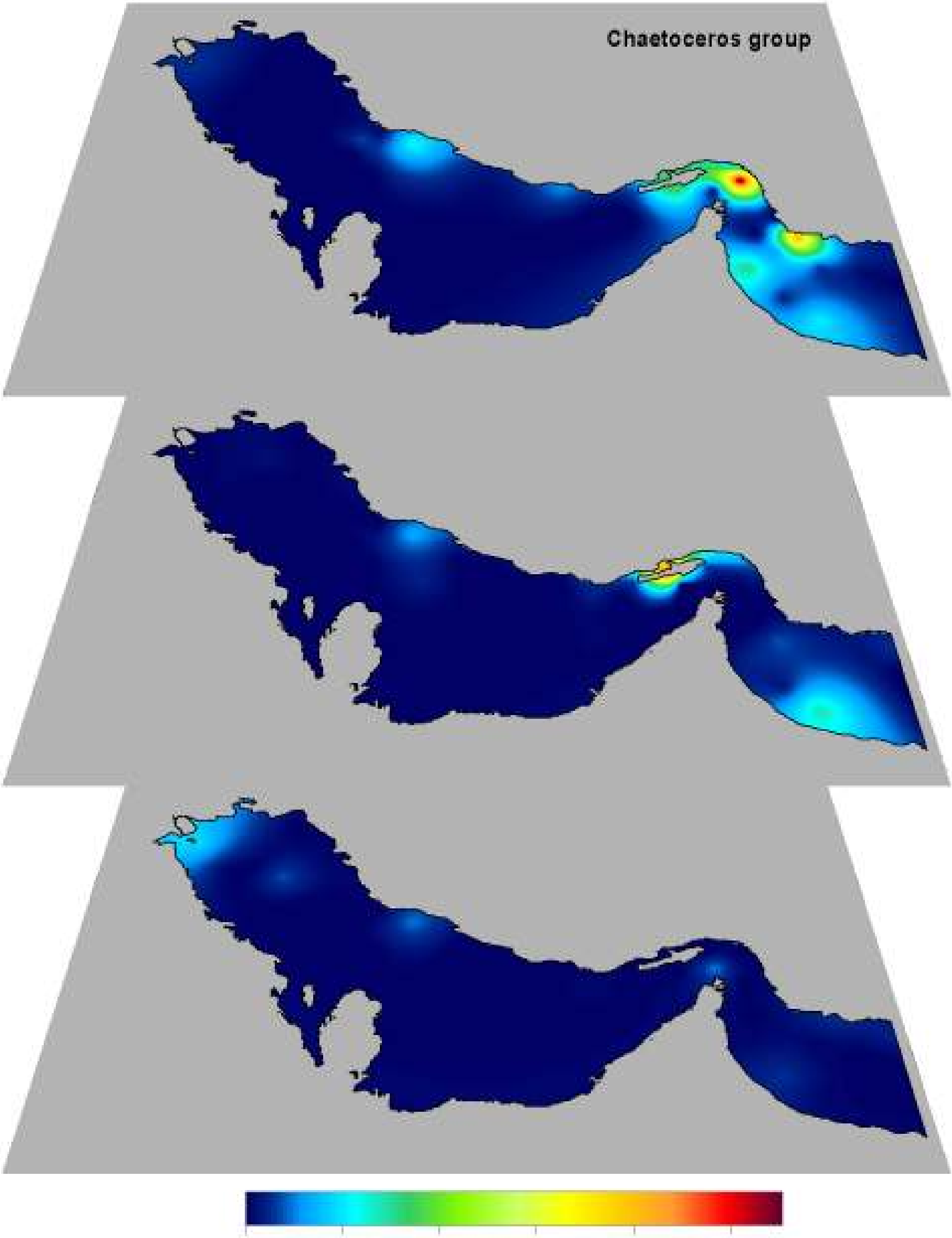

Fig. 21. Interpolated spatial distribution of the abundance (cells/L) of *Chaetoceros* spp. in the ROPME Sea Area during Winter 2006 for the surface (top plot), middle (middle plot), and bottom (low plot) layers.

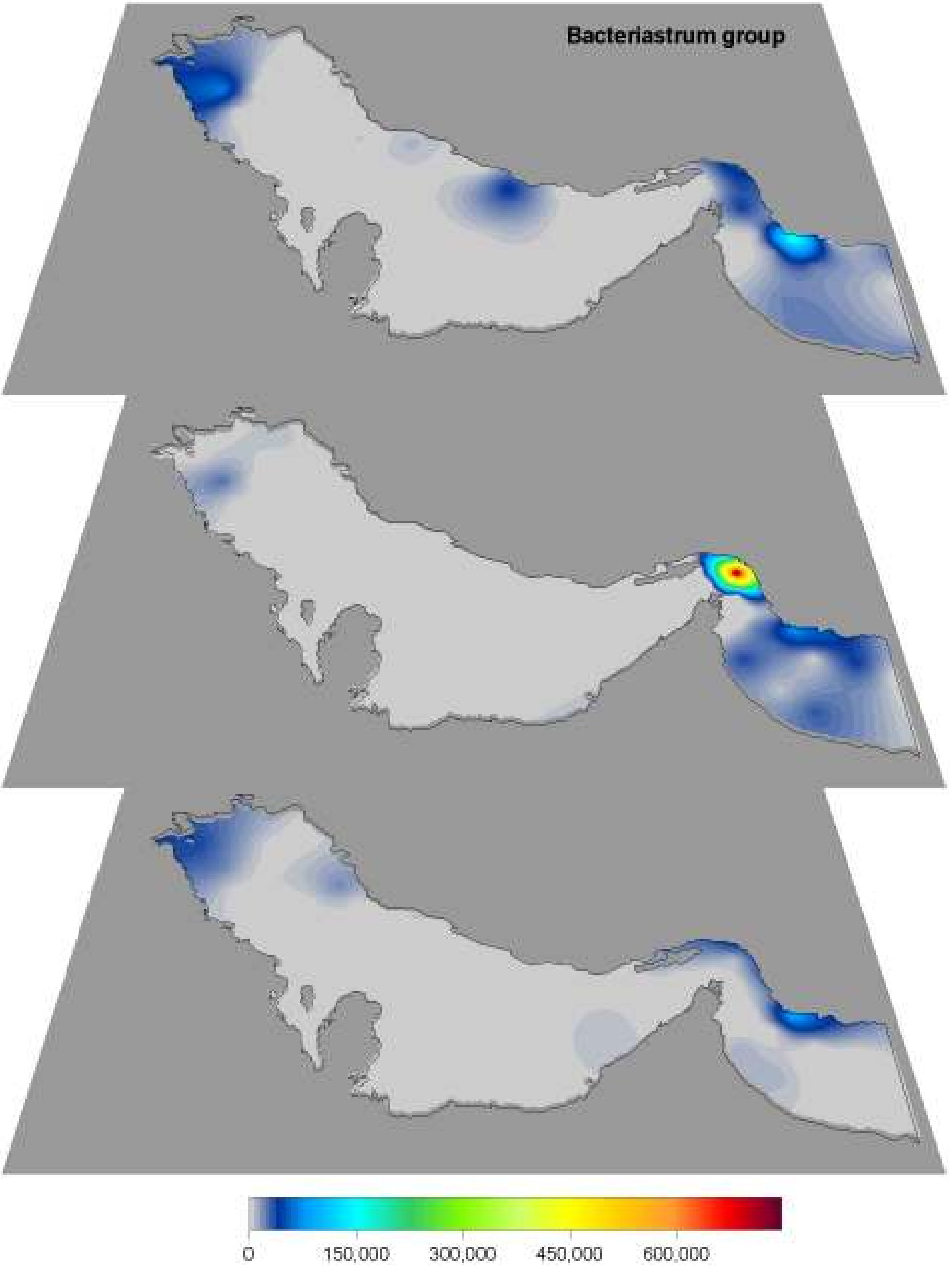

Fig. 22. Interpolated spatial distribution of the abundance (cells/L) of *Bacteriastrum* spp. in the ROPME Sea Area during Winter 2006 for the surface (top plot), middle (middle plot), and bottom (low plot) layers.

Total Abundance of *Guinardia* Group - Fig. 24.

The *Guinardia* group includes morphologically close and related forms from the two genera, *Guinardia* and *Dactyliosolen* with small- and large-sized chain-forming diatoms. 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* group (> 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.

Abundance of *Skeletonema costatum* - Fig. 25.

The small-sized chain-forming diatom *Skeletonema costatum* was observed occasionally in the samples, often in high concentrations. Its maximal 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 costatum* (> 10^5 cells/L) was recorded in the waters off the Iranian coast in the central part of the inner RSA.

Abundance of *Lauderia borealis* - Fig. 26.

The medium-sized chain-forming diatom *Lauderia borealis* was commonly found in the RSA phytoplankton, 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.

Total Abundance of *Cerataulina* spp**.** - Fig. 27.

The genus *Cerataulina* includes two species. Only *Cerataulina pelagica* was commonly observed in the RSA phytoplankton, sometimes in high abundance. When this species was abundant, its contribution to total phytoplankton abundance reached up to 52%; the highest concentration reached 5.3×10^4 cells/L. High abundance of *Cerataulina pelagica* (> 10^4 cells/L) was recorded mainly in the Sea of Oman and a localized peak was recorded in Kuwait's waters.

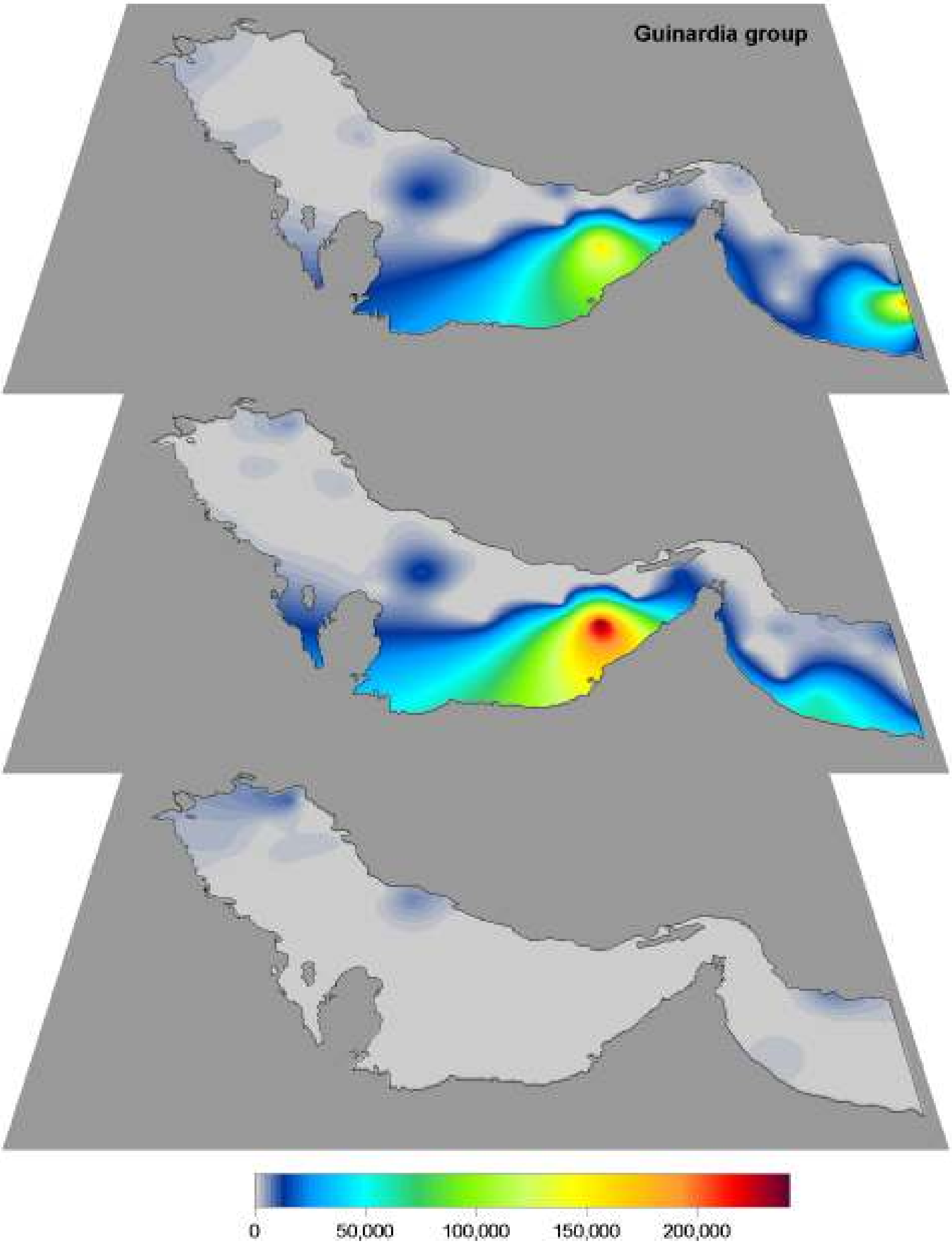

Fig. 23. Interpolated spatial distribution of the abundance (cells/L) of the *Guinardia* group in the ROPME Sea Area during Winter 2006 for the surface (top plot), middle (middle plot), and bottom (low plot) layers.

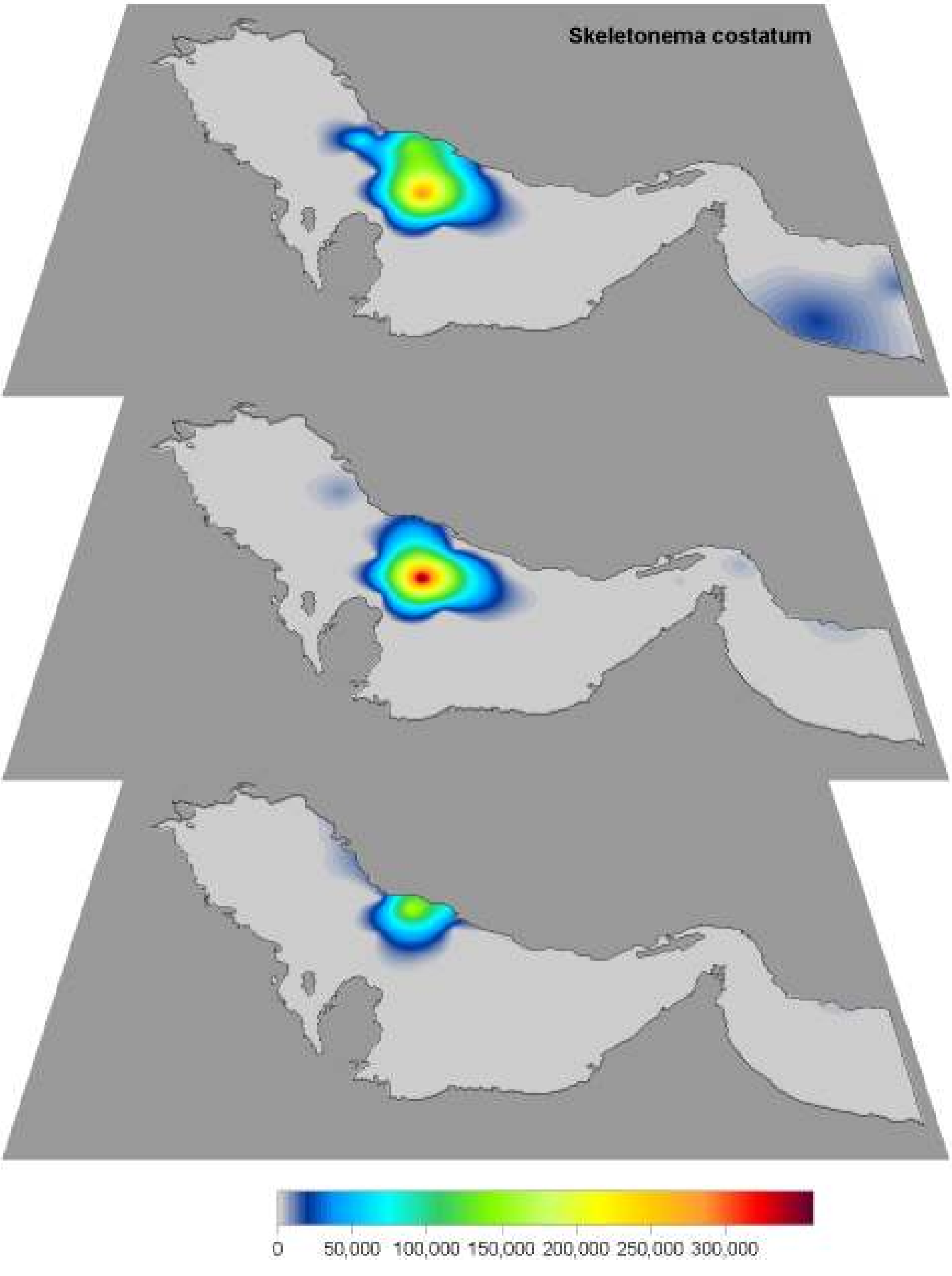

Fig. 24. Interpolated spatial distribution of the abundance (cells/L) of *Skeletonema costatum* in the ROPME Sea Area during Winter 2006 for the surface (top plot), middle (middle plot), and bottom (low plot) layers.

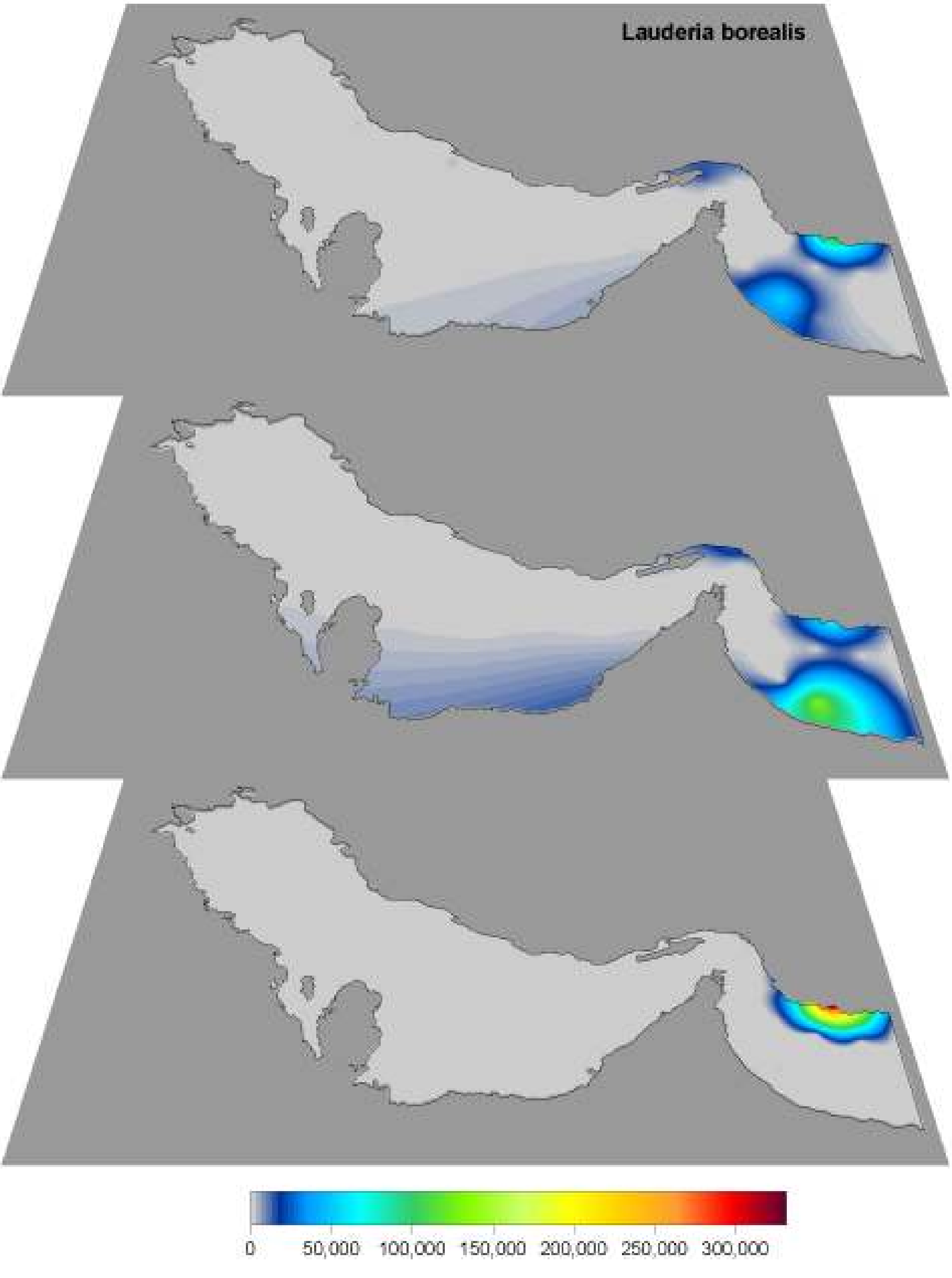

Fig. 25. Interpolated spatial distribution of the abundance (cells/L) of *Lauderia borealis* in the ROPME Sea Area during Winter 2006 for the surface (top plot), middle (middle plot), and bottom (low plot) layers.

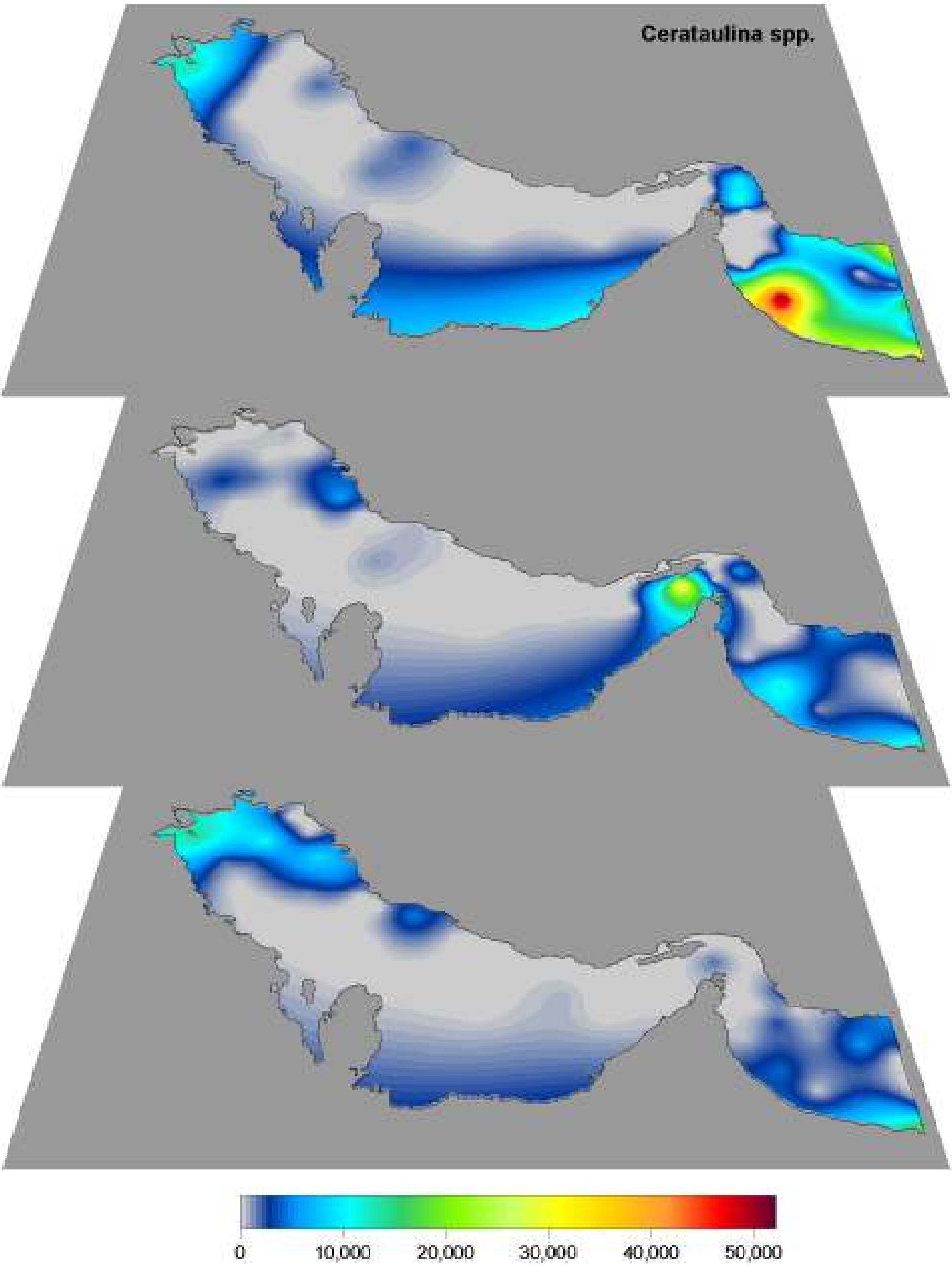

Fig. 26. Interpolated spatial distribution of the abundance (cells/L) of *Cerataulina* spp. in the ROPME Sea Area during Winter 2006 for the surface (top plot), middle (middle plot), and bottom (low plot) layers.

Total Abundance of the *Rhizosolenia* Group - Fig. 28.

The *Rhizosolenia* group includes morphologically close and related forms from the genera *Rhizosolenia*, *Proboscia*, *Pseudosolenia* and *Neocalyptrella* with medium- and large-sized elongated single or colonial diatoms. This group comprised occasionally up to 56% of the total phytoplankton abundance; the highest concentration reached 6.9×10^4 cells/L. Occasional peaks of *Rhizosolenia* group (> 10^4 cells/L) was observed in the north-western part of the inner Sea (St. 7), in the central part of the inner RSA off the Iranian coast (St. 11a) and off Qatar (St. 36) as well as in the Sea of Oman off the coast of Oman (St. 25a).

Total Abundance of *Leptocylindrus* spp. - Fig. 29.

The genus *Leptocylindrus* included three species, of which *Leptocylindrus 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 north-western part of the inner Sea, in the southern part of the inner RSA near the Strait of Hormuz (off the Iranian coast) and in the Sea of Oman.

Total Abundance of *Hemiaulus* spp. - Fig. 30.

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 phytoplankton, 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 north-western part of RSA; the second maximum was recorded in Sea of Oman.

Total Abundance of *Coscinodiscus* Group - Fig. 31.

The *Coscinodiscus* group includes morphologically close and related forms from the genera *Coscinodiscus*, *Thalassiosira*, *Stellarima, Actinocyclus* and *Hemidiscus,* which are generally large-sized diatoms. Some species of this group were frequently observed in the phytoplankton, 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.

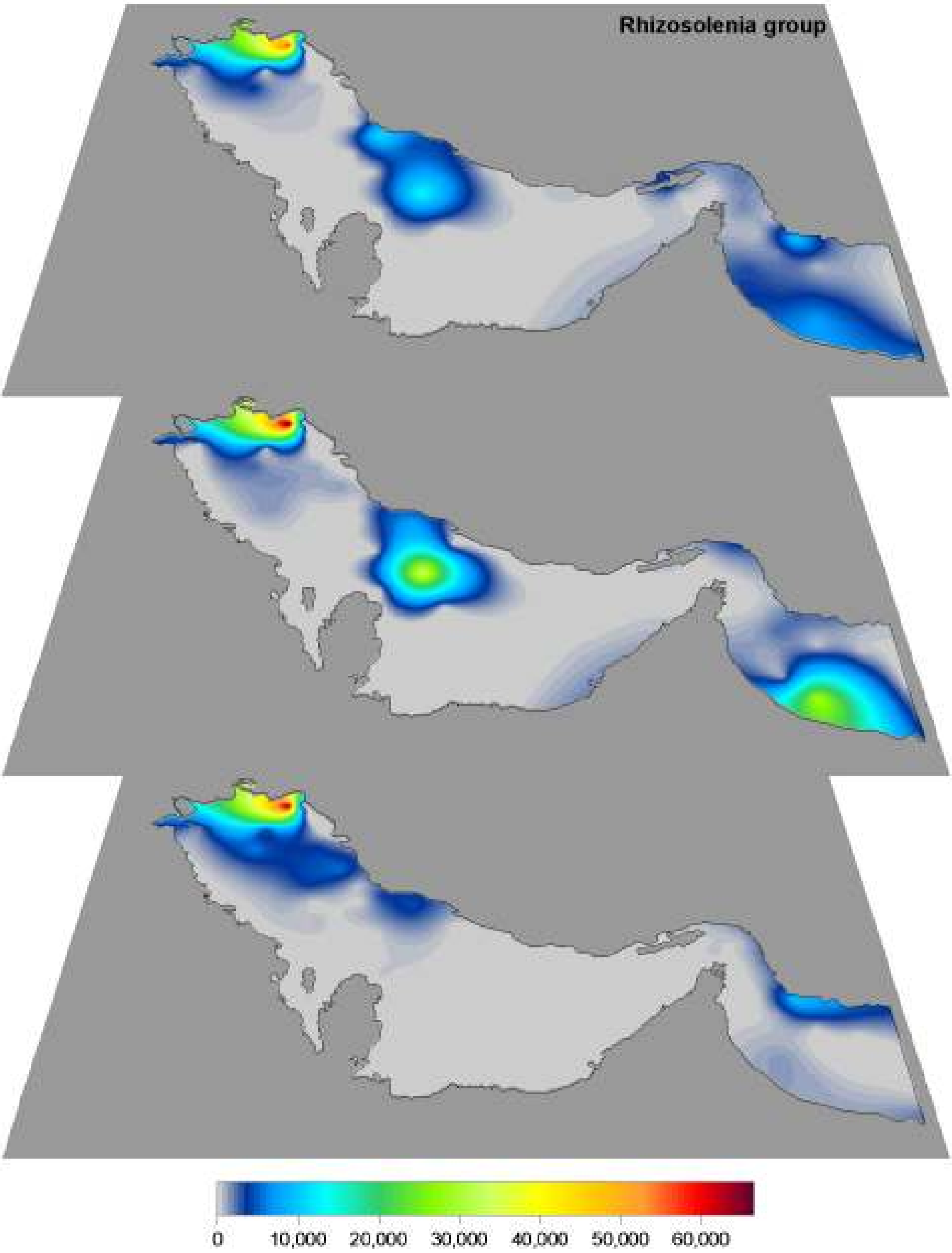

Fig. 27. Interpolated spatial distribution of the abundance (cells/L) of the *Rhizosolenia* group in the ROPME Sea Area during Winter 2006 for the surface (top plot), middle (middle plot), and bottom (low plot) layers.

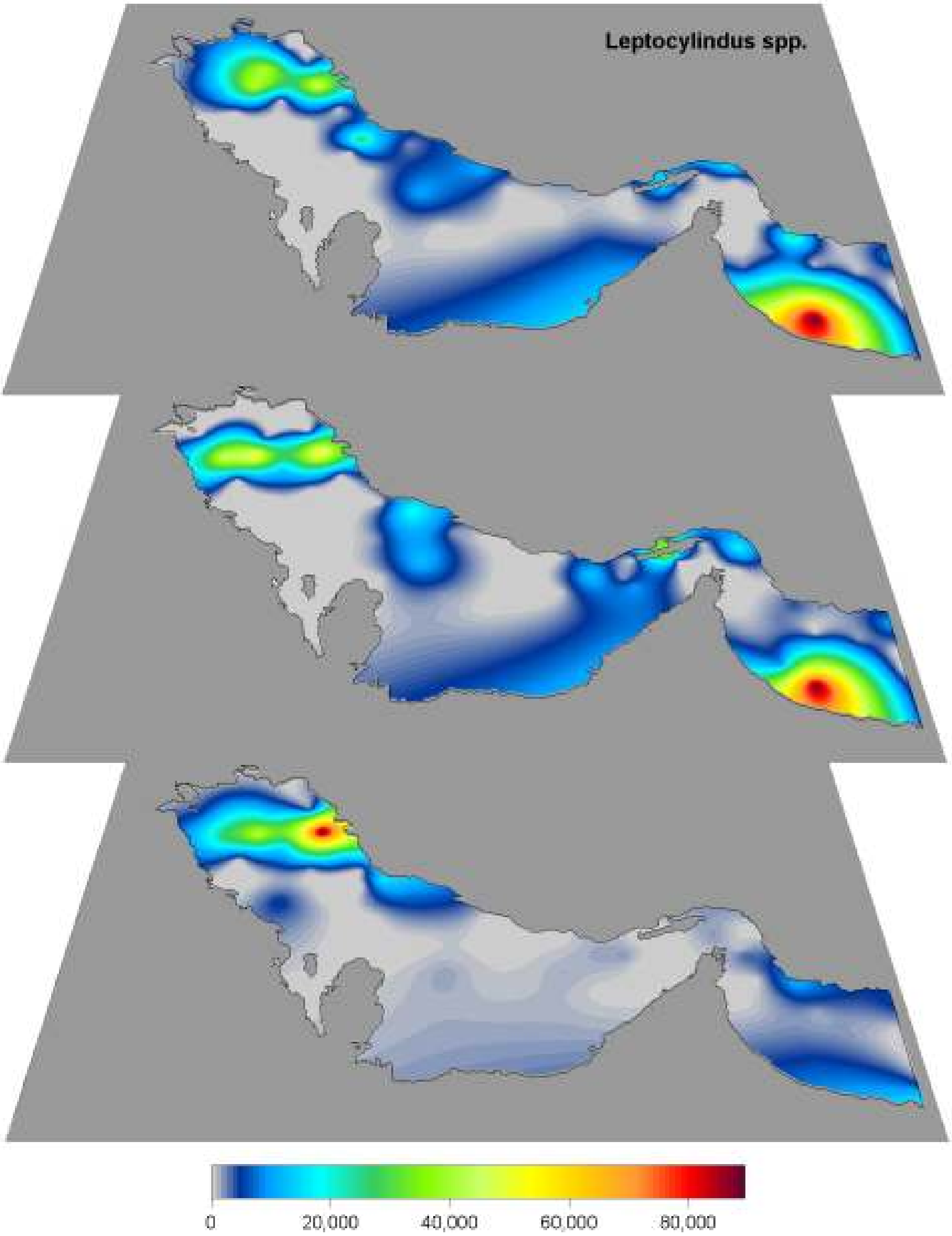

Fig. 28. Interpolated spatial distribution of the abundance (cells/L) of *Leptocylindrus* spp. in the ROPME Sea Area during Winter 2006 for the surface (top plot), middle (middle plot), and bottom (low plot) layers.

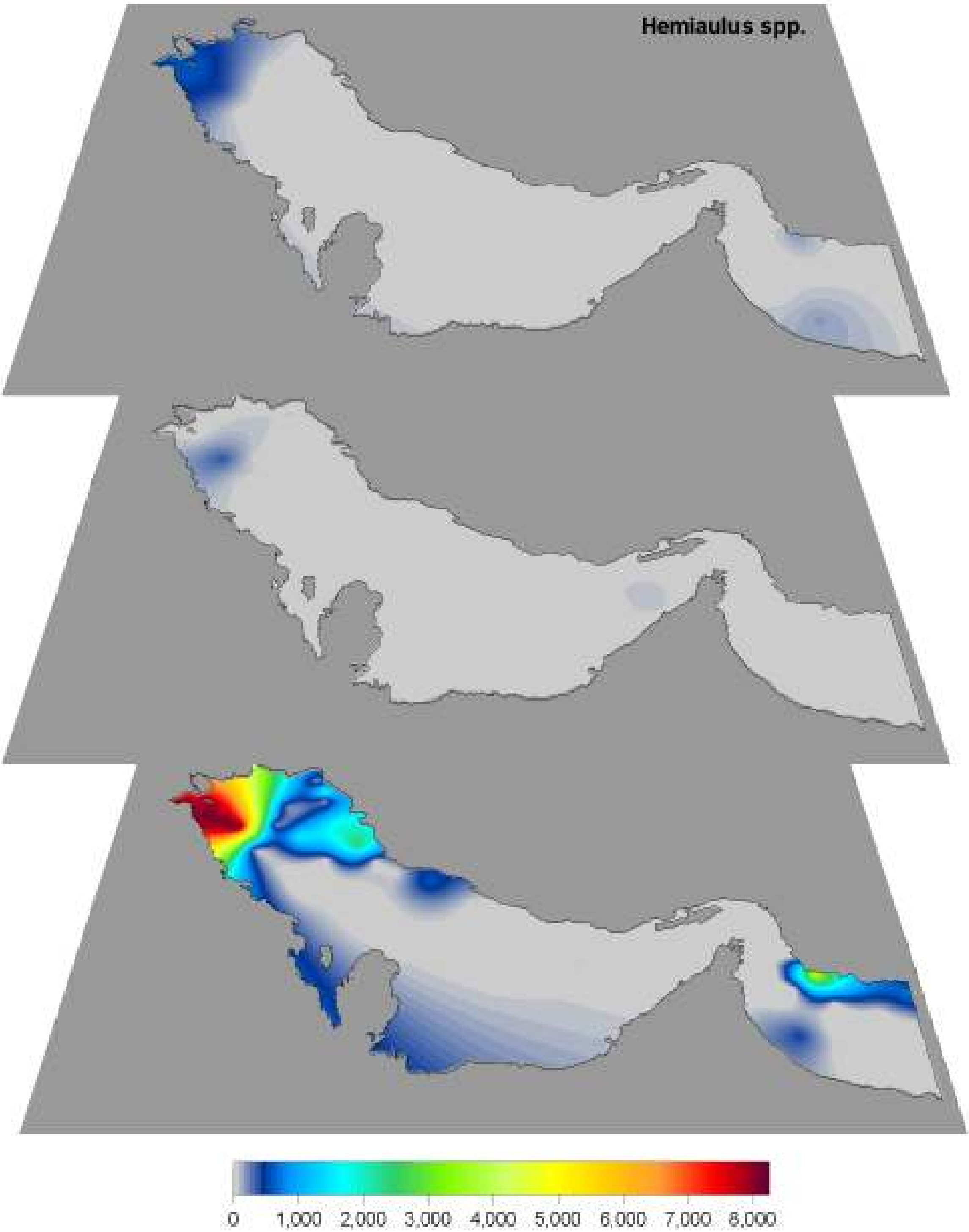

Fig. 29. Interpolated spatial distribution of the abundance (cells/L) of *Hemiaulus* spp. in the ROPME Sea Area during Winter 2006 for the surface (top plot), middle (middle plot), and bottom (low plot) layers.

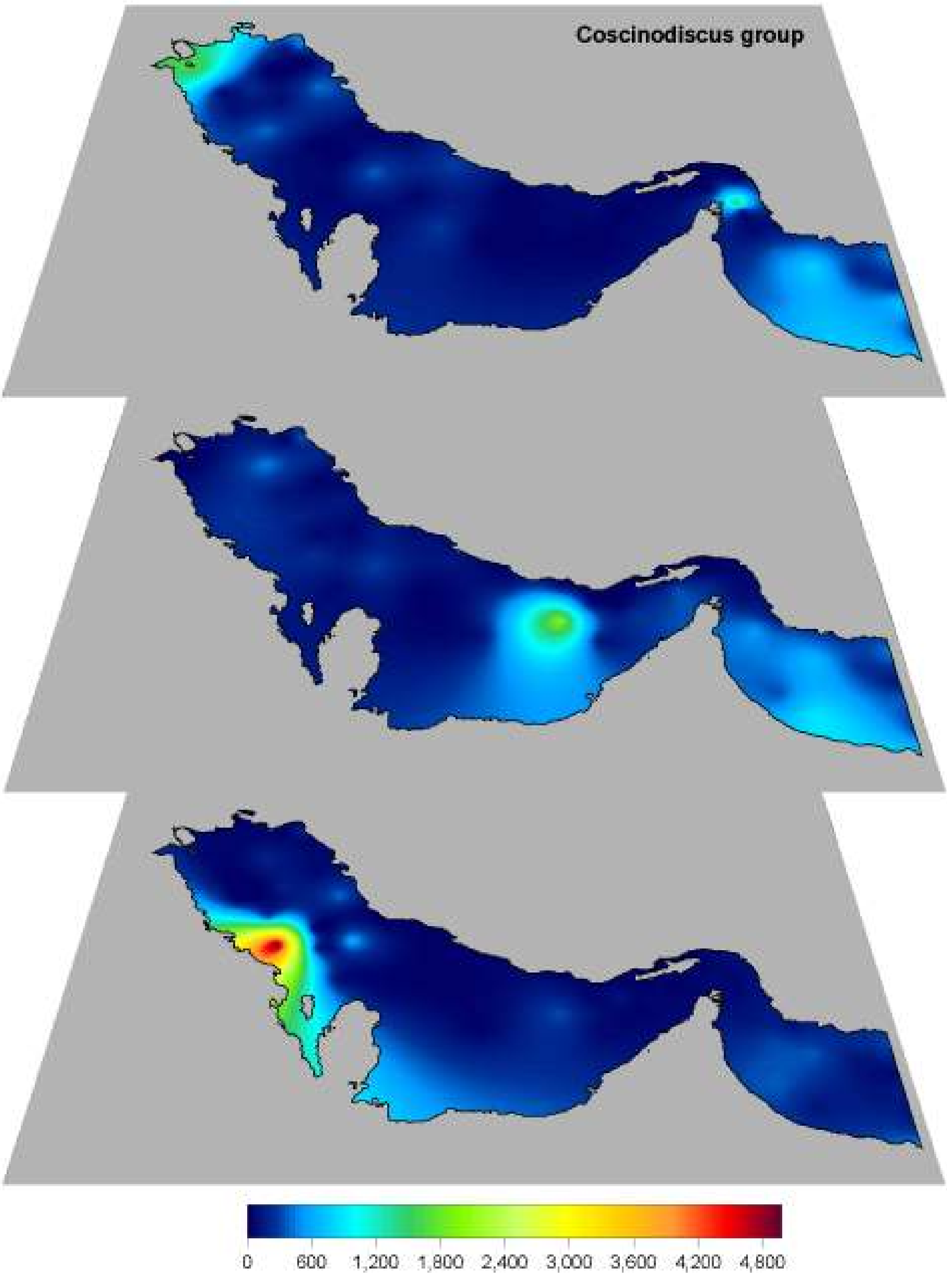

Fig. 30. Interpolated spatial distribution of the abundance (cells/L) of *Coscinodiscus* group in the ROPME Sea Area during Winter 2006 for the surface (top plot), middle (middle plot), and bottom (low plot) layers.

Total Abundance of *Odontella* spp. - Fig. 32.

The genus *Odontella* represented by three species (*O. aurita*, *O. mobiliensis* and *O. sinensis*) contains medium- and large-sized single or colonial diatom algae. 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.

Total Abundance of Pennate Diatoms - Fig. 33.

Along with centric diatoms, pennate diatom forms frequently occurred in the RSA phytoplankton community. Rather high densities of diatoms from the genera *Diploneis*, *Pleurosigma*, *Navicula*, *Trachyneis*, *Nitzschia*, *Pseudo-nitzschia*, *and Surirella* were detected in the examined RSA samples. Significant contribution of this group to the total phytoplankton abundance was recorded especially in the waters off the Iranian coast (47%, St. 27; up to 79% at St. 11a). The highest concentration reached 5.1×10^5 cells/L. The maximum abundance of pennate diatoms (> 10^5 cells/L) was associated with the waters off the Iranian coast (stations 11a, 27, 39).

Total Abundance of *Pseudo-nitzschia* spp. - Fig. 34.

The genus *Pseudo-nitzschia* includes a few taxa, among them *Pseudo-nitzschia* cf *delicatissima*, which was the most abundant. The genus contains medium-sized chain-forming diatom algae. Species from this genus are known to be producers of toxic domoic acid. 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 waters off the Iranian coast in the central part of the inner RSA.

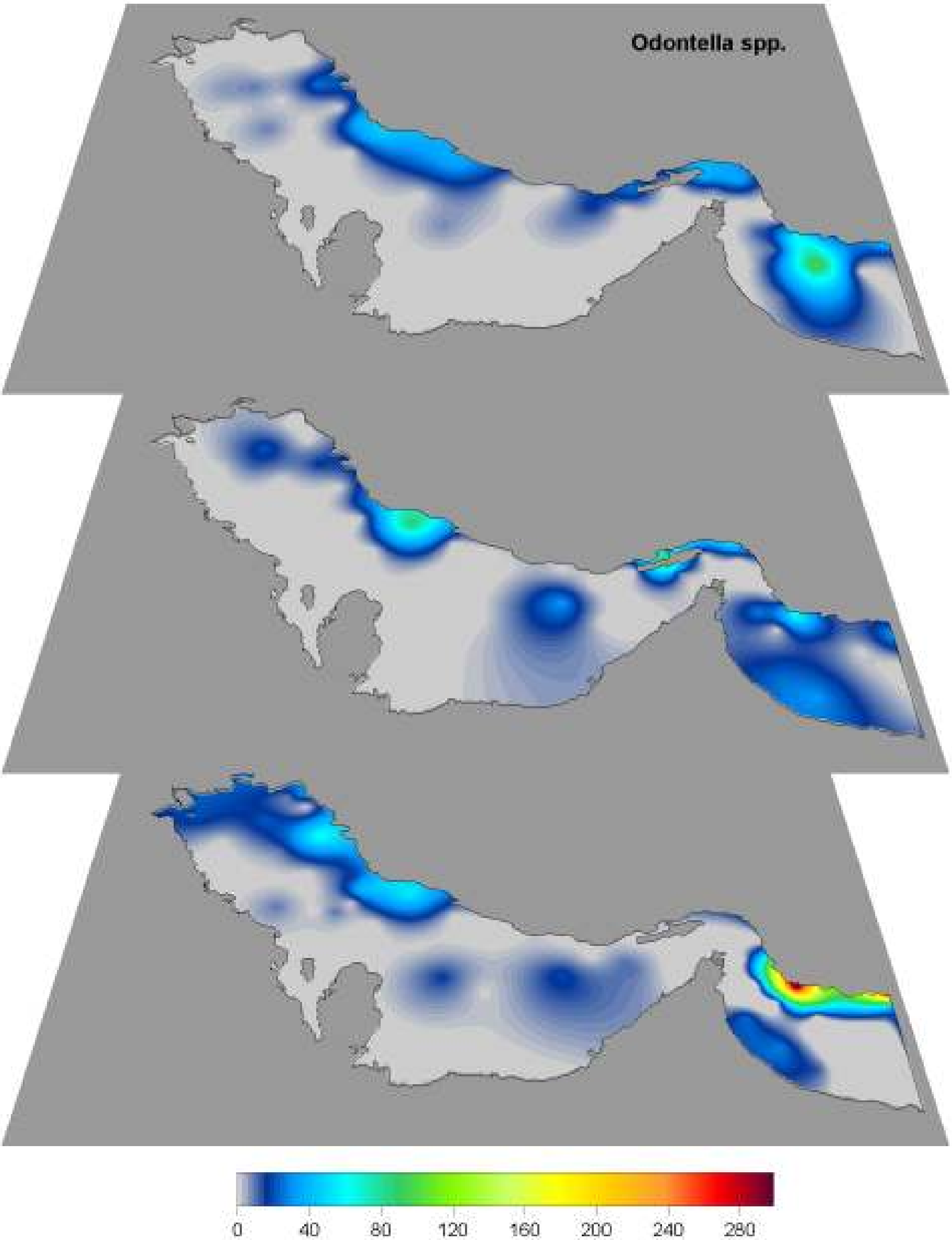

Fig. 31. Interpolated spatial distribution of the abundance (cells/L) of *Odontella* spp. in the ROPME Sea Area during Winter 2006 for the surface (top plot), middle (middle plot), and bottom (low plot) layers.

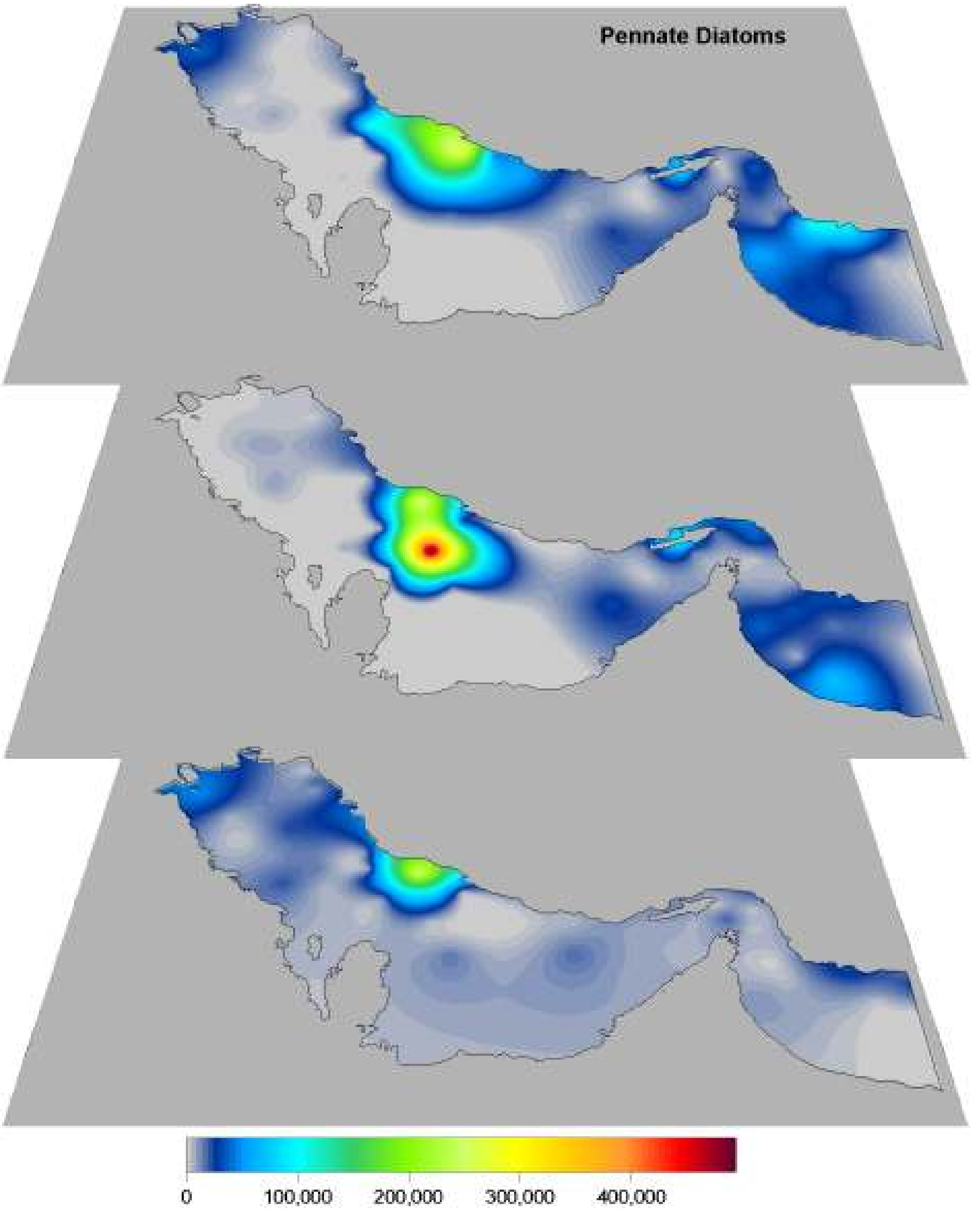

Fig. 32. Interpolated spatial distribution of the total abundance (cells/L) of the pennate diatoms (Bacillariophyceae) in the ROPME Sea Area during Winter 2006 for the surface (top plot), middle (middle plot), and bottom (low plot) layers.

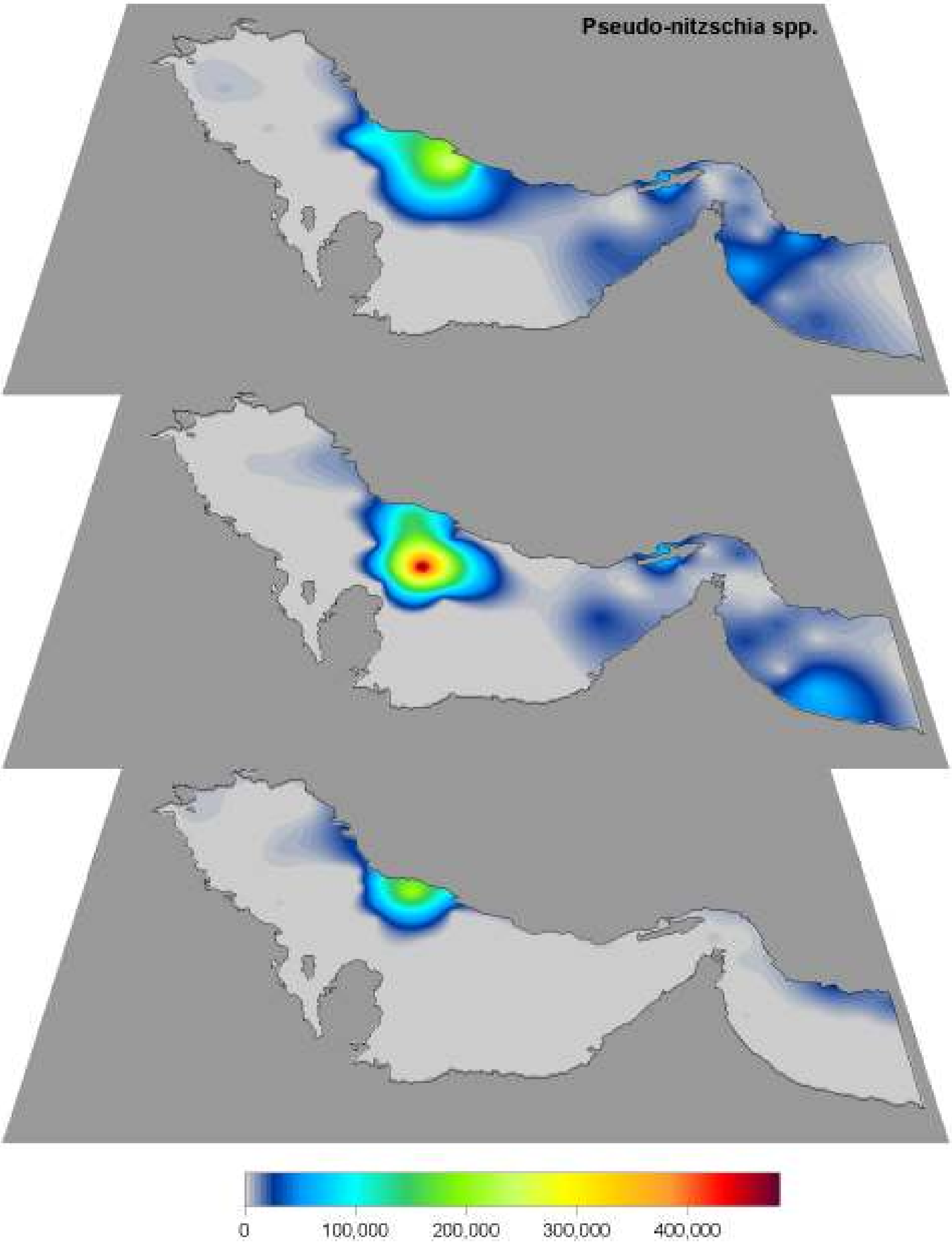

Fig. 33. Interpolated spatial distribution of the abundance (cells/L) of *Pseudo-nitzschia* spp. in the ROPME Sea Area during Winter 2006 for the surface (top plot), middle (middle plot), and bottom (low plot) layers.

Total Abundance of *Thalassionema* Group - Fig. 35.

The *Thalassionema* group includes morphologically close and related forms from the two genera *Thalassionema* and *Thalassiothrix*, with medium- and large-sized colonial diatoms. Species of this group were commonly observed in the RSA phytoplankton and *Thalassionema nitzschioides* has ubiquitous occurrence. When abundant, species from this group contributed up to 23% of the total phytoplankton abundance; the highest concentration reached 3.3×10^4 cells/L. High abundance of this group (> 10^4 cells/L) was mostly associated with the northwestern part of the inner RSA.

Total Abundance of Dinoflagellates (Dinophyceae) - Fig. 36.

In general, after diatoms, dinoflagellates are regarded as the second significant contributor to the total abundance of phytoplankton. 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 bigger contributor to dinoflagellate abundance was contributed by small-sized *Gymnodinium*-like flagellates (88%; 4.7×10^5 cells/L). The spatial distribution of the group is displayed in Fig. 37.

Total Abundance of *Protoperidinium* spp. - Fig. 38.

Among dinoflagellates, *Protoperidinium* genus was the most diverse and rather abundant; it includes small- to large-sized mainly heterotrophic dinoflagellates. When abundant, *Protoperidinium* spp. contributed up to 16% of the total phytoplankton abundance; the highest concentration reached up to 1.2×10^4 cells/L. The 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.

Total Abundance of *Oxytoxum* Group - Fig. 39.

The *Oxytoxum* group includes morphologically close and related species from the genera *Oxytoxum* and *Corythodinium*, which includes small- and medium-sized armored phototrophic dinoflagellates. Some of these species were frequently observed in the RSA samples and 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

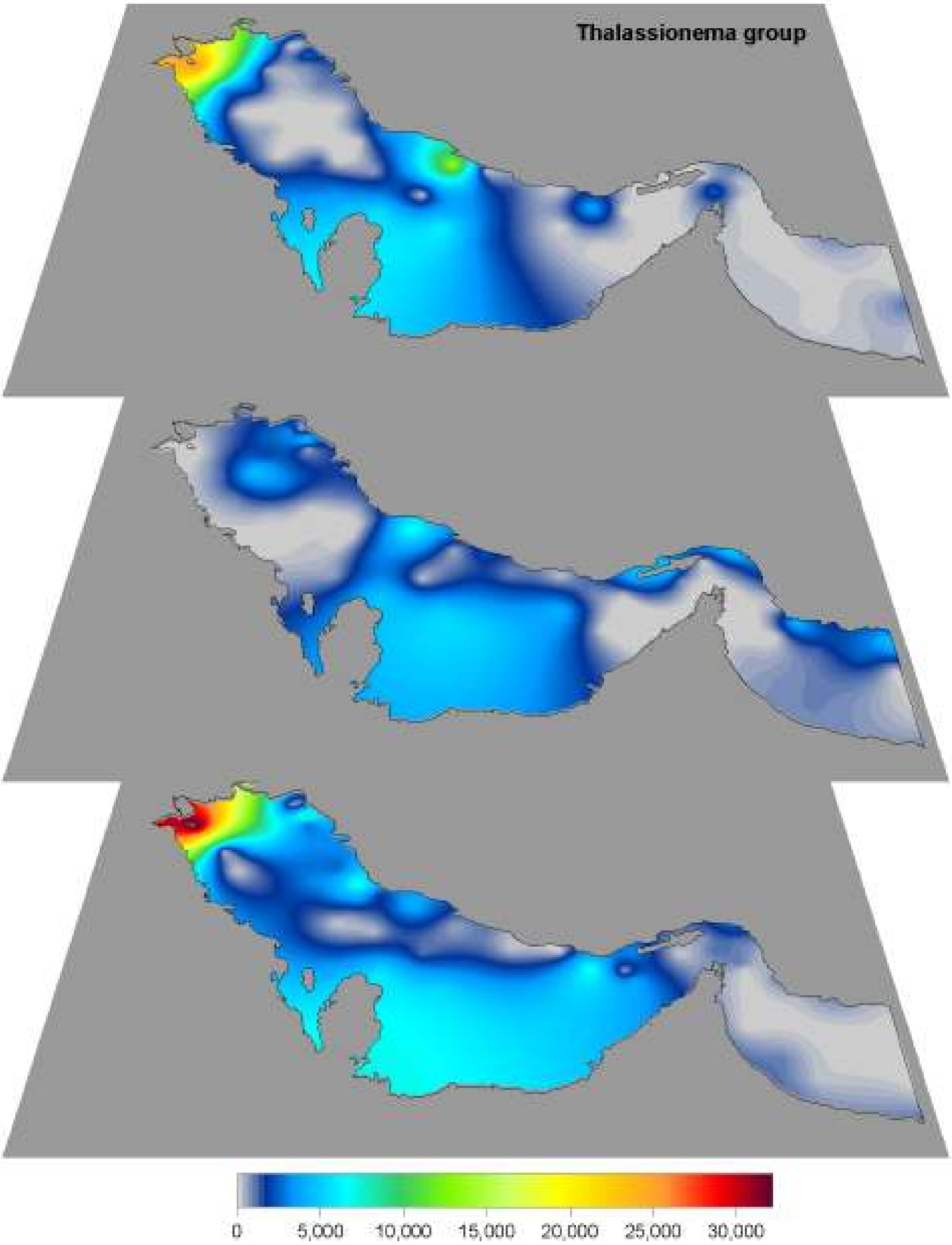

Fig. 34. Interpolated spatial distribution of the abundance (cells/L) of *Thalassionema* group in the ROPME Sea Area during Winter 2006 for the surface (top plot), middle (middle plot), and bottom (low plot) layers.

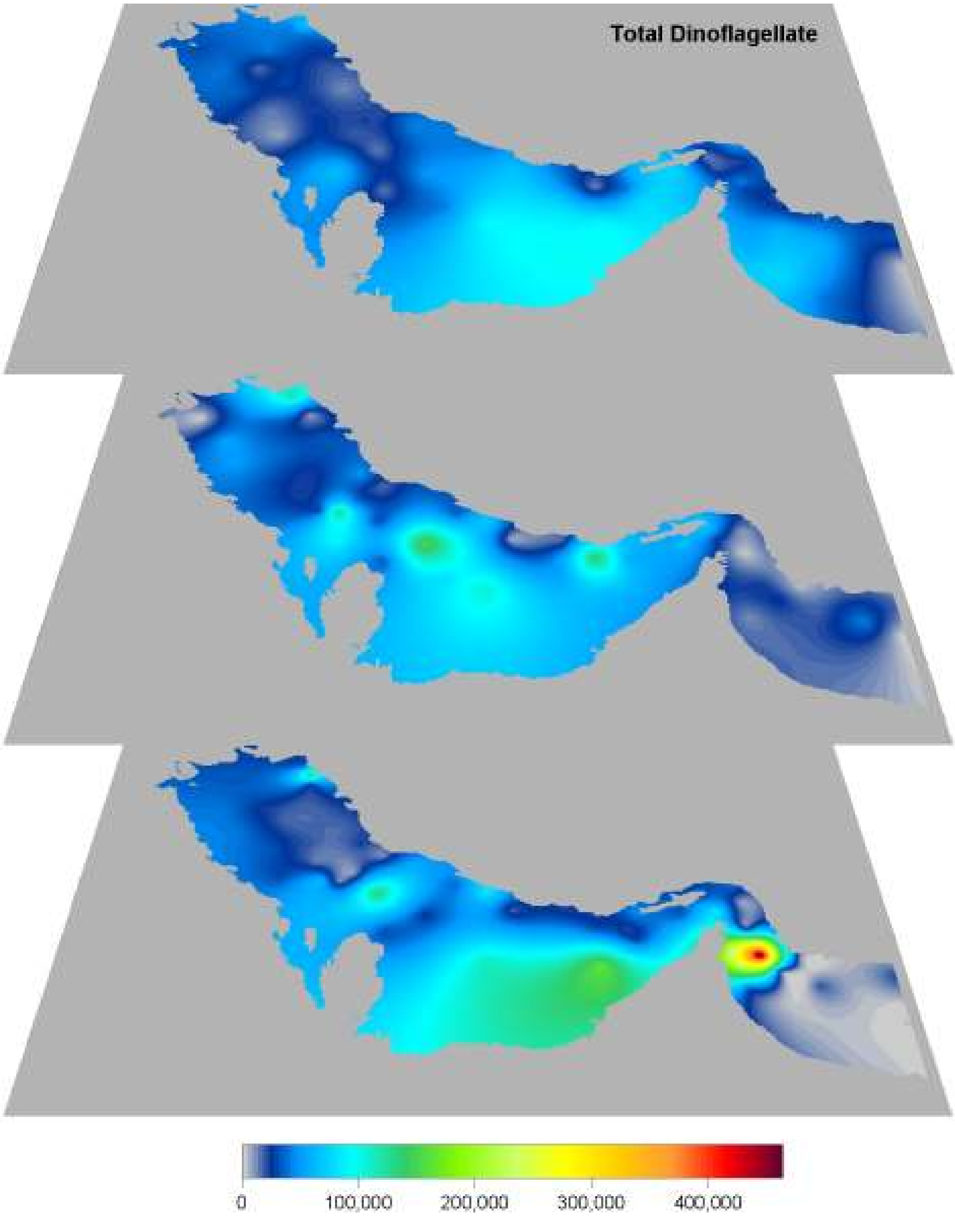

Fig. 35. Interpolated spatial distribution of the total abundance (cells/L) of dinoflagellates (Dinophyceae) in the ROPME Sea Area during Winter 2006 for the surface (top plot), middle (middle plot), and bottom (low plot) layers.

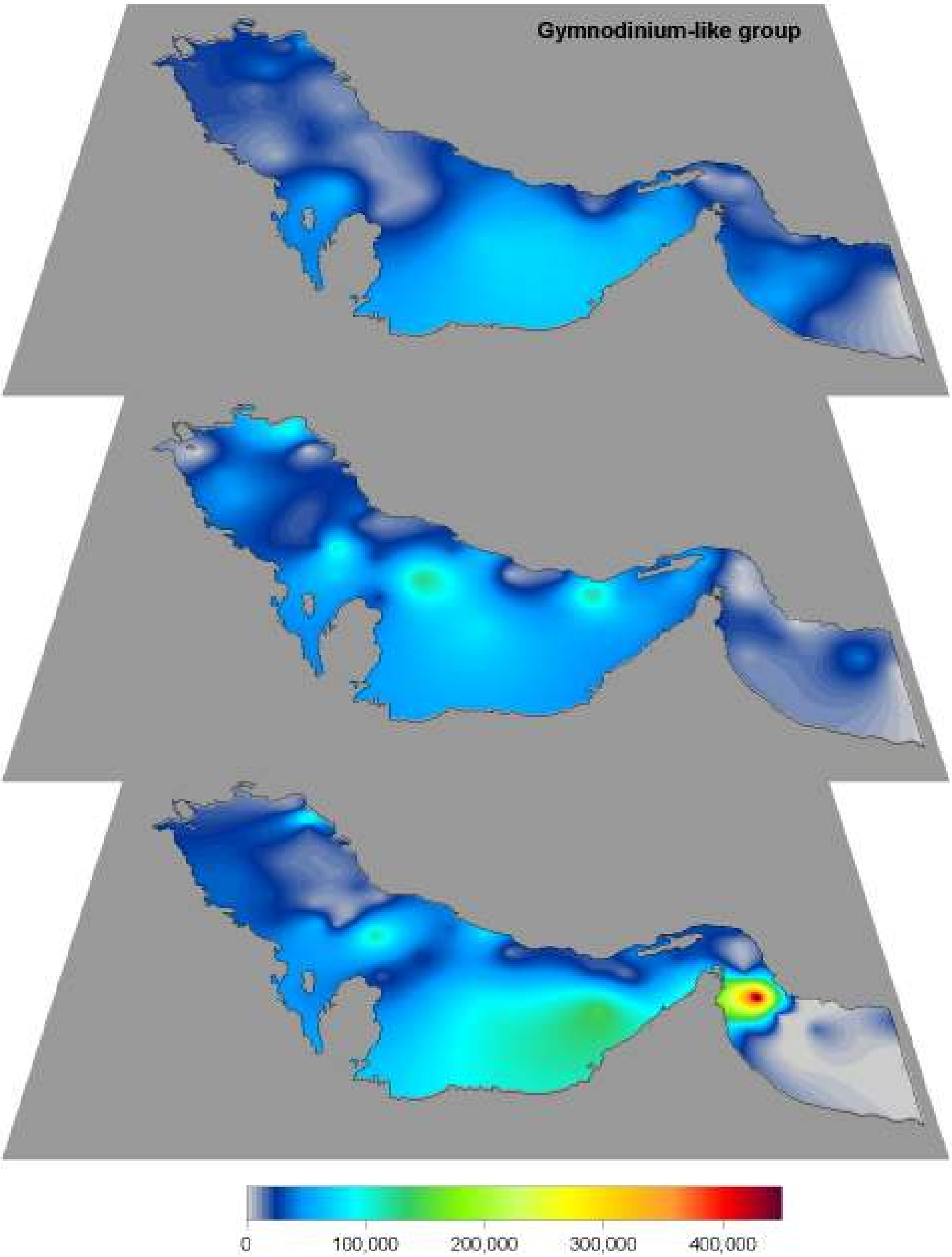

Fig. 36. Interpolated spatial distribution of the abundance (cells/L) of the *Gymnodinium*-like group in the ROPME Sea Area during Winter 2006 for the surface (top plot), middle (middle plot), and bottom (low plot) layers.

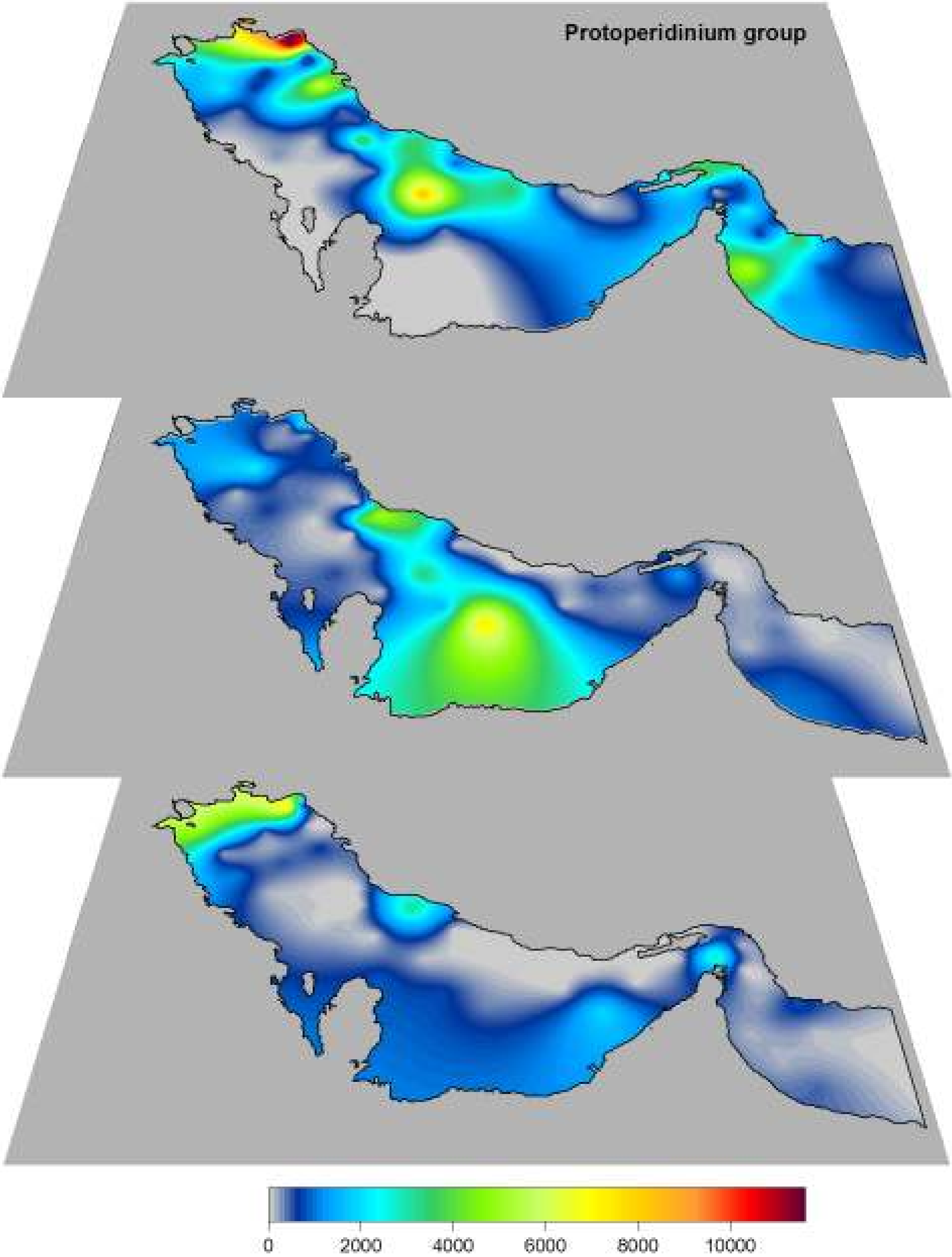

Fig. 37. Interpolated spatial distribution of the abundance (cells/L) of *Protoperidinium* spp. in the ROPME Sea Area during Winter 2006 for the surface (top plot), middle (middle plot), and bottom (low plot) layers.

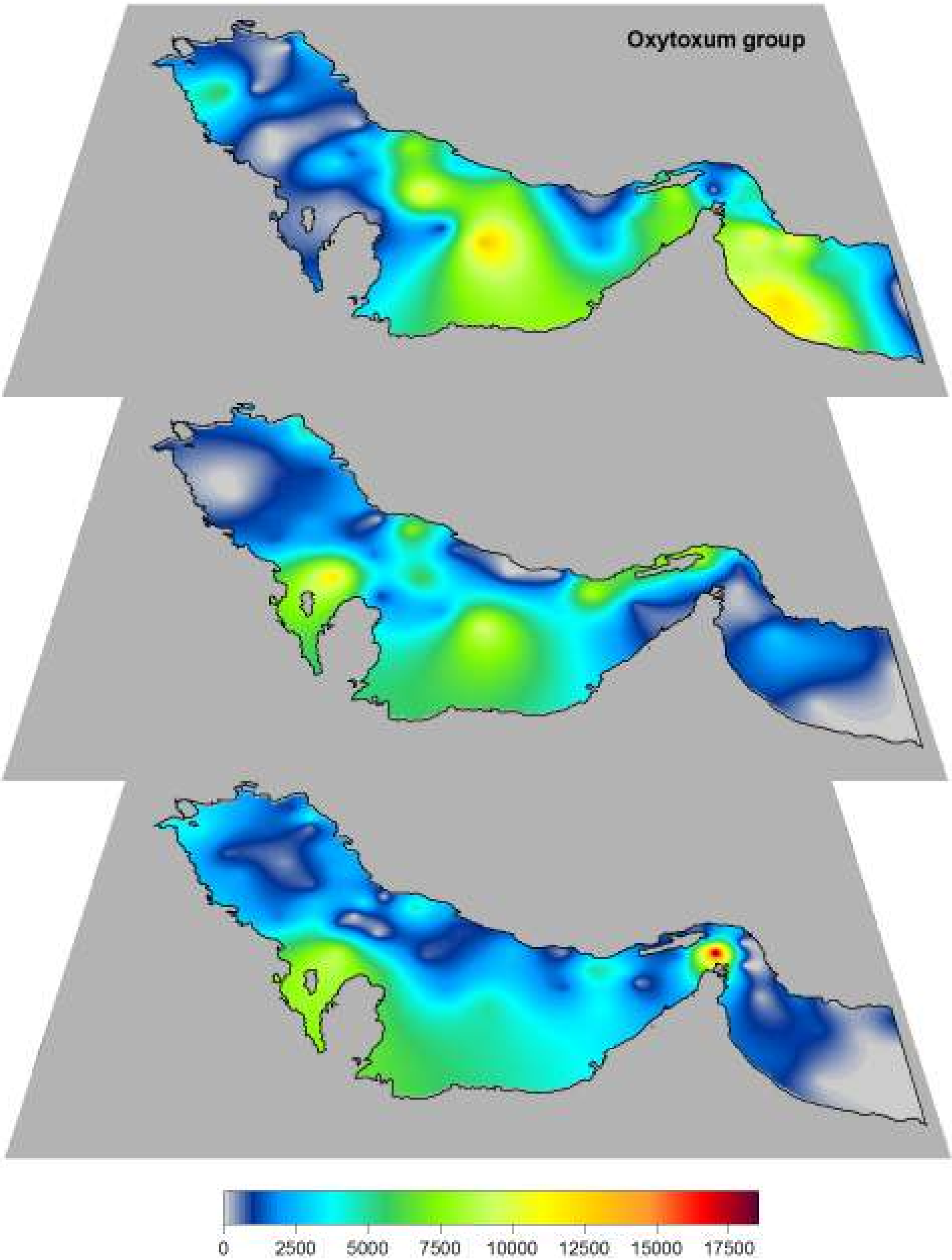

Fig. 38. Interpolated spatial distribution of the abundance (cells/L) of the *Oxytoxum* group in the ROPME Sea Area during Winter 2006 for the surface (top plot), middle (middle plot), and bottom (low plot) layers.

Total Abundance of *Heterocapsa* spp. - Fig. 40.

These small-sized armored autotrophic dinoflagellates were frequently encountered in the RSA samples. When abundant, they contributed up to 14% of the total phytoplankton abundance; the highest concentration reached 3.2×104 cells/L. High abundance of this genus (> 104 cells/L) was associated with waters of the southern part of the inner RSA, Strait of Hormuz and Sea of Oman.

Total Abundance of *Torodinium* spp. - Fig. 41.

These medium- and large-sized unarmored autotrophic dinoflagellates were commonly detected in 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 1.4×104 cells/L. High abundance of this genus (> 104 cells/L) was mainly associated with the waters of the central part of the inner RSA, with localized peak in the Sea of Oman.

Total Abundance of *Gyrodinium* spp. - Fig. 42.

These medium- and large-sized unarmored autotrophic dinoflagellates 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 9.9×103 cells/L. The spatial distribution of this genus was localized. High abundance of this genus (> 103 cells/L) was strongly associated with the waters of the Sea of Oman.

Total Abundance of *Ceratium* spp. - Fig. 43.

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 most northern part of the north-western waters of the inner RSA.

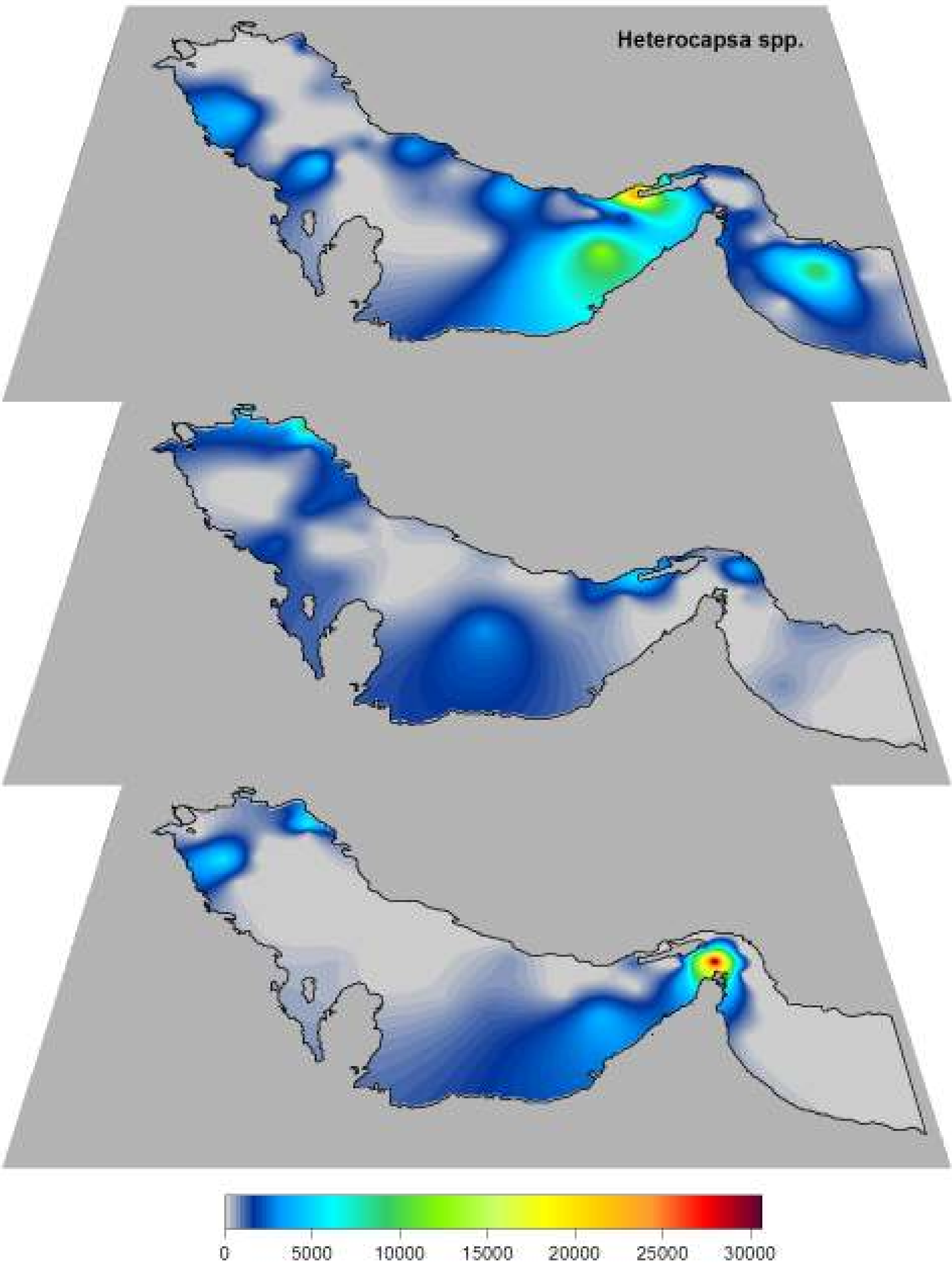

Fig. 49. Interpolated spatial distribution of the abundance (cells/L) of *Heterocapsa* spp. in the ROPME Sea Area during Winter 2006 for the surface (top plot), middle (middle plot), and bottom (low plot) layers.

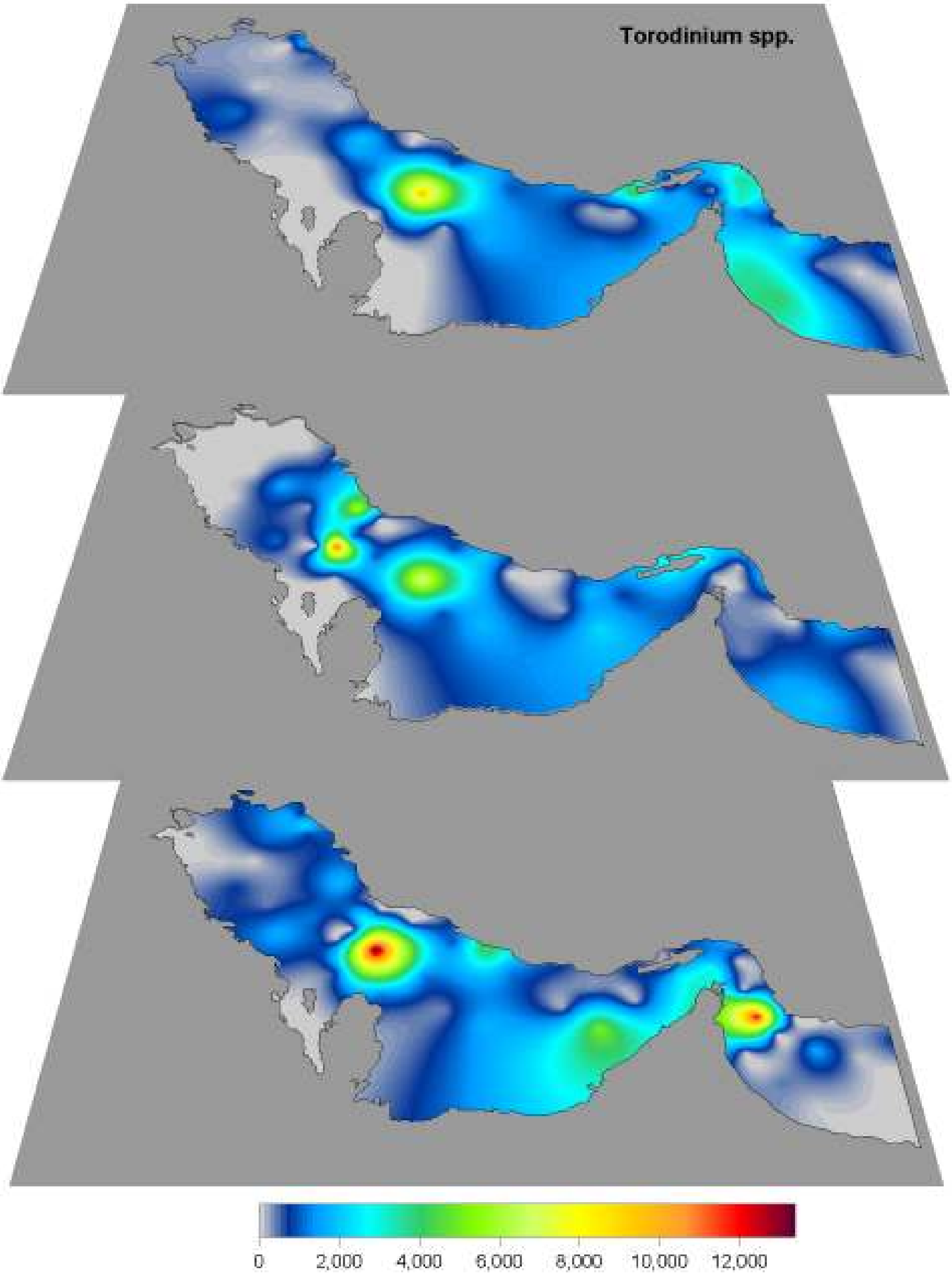

Fig. 40. Interpolated spatial distribution of the abundance (cells/L) of *Torodinium* spp. in the ROPME Sea Area during Winter 2006 for the surface (top plot), middle (middle plot), and bottom (low plot) layers.

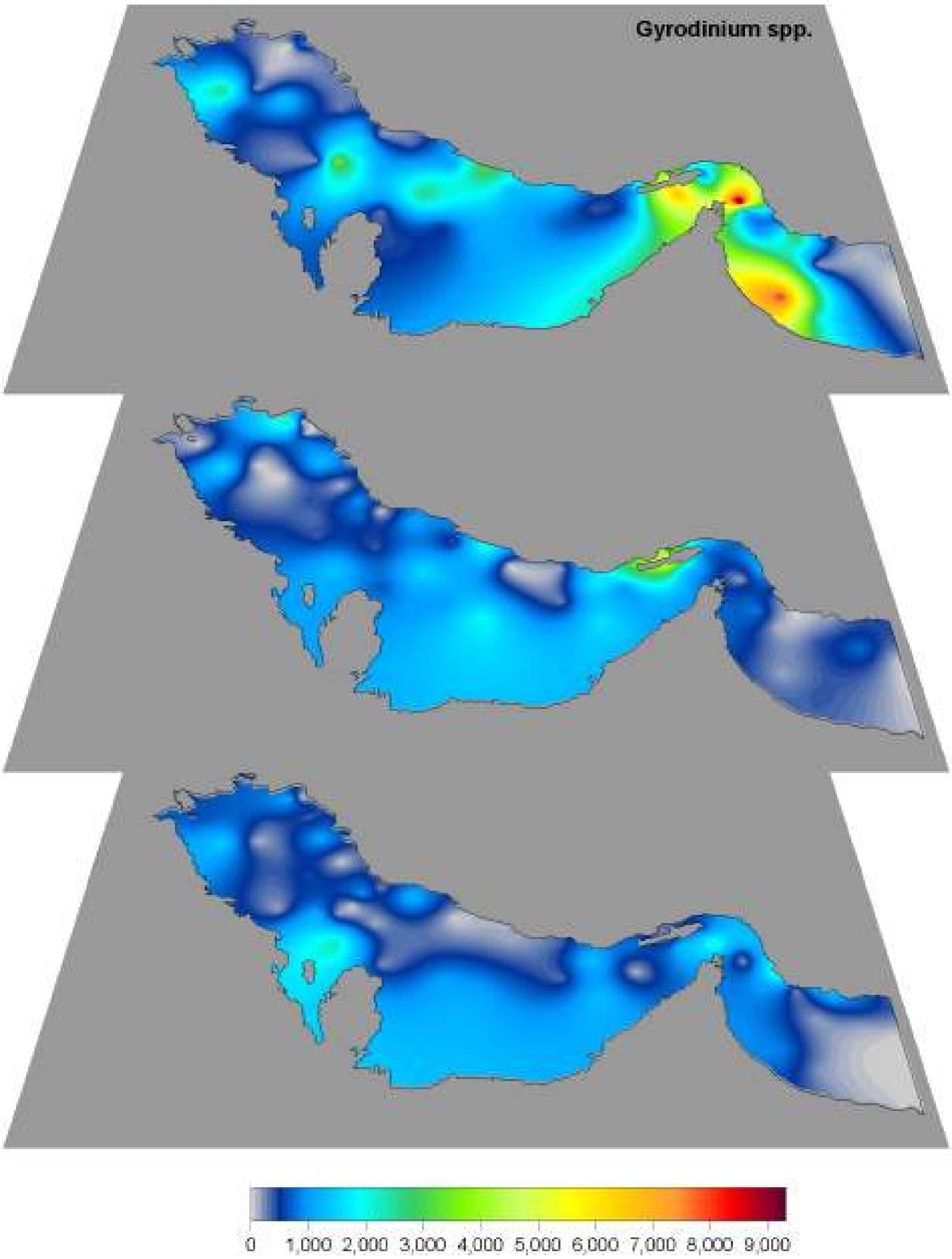

Fig. 41. Interpolated spatial distribution of the abundance (cells/L) of *Gyrodinium* spp. in the ROPME Sea Area during Winter 2006 for the surface (top plot), middle (middle plot), and bottom (low plot) layers.

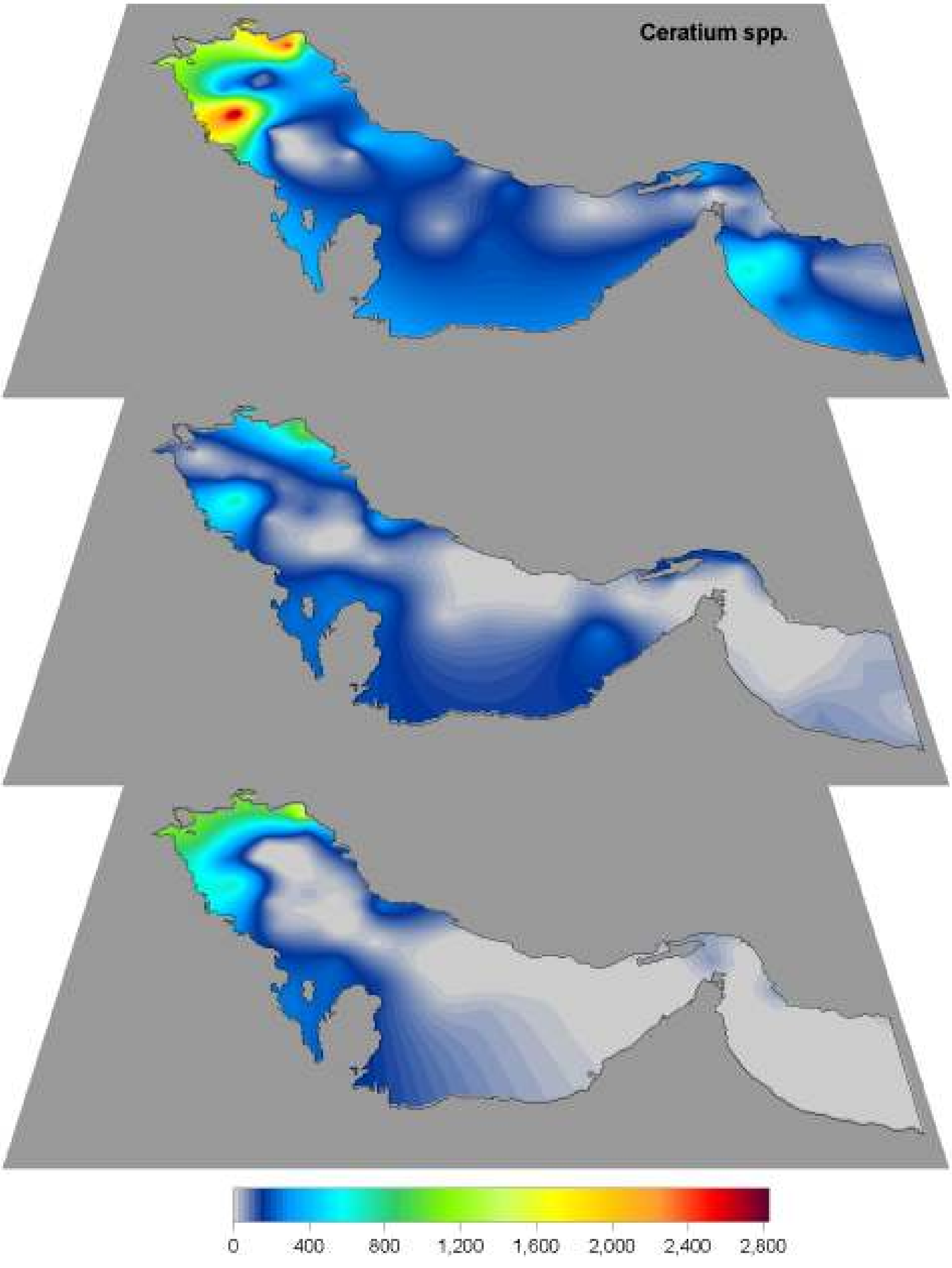

Fig. 42. Interpolated spatial distribution of the abundance (cells/L) of *Ceratium* spp. in the ROPME Sea Area during Winter 2006 for the surface (top plot), middle (middle plot), and bottom (low plot) layers.

Total Abundance of *Alexandrium* spp. - Fig. 44.

The genus *Alexandrium* includes medium-sized autotrophic armored dinoflagellates. Many species of this genus are known to be toxins producers. *A. tamiyavanichii* was occasionally observed in samples. Highest abundance reached 2.0×10^3 cells/L (less than 2% of the total phytoplankton abundance). Maximum abundance of this genus (> 10^3 cells/L) was strongly associated with the waters of the Sea of Oman.

Abundance of *Karenia brevis* - Fig. 45.

This medium-sized autotrophic and potentially toxic dinoflagellate was rarely encountered in the RSA samples, 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.

Total Abundance of the Small-sized *Prorocentrum* Group - Fig. 46.

This group includes morphologically close and related small-sized species from the genera *Prorocentrum* and *Mesoporos*, some of which were frequently observed in the samples. When abundant, these species contributed up to 13% of the total phytoplankton abundance; the highest concentration reached 4.2×10^3 cells/L. High abundance of this group (> 10^3 cells/L) was occasionally detected in the central part of the inner RSA and in Sea of Oman.

Total Abundance of the Medium-sized *Prorocentrum* spp. - Fig. 47.

These medium-sized autotrophic armored dinoflagellates were commonly observed in the RSA samples. When abundant, these species contributed up to 4% of the total phytoplankton abundance; the highest concentration reached 4.0×10^3 cells/L. High abundance of this group (> 10^3 cells/L) was occasionally detected in the northwestern and central part of the inner RSA.

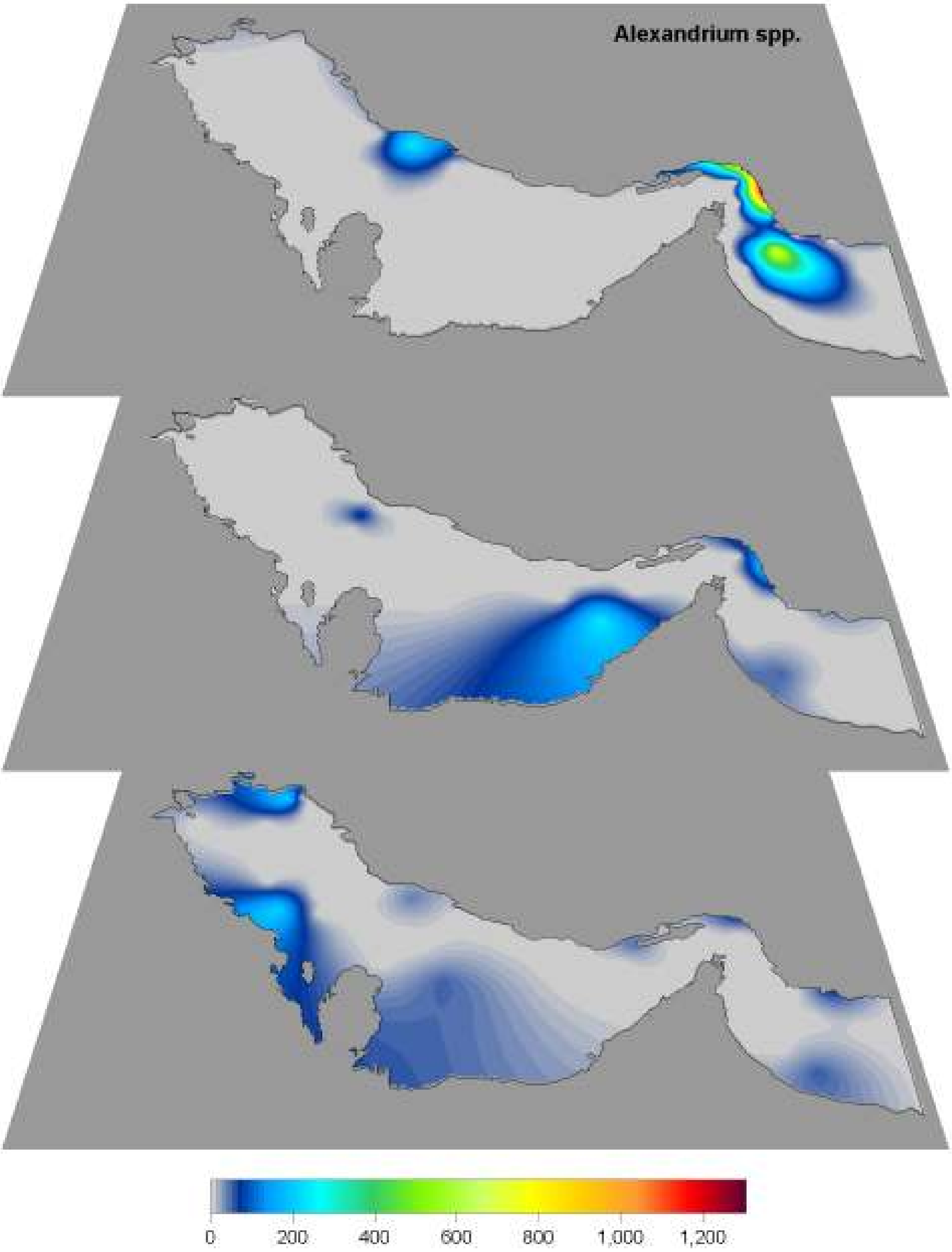

Fig. 43. Interpolated spatial distribution of the abundance (cells/L) of *Alexandrium* spp. in the ROPME Sea Area during Winter 2006 for the surface (top plot), middle (middle plot), and bottom (low plot) layers.

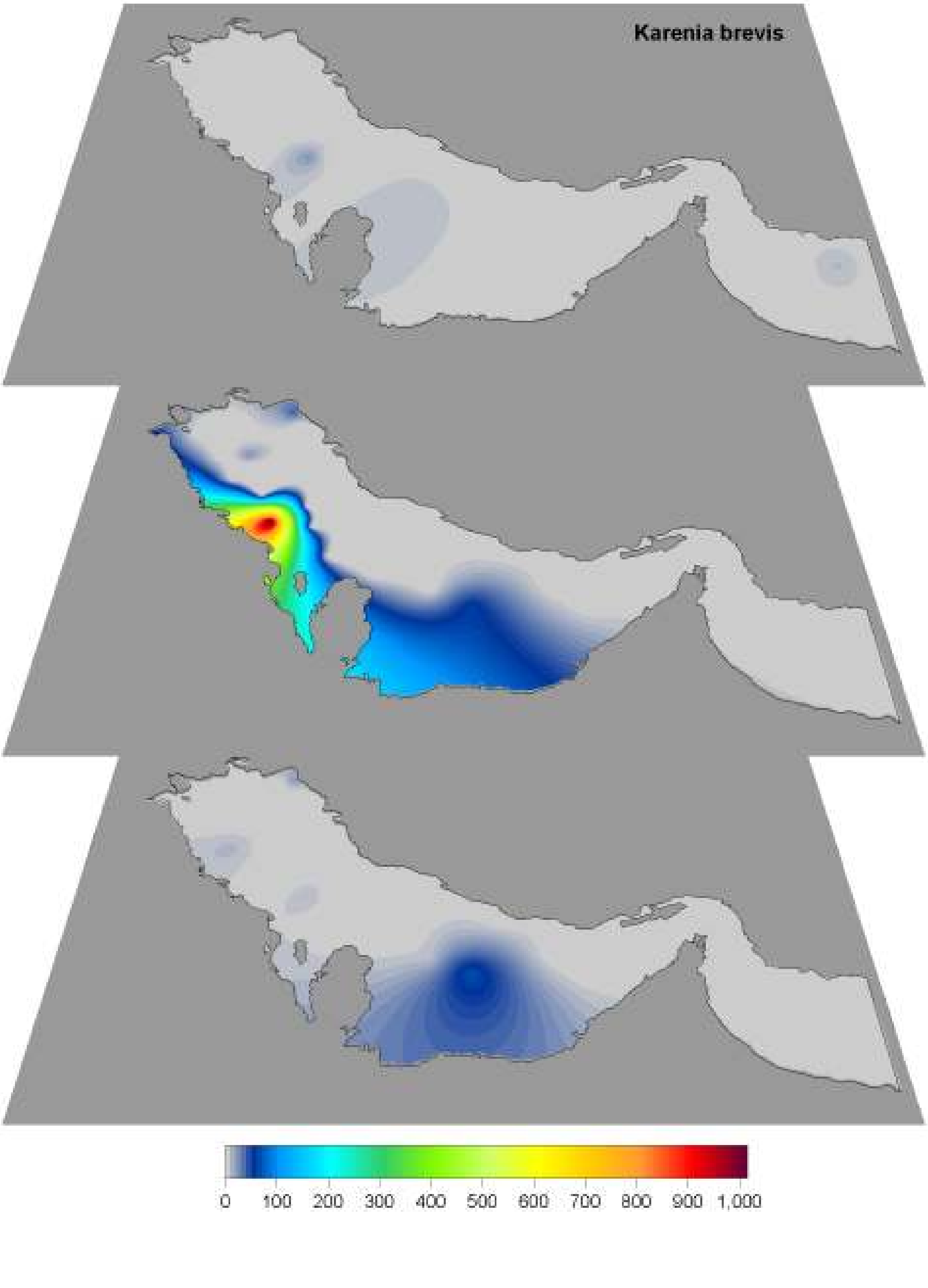

Fig. 44. Interpolated spatial distribution of the abundance (cells/L) of *Karenia brevis* in the ROPME Sea Area during Winter 2006 for the surface (top plot), middle (middle plot), and bottom (low plot) layers.

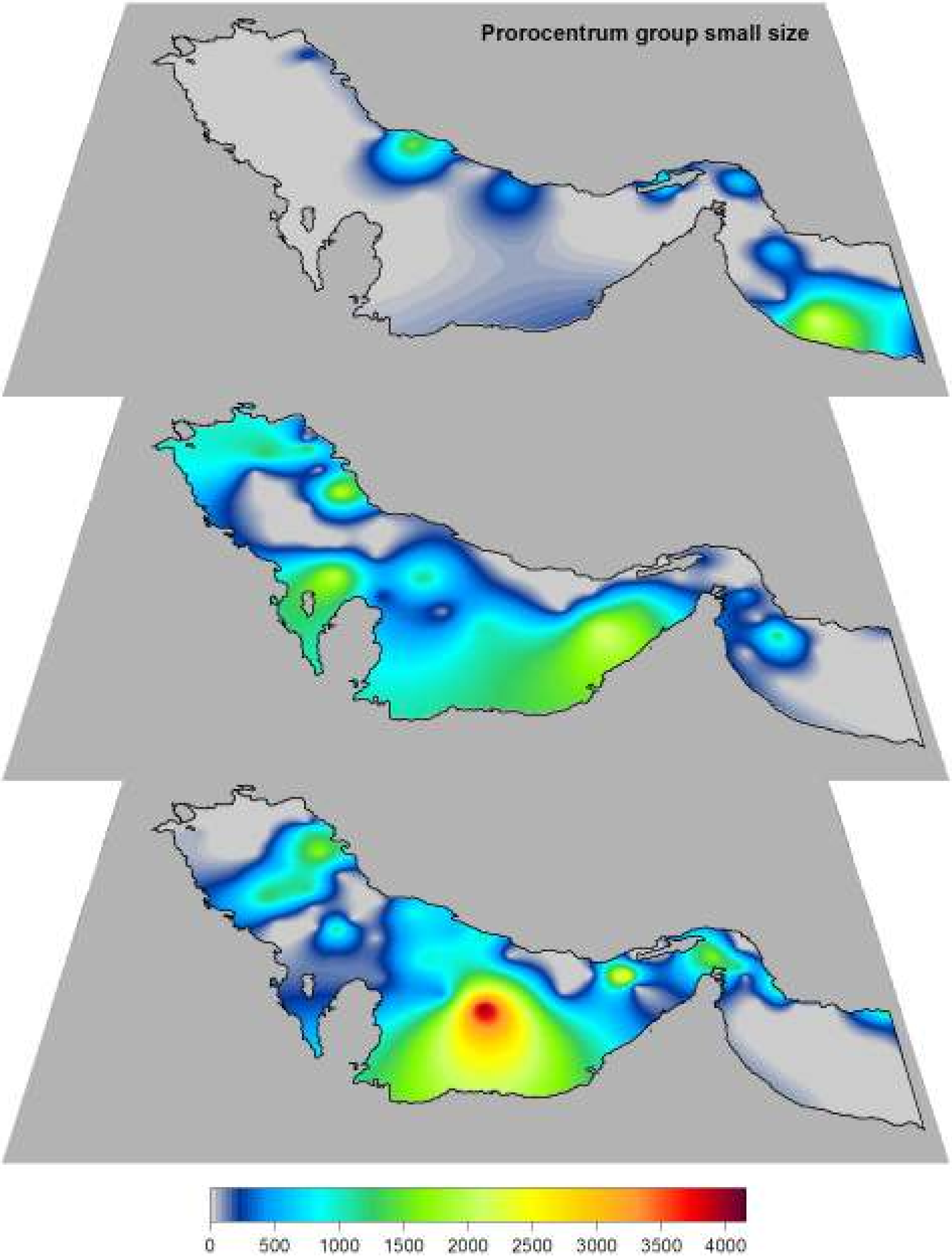

Fig. 45. Interpolated spatial distribution of the abundance (cells/L) of the small-sized *Prorocentrum* group in the ROPME Sea Area during Winter 2006 for the surface (top plot), middle (middle plot), and bottom (low plot) layers.

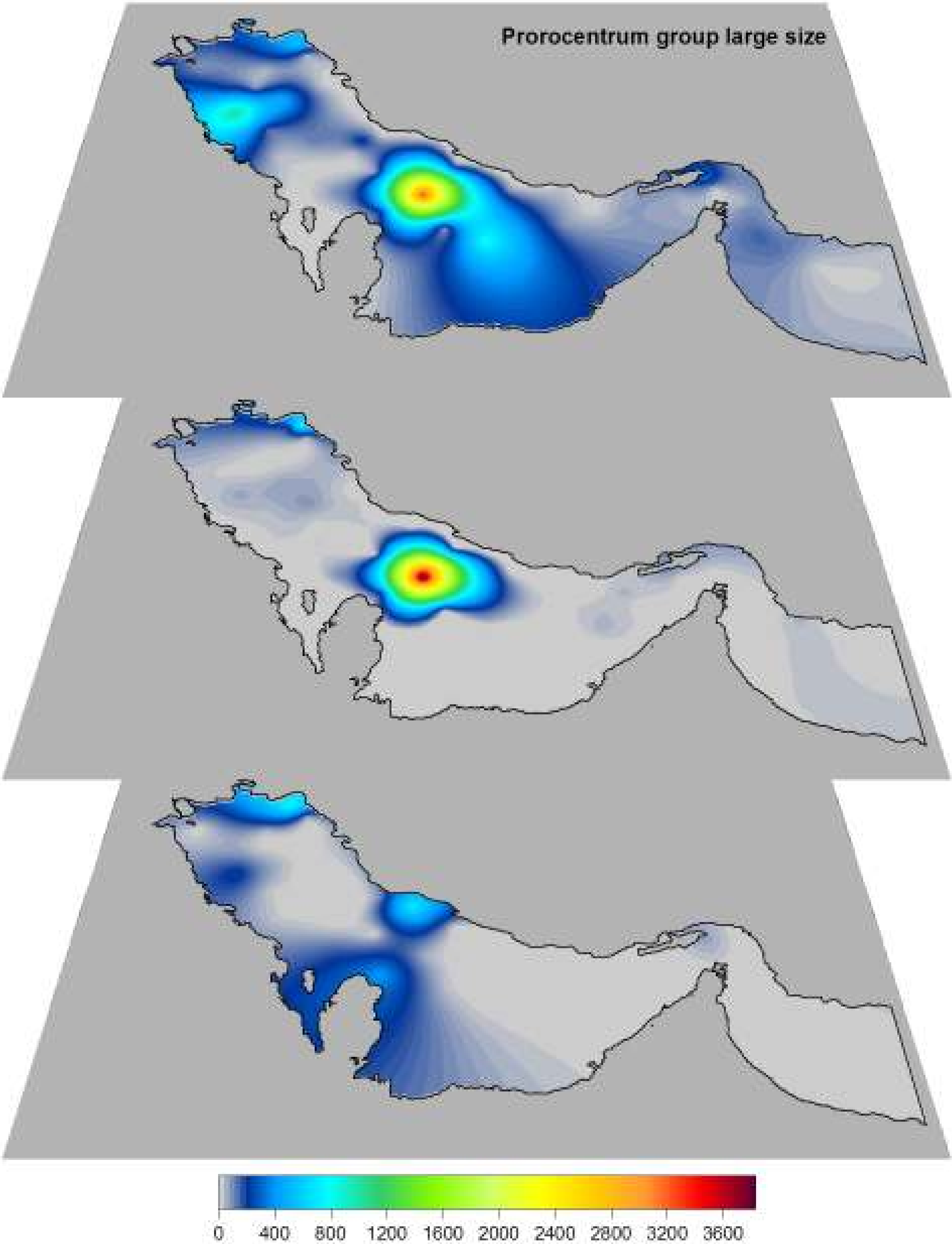

Fig. 46. Interpolated spatial distribution of the abundance (cells/L) of the medium-sized *Prorocentrum* spp. in the ROPME Sea Area during Winter 2006 for the surface (top plot), middle (middle plot), and bottom (low plot) layers.

Total Abundance of *Gonyaulax* Group - Fig. 48.

This group includes morphologically close and related medium- and large-sized autotrophic dinoflagellates from the genera *Gonyaulax*, *Goniodoma*, *Lingulodinium*, and *Spiraulax*. Some of these were frequently observed in the samples in quite low abundance. Maximum abundance (less than 4% of the total phytoplankton abundance; density of 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.

Total Abundance of the *Noctiluca* Group - Fig. 49.

This group includes morphologically close and mostly large-sized species from the genera *Noctiluca*, *Pyrocystis*, *Kofoidinium*, *Pronoctiluca* and *Dissodinium*. Some species were frequently observed in the samples but in rather low abundance (less than 2% of total phytoplankton abundance; with density not more than 1.2×10^3 cells/L). Maximum abundance (density) of this group ($> 10^3$ cells/L) was mainly associated with the Sea of Oman. Localized maximum abundance was observed in Kuwait's waters in the northwestern part of the inner RSA.

Total Abundance of the *Dinophysis* spp. - Fig. 50.

These medium-sized autotrophic armored dinoflagellates were rare 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; abundance of $< 3.9\times10^2$ cells/L). Local peaks ($> 10^2$ cells/L) were sporadically noted throughout the RSA.

Total Abundance of the *Amphisolenia* Group - Fig. 51.

This group includes large-sized heterotrophic and rarely observed species from the *Amphisolenia* and *Triposolenia* genera. Species were present in samples in very low concentrations (< 1% of total phytoplankton abundance; density < 50 cells/L). The group was strongly associated with the open deep-sea waters of the Sea of Oman, often in the middle and bottom layers.

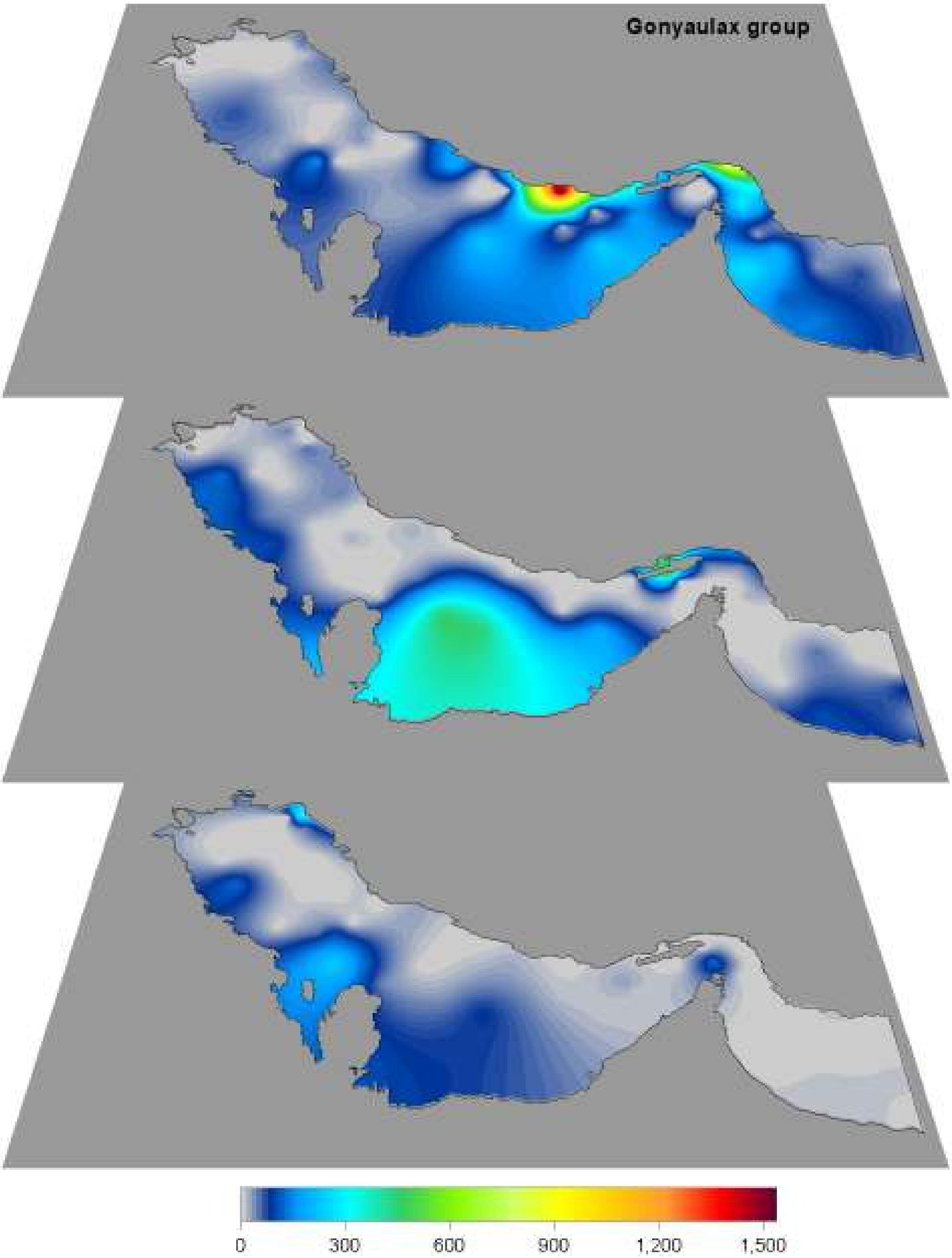

Fig. 47. Interpolated spatial distribution of the abundance (cells/L) of *Gonyaulax* group in the ROPME Sea Area during Winter 2006 for the surface (top plot), middle (middle plot), and bottom (low plot) layers.

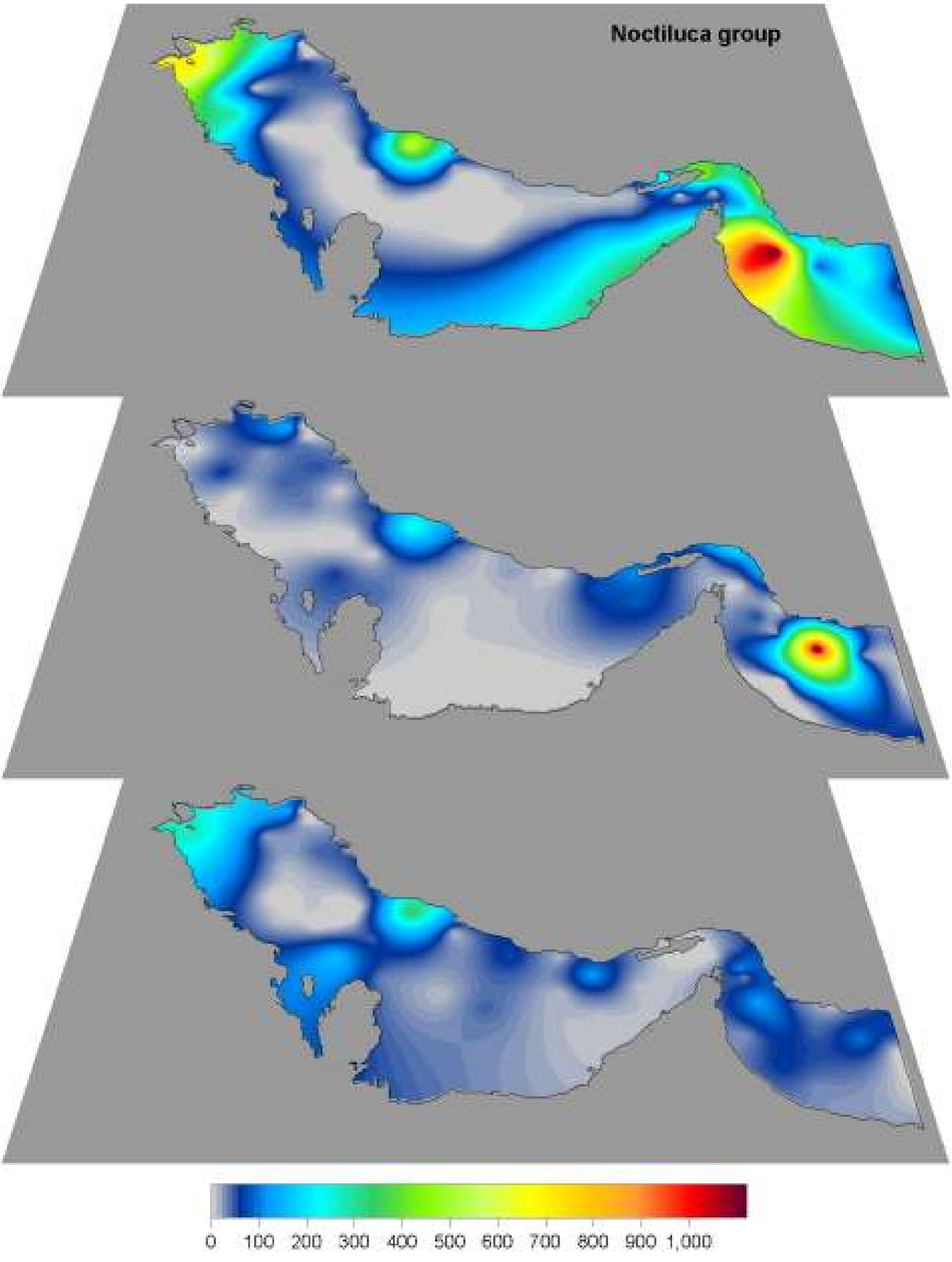

Fig. 48. Interpolated spatial distribution of the abundance (cells/L) of *Noctiluca* group in the ROPME Sea Area during Winter 2006 for the surface (top plot), middle (middle plot), and bottom (low plot) layers.

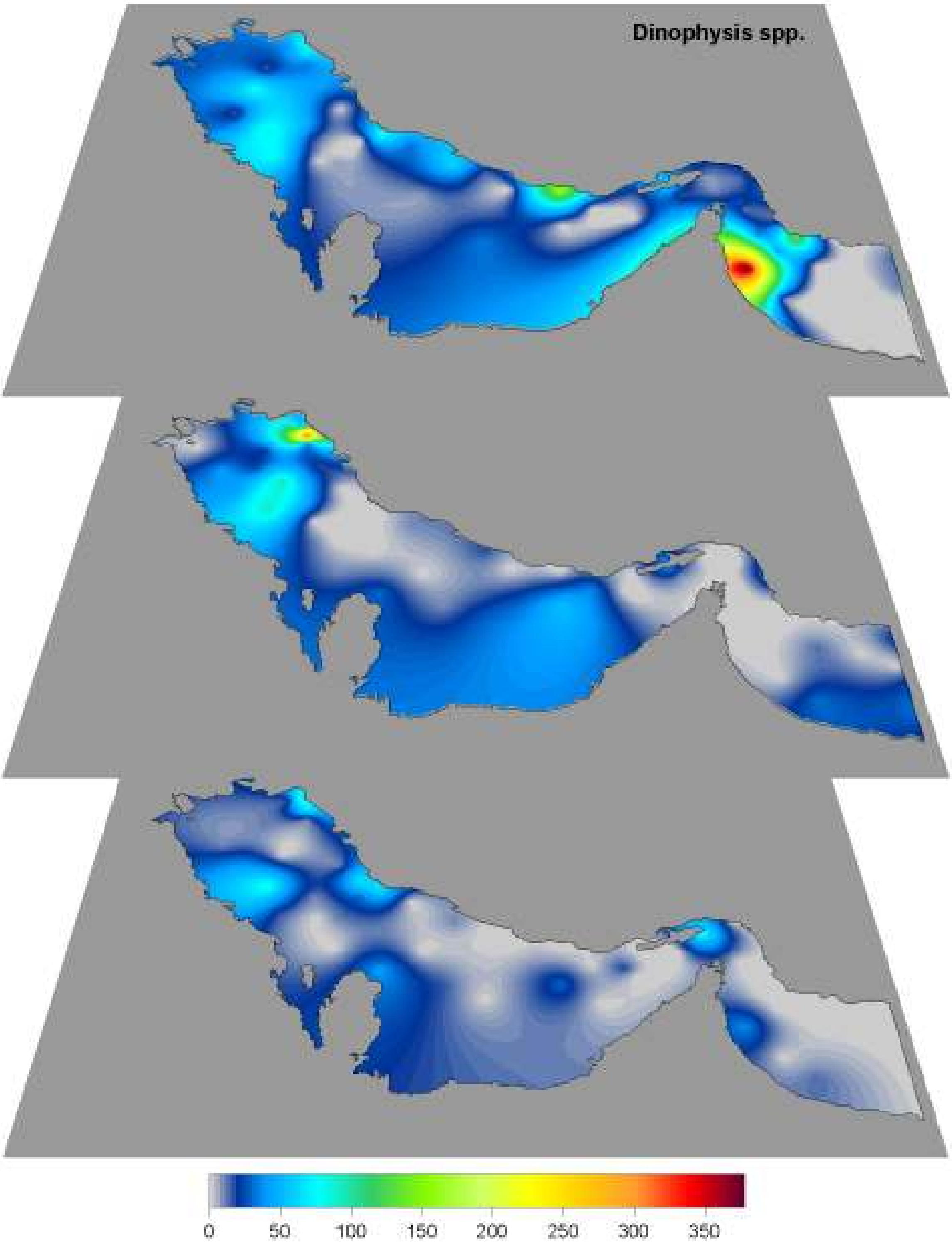

Fig. 49. Interpolated spatial distribution of the abundance (cells/L) of *Dinophysis* spp. in the ROPME Sea Area during Winter 2006 for the surface (top plot), middle (middle plot), and bottom (low plot) layers.

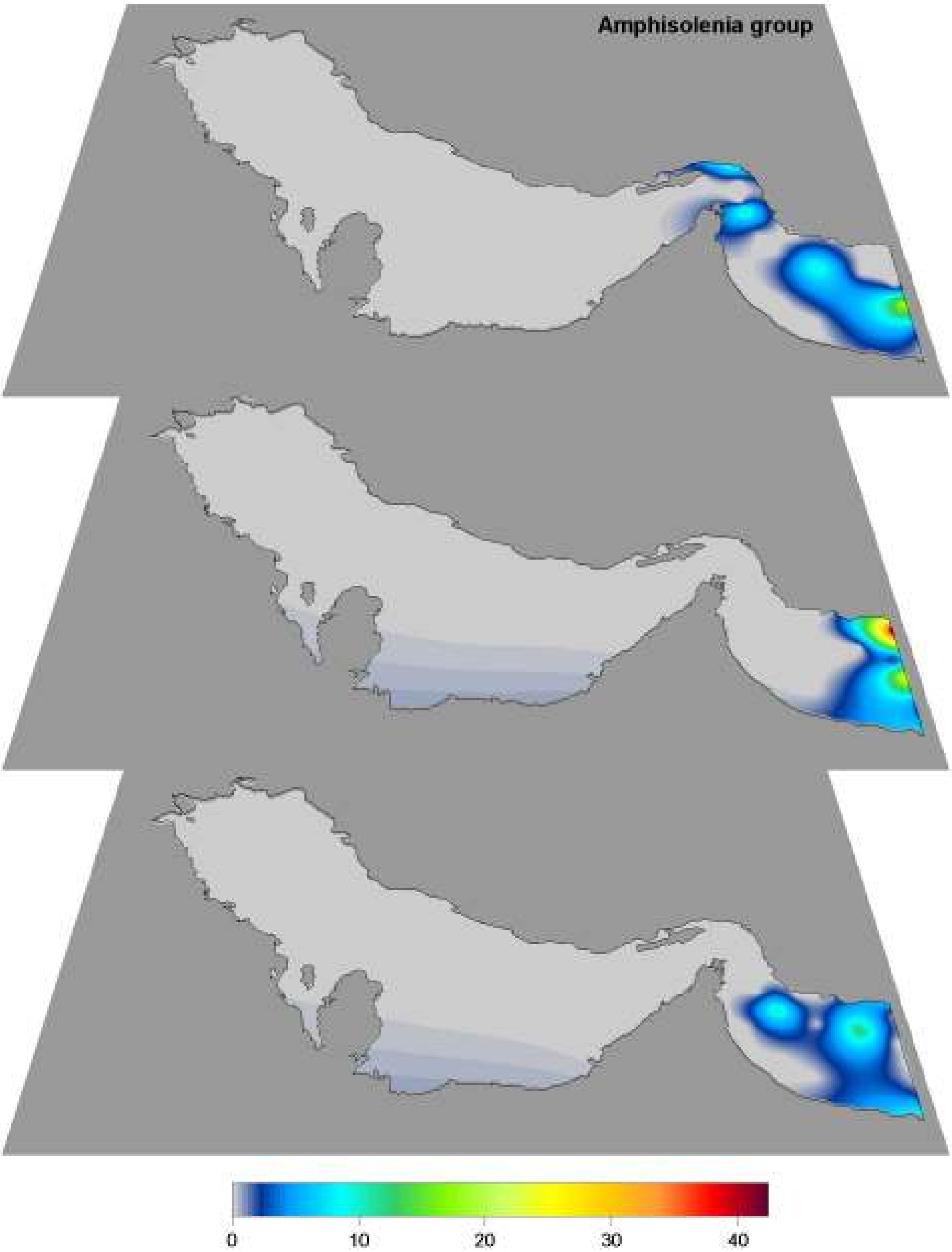

Fig. 50. Interpolated spatial distribution of the abundance (cells/L) of *Amphisolenia* group in the ROPME Sea Area during Winter 2006 for the surface (top plot), middle (middle plot), and bottom (low plot) layers.

Total Abundance of the Blue-green Algae (Cyanophyceae) - Fig. 52.

Blue-green algae were frequently found in the RSA samples (*Trichodesmium* sp.), but never reached high abundance. The abundance of blue-green algae was low compared to that of the other main taxonomical groups of phytoplankton, such as diatoms and dinoflagellates. Maximum contribution of the Cyanophyceae to the total phytoplankton abundance did not exceed 2%; the highest concentration reached 1.1×10^{3} cells/L. Maximum abundance (> 10^{3} cells/L) was encountered in the southern part of the inner RSA.

Total Abundance of the Silicoflagellates (Dictyochophyceae) - Fig. 53.

Silicoflagellates were commonly found in low abundance. The concentrations of *Dictyocha* spp. did not reach higher than 6.7×10^{2} cells/L (4% of the total phytoplankton abundance). Relatively high abundance (> 10^{2} cells/L) of this group was recorded in the waters of the Sea of Oman.

Total Abundance of Cryptophyceae - Fig. 54.

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.

Total Abundance of Euglenophyceae - Fig. 55.

Euglenids were frequently encountered in the RSA samples (*Eutreptiella* sp.), but never reached high concentrations. The abundance of the above species was low 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.

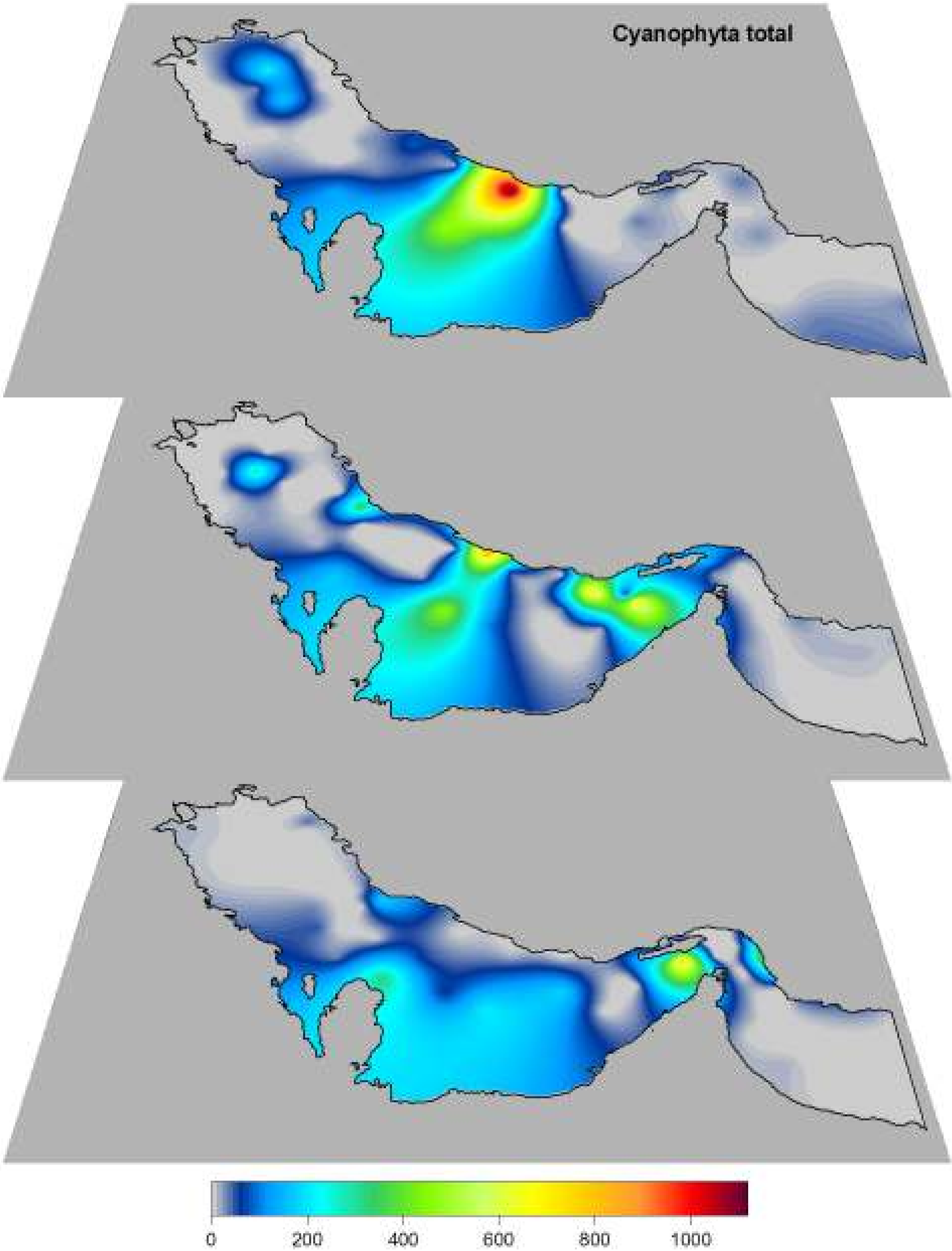

Fig. 51. Interpolated spatial distribution of the total abundance (cells/L) of the blue-green algae (Cyanophyceae) in the ROPME Sea Area during Winter 2006 for the surface (top plot), middle (middle plot), and bottom (low plot) layers.

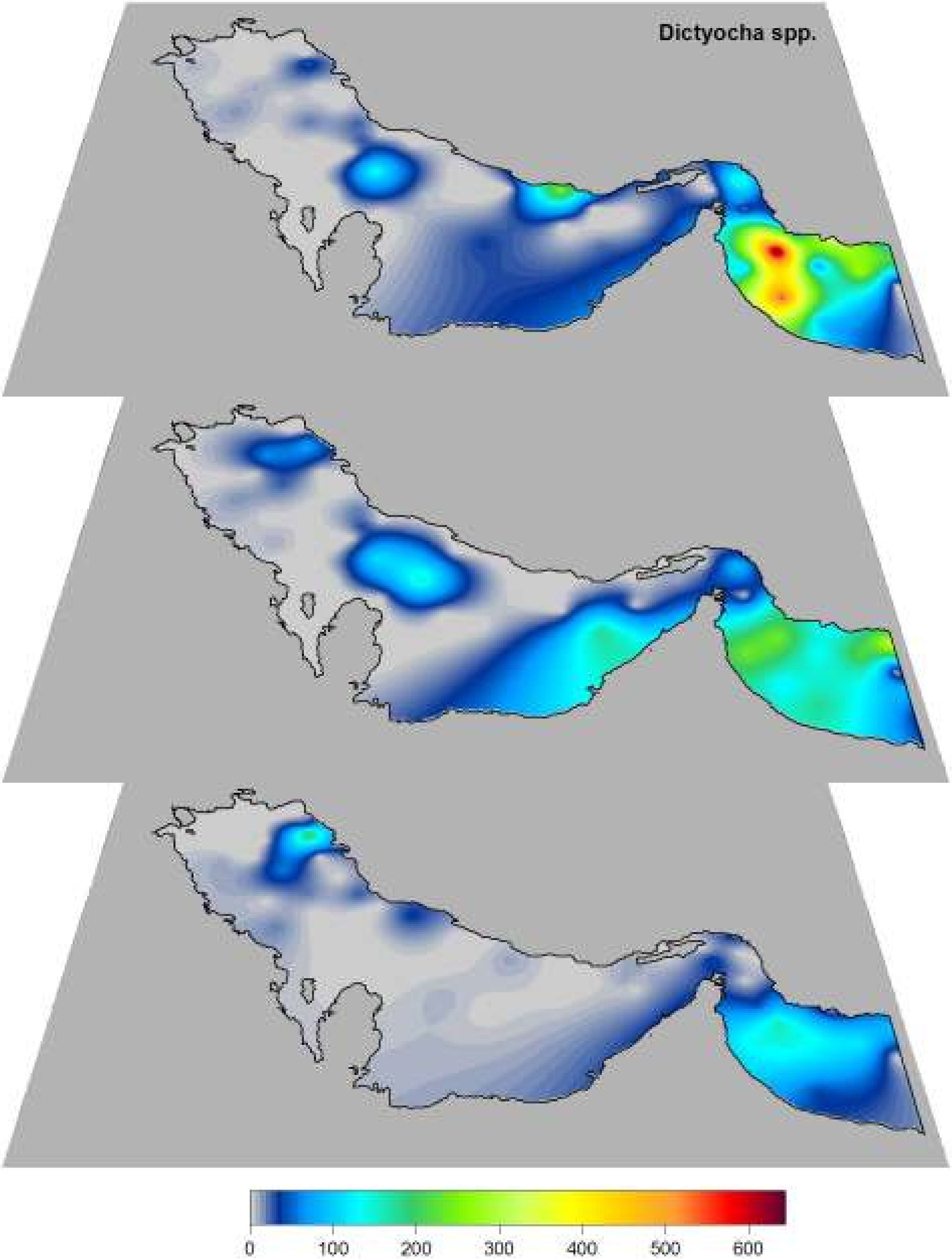

Fig. 52. Interpolated spatial distribution of the total abundance (cells/L) of silicoflagellates (Dictyochophyceae) in the ROPME Sea Area during Winter 2006 for the surface (top plot), middle (middle plot), and bottom (low plot) layers.

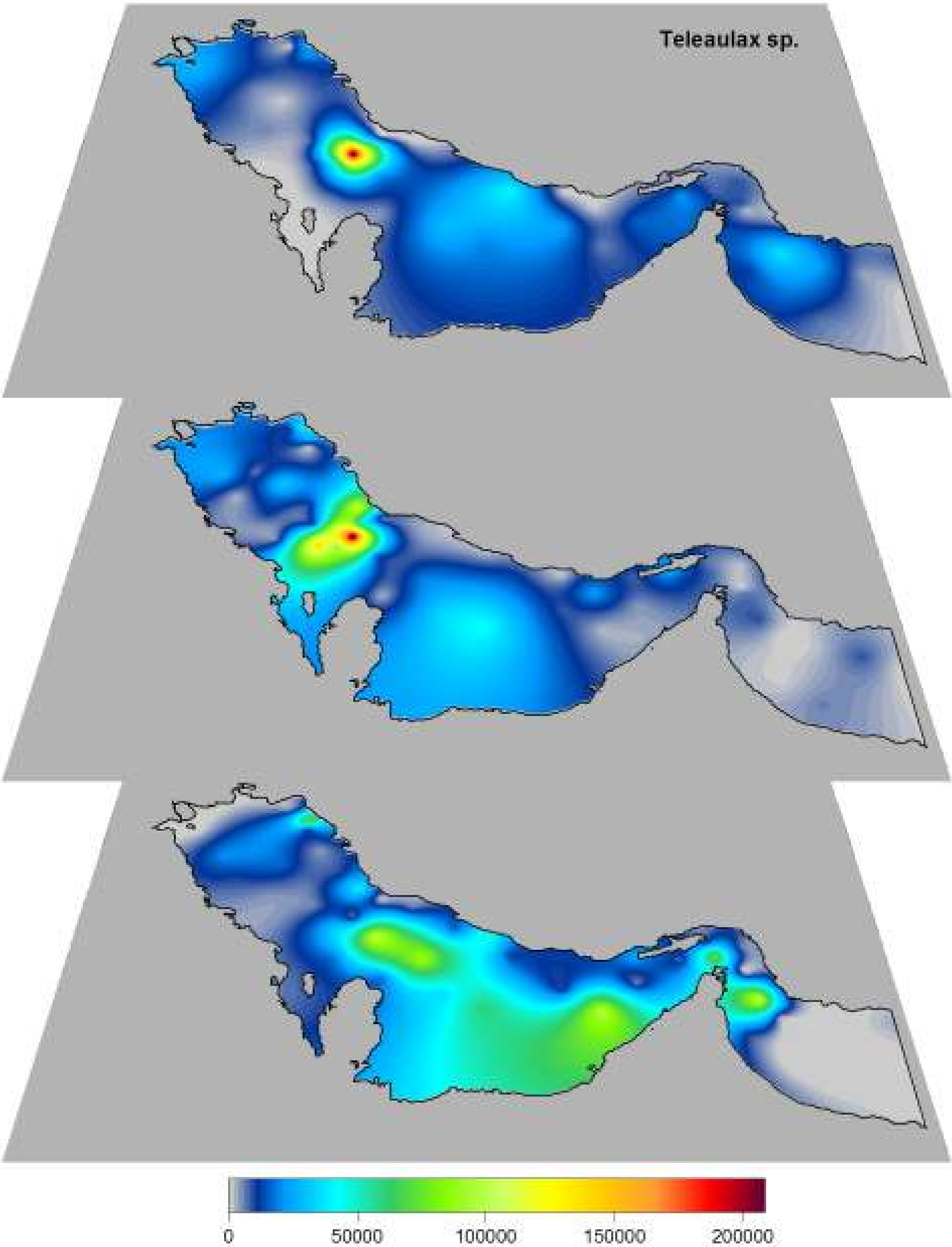

Fig. 53. Interpolated spatial distribution of the abundance (cells/L) of Cryptophyceae (*Teleaulax* sp.) in the ROPME Sea Area during Winter 2006 for the surface (top plot), middle (middle plot), and bottom (low plot) layers.

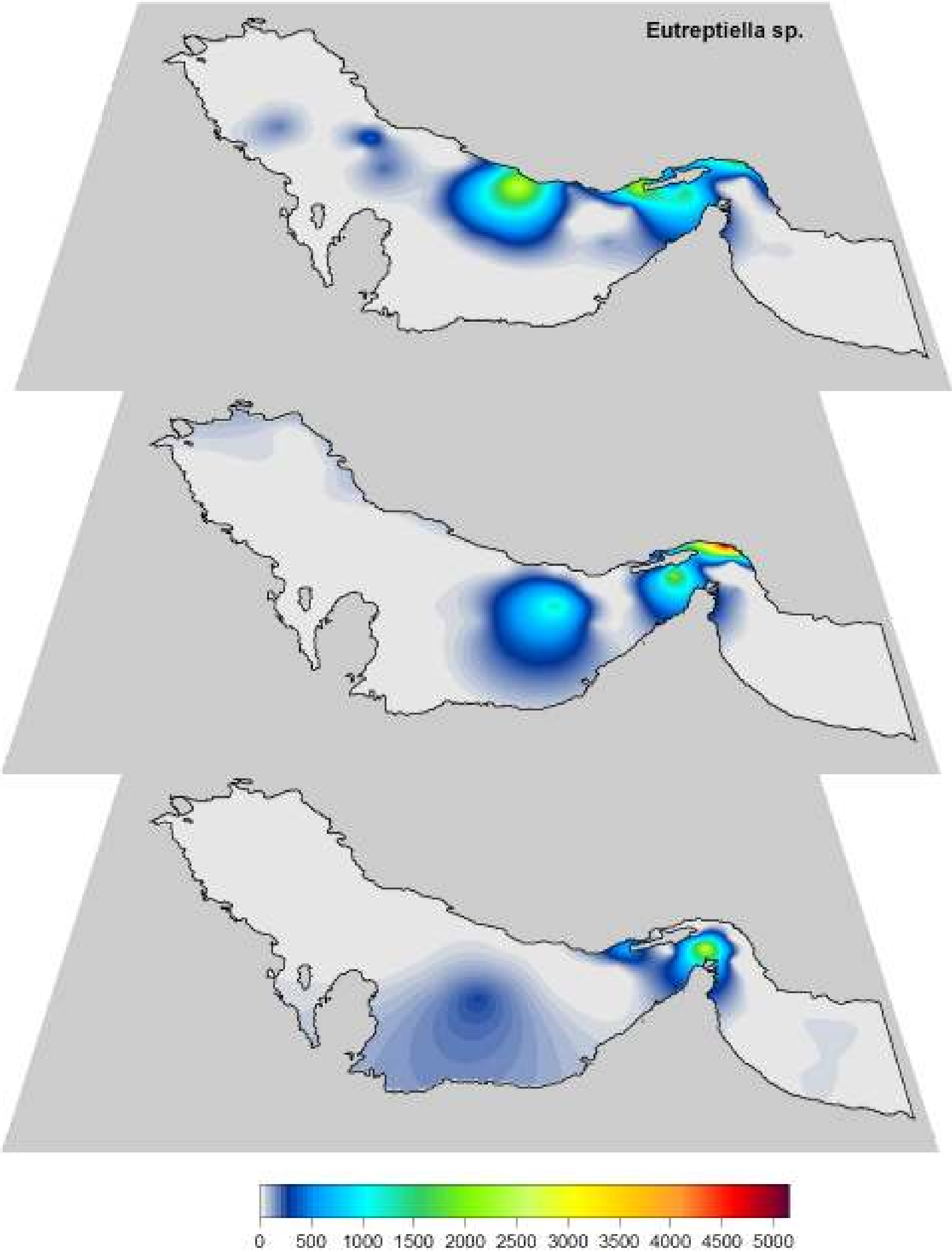

Fig. 54. Interpolated spatial distribution of the abundance (cells/L) of Euglenophyceae (*Eutreptiella* sp.) in the ROPME Sea Area during Winter 2006 for the surface (top plot), middle (middle plot), and bottom (low plot) layers.

Total Abundance of Prymnesiophyceae - Fig. 56.

The occurrence of *Phaeocystis* sp. was rare in the RSA samples. Relatively higher occurrences were observed in the waters of the Sea of Oman. Earlier studies in the waters of Kuwait (Al-Yamani *et al*., 2004) indicated blooms of the above species during winter and early spring.

Total Abundance of Ebridiida - Fig. 57.

Zooflagelates may be occasionally present in the plankton of the RSA. Heterotrophic medium-sized *Ebria tripartita* was observed in the samples but in very low concentrations (not higher than 1.3×10^2 cells/L, < 2% of total phytoplankton abundance). It was sporadically distributed mainly within the northwestern part of the inner RSA.

3.8 Integration of Total Phytoplankton Abundance, Phytoplankton Biomass (concentration of chlorophyll-*a*), Physical and Chemical Oceanographic Variables: A Comparative Analysis

In order to compare the distribution of phytoplankton abundance with phytoplankton biomass (chlorophyll-*a* concentration) as well as the relationships between phytoplankton abundance and the key physico-chemical variables, correlation coefficients among variables were calculated using the Pearson linear correlation method.

The analyzed data included phytoplankton abundance (cells/L), laboratory measured chlorophyll-*a* and phaeophytin concentrations, *in-situ* measured chlorophyll-*a* as well as water salinity, temperature, pH, turbidity and concentrations of oxygen, nitrites, nitrates, phosphates and silicates. Laboratory measurements of chlorophyll-*a* and phaeophytin concentrations in the samples collected during the ROPME Winter 2006 cruise have been previously performed and reported by Al-Yamani *et al*. (2007).

The results of the correlation analysis showed a good agreement between phytoplankton abundance and phytoplankton biomass (Table 12). High positive and statistically significant correlations were detected between total phytoplankton abundance and both the *in-situ* and the laboratory-measured concentrations of chlorophyll-*a* (R=0.65-0.67, $p<0.0001$, coefficient of determination 0.42-0.44).

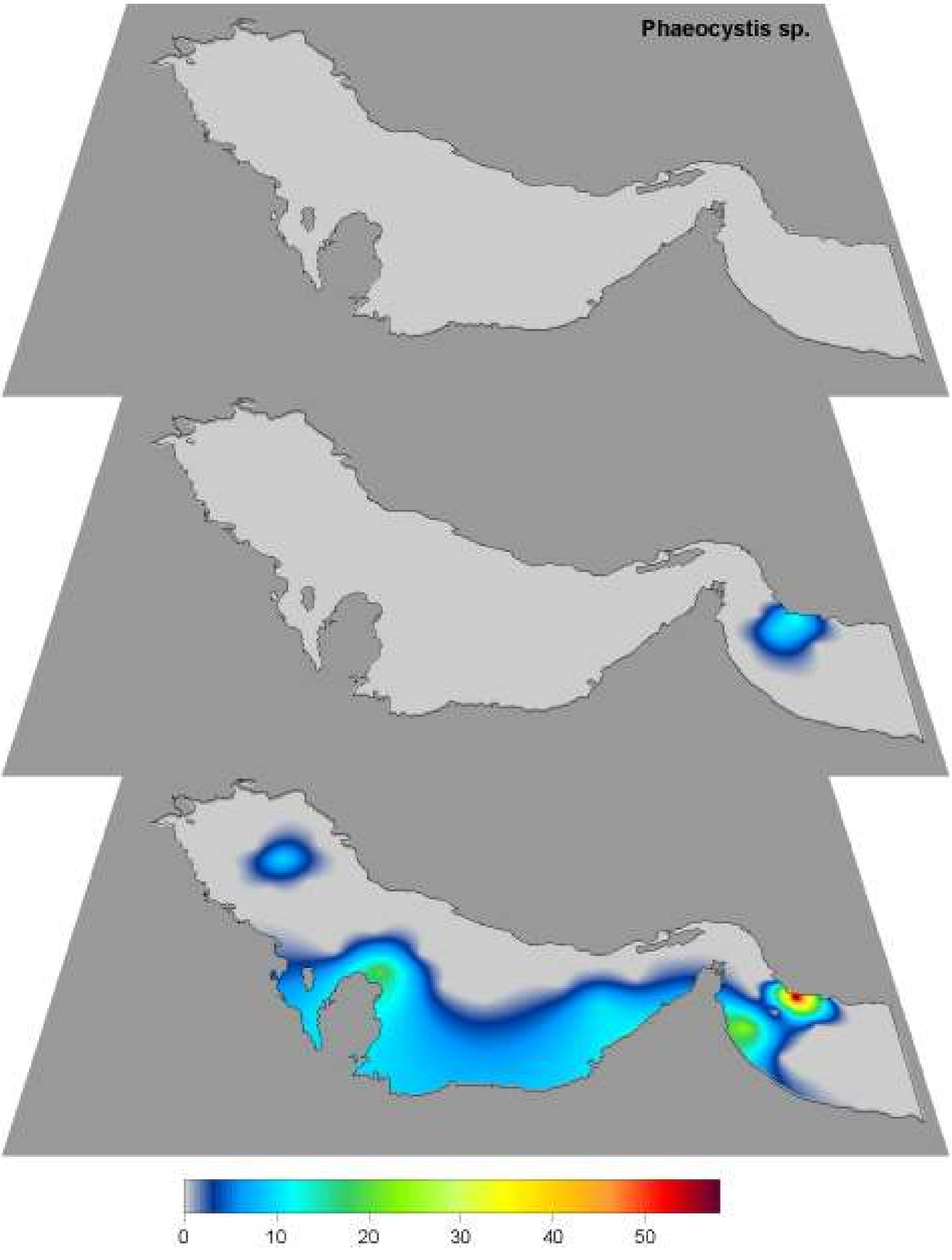

Fig. 55. Interpolated spatial distribution of the abundance (cells/L) of Prymnesiophyceae (*Phaeocystis* sp.) in the ROPME Sea Area during Winter 2006 for the surface (top plot), middle (middle plot), and bottom (low plot) layers.

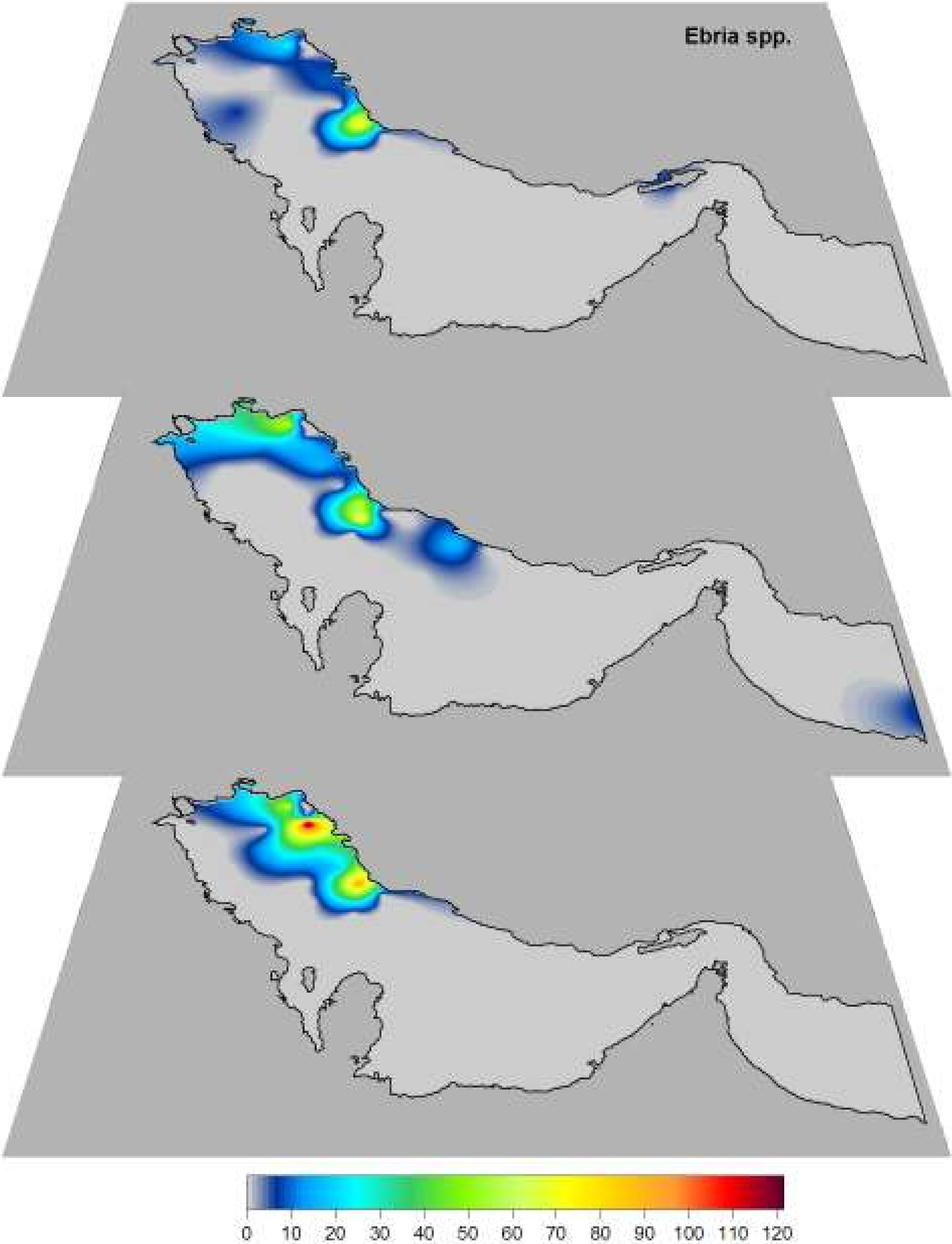

Fig. 56. Interpolated spatial distribution of the abundance (cells/L) of Ebridiida (*Ebria tripartite*) in the ROPME Sea Area during Winter 2006 for the surface (top plot), middle (middle plot), and bottom (low plot) layers.

Table 12. Results of the Correlation Analysis (Pearson linear correlation method) between Phytoplankton Abundance, Concentration of Chlorophyll-*a* and the Environmental Variables.

Tax Group refers to phytoplankton taxonomical group, TOTAL refers to total phytoplankton abundance, DIAT refers to the abundance of diatoms, DINO refers to the abundance of dinoflagellates, GYMND refers to the abundance of small-sized *Gymnodinium*-like flagellates, CYANO refers to the abundance of Cyanophyceae, SILICO refers to the abundance of silicoflagellates, and CRYPTO refers to the abundance of Cryptophyceae. Correlation coefficient values in bold are significantly different from 0 with a significance level α=0.05.

Tax Group	**TOTAL**	**DIAT**	**DINO**	**GYMND**	**CYANO**	**SILICO**	**CRYPTO**
	1	*2*	*3*	*4*	*5*	*6*	*7*
Pearson correlation coefficients:							
Chl-*a* (lab.)	**0.65**	**0.68**	-0.04	-0.10	-0.02	**0.43**	-0.09
Chl-*a* (*in-situ*)	**0.67**	**0.68**	0.05	0.00	-0.02	**0.29**	-0.05
Phaeophytin	**0.46**	**0.48**	-0.03	-0.07	-0.05	**0.39**	-0.08
Temperature	**0.22**	**0.25**	-0.02	-0.03	0.08	**0.30**	**-0.20**
Salinity	**-0.23**	**-0.30**	**0.21**	**0.21**	0.09	**-0.42**	**0.30**
Oxygen	**0.17**	0.13	**0.16**	0.11	0.00	**-0.20**	**0.19**
pH	-0.03	-0.08	**0.15**	0.12	0.00	**-0.19**	**0.18**
Turbidity	0.05	0.06	-0.04	-0.04	0.02	-0.04	-0.08
NO_2	-0.09	-0.10	-0.05	0.03	-0.13	0.15	**0.19**
NO_3	**-0.19**	-0.12	**-0.43**	**-0.38**	-0.16	**0.24**	**-0.26**
NH_3	0.03	0.03	0.07	0.05	-0.04	0.16	-0.06
PO_4	-0.13	-0.06	**-0.40**	**-0.36**	-0.14	**0.27**	**-0.25**
SiO_2	**-0.22**	**-0.19**	**-0.26**	**-0.19**	-0.10	-0.004	-0.06
p-values:							
	1	*2*	*3*	*4*	*5*	*6*	*7*
Chl-*a* (lab.)	**< 0.0001**	**< 0.0001**	0.578	0.181	0.757	**< 0.0001**	0.213
Chl-*a* (*in-situ*)	**< 0.0001**	**< 0.0001**	0.464	0.991	0.809	**< 0.0001**	0.519
Phaeophytin	**< 0.0001**	**< 0.0001**	0.695	0.321	0.512	**< 0.0001**	0.269
Temperature	**0.002**	**0.000**	0.795	0.694	0.297	**< 0.0001**	**0.005**
Salinity	**0.002**	**< 0.0001**	**0.004**	**0.004**	0.225	**< 0.0001**	**< 0.0001**
Oxygen	**0.018**	0.079	**0.027**	0.140	0.992	**0.006**	**0.007**
pH	0.644	0.280	**0.039**	0.093	0.989	**0.010**	**0.012**
Turbidity	0.514	0.382	0.593	0.571	0.773	0.607	0.270
NO_2	0.333	0.243	0.581	0.750	0.135	0.087	**0.035**
NO_3	**0.032**	0.198	**< 0.0001**	**< 0.0001**	0.081	**0.008**	**0.003**
NH_3	0.723	0.725	0.462	0.553	0.626	0.066	0.494
PO_4	0.142	0.515	**< 0.0001**	**< 0.0001**	0.107	**0.002**	**0.005**
SiO_2	**0.013**	**0.032**	**0.004**	**0.030**	0.277	0.963	0.517

Table 12. Contd.

Coefficients of determination (R^2):							
	1	*2*	*3*	*4*	*5*	*6*	*7*
Chl-*a* (lab)	**0.422**	**0.461**	0.002	0.009	0.001	**0.185**	0.008
Chl-*a* (*in-situ*)	**0.443**	**0.456**	0.003	0.000	0.000	**0.085**	0.002
Phaeophytin	**0.209**	**0.230**	0.001	0.005	0.002	**0.152**	0.006
Temperature	**0.049**	**0.062**	0.000	0.001	0.006	**0.089**	**0.041**
Salinity	**0.052**	**0.090**	**0.043**	**0.044**	0.008	**0.180**	**0.090**
Oxygen	**0.029**	0.016	**0.026**	0.012	0.000	**0.039**	**0.037**
pH	0.001	0.006	**0.022**	0.015	0.000	**0.034**	**0.033**
Turbidity	0.002	0.004	0.002	0.002	0.000	0.001	0.006
NO_2	0.008	0.011	0.002	0.001	0.018	0.023	**0.035**
NO_3	**0.036**	0.013	**0.187**	**0.142**	0.024	**0.055**	**0.068**
NH_3	0.001	0.001	0.004	0.003	0.002	0.027	0.004
PO_4	0.017	0.003	**0.161**	**0.127**	0.021	**0.073**	**0.062**
SiO_2	**0.049**	**0.036**	**0.066**	**0.037**	0.009	0.000	0.003

(Table 12; Figs. 58 A and 58 B). Figure 58 C displays the correlation between the concentration of chlorophyll-*a* and higher phytoplankton abundance (> 10^5 cells/L), while Fig. 58 D display the correlation between the concentration of chlorophyll-*a* and lower phytoplankton abundance (≤ 10^5 cells/L). Spatial distribution pattern of total phytoplankton abundance (Fig. 16) was similar to that of chlorophyll-*a* concentration (Fig 59).

Diatoms as was discussed above dominated total phytoplankton abundance. Hence, high positive correlation was observed (R=0.68, p<0.0001, r^2=0.46) between the abundance of this group and chlorophyll-*a*, whereas significant correlation between the other phytoplankton groups and chlorophyll-*a* was not detected. Correlation between phytoplankton abundance and phaeophytin concentration was significantly lower than that for chlorophyll.

In general, there were no significant relationships between the physicochemical variables and the total phytoplankton abundances or the densities of the main taxonomical groups. Total phytoplankton abundance was slightly positively correlated with water temperature and oxygen concentration and negatively correlated with water salinity, nitrates and silicates, with low correlation coefficients (Table 12). Low positive statistically significant correlation was found between the abundances of dinoflagellates and naked flagellate *Teleaulax* sp. (Cryptophyceae) and salinity. Negative correlations were detected between dinoflagellates and nitrates, phosphates and silicates. Similar results were observed for Cryptophyceae, whereas the opposite relationships were found for the silicoflagellates. Although some correlations were detected between the various phytoplankton groups and the physico-chemical factors, the results showed low levels of correlation coefficients, making interpretation of these results difficult, indicating non-linear relationships.

In order to detect the optimal environmental conditions for the phytoplankton development, examined area based on the level of phytoplankton abundance, the RSA was divided into two different zones: areas that are typified of higher phytoplankton concentrations (more than 0.5×10^6 cells/L) were grouped in high-abundant zone, and areas, which are characterized by, low phytoplankton abundance. Environmental factors (physico-chemical variables) for each zone were analyzed separately (Table 13). The obtained results indicate that, in general, high levels of phytoplankton abundance were associated with relatively warmer, low salinity and nutrient-poor waters; however, these results were not statistically significant. The most probable reason for the negative trend of phytoplankton abundance with the concentrations of nutrients concentrations could be due to the active consumption of nutrients by the microalgae during their growth and bloom conditions. Moreover, water temperature and salinity do not appear to be limiting factors for phytoplankton development during this study.

It is important to mention that there were missing results of nutrient concentrations for the sampled stations (130 nutrient measurements against 191 phytoplankton samples). Moreover, QA/QC methods for nutrient analysis were not applied during the winter cruise, making interpretation of the results difficult.

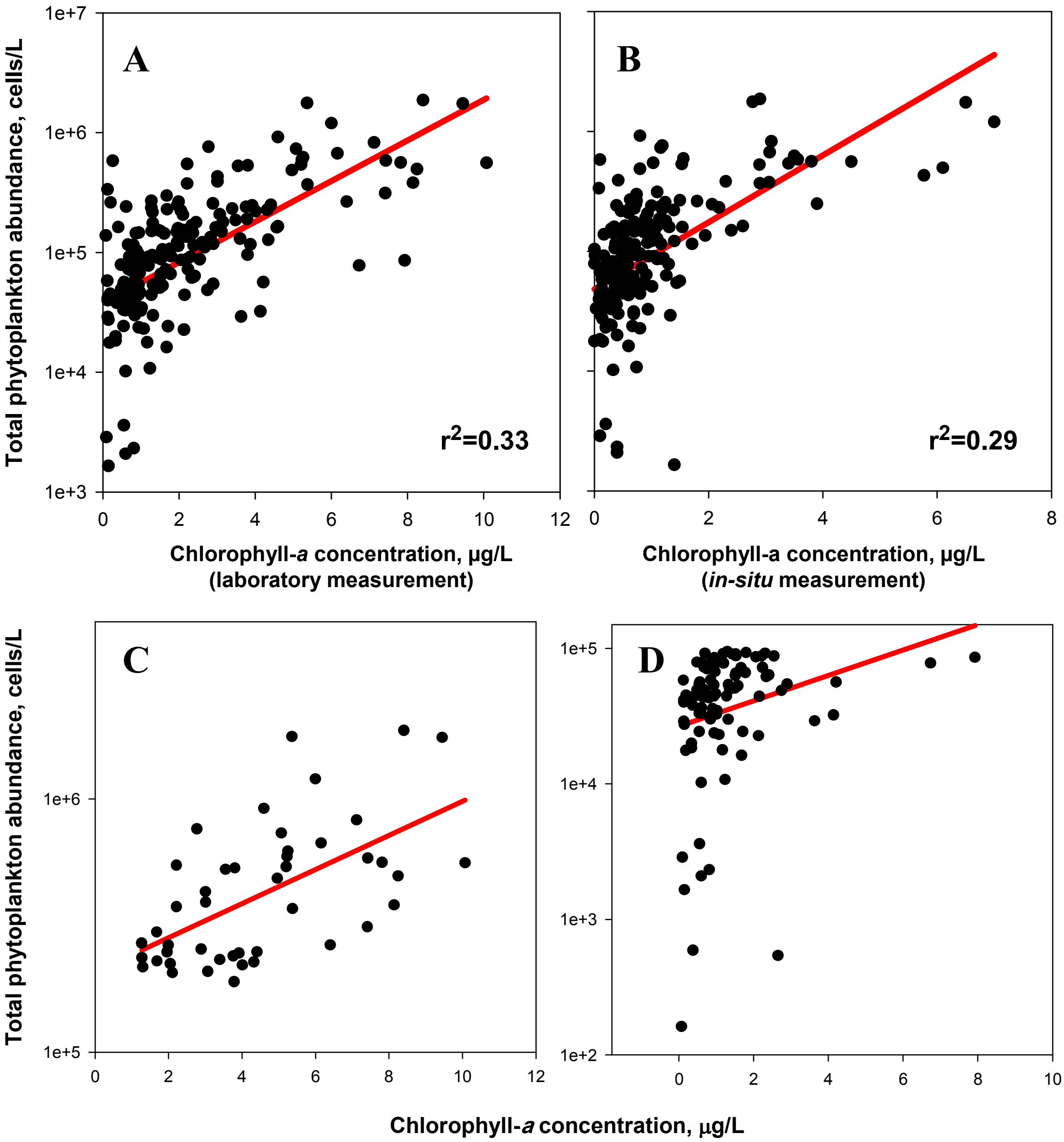

Fig. 57. Correlation between total phytoplankton abundance and the concentration of chlorophyll-*a*. A – total phytoplankton abundance against laboratory measured chlorophyll-*a* concentration; B – total phytoplankton abundance against *in-situ* measured chlorophyll-*a* concentration; C – maximal levels of total phytoplankton abundance against laboratory measured chlorophyll-*a* concentration; D – minimal levels of total phytoplankton abundance against laboratory measured chlorophyll-*a* concentration.

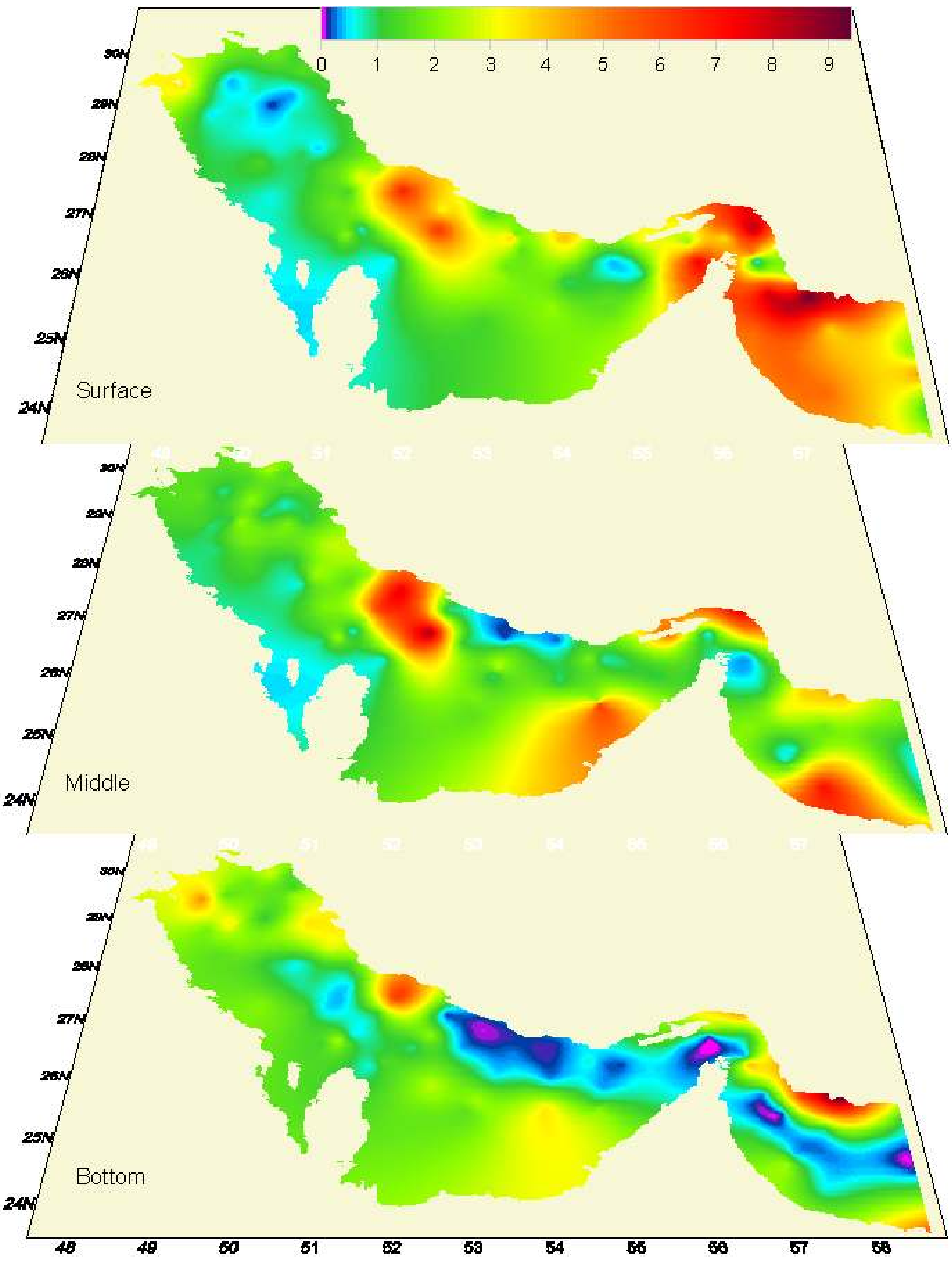

Fig. 58. Spatial distribution of chlorophyll-*a* concentrations (µg/L) in the ROPME Sea Area during Winter 2006 for the surface, middle, and bottom layers (source: Al-Yamani *et al.*, 2007).

Table 13. Mean ± STD (Standard Deviation), Minimum, and Maximum Values for the Different Measured Environmental Variables in the Low Phytoplankton Abundance Zone and in the High Abundance Areas

Environmental Factor	Phytoplankton Abundance > 0.5×10^6	Phytoplankton Abundance < 0.5×10^6
Temperature, °C	22.5 ± 0.9 (20.7-23.7)	21.0 ± 2.0 (16.6-23.7)
Salinity, psu	37.8 ± 1.5 (36.4-40.1)	39.1 ± 1.9 (36.2-44.0)
Oxygen, mg/L	6.9 ± 0.8 (5.0-8.2)	6.4 ± 1.2 (1.0-8.8)
pH	8.0 ± 0.2 (7.2-8.3)	8.1 ± 0.2 (7.0-8.5)
Turbidity, NTU	3.2 ± 1.1 (1.7-5.3)	3.2 ± 2.2 (1.6-18.3)
NO_2, µg/L	3.8 ± 2.4 (0.8-10.3)	6.7 ± 6.5 (0.0-28.1)
NO_3, µg/L	52.8 ± 55.8 (4.2-223.5)	90.0 ± 102.1 (1.1-451.5)
NH_3, µg/L	6.0 ± 3.6 (1.5-12.6)	6.6 ± 5.1 (0.6-33.1)
PO_4, µg/L	14.3 ± 6.2 (5.0-26.5)	18.4 ± 14.2 (1.0-70.6)
SiO_3, µg/L	47.6 ± 47 (1.5-208.5)	65.1 ± 57 (3.6-316.4)

4. Conclusions

The key findings for this study are summarized below:

- The phytoplankton community in the RSA during winter 2006 was very diverse with 337 identified taxa, representing nine classes. Diatoms and dinoflagellates were the most diverse groups. The phytoplankton species diversity in this study was similar to the higher levels of phytoplankton diversity records, which were reported previously within the RSA. About 15 phytoplankton species were reported to be dominant in the RSA. A total of 59 identified taxa belonging to five different classes, are considered potentially harmful species, out of which, 21 species are potentially toxic to humans.

- Species composition of phytoplankton significantly varied with depth especially for the most prevalent species. Naked flagellates increased gradually from the surface layer to the bottom layer. The opposite trend was detected for the dominant species from the *Chaetoceros* genus. Phytoplankton was more abundant in the surface layer, and mean phytoplankton abundance gradually decreased from the surface layer to the bottom (two times less than surface) layer.

- A high diversity level characterized the winter phytoplankton community in the RSA. Species richness reached to 155 identified phytoplankton taxa per sample (mean of 110.4 ± 21.4); Margalef's Index reached 11.53 (mean of 8.50 ± 1.40); species diversity (Shannon's Index) reached to 2.89 (mean of 2.05 ± 0.48). Species richness was positively correlated with total phytoplankton abundance, whereas reverse trends were found in the correlation between phytoplankton abundance and species diversity and community evenness.

- Analysis of phytoplankton spatial distribution of the RSA revealed a macro-scale heterogeneity within the phytoplankton community. Significant differences were detected between the samples collected in the inner RSA and those from the Sea of Oman. Four different areas can be outlined within the studied RSA in accordance with similarity between samples. Within each outlined area a distinct phytoplankton association was described.

- Total phytoplankton abundance in the RSA waters varied from 162 cells/L up to 1.9×10^6 cells/L (mean of $1.87 \times 10^5 \pm 2.76 \times 10^5$ cells/L). The lowest concentrations of phytoplankton were associated with the deeper waters in the Sea of Oman. Moreover, rather low phytoplankton abundance was recorded within the waters off the Saudi Arabian coast, near Qatar and in the southern part of the inner RSA. Phytoplankton blooms (concentrations that were close to two million cells per liter) coincided with the Strait of Hormuz area and with waters off the Iranian shores. Phytoplankton abundances that exceeded one million cells per liter were observed in the central part of the inner RSA off Qatar. Moreover, high phytoplankton abundance (0.5-1 million cells per liter) was encountered off the Omani coast and the Iranian coast in the Sea of Oman as well as off the Iranian coast in the inner RSA and in Kuwait's waters. The maximal levels of phytoplankton abundance were supported by the presence of small-sized chain-forming diatoms such as *Chaetoceros* spp., *Pseudo-nitzschia* spp. and *Skeletonema costatum*.

- In general, the different phytoplankton species were characterized by independent spatial distribution, however, high level of similarity was detected within very limited number of pairs and groups of phytoplankton species, whereas the total abundances of the two main contributors to the phytoplankton community – the diatoms and dinoflagellates - were distributed in a complementary manner.

- There was a good agreement between phytoplankton abundance and chlorophyll-*a* concentration. High positive and statistically significant correlations were detected between total phytoplankton abundance and both the *in-situ* and laboratory-measured concentrations of chlorophyll-*a* (R=0.65-0.67, $p<0.0001$, coefficient of determination 0.42-0.44).

Based on the above findings, it is vital that a comprehensive study on phytoplankton be carried out during the spring, fall and summer seasons to understand the dynamics of the phytoplankton community for the RSA. In addition a biodiversity phytoplankton list is to be compiled including data from all seasons.

Annex 1. Systematic Arrangement of the Phytoplankton Taxa Encountered in the ROPME Sea Area during Winter 2006.

The diatoms' classification below 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 following modifications in relation to the recently erected or revised taxa: 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).

PROKARIOTA

Division **CYANOPHYTA**

Class **Cyanophyceae**
- Order **Chroococcales**
  - Family **Phormidiaceae**
    - Genus ***Trichodesmium***
      - *Trichodesmium* sp.
    - Genus ***Anabaena* (?)**
      - *Anabaena*-like? sp.

EUKARIOTA

Division **CHROMOPHYTA**

Class **Bacillariophyceae**
- Order **Biddulphiales**
  - Suborder **Coscinodiscineae**
    - Family **Thalassiosiraceae**
      - Genus ***Cyclotella***
        - *Cyclotella stylorum*
        - *Cyclotella striata*
      - Genus ***Detonula***
        - *Detonula pumila*
      - Genus ***Lauderia***
        - *Lauderia borealis*
      - Genus ***Planktoniella***
        - *Planktoniella sol*
      - 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 mediterranium
Leptocylindrus minimum
Genus ***Corethron***
Corethron histrix
Corethron cf *criophilum*
Family **Coscinodiscaceae**
Genus ***Coscinodiscus***
Coscinodiscus asteromphalus
Coscinodiscus granii
Coscinodiscus janischii v. *arafurensis*
Coscinodiscus oculus-iridis
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
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 cohlea
Rhizosolenia hebetata v. *semispina*
Rhizosolenia hyalina
Rizosolenia 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 haukii
Hemiaulus membranaceus
Hemiaulus sinensis
Family **Cymatosiraceae**
Genus ***Cymatosira***
Cymatosira cf *lorenziana*
Family **Chaetocerotaceae**
Genus ***Bacteriastrum***
Bacteriastrum delicatulum
Bacteriastrum furcatum
Bacteriastrum hyalinum
Genus ***Chaetoceros***
Chaetoceros brevis
Chaetoceros coarctatus
Chaetoceros compressus
Chaetoceros curvisetus
Chaetoceros decipiens
Chaetoceros cf *dichaeta*
Chaetoceros denticulatus
Chaetoceros diversus

Chaetoceros lauderi
Chaeoceros lorenzianus
Chaetoceros messanensis
Chaetoceros peruvianus
Chaetoceros peruvianus f. *gracilis*
Chaetoceros pseudocurvisetus
Chaetoceros socialis
Chaetoceros tortissimus
Chaetoceros sp.
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 robertsianum
Family **Biddulphiaceae**
Genus ***Biddulphia***
Biddulphia pulchella
Biddulphia tuomeyi

Order **Bacillariales**
Suborder **Fragilariineae**
Family **Licmophoraceae**
Genus ***Licmophora***
Licmophora abbreviata
Family **Thalassionemataceae**
Genus ***Thalassionema***
Thalassionema nitzschioides
Family **Thalassionemataceae**
Genus ***Thalassionema***
Thalassionema nitzschioides
Family **Thalassionemataceae**
Genus ***Lioloma***
Lioloma pacifica
Genus ***Thalassionema***
Thalassionema nitzschioides

Genus ***Thalassiothrix***
Thalassiothrix fraunfeldi

Thalassiothrix longissima

Suborder **Bacillariineae**

Family **Gomphonemataceae**

Genus ***Gomphonema***

Gomphonema sp.

Family **Naviculaceae**

Genus ***Caloneis***

Caloneis liber

Genus ***Diploneis***

Diploneis weissflogii

Diploneis bombus

Genus ***Ephemera***

Ephemera planamembranacea

Genus ***Gyrosigma***

Gyrosigma balticum

Gyrosigma sp.

Genus ***Haslea***

Haslea sp.

Genus ***Lirella***

Lirella cf *abrupta*

Genus ***Mastogloia***

Mastogloia sp.

Genus ***Mastoneis***

Mastoneis biformis

Genus ***Meuniera***

Meuniera membranacea

Genus ***Navicula***

Navicula sp.

Genus ***Petroneis***

Petroneis granulata

Genus ***Plagiotropis***

Plagiotropis lepidoptera

Plagiotropis tayrecta

Plagiotropis sp.

Genus ***Pleurosigma***

Pleurosigma diverse-striata

Pleurosigma naviculacea

Pleurosigma planctonicum

Pleurosigma sp.

Genus ***Trachyneis***

Trachyneis antillarum

Trachyneis debui

Family **Catenulaceae**

Genus ***Amphora***

Amphora cf *angustata*

Amphora cf *crassa*

Amphora cf *proteus*

Amphora obtusa

Amphora ostrearia v. *ostrearia*

Amphora sp.

Family **Bacillariaceae**
Genus ***Bacillaria***
Bacillaria paxillifera
Bacillaria socialis
Genus ***Cylindrotheca***
Cylindrotheca closterium
Genus ***Cymatonitzschia***
Cymatonitzschia marina
Genus ***Nitzschia***
Nitzschia longissima v. *longissima*
Nitzschia longissima v. *parva*
Nitzschia lorenziana
Nitzschia sigma
Nitzschia sigmaformis
Genus ***Psammodyction***
Psammodyction panduriforme
Genus ***Pseudo-nitzschia***
Pseudo-nitzschia cf *delicatissima*
Pseudo-nitzschia pungens
Pseudo-nitzschia cf *seriata*
Pseudo-nitzschia spp.
Family **Enthomoneidaceae**
Genus ***Enthomoneis***
Enthomoneis sulcata
Enthomoneis sp.
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 rotundata
Dinophysis rudgei
Dinophysis sp.

Genus ***Histioneis***
Histioneis costata
Histioneis cymballaria

Genus ***Ornithocercus***
Ornithocercus margificus
Ornithocercus quadratus
Ornithocercus splendida
Ornithocercus steinii

Genus ***Triposolenia***
Triposilenia bicornis

Order **Gymnodiniales**

Family **Gymnodiniaceae**

Genus ***Akashiwo***
Akashiwo sanguinea

Genus ***Balechina***
Balechina coerulea

Genus ***Cochlodinium***
Cochlodinium brandtii
Cochlodinium polykrikoides
Cochlodinium sp.

Genus ***Gymnodinium***
Gymnodinium catenatum
Gymnodinium spp.

Genus ***Gyrodinium***
Gyrodinium falcatum
Gyrodinium fusiforme
Gyrodinium spirale
Gyrodinium sp.

Genus ***Karenia***
Karenia brevis

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 velelloides

Family **Noctilucaceae**

Genus ***Noctiluca***

Noctiluca scintillans

Family **Protodiniferaceae**

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 fusis

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 var. *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. *compessum*

Family **Gonyaulacaceae**

Genus ***Alexandrium***

Alexandrium tamiyavanichii

Genus ***Gonyaulax***

Gonyaulax birostris
Gonyaulax digitalis
Gonyaulax fragilis
Gonyaulax hyalinum
Goniaulax polygramma
Gonyaulax scrippsae
Gonyaulax spinifera
Gonyaulax turbinei
Gonyaulax verior

Genus ***Lingulodinium***

Lingulodinium polyedra

Genus ***Protoceratium***

Protoceratium reticulatum

Family **Oxytoxaceae**

Genus ***Corythodinium***

Corythodinium constrictum
Corythodinium tesselatum

Genus ***Oxytoxum***

Oxytoxum curvatulus
Oxytoxum elegans
Oxytoxum milnieri
Oxytoxum sceptrum
Oxytoxum scolopax
Oxytoxum variabile

Family **Peridiniaceae**

Genus ***Diplopelta***

Diplopelta bomba
Diplopelta parva
Diplopelta steinii

Genus ***Diplopsalis***

Diplopsalis lenticula

Genus ***Peridinium***

Peridinium bipes
Peridinium quinquecorne

Genus ***Protoperidinium***

Protoperidinium abei
Protoperidinium cf *achromaticum*
Protoperidinium biconicum
Protoperidinium claudicans
Protoperidinium conicoides
Protoperidinium conicum
Protoperidinium curtipes
Protoperidinium curvipes
Protoperidinium denticulatum
Protoperidinium depressum

Protoperidinium divergens
Protoperidinium globulus
Protoperidinium grande
Protoperidinium hamatum
Protoperidinium latissimum
Protoperidinium leonis
Protoperidinium marielebourae
Protoperidinium mite
Protoperidinium murrayi
Protoperidinium oblongum
Protoperidinium obtusum
Protoperidinium oceanicum
Protoperidinium ovatum
Protoperidinium cf *oviforme*
Protoperidinium ovum
Protoperidinium pellucidum
Protoperidinium pentagonum
Protoperidinium punctulatum
Protoperidinium quarnerense
Protoperidinium steinii
Protoperidinium subinerme
Protoperidinium thorianum
Protoperidinium spp.

Genus ***Scrippsiella***
Scrippsiella trochoidea
Scrippsiella sp.

Family **Podolampadaceae**

Genus ***Podalampas***
Podalampas bipes
Podalampas palmipes

Genus ***Pyrophacus***
Pyrophacus horologium
Pyrophacus steinii

Peridiniales *incertae sedis*

Genus ***Heterocapsa***
Heterocapsa triquetra
Heterocapsa sp.

Genus ***Spiraulax***
Spiraulax jolliffei

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 triestinum
Order **Pyrocystales**
Family **Pyrocystaceae**
Genus ***Dissodinium***
Dissodinium pseudolunula
Genus ***Pyrocystis***
Pyrocystis fusiformis
Pyrocystis noctiluca
Pyrocystis robusta
Pyrocystis obtusa

Class **Cryptophyceae**
Order **Cryptomonadales**
Family **Cryptomonadaceae**
Genus ***Teleaulax***
Teleaulax sp.

Class **Prymnesiophyceae**
Order **Prymnesiales**
Family **Phaeocystaceae**
Genus ***Phaeocystis***
Phaeocystis sp.

Class **Dictyochophyceae**
Order **Dictyochales**
Family **Dictyochaceae**
Genus ***Dictyocha***
Dictyocha fibula
Dictiocha speculum

Division **CHLOROPHYTA**
Class **Euglenophyceae**
Order **Euglenales**
Family **Eutreptiaceae**
Genus ***Eutreptiella***
Eutreptiella sp.

Class **Prasinophyceae**
Order **Chlorodendrales**
Family **Halosphaeraceae**
Genus ***Prerosperma***
Pterosperma eurypteron
Pterosperma polygonum
Pterosperma undulatum
Genus ***Pyramimonas***
Pyramimonas sp.

Phyllum **ZOOMASTIGOPHORA**
Class **Ebriidea**
Order **Ebriida**
Family **Ebriidae**
Genus ***Ebria***
Ebria tripartita

Annex 2. Mean (± STD, standard deviation) Phytoplankton Species Abundance as well as Minimum (Min) and Maximum (Max) Abundances for each Sampled Depth (surface, middle and bottom layers).

Taxon	Abundance, cell/L [Mean±STD (Min-Max)]		
	Surface	Middle	Bottom
Bacillariophyceae			
Actinocyclus curvatulus	3.5±12.8 (0-83)	9.2±17.5 (0-76)	3.8±16 (0-122)
Actinocyclus octonarius	0.8±3.3 (0-20)	3.5±8.6 (0-41)	1.4±7.5 (0-54)
Actinoptychus senarius	-	0.7±5.4 (0-43)	-
Amphora cf angustata	0.2±1.8 (0-15)	-	-
Amphora cf coffeaeformis	-	28.2±156.7 (0-892)	-
Amphora cf crassa	-	-	0.2±1.3 (0-10)
Amphora cf proteus	-	-	0.2±1.2 (0-10)
Amphora ostrearia	35.1±121.4 (0-920)	59.7±277.7 (0-2131)	25±99.8 (0-779)
Asteromphalus flabellatus	3.4±10.8 (0-65)	1±4.5 (0-28)	0.2±1.7 (0-13)
Asteromphalus heptactis	1±4.5 (0-29)	2.3±7 (0-32)	0.5±2.1 (0-10)
Bacillaria paxillefera	12±89.2 (0-712)	1.2±8.1 (0-64)	49.3±198 (0-1178)
Bacillaria socialis	0.4±2.5 (0-19)	0.7±5.2 (0-41)	3±24.1 (0-193)
Bacteriastrum delicatulum	7817.4±24718.5 (0-178750)	81.5±334.4 (0-2226)	6545.6±14698.9 (0-86598)
Bacteriastrum furcatum	-	19187±98992 (0-778571)	34.5±184 (0-1335)
Bacteriastrum hyalinum	3354.6±10314.9 (0-47274)	814.3±3293.9 (0-24516)	338.4±1682.7 (0-13132)
Bellerochea horologicalis	15.3±87 (0-634)	11.2±48.5 (0-315)	26.1±120.3 (0-855)
Biddulphia pulchella	-	0.1±1.1 (0-8)	0.2±1.2 (0-10)
Biddulphia tuomeyi	-	0.3±2.6 (0-20)	0.8±6.6 (0-53)
Caloneis liber	4±10.7 (0-67)	9.1±17.4 (0-81)	38.1±55.9 (0-216)

Campylodiscus sp.	-	0.5±2.7 (0-19)	0.3±1.7 (0-10)
Cerataulina bicornis	27.3±215.6 (0-1725)	-	-
Cerataulina pelagica	4129.1±10160.3 (0-53479)	1670.9±5136.8 (0-33184)	1682.7±4076.7 (0-25567)
Chaetoceros brevis	212±1156.4 (0-7500)	69.5±473.9 (0-3718)	827.2±6359.7 (0-50893)
Chaetoceros cf dichaeta	421.3±1786 (0-12500)	8.2±21.9 (0-81)	42.6±254.1 (0-2003)
Chaetoceros coarctatus	167.4±343.1 (0-1388)	172±449.6 (0-2691)	25.1±55.8 (0-286)
Chaetoceros compressus	9777±65955.8 (0-527933)	30907.2±193609.1 (0-1534884)	2800.8±13807.2 (0-108663)
Chaetoceros curvisetus	47498.1±161702.7 (0-1155000)	17406.9±61119.6 (0-368817)	5638.9±22525.2 (0-175904)
Chaetoceros decipiens	24.7±186.5 (0-1493)	21.2±138.3 (0-1092)	12.5±71.6 (0-558)
Chaetoceros denticulatus	212.7±667.2 (0-3737)	72.7±476.5 (0-3777)	104.9±329.3 (0-1781)
Chaetoceros diversus	2.3±13.4 (0-105)	2±11.8 (0-91)	28±191.8 (0-1526)
Chaetoceros lauderi	47.9±266.2 (0-2098)	-	126.9±978.6 (0-7831)
Chaetoceros lorenzianus forma A	3605.6±10649 (0-62105)	848.7±2838.8 (0-19076)	1089.9±2874.6 (0-14691)
Chaetoceros lorenzianus forma B	9785.5±27677.6 (0-172632)	4051.4±12621.9 (0-78895)	1607.5±7570.2 (0-58810)
Chaetoceros messanensis	299.5±2278.4 (0-18229)	44.8±258.5 (0-2027)	8±22.7 (0-145)
Chaetoceros peruvianus	52.8±193.2 (0-1344)	192.7±1035.9 (0-6488)	287.6±1778 (0-14043)
Chaetoceros peruvianus f. gracilis	1.2±5.5 (0-35)	-	18.1±126.1 (0-1002)
Chaetoceros pseudocurvisetus	4828.5±15509.4 (0-82105)	935±3065 (0-15714)	6645.8±22833.1 (0-140368)
Chaetoceros socialis	15454.9±87864 (0-574713)	408.1±2386.8 (0-16925)	159.2±879.2 (0-6260)
Chaetoceros sp. 2 *(fragments)*	2±16.2 (0-130)	-	-
Chaetoceros sp. 3 *(fragments)*	82.2±657.2 (0-5258)	-	-
Chaetoceros spp.	-	1±8.2 (0-65)	0.5±4 (0-32)
Chaetoceros tortissimus	31499.7±205721.1 (0-1643226)	2306.6±7897.7 (0-45559)	264.3±720.9 (0-3712)
Climacodium frauenfeldianum	200.5±374.6 (0-2413)	259.8±901.6 (0-6708)	82.8±167.3 (0-977)
Cocconeis sp.	-	13.9±110 (0-873)	-

Corethron criophilum	-	10.5±75.9 (0-601)	11.9±39.3 (0-250)
Corethron histrix	32.1±119.6 (0-880)	65.2±231.1 (0-1766)	124.5±763.2 (0-6108)
Coscinodiscus asteromphalus	1.9±5.2 (0-25)	2.5±6.7 (0-35)	1.2±3.8 (0-20)
Coscinodiscus granii	1.9±8.3 (0-60)	7.6±17.4 (0-107)	9.4±19.7 (0-115)
Coscinodiscus janischii	2.4±19.2 (0-154)	4.4±13.6 (0-75)	3.2±9.5 (0-67)
Coscinodiscus oculus-irdis	31.6±185.5 (0-1487)	19.2±39.6 (0-197)	8±12.9 (0-67)
Coscinodiscus radiatus	5.9±12.6 (0-65)	7.2±11.9 (0-55)	6.2±14 (0-98)
Coscinodiscus wailesii	0.4±2.2 (0-16)	0.7±2.7 (0-13)	0.8±2.9 (0-13)
Cosciodiscus sp. 1	6.3±26.6 (0-200)	4.7±16.2 (0-84)	5.6±24.5 (0-176)
Cyclotella spp. (C. stylorum + C. striata)	50.7±257.9 (0-1983)	235.4±1271.9 (0-9932)	392.5±1136.2 (0-6576)
Cylindrotheca closterium	553.7±1656.7 (0-11250)	396.3±1012.8 (0-6686)	374.4±664.6 (0-2827)
Cymatonitzschia marina	37.7±273.8 (0-2191)	35±127 (0-766)	247±596.9 (0-4006)
Cymatosira cf lorenziana	0.3±2 (0-16)	55.3±439 (0-3484)	2.7±11.5 (0-66)
Dactyliosolen phuketensis	-	1.7±13.3 (0-106)	48.4±185.5 (0-995)
Detonula pumila	566±2882.1 (0-21930)	1071.9±6938.3 (0-53785)	51.1±390.7 (0-3125)
Diploneis cf bombus	21.6±44.6 (0-218)	47.7±90.4 (0-467)	327.4±762.7 (0-4986)
Diploneis weissflogii	59.7±252.1 (0-1651)	65.6±184.8 (0-1145)	481.2±796.9 (0-3434)
Ditylim brightwellii	28.4±227.3 (0-1818)	-	1.2±7.3 (0-56)
Enthomoneis sp. 1	-	-	0.3±1.9 (0-11)
Enthomoneis sulcata	1.4±5.3 (0-35)	2.6±12.1 (0-89)	4.9±12.5 (0-75)
Ephemera planamembranacea	0.4±2.7 (0-20)	33.5±185.7 (0-1445)	18.5±60.4 (0-452)
Eucampia cornuta	417.5±1477.9 (0-8125)	185.9±718.3 (0-5377)	138.9±453.6 (0-2442)
Eucampia zodiacus	1226±5230.6 (0-35116)	677.2±3008.7 (0-22852)	446.8±2000 (0-15113)
Gomphonema sp.	-	-	0.6±4.6 (0-37)
Guinardia delicatula	6543.6±29956.9 (0-183030)	5696±31431.1 (0-246257)	140.3±667.5 (0-5089)

Guinardia delicatula forma B	442.8±2753.6 (0-21759)	7±42.9 (0-319)	24.9±83.6 (0-461)
Guinardia flaccida	105.3±176.4 (0-842)	174.7±680.4 (0-4943)	299.9±1153.3 (0-8888)
Guinardia striata	237.3±489.8 (0-2346)	1168.7±5997.1 (0-47043)	240±591.5 (0-3680)
Gyrosigma balticum	-	0.1±1.2 (0-9)	-
Gyrosigma sp.	-	-	0.6±4.6 (0-37)
Haslea sp.	11.4±26.2 (0-117)	15.1±48 (0-361)	4.3±10.3 (0-49)
Hemiaulus hauckii	93.8±430.7 (0-2832)	14±80.9 (0-637)	9.2±71.3 (0-570)
Hemiaulus membranaceus	18.9±52.9 (0-344)	24.8±70.2 (0-296)	108.8±526.8 (0-3866)
Hemiaulus sinensis	124.1±638.2 (0-3995)	72.5±448 (0-3554)	389.2±1452.4 (0-8191)
Hemidiscus cuneiformis	0.2±1.3 (0-11)	-	-
Lauderia borealis	3476.9±16076.5 (0-117650)	4156.9±18844.7 (0-129839)	6837.5±43440.4 (0-341523)
Leptocylindrus danicus	3052.4±6847.8 (0-40365)	3586.7±8598.4 (0-47043)	5246.9±13460 (0-92346)
Leptocylindrus mediterraneus	1.7±13.8 (0-110)	4.2±17.1 (0-94)	80.9±291.6 (0-1739)
Leptocylindrus minimus	25.3±127.3 (0-891)	14.6±82.4 (0-535)	111.1±418.9 (0-2280)
Licmophora abbreviata	0.9±3.8 (0-22)	0.3±1.5 (0-9)	0.8±3.5 (0-20)
Lioloma pacifica	0.2±1.9 (0-15)	-	-
Lithodesmium undulatum	11±54.3 (0-309)	3.9±17.8 (0-131)	4.9±18.7 (0-111)
Lyrella abrupta	-	0.2±1.2 (0-9)	0.8±5.9 (0-46)
Mastogloia sp.	-	-	54.7±329.6 (0-2625)
Meuniera membranacea	48.8±135.2 (0-809)	70.8±271.8 (0-1738)	122.8±524 (0-3398)
Navicula spp.	134.8±356 (0-2082)	535.8±1579.7 (0-11512)	663.3±910.9 (0-3374)
Neocalyptrella robusta	1.3±4.1 (0-21)	1.8±5.7 (0-26)	1.3±4.3 (0-25)
Nitzschia cf sigma	0.8±4.3 (0-31)	1.5±7 (0-49)	2.4±13.3 (0-80)
Nitzschia cf sigmaformis	9.7±60.3 (0-479)	20.4±136.6 (0-1080)	5.5±26.8 (0-209)
Nitzschia fluminensis	128.4±640.9 (0-4368)	-	2.1±9 (0-59)

Nitzschia longissima v. longissima	2.1±9.6 (0-65)	0.3±2.6 (0-20)	0.1±1.1 (0-9)
Nitzschia longissima v. parva	-	0.6±4.7 (0-37)	-
Nitzschia lorenziana	12.8±82.2 (0-657)	5.3±12.7 (0-67)	13.5±24.1 (0-152)
Nitzschia sigma	1.6±5.9 (0-36)	0.2±1.3 (0-10)	5.4±12 (0-59)
Nitzschia sp. 1	5669.6±13481.5 (0-81250)	4434.7±13351.5 (0-102099)	2662.4±4111 (0-27143)
Nitzschia sp. 5	0.1±0.8 (0-6)	-	-
Nitzschia sp. 6	3±10.6 (0-67)	21.4±99.4 (0-589)	336.7±765 (0-4074)
Odontela sinensis	7.9±19.2 (0-104)	4.3±12.8 (0-65)	20.1±75.9 (0-488)
Odontella aurita	-	0.3±2.7 (0-21)	0.3±1.6 (0-9)
Odontella mobiliensis	4±8.9 (0-37)	5.2±18 (0-102)	5.5±12 (0-54)
Palmeria hardmaniana	-	1.6±5.3 (0-26)	1.7±4.7 (0-25)
Paralia sulcata	2.6±12.7 (0-75)	6.8±21.1 (0-104)	18±69.5 (0-517)
Petrodictyon gemma	0.1±1 (0-8)	-	1.4±11.6 (0-93)
Petroneis granulata	-	0.3±2.3 (0-18)	-
Plagiotropis lepidoptera	3.2±13.7 (0-100)	41.4±82.2 (0-434)	23.9±58.1 (0-394)
Plagiotropis sp. 1	39.2±89.8 (0-557)	-	0.2±1.3 (0-10)
Plagiotropis sp. 2	-	2.4±16.5 (0-130)	2.5±12.5 (0-78)
Planktoniella sol	86.2±193.8 (0-1003)	76.5±173 (0-843)	47.4±97.8 (0-594)
Pleurosigma diverse-striatum	82.1±217.2 (0-1349)	170±365.3 (0-2703)	383.8±702.6 (0-3720)
Pleurosigma naviculaceum	42.3±119 (0-671)	101.7±213.9 (0-1145)	300.9±641.6 (0-3324)
Pleurosigma planctonicum	-	-	1.4±5.3 (0-24)
Pleurosigma sp. 1	79.2±213 (0-1214)	49.2±173.3 (0-1303)	46.2±200.1 (0-1148)
Podosira stelliger	0.6±2.8 (0-16)	-	0.3±2.7 (0-21)
Porosira sp.	2.1±7.2 (0-40)	1.1±5.7 (0-43)	-
Probosca alata f. gracillima	267.6±811 (0-4954)	28.6±100.8 (0-649)	48±228.6 (0-1422)

Proboscia alata	48.9±108.3 (0-640)	188±760.8 (0-5645)	112.9±589.3 (0-4639)
Proboscia indica	45.4±149.6 (0-1131)	112.6±662.7 (0-5252)	159.1±644.2 (0-4967)
Psammodyction panduriformis	-	0.6±3.3 (0-19)	0.3±1.5 (0-9)
Pseudonitzschia delicatissima group	15281.3±40342.4 (0-254393)	16220.7±61133.3 (0-456606)	7003.8±29922.1 (0-217143)
Pseudonitzschia pungens	730.2±3153.9 (0-21250)	1376.4±5557.2 (0-42617)	220.1±1614.3 (0-12919)
Pseudonitzschia seriata group	393.1±2606.9 (0-20593)	-	106.7±853.5 (0-6828)
Pseudonitzschia sp. 3	109.5±822.6 (0-6573)	-	-
Pseudonitzschia sp. 5	2909.7±9206.8 (0-57931)	2.3±18.2 (0-145)	-
Pseudosolenia calcar-avis	0.7±3.2 (0-21)	1.1±4.2 (0-27)	1.1±4.8 (0-33)
Rhizosolenia bergonii	5.4±15 (0-80)	5.5±17.6 (0-114)	6.8±15.4 (0-84)
Rhizosolenia cochlea	6.9±29.6 (0-227)	3.3±12.5 (0-72)	9.1±33.3 (0-231)
Rhizosolenia hebetata f. semispina	666.5±1847.1 (0-10833)	1145.7±4950.3 (0-32876)	321.8±575.3 (0-3393)
Rhizosolenia hyalina	24.3±39 (0-213)	25.7±62.5 (0-318)	29.2±70.9 (0-441)
Rhizosolenia imbricata	80.2±171 (0-920)	61.7±116.1 (0-458)	81.9±177.7 (0-989)
Rhizosolenia setigera	46.5±119.2 (0-800)	26.8±55.4 (0-316)	25.8±60.6 (0-362)
Rhizosolenia shrubsolei	1345.8±7285.2 (0-58373)	1293.9±8063.2 (0-64156)	1589.7±7469.4 (0-59505)
Rhizosolenia sp. 1	2.1±8.9 (0-51)	1.2±7.2 (0-56)	2.4±10.7 (0-72)
Skeletonema costatum	10062.8±43218.7 (0-301667)	7003.1±46991.7 (0-371373)	2909.3±21474.1 (0-171905)
Stephanopyxis palmeriana	65±155.3 (0-900)	35.2±75.5 (0-379)	62±167.9 (0-1113)
Streptotheca indica	78.6±286.6 (0-1886)	23.6±69.8 (0-487)	11.8±45.2 (0-300)
Streptotheca tamesis	14.8±34.1 (0-135)	4.4±12.7 (0-78)	3.5±8.2 (0-36)
Surirella fastuosa	29.7±135.3 (0-1000)	86.5±544.4 (0-4325)	105.9±218.2 (0-1146)
Surirella fastuosa forma B	0.8±4.2 (0-29)	5.3±36 (0-284)	3.2±11.4 (0-61)
Synedra sp. 1	29.6±131.5 (0-750)	1.1±4.2 (0-23)	1±4.3 (0-27)
Synedra sp. 2	-	-	0.2±1.5 (0-12)

Thalassionema nitzschioides	1244±3373.2 (0-22659)	1460.1±1831.5 (0-6961)	2110.2±4271.5 (0-31325)
Thalassiosira eccentrica	72.6±216.7 (0-1618)	86.9±258.5 (0-1988)	114.2±624.9 (0-4986)
Thalassiosira oestrupii	378.9±1157.5 (0-7286)	337.4±566.3 (0-2655)	676.3±2470.8 (0-18838)
Thalassiosira spp.	1.6±9.3 (0-67)	1.1±8.6 (0-68)	-
Thalassiothrix frauenfeldii	160.4±573.3 (0-3636)	40.6±94.4 (0-495)	212.8±367.9 (0-1255)
Thalassiothrix longissima	31.9±129 (0-989)	39.2±149.9 (0-845)	23±76 (0-501)
Trachyneis antillarum	18.7±56.4 (0-335)	30.2±57.8 (0-296)	87.9±161 (0-1090)
Trachyneis debyi	1±3.2 (0-17)	0.8±3.2 (0-19)	1.5±5.9 (0-39)
Triceratium robertsianum	0.1±0.8 (0-6)	0.2±1.3 (0-10)	0.2±2 (0-16)
Dinophyceae			
Achradina pulchra	7.2±23 (0-146)	21.1±58.4 (0-427)	13±31.5 (0-184)
Actiniscus pentasterias	2.4±16.2 (0-130)	1.2±4.6 (0-25)	0.3±1.9 (0-11)
Akashiwo sanguinea	0.1±0.9 (0-7)	0.1±1 (0-8)	-
Alexandrium tamiyavanichii	62.3±271.9 (0-1967)	13±48.1 (0-278)	12.6±38.7 (0-213)
Amphisolenia bidentata	0.8±3.3 (0-19)	1.2±6.5 (0-46)	0.2±1.6 (0-13)
Amphisolenia globifera	-	-	0.4±2.1 (0-13)
Balechina coerulea	3.5±5.1 (0-20)	0.7±3.7 (0-27)	0.6±3 (0-20)
Ceratium breve	8.1±12.6 (0-65)	6.7±14.3 (0-72)	3.4±8.5 (0-33)
Ceratium candelabrum	1.9±9.4 (0-65)	0.2±1.9 (0-15)	0.6±4.5 (0-36)
Ceratium dens	10.3±35.2 (0-227)	1.2±7.2 (0-56)	1±5 (0-32)
Ceratium extensum	4.3±21.3 (0-167)	0.3±2.2 (0-17)	-
Ceratium falcatum	1.2±4.3 (0-21)	1.2±4.1 (0-22)	1.6±9.8 (0-75)
Ceratium furca	92.6±278.6 (0-2056)	27.1±72.5 (0-402)	33±107.8 (0-540)
Ceratium fusis	60.2±95.3 (0-613)	31.6±58.2 (0-247)	20.7±45.9 (0-199)
Ceratium gibberum	1.2±8 (0-64)	5.2±27.8 (0-217)	2.2±10.6 (0-64)

Ceratium hexacanthum	-	0.3±1.6 (0-10)	-
Ceratium horridum	1.9±11 (0-81)	4.2±22.2 (0-168)	3.5±19.6 (0-153)
Ceratium lineatum	58.4±189.9 (0-1480)	14.9±44.8 (0-241)	19.8±75 (0-535)
Ceratium lunula	0.4±2.1 (0-15)	0.7±4.1 (0-29)	-
Ceratium macroceros	0.6±2.7 (0-17)	3.9±11.2 (0-72)	1.6±6.9 (0-48)
Ceratium massiliense	9.1±15.9 (0-70)	3.4±10.1 (0-57)	3±7.7 (0-47)
Ceratium massiliense var. armata	-	0.2±1.2 (0-10)	-
Ceratium minutum	1.3±3.9 (0-22)	0.6±2.4 (0-10)	-
Ceratium ranipes	0.5±2.3 (0-12)	0.2±1.3 (0-11)	0.2±1.6 (0-13)
Ceratium tenue var. buceros	0.9±4 (0-20)	2.2±6.9 (0-39)	-
Ceratium trichoceros	10±14.6 (0-66)	7.7±15.2 (0-74)	3.9±10.3 (0-55)
Ceratium tripos	-	-	1.2±9.5 (0-76)
Ceratium vultur v. sumatranus	2.4±13 (0-83)	0.1±1.1 (0-8)	-
Ceratocorys armata	-	0.2±1.2 (0-9)	0.2±1.3 (0-11)
Cochlodinium brandtii	83.9±200.9 (0-1314)	70.6±88.5 (0-486)	35.4±98.4 (0-692)
Cochlodinium polykrikoides	4±14.6 (0-97)	4.9±34.8 (0-275)	39.6±232.2 (0-1680)
Cochlodinium sp.	5.5±29.4 (0-230)	-	-
Corythodinium constrictum	0.9±4.9 (0-37)	0.5±3.9 (0-31)	0.1±1.2 (0-9)
Corythodinium tesselatum	1.5±5.3 (0-32)	31.6±244.7 (0-1943)	1.9±5.6 (0-30)
Dicroerisma psilonereiella	-	0.8±3.9 (0-20)	3.6±8.3 (0-44)
Dinophysis acuminata	-	1.6±6.5 (0-41)	0.2±1.3 (0-11)
Dinophysis caudata	13.5±49.9 (0-389)	12.1±35.5 (0-238)	7.2±18.1 (0-86)
Dinophysis doryphorum	-	0.3±1.9 (0-12)	-
Dinophysis miles	2.2±5.7 (0-24)	3.1±10.2 (0-72)	1.6±5.2 (0-20)
Dinophysis mitra	0.9±3.3 (0-18)	0.1±1.1 (0-8)	-

Dinophysis nasutum	6±24.2 (0-140)	-	1.7±7.1 (0-46)
Dinophysis rotundata	5.7±9.8 (0-45)	4.8±9.6 (0-53)	1.9±5.2 (0-24)
Dinophysis rudgei	-	-	1.1±3.5 (0-18)
Dinophysis sp. 2	4±11.7 (0-59)	-	0.5±2.7 (0-18)
Diplopelta bomba	38.3±55.3 (0-320)	20.1±21.6 (0-90)	22.7±35.5 (0-177)
Diplopelta parva	1.4±5.4 (0-32)	6.3±18.8 (0-124)	6.7±19.9 (0-112)
Diplopsalis lenticula	7.6±25.9 (0-147)	0.7±3.5 (0-23)	8.7±21.4 (0-96)
Dissodinium pseudolunula	-	0.1±1.2 (0-9)	0.2±1.6 (0-13)
Goniaulax turbynei	8.3±46.9 (0-348)	0.9±4 (0-24)	-
Goniodoma polyedricum	2.1±6.2 (0-29)	1.1±5.7 (0-42)	1±3.1 (0-13)
Gonyaulax birostris	-	0.2±1.9 (0-15)	-
Gonyaulax diegensis	3.4±16.3 (0-118)	-	-
Gonyaulax digitale	3±9.6 (0-70)	1.1±4.7 (0-31)	1.2±4.1 (0-22)
Gonyaulax fragilis + G. hyalina	73.9±228.8 (0-1565)	33.1±88.7 (0-593)	15.8±47.5 (0-325)
Gonyaulax polygramma	6.8±15.9 (0-75)	1.6±5.7 (0-30)	0.7±2.5 (0-11)
Gonyaulax sp. 1	0.1±1.1 (0-9)	-	-
Gonyaulax sp. 2	-	0.2±1.4 (0-11)	-
Gonyaulax sp. 3	0.3±2 (0-16)	-	-
Gonyaulax sp. 5	1.3±4.8 (0-29)	-	-
Gonyaulax spinifera	1.6±5.8 (0-32)	0.9±5.5 (0-43)	2.1±13.3 (0-102)
Gonyaulax verior	0.5±2.7 (0-16)	8.4±49.4 (0-385)	1.7±5.3 (0-28)
Gymnodinium catenatum	101±226.5 (0-1190)	14.6±58.8 (0-408)	3.6±13.8 (0-86)
Gymnodinium sp. 1	24.3±71 (0-417)	8.8±36.1 (0-239)	17.8±75.2 (0-430)
Gymnodinium sp. 11	22.6±103.1 (0-506)	27.8±112.4 (0-637)	46.9±220.9 (0-1264)
Gymnodinium sp. 12	0.4±2.3 (0-16)	-	0.1±1.2 (0-9)

Gymnodinium sp. 13	14.8±83.3 (0-520)	-	-
Gymnodinium sp. 17	50.8±234.7 (0-1532)	-	-
Gymnodinium sp. 1a	767.9±1930.2 (0-9101)	1.3±10.3 (0-82)	-
Gymnodinium sp. 2 (large-sized form)	6.6±19.3 (0-98)	-	-
Gymnodinium -like group	22693.9±16907.8 (0-64466)	32263.1±30838 (0-133938)	34611.2±62899.3 (0-470000)
Gyrodinium calyptoglyphe	-	20.2±137.8 (0-1092)	1.1±5.3 (0-37)
Gyrodinium falcatum	8.1±35.9 (0-266)	2.1±9.4 (0-61)	-
Gyrodinium fusiforme	1323.6±1695.2 (0-8525)	659.4±778.8 (0-4477)	560.4±537.6 (0-2321)
Gyrodinium sp. 5	17.9±40 (0-278)	1.2±4.6 (0-27)	3.4±9.5 (0-51)
Gyrodinium spirale	218±411.7 (0-2577)	55.5±112.5 (0-464)	56.8±127 (0-684)
Heterocapsa sp. 2	240±907.1 (0-4704)	403.5±1246.8 (0-8764)	-
Heterocapsa sp.1	1446.1±3810.9 (0-24828)	461.1±1094.6 (0-5424)	917.5±4189.7 (0-32393)
Heterocapsa triquetra	13.2±68.4 (0-399)	11.8±83.5 (0-662)	0.6±2.4 (0-10)
Histioneis cymballaria	0.3±2.3 (0-19)	-	-
Histoneis costata	0.3±1.5 (0-7)	0.3±1.6 (0-9)	0.1±1.2 (0-9)
Karenia brevis	0.8±3.2 (0-21)	19.1±131.4 (0-1043)	1.8±8.9 (0-68)
Katodinium glandula	-	0.2±1.4 (0-11)	-
Kofoidinium velleloides	-	0.3±1.5 (0-9)	0.3±2.4 (0-19)
Lingulodinium polyedrum	0.3±2 (0-15)	-	-
Mesoporos perforatus	1308.5±2226.5 (0-12801)	782±2037.9 (0-14805)	459.3±1000.8 (0-5220)
Noctiluca scincillans	90.5±154.6 (0-688)	17.8±37.2 (0-213)	15.6±40.7 (0-241)
Ornithocercus magnificus	1.1±4.4 (0-32)	1.3±4.9 (0-34)	0.7±3.1 (0-19)
Ornithocercus quadratus	0.3±2.3 (0-18)	-	0.3±1.7 (0-11)
Ornithocercus splendida	0.2±1.2 (0-10)	-	-
Ornithocercus steinii	2±5.3 (0-24)	0.8±4.2 (0-30)	-

Oxytoxum curvatum	6.1±11.8 (0-67)	3.6±10.2 (0-68)	1.8±5.3 (0-32)
Oxytoxum elegans	-	-	0.2±1.5 (0-12)
Oxytoxum gracilis	374.6±770.2 (0-4510)	167.8±371.1 (0-1757)	93.5±257.5 (0-1222)
Oxytoxum milneri	-	-	0.5±2.6 (0-16)
Oxytoxum sceptrum	1.6±4.2 (0-24)	2±10.4 (0-81)	80.9±457.6 (0-3614)
Oxytoxum scolapax	0.4±3.1 (0-25)	1.3±10.1 (0-80)	-
Oxytoxum sp. 1	1399.5±2522 (0-12258)	53.3±207.5 (0-1138)	203.4±795.1 (0-4724)
Oxytoxum sp. 3	4.7±31.6 (0-253)	125.5±392.6 (0-2428)	171.7±622.5 (0-3793)
Oxytoxum sp. 5	0.4±2.4 (0-17)	-	-
Oxytoxum variabile	1616.4±1704.1 (0-6087)	1898.4±2427.5 (0-11145)	1355.5±2188 (0-14847)
Peridinium bipes	-	-	0.1±1.2 (0-9)
Peridinium quinquecorne	0.7±5.7 (0-45)	-	-
Podalampas bipes	0.2±1.7 (0-13)	0.2±1.4 (0-11)	-
Podalampas palmipes	1.8±3.9 (0-19)	0.5±2.9 (0-20)	0.8±3.2 (0-14)
Polykrikos schwarzii	3±7.2 (0-43)	6±22.8 (0-138)	13±36.6 (0-212)
Pronoctiluca pelagica	3.9±10.9 (0-66)	22.2±144.9 (0-1149)	1.9±7.6 (0-54)
Pronoctiluca spinifera	-	7.4±17.5 (0-87)	18.8±44.6 (0-299)
Prorocentrum balticum	0.5±3.6 (0-29)	0.4±2.5 (0-17)	0.4±2 (0-10)
Prorocentrum compressum	15.5±27.7 (0-158)	5.5±11.2 (0-51)	1.6±3.9 (0-13)
Prorocentrum dentatum	-	145.1±387.8 (0-2025)	199.2±631.8 (0-4222)
Prorocentrum gracilis	26.9±77.1 (0-453)	83±501.4 (0-3964)	38.2±133.1 (0-706)
Prorocentrum micans	128.7±430.1 (0-3333)	5.6±11.6 (0-46)	8.2±18.4 (0-83)
Prorocentrum minimum	129.5±390.8 (0-2279)	137.2±426.3 (0-2229)	232±541.7 (0-2879)
Prorocentrum rhathymum	-	7.1±36.1 (0-280)	6.5±34.5 (0-267)
Prorocentrum sigmoides	0.2±1.3 (0-11)	0.2±1.8 (0-14)	0.5±3 (0-21)

Prorocentrum triestinum	-	18.8±60.9 (0-427)	11.8±38 (0-244)
Protoceratim reticulatum	-	0.5±3.7 (0-29)	0.5±4.2 (0-34)
Protoperedinium biconicum + P. abei	-	0.2±1.3 (0-11)	-
Protoperedinium conicum v. quardafuianum	-	-	0.2±1.4 (0-11)
Protoperedinium curtipes	1.9±6.9 (0-48)	1.7±6.7 (0-42)	2.8±10.1 (0-46)
Protoperedinium curvipes	-	-	10.8±45.9 (0-310)
Protoperedinium denticulatum	-	0.3±2.7 (0-21)	-
Protoperedinium leonis + P. obtusum	-	-	1.3±10.7 (0-85)
Protoperedinium mite	-	5.9±38.1 (0-301)	1.9±9.3 (0-71)
Protoperedinium pentagonum	0.7±3.1 (0-21)	1.8±10.5 (0-72)	1.8±7.8 (0-48)
Protoperidinium conicoides group	1.3±3.9 (0-21)	1±3.1 (0-11)	4.1±14.3 (0-78)
Protoperidinium conicum v. concavum	15±34.4 (0-241)	0.9±3.4 (0-20)	2.3±6.4 (0-38)
Protoperidinium depressum	4.8±11.8 (0-79)	2.9±10.7 (0-72)	1.6±5.5 (0-28)
Protoperidinium divergens	10.8±19.2 (0-93)	5.7±16.7 (0-113)	4.9±18.6 (0-133)
Protoperidinium globulus + P. ovatum	6.6±15.1 (0-71)	4.6±21.7 (0-167)	5±17.1 (0-96)
Protoperidinium grande	7.6±25.7 (0-149)	0.6±3.7 (0-28)	0.7±4.7 (0-36)
Protoperidinium murrayi	-	0.1±1.2 (0-9)	-
Protoperidinium oblongum + P. claudicans	8.9±20.9 (0-100)	1.5±4.7 (0-29)	3.4±17.1 (0-135)
Protoperidinium oceanicum	-	2.9±8.9 (0-52)	2.4±7 (0-40)
Protoperidinium ovum + P. sp. 1	27.9±106.5 (0-785)	18.2±79.5 (0-613)	12.3±61 (0-470)
Protoperidinium pellucidum	22.4±45.2 (0-227)	14.8±43.7 (0-312)	15.3±68.8 (0-535)
Protoperidinium punctulatum + P. marielebourae + P. thorianum	2.1±9.4 (0-59)	2.8±9.8 (0-70)	1.3±6.7 (0-51)
Protoperidinium quarnerense + P. hamatum	19±53.2 (0-296)	60.6±341.6 (0-2703)	18.7±86.4 (0-683)

Protoperidinium sp. 1b (cf *P. pyriforme*)	1.7±8.9 (0-58)	-	-
Protoperidinium sp. 2 + sp. 3	203.4±354.1 (0-1875)	52.8±216.9 (0-1610)	103.8±271 (0-1699)
Protoperidinium sp. 4 (P. cf oviforme)	1.1±4.6 (0-27)	0.4±1.8 (0-9)	1.4±7.3 (0-46)
Protoperidinium sp. 5	0.2±1.7 (0-14)	-	-
Protoperidinium spp. (small-sized group)	149.4±276.2 (0-1379)	326.2±755 (0-3994)	108.7±534.5 (0-4217)
Protoperidinium steinii	17.8±34.6 (0-175)	4.5±18.3 (0-138)	4.8±12.8 (0-81)
Protoperidinium subinerme	10.3±38.5 (0-280)	4.5±20.4 (0-125)	1.3±6.1 (0-39)
Pyrocystis fusiformis	1.6±3.5 (0-12)	2.1±5.3 (0-25)	1.1±3.2 (0-11)
Pyrocystis hamulus	0.2±1.5 (0-12)	-	-
Pyrocystis noctiluca	9.1±15.7 (0-81)	7.9±15.5 (0-72)	9.3±21.5 (0-148)
Pyrocystis obtusa + P. robusta	0.3±1.5 (0-7)	0.6±2.4 (0-11)	0.2±1.3 (0-10)
Pyrodinium bahamense	3.9±16.2 (0-105)	0.3±2.6 (0-20)	-
Pyrophacus horologicum	2.3±7.7 (0-53)	1.7±5.7 (0-31)	1.8±5 (0-21)
Pyrophacus steinii	-	0.3±1.9 (0-12)	-
Scrippsiella sp.	968.5±1971.9 (0-10753)	70.8±326.9 (0-2428)	215±805.9 (0-5742)
Scrippsiella trochoidea	238.3±956.2 (0-7500)	148.4±697 (0-5167)	24.9±70.6 (0-335)
Sinophysis ebriolum	-	-	0.1±1.1 (0-9)
Spiraulax jolliffei	1.7±4.8 (0-21)	0.4±2 (0-11)	0.7±2.6 (0-12)
Torodinium robustum	1083.1±1502.8 (0-9167)	1110.9±1916.6 (0-11875)	1168.9±2410.4 (0-13850)
Torodinium teredo	58±70.3 (0-453)	36.3±50.5 (0-260)	35.3±57.5 (0-376)
Triposolenia bicornis	-	-	0.2±1.7 (0-13)
Warnowia violescens	1.4±4.1 (0-18)	2.2±7.7 (0-47)	1.7±9.3 (0-71)
Cyanophyceae			
Trichodesmium sp. (filaments)	51.3±169.4 (0-1144)	69.3±175.2 (0-828)	35.4±129.2 (0-793)
Anabaena-like? sp.	9.7±30.4 (0-163)	9.2±27.8 (0-150)	13.3±42.3 (0-263)

Dictyochophyceae			
Dictyocha fibula	61.5±130.7 (0-667)	51.5±78.1 (0-343)	23.4±40.6 (0-156)
Dictyocha speculum	0.5±3.5 (0-28)	0.6±2.8 (0-17)	1.3±8.1 (0-64)
Cryptophyceae			
Teleaulax sp.	13641±25596.7 (0-198621)	18957.8±36283.9 (0-219711)	16883.3±24357.7 (0-95000)
Euglenophyceae			
Eutreptiella sp.	184.6±518.2 (0-2656)	157.7±739.5 (0-5368)	59.9±345.8 (0-2699)
Prasinophyceae			
Pterosperma undulatum	0.4±3.1 (0-25)	0.4±2 (0-12)	1.3±4.2 (0-20)
Pterosperma polygonum	-	0.4±2 (0-12)	0.1±1 (0-8)
Pyramimonas sp.	-	19.2±118.6 (0-892)	-
Prymnesiophyceae			
Phaeocystis sp. (colonies)	-	0.4±2.1 (0-13)	2±8.7 (0-62)
Ebriidea			
Ebria tripartite	2.4±10.8 (0-80)	4.2±14.2 (0-75)	6.2±21.8 (0-128)

Annex 3. Species Occurrence at each Sampled Station in the RSA during Winter 2006 in a Descending Order of Abundance.

Taxon	List of stations where species was observed (descending order of abundance)
Actinocyclus curvatulus	95, 90, 34, 25, 39, 23, 88, 25a, 56, 4, 19, 100, 101, 17, 7a, 40, 92, 59, 9a, 27a, 11, 26, 83, 21a, 71, 24, 77
Actinocyclus octonarius	23a, 55, 92, 95, 93, 70, 36, 30, 27a, 11a, 72, 25a, 78, 82, 24, 28a
Actinoptychus senarius	92
Amphora cf *angustata*	43
Amphora cf *coffeaeformis*	34, 33
Amphora cf *crassa*	34
Amphora cf *proteus*	1
Amphora ostrearia	97, 88, 78, 27, 21a, 92, 9a, 95, 34, 19a, 85, 90, 22a, 83, 93, 25a, 30, 79, 14, 33, 14a, 39, 56, 82, 19, 59, 69, 16a, 27a, 50, 7, 87, 11, 8, 4, 23a, 1, 17, 71, 11a
Asteromphalus flabellatus	50, 8, 5a, 27, 11, 71, 70, 72, 11a, 99, 14a, 26, 40, 7a, 17
Asteromphalus heptactis	77, 82, 4, 43, 93, 28a, 22a, 36, 25, 17, 27a, 7a
Bacillaria paxillefera	1, 7, 9a, 14, 26, 19, 23a, 20, 22, 97, 30, 15, 78, 27a, 23
Bacillaria socialis	1, 14, 30
Bacteriastrum delicatulum	88, 14, 1, 87, 97, 55, 21a, 16a, 22a, 98, 93, 95, 90, 79, 78, 23a, 27, 92, 9a, 14a, 66, 100, 19, 19a, 26, 82, 20, 11, 7, 7a, 72, 30, 77, 83, 43, 36, 33, 50, 56, 39, 25a, 85, 27a, 17, 70, 69, 8, 71, 26a, 59, 24, 99, 10a, 25
Bacteriastrum furcatum	14a, 16a, 88, 97, 23a, 87, 92, 25a, 90, 19a, 22a, 21a, 93, 4, 7, 83, 14, 7a, 56, 100, 101, 10a, 11a, 11, 15, 17, 19, 1, 20, 22, 23, 24, 25, 26a, 26, 27a, 27, 28a, 30, 33, 34, 36, 39, 40, 43, 50, 55, 59, 5a, 66, 69, 70, 71, 72, 77, 78, 79, 82, 85, 8, 95, 98, 99, 9a
Bacteriastrum hyalinum	16a, 14a, 85, 83, 26a, 14, 25a, 19, 88, 7, 97, 78, 90, 22a, 36, 20, 87, 95, 93, 82, 98, 19a, 30, 23a, 27, 21a, 1, 43, 72, 15, 11, 92, 22, 4, 59, 50, 7a, 5a, 8, 71, 69, 25, 23, 34, 99, 56, 70, 77, 27a, 39, 33
Bellerochea horologicalis	20, 11a, 30, 19, 9a, 97, 36, 78, 98, 23
Biddulphia pulchella	72, 23
Biddulphia tuomeyi	23, 15
Caloneis liber	15, 19, 27a, 9a, 17, 8, 23, 28a, 7a, 4, 5a, 59, 22, 14, 30, 25, 26, 43, 24, 7, 11, 1, 79, 55, 10a, 70, 56, 39, 33, 20, 11a, 85, 36, 34, 78, 72, 50, 82
Campylodiscus sp.	33, 82, 72, 59
Cerataulina bicornis	22a, 97
Cerataulina pelagica	26a, 93, 98, 77, 22a, 1, 97, 25a, 100, 14a, 9a, 83, 95, 4, 88, 19, 14, 27, 23a, 11, 7a, 90, 21a, 30, 82, 17, 66, 87, 7, 16a, 59, 92, 99, 26, 19a, 39, 8, 36, 20, 11a, 72, 70, 85, 15, 33, 40, 10a, 101, 22, 71, 78

Chaetoceros brevis	27, 88, 26, 7a, 59, 90, 1, 92, 39, 70, 15, 25a, 95, 50, 40
Chaetoceros cf *dichaeta*	88, 27, 97, 16a, 4, 83, 85, 93, 21a, 82, 87, 95, 19, 69, 39, 26a, 19a, 50, 66, 56
Chaetoceros coarctatus	16a, 95, 88, 90, 92, 97, 79, 23a, 22a, 25a, 27, 26, 14a, 87, 93, 8, 27a, 23, 7a, 34, 21a, 19a, 83, 11, 7, 85, 15, 20, 40, 82, 78, 98, 4, 11a, 9a, 69, 10a, 28a, 66, 17, 14, 33, 39, 30, 19, 1
Chaetoceros compressus	78, 79, 27, 7a, 90, 4, 88, 70, 82, 26, 19, 98, 14, 97, 11a, 14a, 8, 92, 39, 9a, 21a, 24, 22a, 69, 11, 23a, 1, 33, 40, 20, 27a, 36, 56, 19a, 72, 95, 66, 83, 93, 100, 59, 26a, 7, 17, 87, 28a, 10a, 71
Chaetoceros curvisetus	88, 25a, 92, 16a, 83, 90, 97, 1, 26a, 85, 95, 93, 87, 22a, 14a, 26, 21a, 23a, 19a, 78, 98, 14, 20, 7, 36, 27, 70, 30, 72, 59, 66, 34, 71, 69, 17, 7a, 77, 56
Chaetoceros decipiens	26, 69, 22a, 97, 19a, 95, 23a, 90, 7, 79
Chaetoceros denticulatus	27, 88, 92, 90, 97, 21a, 23a, 1, 39, 87, 79, 93, 36, 22a, 30, 77, 16a, 14a, 82, 11a, 66, 99, 70, 56, 83, 100, 25a, 25, 78, 95, 4, 34, 14, 69, 26, 5a, 7a, 20, 27a, 43, 10a
Chaetoceros diversus	7a, 11, 11a, 9a, 14, 19, 26, 20
Chaetoceros lauderi	1, 14, 56, 97, 7, 95, 90, 5a, 16a, 25a, 83, 69
Chaetoceros lorenzianus forma A	27, 88, 92, 23a, 90, 97, 22a, 26, 21a, 95, 93, 1, 25a, 20, 87, 16a, 7, 77, 39, 19a, 66, 27a, 56, 14a, 69, 14, 83, 72, 85, 33, 100, 9a, 11, 7a, 40, 59, 71, 82, 36, 79, 11a, 34, 8, 4, 55, 30, 19, 78, 28a, 17, 70, 98
Chaetoceros lorenzianus forma B	27, 14a, 39, 36, 70, 69, 26, 25a, 88, 40, 66, 97, 77, 95, 72, 1, 87, 90, 56, 9a, 22a, 82, 59, 19, 20, 11a, 23a, 11, 7a, 71, 43, 93, 30, 92, 33, 55, 8, 19a, 78, 14, 21a, 83, 85, 99, 34, 17, 4, 10a, 24, 15
Chaetoceros messanensis	25a, 27, 93, 90, 26a, 92, 66, 82, 98, 56, 77, 83, 16a, 11, 14, 22a, 21a, 20, 69, 72, 100, 71, 23, 11a, 26
Chaetoceros peruvianus	14, 7, 1, 27a, 39, 22a, 26a, 27, 40, 88, 7a, 19, 4, 9a, 11, 97, 8, 11a, 17, 69, 20, 16a, 21a, 36, 43, 85, 59, 93, 26, 24, 83, 15, 56
Chaetoceros peruvianus f. *gracilis*	4, 7a, 11, 98, 59, 26, 34
Chaetoceros pseudocurvisetus	1, 82, 22a, 27, 97, 93, 25a, 100, 95, 88, 90, 9a, 14a, 26, 92, 16a, 8, 30, 23a, 14, 87, 7, 19a, 36
Chaetoceros socialis	78, 77, 69, 93, 90, 23a, 55, 23
Chaetoceros tortissimus	14a, 56, 70, 25a, 79, 55, 78, 88, 83, 97, 92, 90, 27, 22a, 82, 16a, 93, 36, 69, 26, 95, 23a, 66, 71, 19a, 87, 21a, 9a, 77, 34, 30, 100, 99, 72, 14, 23
Climacodium frauenfeldianum	36, 69, 40, 7a, 11, 66, 4, 59, 17, 14, 56, 27, 72, 25a, 28a, 30, 8, 78, 15, 92, 71, 5a, 20, 7, 14a, 39, 16a, 23, 9a, 19, 22, 26, 83, 1, 87, 27a, 11a, 77, 85, 90, 50, 100, 97, 33, 21a, 22a, 101, 34, 43, 19a, 26a, 79, 88, 25, 55, 98, 70, 24, 93
Cocconeis sp.	33
Corethron criophilum	30, 9a, 7a, 90, 95, 88, 22a, 59, 98, 21a, 11, 17, 43
Corethron histrix	19, 9a, 30, 66, 7a, 39, 25a, 20, 95, 43, 88, 93, 26, 23a, 14a, 92, 11, 17, 36, 22a, 90, 100, 97, 83, 50, 78, 55, 27, 69, 40, 15, 82, 21a, 70, 8, 26a, 71, 25, 19a, 87, 24, 79, 27a, 11a, 14
Coscinodiscus asteromphalus	56, 16a, 69, 85, 70, 19a, 92, 77, 9a, 30, 100, 25a, 28a, 14, 7a, 27a, 10a, 24, 72, 26
Coscinodiscus granii	23, 66, 88, 4, 25, 8, 39, 26, 55, 7a, 43, 15, 90, 19, 30, 1, 83, 22, 22a, 93, 11, 17, 87, 59, 10a, 11a, 40, 9a, 95, 71, 20

Coscinodiscus janischii	40, 27a, 28a, 85, 20, 26a, 14a, 26, 98, 93, 87, 90, 92, 56, 24, 1, 17, 33, 10a, 43
Coscinodiscus oculus-irdis	83, 27a, 72, 100, 11a, 22a, 24, 87, 30, 95, 28a, 14, 90, 98, 14a, 97, 23a, 26, 9a, 93, 71, 92, 69, 21a, 101, 25a, 56, 1, 8, 10a, 7, 39, 78, 20, 79, 5a, 19a, 88, 11, 59, 26a, 15, 36, 99, 77, 19, 25, 34, 23, 22, 40
Coscinodiscus radiatus	19, 43, 14, 93, 30, 83, 11, 72, 7a, 26, 22a, 87, 4, 97, 90, 25a, 69, 15, 56, 71, 27a, 99, 59, 66, 82, 24, 34, 101, 33, 10a, 5a, 9a, 70, 92, 55, 23a, 25, 1, 8, 40, 17
Coscinodiscus wailesii	27a, 88, 87, 22a, 9a, 92, 90, 11a
Cosciodiscus sp. 1	30, 19, 27, 97, 19a, 25a, 23a, 15, 90, 22a, 40, 21a, 92, 39, 14a, 7a, 24, 20
Cyclotella spp. *(C. stylorum + C. striata)*	27a, 17, 7a, 28a, 8, 4, 7, 25, 9a, 50, 88, 40, 14, 66, 43, 5a, 30, 39, 55, 69, 95, 36, 82, 72, 19, 83, 11, 14a, 87, 79, 59, 71, 70, 34, 23a, 27, 26a, 92, 100, 56, 15, 20
Cylindrotheca closterium	88, 66, 55, 27, 36, 14a, 43, 25a, 23, 27a, 39, 97, 16a, 59, 69, 87, 19a, 1, 17, 92, 22a, 20, 72, 19, 78, 15, 70, 7, 79, 34, 28a, 10a, 30, 40, 85, 83, 93, 82, 23a, 90, 56, 71, 21a, 25, 50, 33, 4
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Eucampia cornuta	88, 16a, 93, 25a, 27, 7a, 36, 82, 66, 83, 26a, 97, 22a, 56, 90, 14a, 92, 23a, 87, 21a, 85, 78, 39, 70, 98, 40, 79, 30, 19a, 77, 9a, 11, 69, 55, 43, 95, 15, 99, 59, 72
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Cochlodinium brandtii	50, 66, 59, 43, 33, 27a, 34, 70, 36, 30, 10a, 24, 40, 69, 83, 71, 56, 39, 82, 85, 78, 23a, 25a, 21a, 23, 27, 55, 5a, 17, 8, 77, 72, 25, 14, 87, 14a, 92, 16a, 22, 11, 20, 26, 88, 28a, 7, 93, 79, 95, 22a, 90, 15, 26a, 9a, 19a, 98, 97, 7a
Cochlodinium polykrikoides	50, 43, 56, 16a, 77, 19a, 69, 85, 72, 24, 14, 8
Cochlodinium sp.	78, 77, 8, 82, 7a, 11, 17
Corythodinium constrictum	92, 26a, 25a, 101, 59
Corythodinium tesselatum	28a, 25a, 90, 55, 33, 85, 100, 14a, 26a, 16a, 93, 66, 27a, 22, 83, 50
Dicroerisma psilonereiella	90, 71, 23a, 95, 21a, 39, 16a, 85, 5a, 4, 15, 66, 55, 7a, 28a
Dinophysis acuminata	78, 87, 66, 69, 82

Dinophysis caudata	92, 28a, 27a, 15, 7a, 7, 5a, 79, 23, 14, 34, 17, 39, 11, 1, 59, 50, 22a, 66, 87, 20, 19a, 82, 90, 8, 4, 93, 33, 43
Dinophysis doryphorum	95, 66
Dinophysis miles	28a, 23, 20, 15, 43, 19a, 26, 34, 50, 11a, 69, 8, 39, 27, 11, 4, 16a, 14, 10a, 33, 36, 7a
Dinophysis mitra	8, 11, 9a, 4, 7a
Dinophysis nasutum	88, 56, 11a, 15, 70, 50, 40, 9a, 26, 20
Dinophysis rotundata	17, 28a, 59, 9a, 11, 25a, 101, 27, 14a, 39, 8, 20, 92, 100, 30, 90, 11a, 4, 40, 7a, 14, 21a, 22a, 16a, 26a, 15, 7, 99, 77, 34, 82, 27a, 79, 23, 43, 66, 24
Dinophysis rudgei	25, 92, 24, 19, 22, 23
Dinophysis sp. 2	78, 7, 56, 87, 83, 71, 22, 77, 85, 82, 90
Diplopelta bomba	93, 5a, 92, 9a, 19, 14, 78, 25a, 87, 36, 97, 83, 8, 98, 39, 21a, 79, 16a, 27, 11a, 11, 95, 66, 17, 26a, 28a, 7a, 15, 26, 19a, 23, 4, 22a, 90, 88, 22, 7, 25, 1, 24, 43, 27a, 82, 77, 33, 69, 40, 85, 30, 70, 100, 59, 14a, 20, 23a, 71, 56, 101, 34, 55, 10a
Diplopelta parva	14, 1, 5a, 11a, 7a, 92, 9a, 82, 27a, 30, 78, 66, 21a, 36, 20, 72, 33, 27, 85, 99, 22a, 4, 97, 15, 7, 25, 39
Diplopsalis lenticula	78, 56, 17, 9a, 14, 72, 8, 71, 69, 36, 5a, 85, 15, 83, 23a, 93, 70, 39, 14a, 4, 11, 34, 24, 79, 20, 10a, 77, 1
Dissodinium pseudolunula	26a, 27
Goniaulax turbynei	14a, 87, 9a, 19, 26a, 15, 66, 20
Goniodoma polyedricum	8, 101, 11, 19a, 55, 9a, 26, 25a, 21a, 5a, 34, 23a, 100, 27, 20, 23
Gonyaulax birostris	85
Gonyaulax diegensis	90, 93, 95, 87, 69
Gonyaulax digitale	33, 14, 5a, 25a, 27, 66, 40, 34, 85, 26a, 55, 1, 72, 83, 11, 9a, 50, 43, 79, 26, 17
Gonyaulax fragilis + *G. hyalina*	56, 16a, 78, 50, 27a, 66, 83, 70, 92, 85, 72, 10a, 39, 25a, 71, 33, 82, 100, 24, 43, 14, 15, 23, 30, 26a, 79, 95, 87, 5a, 7, 36, 97, 59, 20, 26, 14a, 17, 25, 27, 22, 77, 34, 19, 93, 55, 28a, 40
Gonyaulax polygramma	5a, 90, 92, 8, 36, 26a, 93, 25a, 101, 85, 14, 43, 16a, 21a, 17, 82, 11, 99, 87, 28a, 7a
Gonyaulax sp. 1	69
Gonyaulax sp. 2	87
Gonyaulax sp. 3	56
Gonyaulax sp. 5	43, 30, 23, 9a, 50, 77
Gonyaulax spinifera	33, 5a, 16a, 100, 66, 85, 87, 79, 77
Gonyaulax verior	43, 50, 5a, 28a, 39, 8, 36, 69, 10a, 15, 34
Gymnodinium catenatum	27, 55, 43, 36, 77, 26, 78, 69, 93, 70, 14a, 66, 25a, 19a, 9a, 59, 82, 39, 16a, 23, 33, 90, 21a, 79, 97, 92, 83, 88, 22a, 71, 72, 50, 85, 23a, 34, 101, 10a, 14, 95, 40
Gymnodinium sp. 1	50, 43, 55, 36, 70, 30, 10a, 40, 14, 27, 59, 24, 85, 23, 82, 92, 25a, 90, 16a, 78, 72, 83, 22, 87, 97, 23a, 28a
Gymnodinium sp. 11	69, 28a, 72, 66, 56, 43, 30, 71, 55, 70, 90

Gymnodinium sp. 12	50, 39, 56
Gymnodinium sp. 13	39, 50
Gymnodinium sp. 17	50, 56, 66, 69
Gymnodinium sp. 1a	27a, 11a, 50, 56, 55, 88, 77, 14, 90, 10a, 43, 24, 78, 66, 87, 22a, 71, 69
Gymnodinium sp. 2 (large-sized form)	66, 72, 71, 78, 90, 26a, 97, 19a, 85, 25a, 101, 70, 25, 34, 7a
Gymnodinium-like group	19a, 66, 50, 59, 33, 28a, 40, 43, 36, 69, 30, 72, 24, 27a, 7, 77, 78, 70, 5a, 4, 10a, 39, 71, 14, 79, 16a, 27, 95, 20, 11, 92, 15, 21a, 7a, 90, 93, 23a, 22a, 25, 56, 82, 87, 55, 17, 23, 22, 34, 9a, 19, 8, 1, 26, 97, 85, 25a, 83, 11a, 88, 14a, 100, 99, 26a, 101, 98
Gyrodinium calyptoglyphe	69, 34, 71, 50, 33, 23, 39, 25a
Gyrodinium falcatum	79, 88, 36, 92, 27, 16a, 93, 23a, 39, 5a
Gyrodinium fusiforme	78, 83, 77, 93, 14a, 92, 82, 33, 40, 14, 16a, 70, 87, 24, 66, 50, 7, 36, 26, 88, 9a, 21a, 90, 20, 19a, 25a, 72, 43, 69, 25, 79, 71, 97, 7a, 10a, 27, 5a, 85, 22, 17, 56, 1, 55, 8, 39, 59, 15, 23a, 30, 34, 27a, 22a, 23, 28a, 4, 95, 11a, 98, 19, 11, 26a, 101, 99, 100
Gyrodinium sp. 5	50, 83, 77, 33, 70, 90, 93, 85, 87, 56, 92, 78, 72, 59, 97, 30, 88, 66, 10a, 23a, 71, 95, 34, 69, 39, 16a, 7a, 55, 43, 27
Gyrodinium spirale	93, 87, 83, 77, 16a, 36, 27, 14a, 14, 21a, 30, 78, 70, 90, 24, 88, 56, 19a, 92, 26, 40, 66, 33, 25a, 39, 85, 82, 43, 97, 71, 69, 72, 10a, 23a, 9a, 22a, 20, 79, 59, 25, 55, 22, 23, 26a, 19, 11, 34, 17, 50, 4, 28a, 15, 95, 98, 27a, 8, 11a, 5a
Heterocapsa sp. 2	27a, 90, 5a, 7, 72, 69, 17, 19, 26a, 9a, 4, 33, 8, 98, 99, 20, 56, 95, 71, 22, 30, 39
Heterocapsa sp.1	82, 70, 66, 95, 28a, 14, 77, 78, 27a, 10a, 55, 14a, 50, 27, 85, 59, 16a, 23, 26, 87, 7, 79, 71, 25a, 40, 92, 43, 36, 88, 9a, 93, 97, 8, 26a, 90, 23a, 100, 33, 72, 98, 19a
Heterocapsa triquetra	4, 28a, 14, 26a, 78, 50, 90, 15, 79, 1, 77, 56
Histioneis cymballaria	92
Histoneis costata	34, 28a, 23, 10a, 39, 7a
Karenia brevis	23, 50, 27a, 10a, 11, 7, 43, 5a, 17, 23a, 34, 36
Katodinium glandula	101
Kofoidinium velleloides	1, 69, 9a
Lingulodinium polyedrum	78, 7a
Mesoporos perforatus	7, 27, 66, 14, 34, 27a, 78, 1, 33, 25a, 11a, 70, 50, 8, 83, 26a, 85, 72, 7a, 82, 36, 9a, 26, 22a, 5a, 93, 10a, 71, 99, 16a, 69, 28a, 4, 21a, 98, 95, 87, 77, 43, 97, 55, 101, 100, 90, 23, 88, 14a, 15, 20, 22, 30, 40, 59, 79, 19, 39, 25, 19a, 23a, 56, 11, 17
Noctiluca scincillans	90, 1, 92, 27, 87, 19a, 7, 14, 26a, 93, 16a, 79, 5a, 25a, 97, 23a, 14a, 11a, 21a, 88, 85, 4, 83, 66, 22a, 78, 95, 20, 7a, 11, 9a, 8, 98, 100, 17, 27a, 23, 72, 26, 99, 70, 15, 24, 101, 40, 19
Ornithocercus magnificus	8, 28a, 15, 26a, 90, 100, 66, 50, 9a, 78, 43, 30

Ornithocercus quadratus	28a, 11
Ornithocercus splendida	87
Ornithocercus steinii	25a, 19a, 14a, 90, 92, 26a, 97, 78, 23a, 56
Oxytoxum curvatum	36, 50, 43, 24, 27, 20, 26, 40, 30, 25, 55, 66, 71, 34, 56, 17, 19, 11, 78, 69, 9a, 79, 23, 11a, 10a, 39, 7a
Oxytoxum elegans	92
Oxytoxum gracilis	93, 26, 9a, 39, 27a, 59, 72, 92, 19, 22, 55, 7a, 27, 8, 50, 78, 16a, 36, 69, 26a, 11, 90, 15, 7, 87, 33, 10a, 28a, 66, 23, 83, 56, 43, 19a, 85, 25, 77, 4, 24, 21a, 23a, 100
Oxytoxum milneri	40, 23a
Oxytoxum sceptrum	1, 69, 9a, 27, 55, 21a, 14, 7a, 72, 71, 50, 25a, 56, 25, 59, 22a, 83, 93, 23a, 97, 36, 70, 82, 40, 33, 43, 66
Oxytoxum scolapax	19a, 82
Oxytoxum sp. 1	50, 36, 88, 19a, 25a, 10a, 82, 93, 95, 26, 27, 55, 92, 90, 59, 72, 71, 77, 14a, 97, 23a, 30, 20, 78, 15, 87, 39, 19, 40, 25, 43, 33, 66, 22, 24, 7a
Oxytoxum sp. 3	69, 33, 34, 50, 10a, 20, 71, 72, 59, 27, 43, 90, 23, 30, 56, 55, 83, 28a
Oxytoxum sp. 5	69, 56
Oxytoxum variabile	33, 82, 27, 78, 50, 79, 77, 70, 69, 87, 27a, 16a, 36, 28a, 90, 66, 71, 14, 24, 92, 88, 93, 55, 34, 83, 5a, 23a, 25a, 40, 95, 22a, 22, 59, 85, 19a, 8, 97, 43, 7, 14a, 21a, 19, 17, 7a, 11a, 23, 4, 72, 39, 10a, 1, 20, 30, 9a, 25, 26, 56, 15, 26a, 11, 99, 101
Peridinium bipes	33
Peridinium quinquecorne	28a
Podalampas bipes	27, 87
Podalampas palmipes	21a, 92, 14a, 99, 23a, 85, 98, 90, 83, 56, 77, 78, 43, 11a, 66, 27
Polykrikos schwarzii	97, 87, 27, 11a, 16a, 79, 99, 33, 7, 70, 77, 14a, 17, 82, 90, 71, 8, 78, 21a, 93, 69, 55, 22, 11, 50, 72, 66, 39, 14
Pronoctiluca pelagica	95, 23a, 72, 78, 69, 92, 88, 34, 90, 16a, 87, 30, 71, 83, 85, 14a, 93, 15, 55, 40, 70, 59
Pronoctiluca spinifera	27, 19a, 69, 71, 70, 90, 22a, 55, 93, 14a, 40, 39, 85, 78, 23a, 77, 95, 59, 83, 16a, 26, 34, 82, 33, 92, 56, 72, 17, 23, 50
Prorocentrum balticum	87, 8, 71, 79, 14, 10a
Prorocentrum compressum	14, 78, 88, 26a, 87, 66, 25a, 14a, 93, 33, 98, 27, 90, 85, 95, 100, 70, 83, 8, 101, 4, 92, 71, 22a, 19a, 97, 21a, 5a, 82, 16a, 34, 23a, 79, 7, 99, 28a, 50, 56, 55, 10a
Prorocentrum dentatum	50, 98, 8, 19, 4, 36, 9a, 27, 66, 7, 20, 77, 39, 33, 21a, 22a, 82, 27a, 43, 79, 26, 25, 14, 15
Prorocentrum gracilis	36, 27a, 7, 27, 34, 5a, 7a, 33, 14, 11a, 17, 28a, 23, 11, 4, 59, 40, 50, 15, 26a, 14a, 97, 78, 71, 43, 56, 77, 26, 1, 85, 16a, 20, 87, 24, 83, 9a, 55, 10a, 66, 39, 30
Prorocentrum micans	36, 50, 5a, 7, 79, 7a, 26, 27a, 19a, 33, 15, 34, 22, 30, 39, 43, 16a, 17, 9a, 66, 90, 92, 87, 1, 72, 27, 71, 78, 14, 59, 20, 97, 19, 70, 98, 77, 85, 14a, 55, 93, 11, 8, 11a, 25, 22a, 26a, 40, 21a, 82, 4, 100, 10a, 24, 25a, 99, 101, 28a, 56, 23

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Prorocentrum rhathymum	27a, 7, 17, 28a, 14, 79, 16a, 5a, 70, 71, 10a, 22, 40, 72
Prorocentrum sigmoides	15, 16a, 87, 90
Prorocentrum triestinum	50, 5a, 34, 43, 27, 1, 14, 26, 15, 8, 28a, 66, 9a, 30, 7a, 25, 11a, 23a, 26a, 36, 56, 78, 33, 27a, 39, 10a, 24, 69, 79
Protoceratim reticulatum	50
Protoperedinium biconicum +. *P. abei*	4
Protoperedinium conicum v. quardafuianum	90
Protoperedinium curtipes	8, 33, 11, 7, 5a, 16a, 4, 88, 7a, 93, 90, 23a, 77, 27, 69, 9a, 17
Protoperedinium curvipes	25a, 87, 43, 16a, 21a, 26a
Protoperedinium denticulatum	26
Protoperedinium leonis + *P. obtusum*	21a
Protoperedinium mite	25a, 97, 92, 26, 17, 11, 15, 14, 23, 72
Protoperedinium pentagonum	28a, 1, 8, 93, 26a, 11, 97, 78, 39
Protoperidinium conicoides group	9a, 19, 11, 27, 87, 97, 82, 4, 78, 15, 17, 27a, 20, 83, 77, 39, 26, 36
Protoperidinium conicum v. concavum	92, 87, 16a, 93, 85, 27, 8, 90, 97, 23a, 7, 25a, 33, 77, 9a, 83, 21a, 22a, 82, 78, 36, 1, 19, 26a, 98, 30, 11, 14, 15, 40, 4, 39
Protoperidinium depressum	14, 4, 27, 9a, 5a, 8, 97, 30, 24, 11a, 10a, 39, 83, 16a, 95, 11, 7a, 23, 50, 56, 36, 17
Protoperidinium divergens	33, 5a, 92, 90, 87, 14, 7a, 8, 7, 79, 101, 4, 100, 28a, 97, 26a, 21a, 16a, 93, 78, 88, 83, 34, 27, 11a, 22a, 85, 25a, 1, 27a, 40, 55, 39, 17, 30
Protoperidinium globulus + *P. ovatum*	27, 1, 23, 25a, 26, 79, 9a, 90, 39, 85, 55, 16a, 88, 27a, 92, 8, 30, 22a, 11, 87, 5a, 70, 7, 17, 33, 71, 66, 83, 40
Protoperidinium grande	1, 90, 88, 27, 39, 8, 66, 11a, 14a, 25a, 87, 83, 50, 79, 40
Protoperidinium murrayi	27
Protoperidinium oblongum + *P. claudicans*	1, 16a, 88, 97, 27, 93, 25a, 87, 83, 26a, 85, 98, 78, 11a, 7, 15, 4, 26, 14a, 90, 11, 14, 23
Protoperidinium oceanicum	11a, 27, 19a, 22a, 66, 16a, 95, 87, 98, 93, 15, 78, 90, 77
Protoperidinium ovum + *P.* sp. 1	27, 66, 36, 11a, 78, 14, 25a, 77, 10a, 93, 87, 59, 33, 14a, 5a, 26a, 16a, 71, 23a, 7, 15, 82, 70, 7a, 100, 23, 99, 85, 98, 101, 83, 11, 40, 39, 20, 30

Protoperidinium pellucidum	7, 36, 93, 92, 25a, 5a, 17, 97, 90, 1, 11a, 27, 87, 16a, 7a, 77, 11, 26, 4, 14a, 19a, 14, 28a, 55, 22a, 99, 100, 23, 9a, 85, 82, 98, 95, 26a, 15, 56, 71, 23a, 25, 101, 27a, 10a, 24, 83, 43, 33, 78, 34
Protoperidinium punctulatum + P. marielebourae + P. thorianum	69, 78, 87, 70, 27a, 4, 8, 85, 16a, 95, 90, 14, 33, 15, 7
Protoperidinium quarnerense + P. hamatum	11a, 9a, 25a, 98, 11, 27, 78, 4, 8, 39, 97, 93, 82, 90, 14a, 24, 101, 16a, 19, 36, 15, 71, 92, 28a, 5a, 23, 77, 56, 26, 21a, 100, 69, 40, 55, 85, 30, 87, 22, 70, 66
Protoperidinium sp. 1b *(*cf *P. pyriforme)*	70, 22a, 39
Protoperidinium sp. 2 + sp. 3	27, 88, 14, 7, 16a, 93, 11a, 83, 25a, 14a, 43, 9a, 27a, 98, 85, 97, 90, 7a, 36, 26, 26a, 15, 87, 33, 55, 100, 34, 8, 21a, 92, 95, 20, 19a, 69, 19, 72, 77, 1, 82, 101, 5a, 79, 25, 24, 40, 23a, 10a, 4, 17, 70, 39, 56, 66, 59, 78, 28a, 22a, 99, 50, 30
Protoperidinium sp. 4 *(P.* cf *oviforme)*	27, 11a, 28a, 25a, 66, 10a, 11, 8, 9a
Protoperidinium sp. 5	39
Protoperidinium spp. (small-sized group)	1, 26, 36, 27, 11, 11a, 78, 66, 77, 14, 93, 33, 17, 39, 28a, 92, 23, 26a, 30, 25a, 4, 7a, 5a, 9a, 15, 98, 71, 90, 50, 21a, 27a, 40, 7, 79, 22a, 70, 19, 20, 87, 22, 19a, 56, 43, 69, 8, 85, 10a, 24, 95, 83, 59, 25, 82, 34
Protoperidinium steinii	11a, 66, 27, 90, 93, 9a, 8, 97, 36, 26, 11, 79, 25a, 19a, 78, 92, 28a, 33, 22a, 88, 14a, 87, 5a, 23a, 22, 20, 39, 34, 85, 16a, 70, 15, 19, 1, 25, 7a, 56, 23, 14, 30
Protoperidinium subinerme	88, 66, 98, 1, 25a, 93, 97, 87, 83, 16a, 5a, 82, 26, 19a, 26a, 27, 11, 9a, 11a, 19
Pyrocystis fusiformis	8, 36, 11, 9a, 17, 7a, 72, 16a, 85, 21a, 4, 25a, 70, 20, 100, 101, 11a, 69, 50, 56, 23, 66, 30
Pyrocystis hamulus	14a
Pyrocystis noctiluca	33, 16a, 26a, 14a, 66, 83, 93, 87, 25a, 79, 11a, 1, 97, 36, 9a, 27, 98, 88, 99, 19, 20, 50, 22a, 78, 26, 39, 23a, 90, 30, 70, 100, 8, 22, 55, 72, 59, 7a, 19a, 21a, 101, 5a, 92, 14, 71, 69, 43
Pyrocystis obtusa + P. robusta	11, 90, 34, 50, 9a, 10a, 66, 7a
Pyrodinium bahamense	66, 88, 23a, 70, 78, 25a
Pyrophacus horologicum	7a, 4, 1, 9a, 78, 14, 23a, 27, 16a, 26a, 87, 98, 22a, 28a, 11, 8, 56
Pyrophacus steinii	93, 78
Scrippsiella sp.	7, 27a, 9a, 92, 16a, 79, 50, 7a, 82, 90, 55, 27, 34, 85, 26, 87, 43, 66, 88, 40, 59, 77, 36, 14, 26a, 95, 1, 28a, 70, 72, 4, 19a, 5a, 97, 15, 23a, 100, 69, 71, 8, 30, 78, 17, 20, 19, 21a, 22
Scrippsiella trochoidea	36, 50, 27a, 26, 55, 7, 77, 79, 25, 43, 99, 1, 27, 40, 82, 78, 88, 14, 19, 14a, 17, 5a, 20, 59, 83, 30, 92, 9a, 69, 101, 23a, 23, 24, 7a, 70, 71, 72, 33, 15, 100, 93, 8, 19a, 22, 98, 90, 16a, 97, 66, 34, 95, 85, 4, 11, 56, 10a
Sinophysis ebriolum	27

Spiraulax jolliffei	93, 23a, 78, 22a, 100, 14a, 87, 90, 16a, 8, 95, 34, 33, 28a
Torodinium robustum	36, 30, 19a, 24, 66, 40, 20, 70, 77, 16a, 93, 87, 79, 26, 50, 25a, 19, 92, 83, 14a, 82, 97, 22a, 23, 95, 90, 28a, 78, 88, 39, 25, 34, 22, 27a, 69, 55, 56, 7a, 7, 85, 9a, 5a, 72, 43, 17, 4, 59, 8, 11a, 15, 21a, 71, 10a, 33, 14, 27, 1, 23a, 11, 101, 98, 26a, 100
Torodinium teredo	36, 5a, 70, 34, 33, 26, 40, 19a, 50, 78, 87, 72, 82, 55, 14, 16a, 77, 71, 83, 23a, 43, 24, 7a, 69, 30, 22, 27, 79, 66, 11a, 25, 10a, 85, 39, 17, 15, 59, 9a, 23, 90, 8, 28a, 7, 93, 88, 14a, 92, 56, 20, 11, 95, 19, 27a, 4, 1, 97, 25a, 21a
Triposolenia bicornis	23a
Warnowia violescens	70, 30, 66, 28a, 23a, 97, 21a, 9a, 72, 78, 95, 10a, 69, 55, 14
Trichodesmium sp. (filaments)	40, 55, 77, 43, 69, 72, 87, 20, 11, 70, 11a, 50, 4, 78, 7a, 79, 27, 36, 34, 16a, 14a, 26a, 88, 71, 97, 24, 28a, 25a, 100, 19a, 92, 26, 82, 33, 66, 23, 5a, 93, 95, 23a, 21a, 22a, 15, 1, 59, 10a, 83, 7, 27a
Anabaena-like? sp. (filaments)	34, 50, 33, 59, 43, 36, 23, 10a, 55, 30, 22, 27, 40, 39, 15, 69, 11a, 16a
Dictyocha fibula	90, 93, 22a, 23a, 19a, 92, 88, 97, 25a, 95, 21a, 14a, 56, 30, 8, 66, 36, 16a, 83, 100, 28a, 7a, 82, 4, 20, 26, 27, 26a, 98, 77, 78, 5a, 17, 101, 50, 71, 70, 43, 69, 23, 85, 55, 87, 14, 11, 40
Dictyocha speculum	8, 22a, 97, 71, 20, 23, 1
Ebria tripartite	20, 8, 7, 26, 9a, 19, 7a, 39, 101, 4, 11, 78, 5a
Teleaulax sp.	25, 10a, 24, 20, 30, 19a, 28a, 50, 36, 26, 66, 43, 82, 33, 27a, 40, 55, 19, 14, 7a, 78, 4, 77, 59, 69, 90, 70, 11, 39, 71, 22, 1, 9a, 72, 8, 88, 95, 92, 17, 87, 34, 79, 15, 16a, 5a, 27, 7, 93, 14a, 22a, 56, 97, 23a, 25a, 85, 23, 83, 21a, 11a, 99, 26a
Pyramimonas sp.	34, 56
Eutreptiella sp.	16a, 77, 70, 82, 55, 59, 79, 87, 50, 26, 40, 72, 43, 30, 66, 15, 85, 56, 71, 78, 36, 90, 4, 19, 23a, 7, 27a, 22a, 25a, 95, 93, 20, 10a, 11, 25, 69, 33, 24, 34, 7a, 14
Pterosperma undulatum	50, 55, 25, 85, 23a, 87, 90, 59, 27
Pterosperma polygonum	93, 92, 7
Phaeocystis sp. (colonies)	88, 92, 34, 66, 90, 7a

Annex 4. Occurrence of the Encountered Phytoplankton Taxa in the RSA during Winter 2006 at the Different Stations Sampled.

Frequency of occurrence is categorized 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%.

Taxon	Occurrence: Frequency of Occurrence of each Species out of the Total Samples Collected (N= 191)	Occurrence: %	Occurrence Category
Bacillariophyceae			
Actinocyclus curvatulus	35	18.32	occasional
Actinocyclus octonarius	18	9.42	rare
Actinoptychus senarius	1	0.52	very rare
Amphora cf *angustata*	1	0.52	very rare
Amphora cf *coffeaeformis*	2	1.05	rare
Amphora cf *crassa*	1	0.52	very rare
Amphora cf *proteus*	1	0.52	very rare
Amphora ostrearia	73	38.22	frequent
Asteromphalus flabellatus	15	7.85	rare
Asteromphalus heptactis	14	7.33	rare
Bacillaria paxillefera	19	9.95	occasional
Bacillaria socialis	4	2.09	rare
Bacteriastrum delicatulum	91	47.64	frequent
Bacteriastrum furcatum	20	10.47	occasional
Bacteriastrum hyalinum	86	45.03	frequent
Bellerochea horologicalis	14	7.33	rare
Biddulphia pulchella	2	1.05	rare
Biddulphia tuomeyi	2	1.05	rare
Caloneis liber	68	35.60	frequent
Campylodiscus sp.	4	2.09	rare
Cerataulina bicornis	2	1.05	rare
Cerataulina pelagica	105	54.97	common
Chaetoceros brevis	15	7.85	rare
Chaetoceros cf *dichaeta*	26	13.61	occasional
Chaetoceros coarctatus	86	45.03	frequent
Chaetoceros compressus	99	51.83	common
Chaetoceros curvisetus	71	37.17	frequent
Chaetoceros decipiens	12	6.28	rare
Chaetoceros denticulatus	62	32.46	frequent
Chaetoceros diversus	11	5.76	rare
Chaetoceros lauderi	14	7.33	rare

Chaetoceros lorenzianus forma A	121	63.35	common
Chaetoceros lorenzianus forma B	111	58.12	common
Chaetoceros messanensis	34	17.80	occasional
Chaetoceros peruvianus	57	29.84	frequent
Chaetoceros peruvianus f. *gracilis*	7	3.66	rare
Chaetoceros pseudocurvisetus	42	21.99	occasional
Chaetoceros socialis	8	4.19	rare
Chaetoceros sp. 2 (fragments)	1	0.52	very rare
Chaetoceros sp. 3 (fragments)	1	0.52	very rare
Chaetoceros spp.	2	1.05	rare
Chaetoceros tortissimus	65	34.03	frequent
Climacodium frauenfeldianum	121	63.35	common
Cocconeis sp.	1	0.52	very rare
Corethron criophilum	14	7.33	rare
Corethron histrix	83	43.46	frequent
Coscinodiscus asteromphalus	27	14.14	occasional
Coscinodiscus granii	44	23.04	occasional
Coscinodiscus janischii	23	12.04	occasional
Coscinodiscus oculus-irdis	85	44.50	frequent
Coscinodiscus radiatus	62	32.46	frequent
Coscinodiscus wailesii	10	5.24	rare
Cosciodiscus sp. 1	23	12.04	occasional
Cyclotella spp. *(C. stylorum + C. striata)*	61	31.94	frequent
Cylindrotheca closterium	86	45.03	frequent
Cymatonitzschia marina	60	31.41	frequent
Cymatosira cf *lorenziana*	6	3.14	rare
Dactyliosolen phuketensis	7	3.66	rare
Detonula pumila	18	9.42	rare
Diploneis cf *bombus*	105	54.97	common
Diploneis weissflogii	85	44.50	frequent
Ditylim brightwellii	3	1.57	rare
Enthomoneis sp. 1	2	1.05	rare
Enthomoneis sulcata	26	13.61	occasional
Ephemera planamembranacea	35	18.32	occasional
Eucampia cornuta	82	42.93	frequent
Eucampia zodiacus	74	38.74	frequent
Gomphonema sp	1	0.52	very rare
Guinardia delicatula	75	39.27	frequent
Guinardia delicatula forma B	22	11.52	occasional
Guinardia flaccida	119	62.30	common
Guinardia striata	124	64.92	common
Gyrosigma balticum	1	0.52	very rare
Gyrosigma sp.	1	0.52	very rare
Haslea sp.	51	26.70	frequent

Hemiaulus hauckii	26	13.61	occasional
Hemiaulus membranaceus	39	20.42	occasional
Hemiaulus sinensis	40	20.94	occasional
Hemidiscus cuneiformis	1	0.52	very rare
Lauderia borealis	128	67.02	common
Leptocylindrus danicus	134	70.16	common
Leptocylindrus mediterraneus	16	8.38	rare
Leptocylindrus minimus	12	6.28	rare
Licmophora abbreviata	10	5.24	rare
Lioloma pacifica	1	0.52	very rare
Lithodesmium undulatum	18	9.42	rare
Lyrella abrupta	3	1.57	rare
Mastogloia sp.	13	6.81	rare
Meuniera membranacea	67	35.08	frequent
Navicula spp.	101	52.88	common
Neocalyptrella robusta	20	10.47	occasional
Nitzschia cf *sigma*	9	4.71	rare
Nitzschia cf *sigmaformis*	20	10.47	occasional
Nitzschia fluminensis	12	6.28	rare
Nitzschia longissima v. *longissima*	7	3.66	rare
Nitzschia longissima v. *parva*	1	0.52	very rare
Nitzschia lorenziana	55	28.80	frequent
Nitzschia sigma	23	12.04	occasional
Nitzschia sp. 1	119	62.30	common
Nitzschia sp. 5	1	0.52	very rare
Nitzschia sp. 6	36	18.85	occasional
Odontela sinensis	40	20.94	occasional
Odontella aurita	3	1.57	rare
Odontella mobiliensis	43	22.51	occasional
Palmeria hardmaniana	15	7.85	rare
Paralia sulcata	23	12.04	occasional
Petrodictyon gemma	2	1.05	rare
Petroneis granulata	1	0.52	very rare
Plagiotropis lepidoptera	61	31.94	frequent
Plagiotropis sp. 1	24	12.57	occasional
Plagiotropis sp. 2	5	2.62	rare
Planktoniella sol	87	45.55	frequent
Pleurosigma diverse-striatum	160	83.77	ubiquitous
Pleurosigma naviculaceum	108	56.54	common
Pleurosigma planctonicum	5	2.62	rare
Pleurosigma sp. 1	83	43.46	frequent
Podosira stelliger	4	2.09	rare
Porosira sp.	11	5.76	rare
Probosca alata f. *gracillima*	49	25.65	frequent

Proboscia alata	74	38.74	frequent
Proboscia indica	72	37.70	frequent
Psammodyction panduriformis	4	2.09	rare
Pseudonitzschia delicatissima group	150	78.53	ubiquitous
Pseudonitzschia pungens	55	28.80	frequent
Pseudonitzschia seriata group	5	2.62	rare
Pseudonitzschia sp. 3	2	1.05	rare
Pseudonitzschia sp. 5	25	13.09	occasional
Pseudosolenia calcar-avis	12	6.28	rare
Rhizosolenia bergonii	39	20.42	occasional
Rhizosolenia cochlea	29	15.18	occasional
Rhizosolenia hebetata f. *semispina*	126	65.97	common
Rhizosolenia hyalina	80	41.88	frequent
Rhizosolenia imbricata	92	48.17	frequent
Rhizosolenia setigera	82	42.93	frequent
Rhizosolenia shrubsolei	130	68.06	common
Rhizosolenia sp. 1	11	5.76	rare
Skeletonema costatum	39	20.42	occasional
Stephanopyxis palmeriana	69	36.13	frequent
Streptotheca indica	40	20.94	occasional
Streptotheca tamesis	38	19.90	occasional
Surirella fastuosa	88	46.07	frequent
Surirella fastuosa forma B	13	6.81	rare
Synedra sp. 1	18	9.42	rare
Synedra sp. 2	1	0.52	very rare
Thalassionema nitzschioides	158	82.72	ubiquitous
Thalassiosira eccentrica	88	46.07	frequent
Thalassiosira oestrupii	73	38.22	frequent
Thalassiosira spp.	3	1.57	rare
Thalassiothrix frauenfeldii	102	53.40	common
Thalassiothrix longissima	48	25.13	occasional
Trachyneis antillarum	102	53.40	common
Trachyneis debyi	16	8.38	rare
Triceratium robertsianum	3	1.57	rare
Dinophyceae			
Achradina pulchra	62	32.46	frequent
Actiniscus pentasterias	11	5.76	rare
Akashiwo sanguinea	2	1.05	rare
Alexandrium tamiyavanichii	29	15.18	occasional
Amphisolenia bidentata	8	4.19	rare
Amphisolenia globifera	2	1.05	rare
Balechina coerulea	30	15.71	occasional
Ceratium breve	59	30.89	frequent
Ceratium candelabrum	6	3.14	rare

Ceratium dens	18	9.42	rare
Ceratium extensum	9	4.71	rare
Ceratium falcatum	15	7.85	rare
Ceratium furca	88	46.07	frequent
Ceratium fusis	103	53.93	common
Ceratium gibberum	15	7.85	rare
Ceratium hexacanthum	2	1.05	rare
Ceratium horridum	14	7.33	rare
Ceratium lineatum	80	41.88	frequent
Ceratium lunula	4	2.09	rare
Ceratium macroceros	21	10.99	occasional
Ceratium massiliense	47	24.61	occasional
Ceratium massiliense v. *armata*	1	0.52	very rare
Ceratium minutum	12	6.28	rare
Ceratium ranipes	5	2.62	rare
Ceratium tenue v. *buceros*	11	5.76	rare
Ceratium trichoceros	69	36.13	frequent
Ceratium tripos	1	0.52	very rare
Ceratium vultur v. *sumatranus*	4	2.09	rare
Ceratocorys armata	2	1.05	rare
Cochlodinium brandtii	122	63.87	common
Cochlodinium polykrikoides	13	6.81	rare
Cochlodinium sp.	7	3.66	rare
Corythodinium constrictum	5	2.62	rare
Corythodinium tesselatum	18	9.42	rare
Dicroerisma psilonereiella	17	8.90	rare
Dinophysis acuminata	5	2.62	rare
Dinophysis caudata	51	26.70	frequent
Dinophysis doryphorum	2	1.05	rare
Dinophysis miles	26	13.61	occasional
Dinophysis mitra	6	3.14	rare
Dinophysis nasutum	12	6.28	rare
Dinophysis rotundata	52	27.23	frequent
Dinophysis rudgei	6	3.14	rare
Dinophysis sp. 2	11	5.76	rare
Diplopelta bomba	123	64.40	common
Diplopelta parva	30	15.71	occasional
Diplopsalis lenticula	31	16.23	occasional
Dissodinium pseudolunula	2	1.05	rare
Goniaulax turbynei	9	4.71	rare
Goniodoma polyedricum	17	8.90	rare
Gonyaulax birostris	1	0.52	very rare
Gonyaulax diegensis	5	2.62	rare
Gonyaulax digitale	22	11.52	occasional

Gonyaulax fragilis + G. hyalina	74	38.74	frequent
Gonyaulax polygramma	25	13.09	occasional
Gonyaulax sp. 1	1	0.52	very rare
Gonyaulax sp. 2	1	0.52	very rare
Gonyaulax sp. 3	1	0.52	very rare
Gonyaulax sp. 5	6	3.14	rare
Gonyaulax spinifera	10	5.24	rare
Gonyaulax verior	15	7.85	rare
Gymnodinium catenatum	54	28.27	frequent
Gymnodinium sp. 1	34	17.80	occasional
Gymnodinium sp. 11	13	6.81	rare
Gymnodinium sp. 12	3	1.57	rare
Gymnodinium sp. 13	2	1.05	rare
Gymnodinium sp. 17	4	2.09	rare
Gymnodinium sp. 1a	18	9.42	rare
Gymnodinium sp. 2 (large-sized form)	15	7.85	rare
Gymnodinium-like group	182	95.29	ubiquitous
Gyrodinium calyptoglyphe	9	4.71	rare
Gyrodinium falcatum	11	5.76	rare
Gyrodinium fusiforme	180	94.24	ubiquitous
Gyrodinium sp. 5	41	21.47	occasional
Gyrodinium spirale	129	67.54	common
Heterocapsa sp. 2	23	12.04	occasional
Heterocapsa sp.1	61	31.94	frequent
Heterocapsa triquetra	12	6.28	rare
Histioneis cymballaria	1	0.52	very rare
Histoneis costata	6	3.14	rare
Karenia brevis	17	8.90	rare
Katodinium glandula	1	0.52	very rare
Kofoidinium velleloides	3	1.57	rare
Lingulodinium polyedrum	2	1.05	rare
Mesoporos perforatus	113	59.16	common
Noctiluca scincillans	87	45.55	frequent
Ornithocercus magnificus	15	7.85	rare
Ornithocercus quadratus	3	1.57	rare
Ornithocercus splendida	1	0.52	very rare
Ornithocercus steinii	12	6.28	rare
Oxytoxum curvatum	44	23.04	occasional
Oxytoxum elegans	1	0.52	very rare
Oxytoxum gracilis	55	28.80	frequent
Oxytoxum milneri	2	1.05	rare
Oxytoxum sceptrum	32	16.75	occasional
Oxytoxum scolapax	2	1.05	rare
Oxytoxum sp. 1	41	21.47	occasional

Oxytoxum sp. 3	27	14.14	occasional
Oxytoxum sp. 5	2	1.05	rare
Oxytoxum variabile	160	83.77	ubiquitous
Peridinium bipes	1	0.52	very rare
Peridinium quinquecorne	1	0.52	very rare
Podalampas bipes	2	1.05	rare
Podalampas palmipes	18	9.42	rare
Polykrikos schwarzii	37	19.37	occasional
Pronoctiluca pelagica	27	14.14	occasional
Pronoctiluca spinifera	40	20.94	occasional
Prorocentrum balticum	6	3.14	rare
Prorocentrum compressum	57	29.84	frequent
Prorocentrum dentatum	29	15.18	occasional
Prorocentrum gracilis	69	36.13	frequent
Prorocentrum micans	89	46.60	frequent
Prorocentrum minimum	40	20.94	occasional
Prorocentrum rhathymum	17	8.90	rare
Prorocentrum sigmoides	4	2.09	rare
Prorocentrum triestinum	37	19.37	occasional
Protoceratim reticulatum	2	1.05	rare
Protoperedinium biconicum +. *P. abei*	1	0.52	very rare
Protoperedinium conicum v. *quardafuianum*	1	0.52	very rare
Protoperedinium curtipes	20	10.47	occasional
Protoperedinium curvipes	6	3.14	rare
Protoperedinium denticulatum	1	0.52	very rare
Protoperedinium leonis + P. obtusum	1	0.52	very rare
Protoperedinium mite	10	5.24	rare
Protoperedinium pentagonum	10	5.24	rare
Protoperidinium conicoides group	22	11.52	occasional
Protoperidinium conicum v. *concavum*	40	20.94	occasional
Protoperidinium depressum	32	16.75	occasional
Protoperidinium divergens	53	27.75	frequent
Protoperidinium globulus + P. ovatum	36	18.85	occasional
Protoperidinium grande	19	9.95	occasional
Protoperidinium murrayi	1	0.52	very rare
Protoperidinium oblongum + P. claudicans	31	16.23	occasional
Protoperidinium oceanicum	18	9.42	rare
Protoperidinium ovum + P. sp. 1	47	24.61	occasional
Protoperidinium pellucidum	66	34.55	frequent
Protoperidinium punctulatum + P. marielebourae + P. thorianum	17	8.90	rare

Protoperidinium quarnerense + *P. hamatum*	63	32.98	frequent
Protoperidinium sp. 1b (cf *P. pyriforme*)	3	1.57	rare
Protoperidinium sp. 2 + sp. 3	104	54.45	common
Protoperidinium sp. 4 (*P.* cf *oviforme*)	10	5.24	rare
Protoperidinium sp. 5	1	0.52	very rare
Protoperidinium spp. (small-sized group)	86	45.03	frequent
Protoperidinium steinii	55	28.80	frequent
Protoperidinium subinerme	23	12.04	occasional
Pyrocystis fusiformis	29	15.18	occasional
Pyrocystis hamulus	1	0.52	very rare
Pyrocystis noctiluca	74	38.74	frequent
Pyrocystis obtusa + *P. robusta*	8	4.19	rare
Pyrodinium bahamense	6	3.14	rare
Pyrophacus horologicum	23	12.04	occasional
Pyrophacus steinii	2	1.05	rare
Scrippsiella sp.	59	30.89	frequent
Sinophysis ebriolum	1	0.52	very rare
Spiraulax jolliffei	14	7.33	rare
Surirella fastuosa	88	46.07	frequent
Torodinium robustum	156	81.68	ubiquitous
Torodinium teredo	135	70.68	common
Triposolenia bicornis	1	0.52	very rare
Warnowia violescens	19	9.95	occasional
Cryptophyceae			
Teleaulax sp.	166	86.91	ubiquitous
Cyanophyceae			
Anabaena-like? sp. (filaments)	40	20.94	occasional
Trichodesmium sp. (filaments)	73	38.22	frequent
Dictyochophyceae			
Dictyocha fibula	100	52.36	common
Dictyocha speculum	8	4.19	rare
Euglenophyceae			
Eutreptiella sp.	64	33.51	frequent
Prasinophyceae			
Pterosperma polygonum	3	1.57	rare
Pterosperma undulatum	9	4.71	rare
Pyramimonas sp.	2	1.05	rare
Prymnesiophyceae			
Phaeocystis sp. (colonies)	7	3.66	rare
Ebriidae			
Ebria tripartita	23	12.04	occasional

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