Studies on ecology of microphytoplankton from the Northern Indian Ocean

Thesis submitted to the Goa University
for the award of the Degree of
Doctor of Philosophy
in
Marine Sciences

By
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CERTIFICATE

This is to certify that the thesis entitled "Studies on ecology of microphytoplankton from the northern Indian Ocean' submitted by Rajath R. Chitari for the award of Degree of Doctor of Philosophy in Marine Sciences is based on his original studies carried out by him under my supervision. The thesis or any part thereof has not been previously submitted for any other degree or diploma in any Universities or Institutions.

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2019-6-10 11:50

Statement

As required under the University ordinance OB9-A, I state that the present thesis titled " Studies on ecology of microphytoplankton from the northern Indian Ocean" is my original contribution and has not been submitted on any previous occasion. To the best of my knowledge the present study is the first compharensive work of its kind from the area mentioned. The literature related to the problem investigated has been sited. Due acknowledgements have been made wherever facilities and suggestions have been availed of.

Rajath R. Chitari

2019-6-10 11:50

Dedicated to my late father

Shri. Rajaram V. Chitari

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Chapter 1: Introduction

Phytoplankton comprise of several groups of organisms which include diatoms, dinoflagellates, prymnesiophytes flagellates coccolithophores and cyanobacteria. There are at least 25,000 identified species, amongst them diatoms and dinoflagellates are diverse taxonomic group with broad range in size, morphology, behavior, and biochemistry (Tomas, 1997; Taylor et al., 2008), They also have important role in the functioning of ecosystem (Cushing, 1989). Diatoms are known to proliferate in nutrient rich turbulent waters (Margalef, 1978) and transfer organic carbon to higher trophic levels (Smetacek, 1985). Whereas, dinoflagellates prefer stable water column and in depleted nutrient conditions (Barton et al., 2013). The marine food webs dominated by diatoms and dinoflagellates are quite different in mineral export and recycling and thus play different role in regulating biogeochemical cycles (Cushing, 1989). In the ocean, it is estimated that primary producers contribute 45 to 50 GT carbon ($Year^{-1}$) and account for about 96% of the total marine primary productivity (Longhurst et al., 1995).

Phytoplankton community can also be categorized based on size, shape and nutritional mode. The growth of the phytoplankton is controlled by combination of factors such as temperature, light availability and nutrients (Nitrogen, Phosphate, Silicate and Iron) and influenced by physical processes. Variations in phytoplankton biomass have been related to the intra- and inter-annual changes of the environmental variability (Montecino et al., 2006). Long term variability in phytoplankton can be mapped through time series analysis. Such studies help in analysing variations in abundance and species composition over a period of time.

In the microphytoplankton community, *Tripos* is a species rich genera within dinoflagellates. *Tripos* are known to be ubiquitous and slow growing, found in all the seasons and substantially contributing to annual primary production (Dodge and Marshall, 1994). Their distribution ranges from polar to tropics and also from neritic to open ocean (Sournia, 1967; Dodge and Marshall, 1994). In the waters of North Atlantic, Mediterranean Sea, Pacific, Arctic and Indian Ocean some of the forms of *Tripos* are used as water mass indicators and their movement in relation to temperature was also observed (Subrahmanyan, 1968; Dowidar, 1973; Dodge, 1993; Dodge and Marshall, 1994; Okolodkov, 1996; Sanchez et al., 2000; Tunin-Ley et al., 2007). In earlier studies from the waters of Indian subcontinent *Tripos* were reported qualitatively by description and illustration (Subrahmanyan, 1968; Taylor, 1976).

The Bay of Bengal has two different water mass characteristics, with low saline water due to enormous freshwater influx in the northernmost bay and relatively high saline water in the Southern bay due to negligible freshwater discharge. Under such a habitat characteristic, mapping the distribution of *Tripos* is expected to provide new insights.

Phytoplankton cell size varies from one organism to another and also among the individuals. To study the ecosystem application and modelling of food web, it is essential to convert phytoplankton cell abundance into a common currency such as wet weight, nitrogen or carbon biomass (Harrison et al., 2015). Converting phytoplankton abundance to a carbon currency requires an estimate of cell volume. In the Indian Ocean microphytoplankton cell abundance data are available (Devassy and Goes, 1988; Paul et al., 2007; D’Costa et al., 2008; Hegde et al., 2008; Jyothibabu et al., 2008; Patil and Anil 2008; Naik et al., 2010; D’Costa et al., 2010; Patil and Anil, 2011). However, species specific cell volume is meagre (Mitra et al., 2012; Harrison et al., 2015).

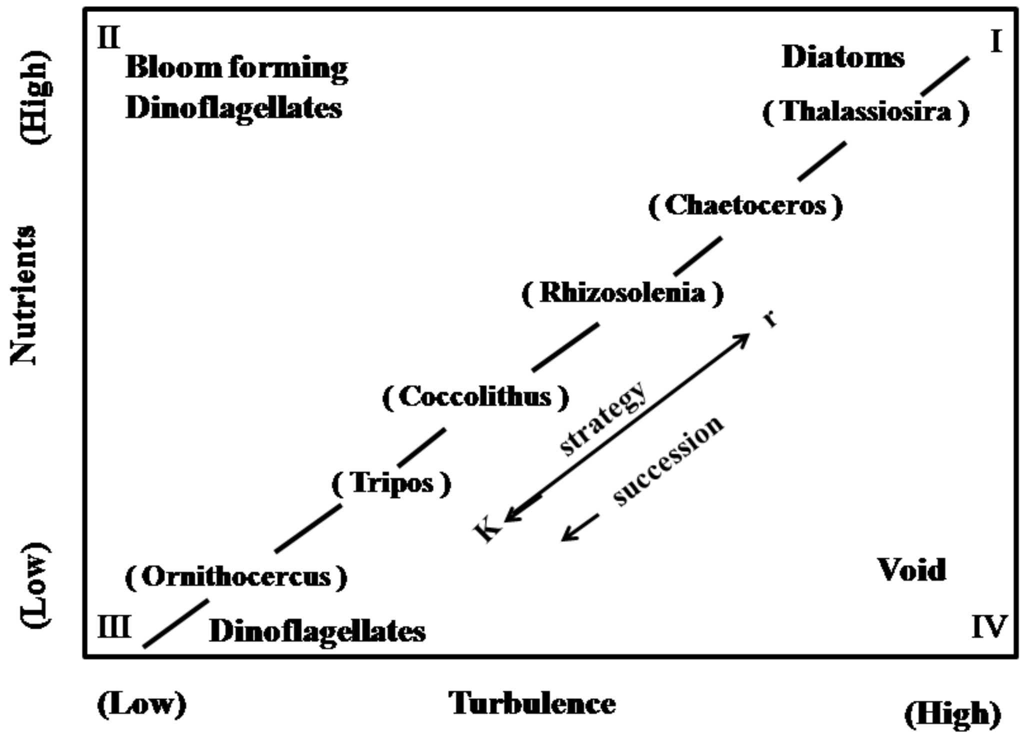

Fig. 1.1 Phytoplankton strategies in different nutrient and turbulent settings along with a plot of principle life forms. (Adapted from Margalef, 1978). The domain is categorized into four different habitat types depicting varying nutrient and turbulent conditions (Low to High). The diagonal line represents the pattern of succession (r v/s K) strategy along with representative forms.

The phytoplankton community is influenced by light and nutrient availability. It has also been observed earlier that shape and cell size of phytoplankton inhabiting similar environments (Margalef, 1978; Smayda, 1980) indicate direct relationship between morphology and physiology (Lewis,1976; Sournia,1982; Alves-De-Souza et al., 2008). Margalef (1978) conceptualized a model known as Margalef Mandala or Margalef elegant model, in which phytoplankton species composition are determined mainly by nutrients and turbulence. In phytoplankton succession, diatoms dominate during the periods of mixing at a high nutrient concentration ('r' strategies) and dinoflagellate prevail under oligotrophic and thermally stratified conditions ('K' strategies) (Fig. 1.1).

Although Margalef's 'r' v/s 'K' adequately explained diatom to dinoflagellate successional stages in several temperate waters (Margalef, 1978). Later based on the Grime's (Grime, 1979) model for terrestrial vegetation, Reynolds (Reynolds, 1988) differentiated r-K concept into three primary strategies. C-strategists (colonist-invasive) are small, fast-growing, high surface to volume ratio, susceptible to grazing and dominate in high nutrient and stratified waters. The S-strategists (stress-tolerance) are large species, slow-growing, low surface to volume ratio, and dominate in oligotrophic, high light conditions in which they can use strategies like mixotrophy and vertical migrations to obtain nutrients. The R-strategists (ruderal) are elongated in shape with high surface to volume ratio prevailing under high mixing conditions. The scheme proposed by Reynolds (Reynolds, 1988) has also been applied towards marine dinoflagellates that produces harmful algal blooms (Smayda and Reynolds, 2001). Since the life forms ('r' v/s 'K') and adaptive strategies (C-S-R) proliferate in different habitat types. Smayda and Reynolds (Smayda and Reynolds, 2001) identified IX different types based on variations in nutrient and water column mixing. The type I habitat is categorized as relatively shallow and mesohaline, reduced watermass exchange with offshore waters, with blooming of intermediate size gymnodinioid species. In type II habitat the nutrient levels are somewhat lower but still elevated with the dominance of peridinians and prorocentroids as blooming taxa. The type III habitat is dominated by *Ceratians*. Their assemblages extend offshore into stratified coastal waters and remain responsive to nutrient loading. The habitat characteristics of type IV to IX are provided in Fig.1.2 referred from Smayda and Reynolds (2001).

Most of the characterization of life forms with reference to habitats is from the temperate waters [for examples Ecuador (Jimenéz, 1993), Japan (Iizuka and Irie, 1969; Iizuka, 1972), Korea (Park, 1991), Norway (Tangen, 1979), Oslofjord (Braarud, 1945), German Bight (Hickel et al., 1989), New York Bight (Falkowski et al., 1980), Kattegat (Granéli et al., 1989), English Channel (Holligan, 1987), North Sea (Dahl and Tangen, 1993), Skagerrak and Gulf of St Lawrence (Blasco et al., 1996)].

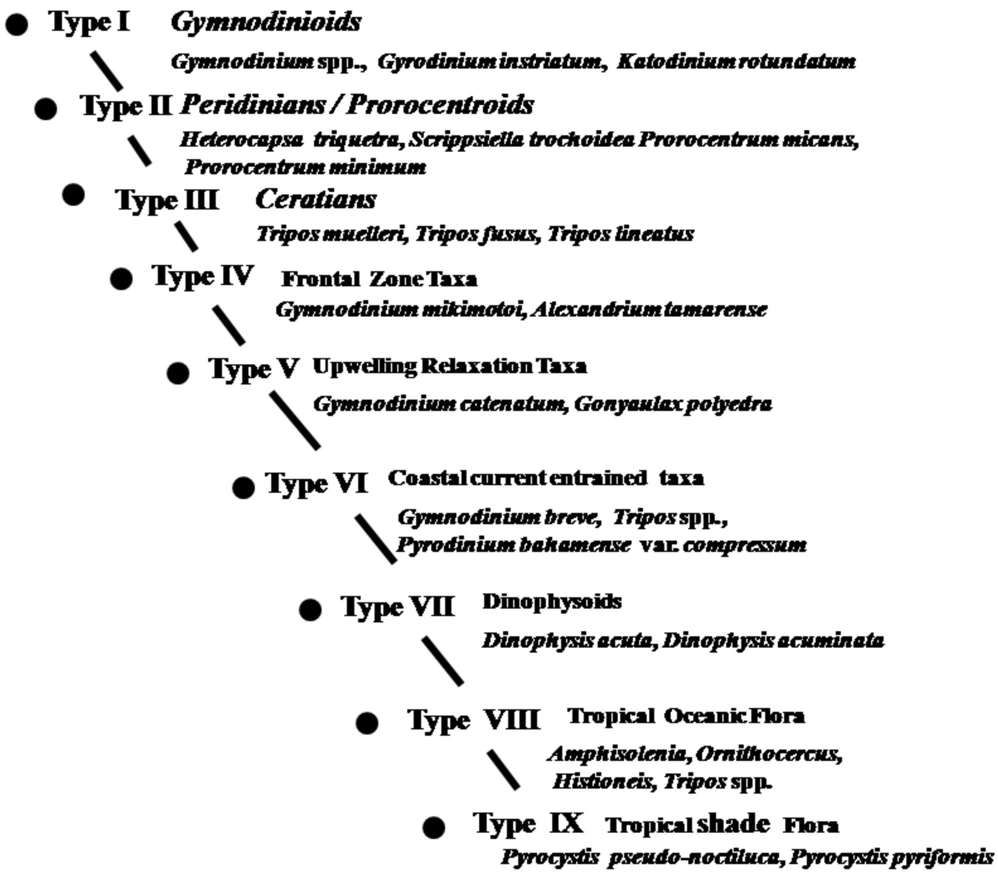

Fig. 1.2 "Dinoflagellate bloom and vegetation life-form Types, and representative species, found along an onshore-offshore gradient of decreasing nutrients, reduced mixing, and deepened euphotic zone." The figure is referred from Smayda and Reynolds(2001).

Apart from dinoflagellates, application of Margalefs Mandala ('r v/s K') and Reynolds Intaglio 'C-S-R' scheme has been applied to diatom population in the temperate waters for e.g fjords of southern Chile (Alves-De-Souza et al., 2008), northwestern Mediterranean Sea (Vila et al., 2005), Ria de Vigo, Galicia, Spain (Nogueira and Figueiras, 2005) and tropical waters of South Eastern Brazil, Continental shelf off Rio de Janeiro (Leles et al., 2014; Moser et al., 2014). Wyatt (2014) in his review with reference to Margalef's model discussed the dynamic features and significance of bloom-forming species and attributed it to suites of traits which results in specific demographic strategies. Glibert (2016) revisited Margalef's Mandala with twelve environmental characteristics or response traits and related it to different phytoplankton types.

There has been no attempt to characterise microphytoplankton community based on habitat characteristics (Margalef's Mandala and Reynolds Intaglio) in the northern Indian Ocean. There are several descriptive studies on phytoplankton diversity and community dynamics for e.g. (D'Costa et al., 2008; Hegde et al., 2008; D'Costa and Anil, 2010; Naik et al., 2010). However, till now no attempt has been made to apply the two models.

Bay of Bengal has unique characteristics such as enormous amount of freshwater discharge by major riverine systems, monsoonal cloud cover, and seasonal reversal of currents influenced by the monsoons that control the physico-chemical characteristics. Hence, this region can be an example of different habitat types in the tropical environment. The Bay of Bengal can be categorized into three different habitats. The northernmost bay with the influence of riverine discharge as Type II, The northernmost part of the bay is also transformed during North East Monsoon to Type III, and the southern bay during South West Monsoon (SWM) and North East Monsoon (NEM) can be categorized as Type V, (See Fig. 1.2) under such a scenario the community structure can be expected to vary both spatially and temporally.

The Arabian Sea and Bay of Bengal form the two arms of Northern Indian Ocean, adjoining the sub-continent of India. The Arabian Sea, productivity is influenced by upwelling during South West Monsoon and convective mixing in the North Eastern part of Arabian Sea.

In order to evaluate the role of microphytoplankton its habitat preference, adaptive strategies in relation to the physico-chemical conditions water samples were collected for the analysis of microphytoplankton from four different tracks of Bay of Bengal, and the north eastern Arabian sea. This study explores the ecology of microphytoplankton from the Northern Indian Ocean.

OBJECTIVES AND OVERVIEW OF THESIS:

Objective 1: Microphytoplankton community structure in the surface waters of the Bay of Bengal and its relation to environmental characteristics

Studies on microphytoplanktonin the Bay of Bengal are mostly confined to shorter spatio-temporal scales and mainly restricted to the western Bay of Bengal, for e.g. (Madhupratap et al., 2003; Madhu et al., 2006; Paul et al., 2007; Jyothibabu et al., 2008; Paul et al., 2008). Dinoflagellates distribution from this region were explored from the perspective of Harmful Algal Blooms (Naik et al., 2010). In the present study efforts were made to evaluate the role of different microphytoplankton groups and their response with seasonally changing environmental conditions by physical processes in the Bay of Bengal. This aspect is presented in (**Chapter 2**). Further, it was also observed that genus *Tripos* is an important component of microphytoplankton. Among the thecate dinoflagellates, *Tripos* represent a significant part of the microphytoplankton community (Tunin-Ley et al., 2007). They are used as watermass indicators in several biogeographic regions (Dowidar, 1973; Dodge, 1993; Dodge and Marshall, 1994; Okolodkov, 1996; Sanchez et al., 2000; Raine et al., 2002). Although there is information available on dinoflagellates from several international expeditions as well as those that have passed through waters along the Indian subcontinent. Most of the authors studied *Tripos* qualitatively by reporting the presence of species in the form of description and illustration (Matzenauer, 1933). From the literature, it can be seen that information on the abundance and diversity of *Tripos* at a spatio-temporal scale is lacking. Since it is understood that the *Tripos* is used as an indicator of water mass as stated above, a study was undertaken to map the distribution of *Tripos* in the Bay of Bengal from October 2006 – September 2011 **(Chapter 3).**

Objective 2: Structural and functional characteristics of microphytoplankton from the Arabian Sea and the Bay of Bengal

Information related to microphytoplankton community, and its distribution are mapped using several research cruises from the Bay of Bengal and Arabian Sea. However such information have primarily documented for primary production, community structure, abundance and diversity (Madhupratap et al., 2003; Madhu et al., 2006; Paul et al., 2007; Jyothibabu et al., 2008; Paul et al., 2008). Phytoplankton cell counts and chlorophyll *a* are generally used to determine the productivity and food web dynamics. In several studies, chlorophyll *a* is mainly used as a proxy to phytoplankton carbon. There are large variations in Carbon to Chlorophyll (C/Chl) ratio and can be seen within and among the species due to variations in physico-chemical conditions such as temperature, nutrients and light. The bulk amount of measured chlorophyll *a* hides the amount of carbon contributed by individual species. It is necessary to convert phytoplankton cell counts to cell volume to measure accurate carbon biomass. Several studies from the northern Indian Ocean provide cell abundance data but lack species specific cell volume and carbon content per cell. In this study, phytoplankton samples collected from the surface waters of Bay of Bengal, northern Arabian Sea, and Dona Paula Bay (located at Goa, West coast of India) were utilized to quantify changes in cell size, cell volume and carbon per cell of diatoms and dinoflagellates. The inter and intra-annual variations in cell volume are also provided from the surface waters of the Bay of Bengal. A comparison is also made with the commonly available forms in all the three regions i.e. Mediterranean, Pacific and North Atlantic with the northern Indian Ocean (**Chapter 4**).

Further, the microphytoplankton datasets comprising diatoms, dinoflagellates were mapped at an inter- and intra-annual scales from the perspective of Margalef's Mandala and Reynolds intaglio (Margalef, 1978; Smayda and Reynolds, 2001). Since the Bay of Bengal experiences variations in physico-chemical characteristics with seasons, it can be expected that microphytoplankton species with different size and shape can use its unique strategies and can adapt towards the magnitude of nutrient and water column mixing. Till now no attempt has been made to apply these models towards microphytoplankton community from the waters of the Indian Ocean. For the first time the two models (Margalef's Mandala and Reynolds' Intaglio model) were applied to identify whether the adaptationsare influenced by the environmental characteristics in the surface waters of the Bay of Bengal (**Chapter 5**).

Arabian Sea and Bay of Bengal that are on the either side of the sub-continent of India have different physico-chemical characteristics. The Arabian Sea shows remarkable changes in physico-chemical conditions with upwelling during South West Monsoon and convective mixing during North East Monsoon in the north eastern part of Arabian Sea (Banse, 1968; Banse and McClain, 1986; Shetye et al., 1994; Madhupratap et al., 1996). The deepening of the mixed layer and nutrient injection from bottom to the surface and sub-surface known to influence phytoplankton community dynamics. Microphytoplankton community and abundance remain poorly understood during the phase of winter convection. In this study the role of different physico-chemical conditions such as nutrients on the variation of microphytoplankton during two different phases of winter i.e. early to peak winter was studied **(Chapter 6)**.

A summary is presented as **(Chapter 7)**.

Chapter 2: Inter- and intra-annual variations in the microphytoplankton from the surface waters of Bay of Bengal

2.1 Introduction

In the marine environment phytoplankton play a key role by forming the base of the food web and having a substantial function in the carbon biogeochemical cycle and nutrient dynamics (Grahm and Wilcox, 2000; Sarmiento and Gruber, 2006; Almandoz et al., 2011). The variations in phytoplankton is associated with the changes in the environmental variables such as water column stability, availability of light, nutrient or grazing pressure (Almandoz et al., 2011). There is a growing impetus to gain greater understanding of phytoplankton community dynamics as phytoplankton are recognized as potential indicators of both climate change (Edwards and Richardson 2004; Edwards et al., 2006) and the effects of anthropogenic influence in the marine environment. In the marine ecosystem changes in turbulent mixing are often accompanied by shifts from dominance of dinoflagellates at weak turbulent mixing to the dominance by diatoms at intense turbulent mixing (Jones and Gowen, 1990; Lauria et al., 1999; Irigoen et al., 2000). Phytoplankton community composition are also influenced by a number strong seasonal cycles in bottom up factors such as light availability, temperature, nutrient loading by rainfall, river runoff and stratification (Thompson et al., 2008). Different phytoplankton species respond differently to the same nutrient conditions because of differing nutrient requirements and half saturation constant among the species (Vallina et al., 2017, Lagus et al., 2004). Long term studies on phytoplankton abundance and its composition from the oligotrophic waters were carried out from the waters of English channel (Widdicombe et al., 2010), Bay of Biscay (Beaugrand et al., 2000) and Northernmost part of the

Adriatic Sea (Giani et al., 2012), Gulf of Gabes (Drira et al., 2009), and Strait of Otranto of Mediterinean (Vilicic et al., 1995). In the Atlantic (Laterme et al., 2005; McQuatters-Gollop, 2007; Olenina et al., 2006) and Pacific wates (Venrick, 1982). In the tropical ocean the typical structure of the water column consists of three distinct layers, a superficial hot mixed layer with low nutrient concentrations, a conspicuous thermocline enriched by diffusion with the nutrient of an underlying layer and the deeper layer characterized by low temperatures and higher nutrient concentrations (Maan and Lazier, 1991).

The region with low nutrient concentrations of the tropical and sub tropical oceans are dominated by small phytoplankton, whereas regions with high nutrient concentrations support large phytoplankton cells (Irwin et al., 2006). The seasonal variations in low latitude waters is least distinct and is attributed to the solar insolation that thermally stratifies the water column. As a result the regions outside the upwelling zones and winter convective induced by seasonal surface cooling in the tropics and sub tropics is permanently oligotrophic and phytoplankton biomass, primary production are low throughout the year with the exception of local forcing that leads to minor variations. The oligotrophic areas are very sensitive to environmental variations and their monitoring is essential for the evaluation of the long term changes in the community structure.

Since the Bay of Bengal is situated in the tropical region, their changes in the environmental conditions driven by monsoon and riverine discharge makes the bay a unique system. After the International Indian Ocean Expedition (IIOE) from 1959 to 1965 several cruises were undertaken to study physical and chemical characteristics of the water column from the Bay of Bengal (Shetye et al., 1991, 1993; Shankar et al., 2002; Sen Gupta et al., 1977; De Sousa et al., 1981; Rao et al., 1994). Biology was also addressed by mapping chlorophyll biomass and primary productivity (Radhakrishna et al., 1978; Madhupratap et al., 2003; Gomes, 2000). Information on phytoplankton biomass quantified using microscopic cell counts are available at very few episodic events.

Most of the studies related to plankton diversity and community dynamics are descriptive with special reference to Microzooplankton (Jyothibabu et al., 2003; Jyothibabu et al., 2008), Diatoms (Paul et al., 2007; Paul et al., 2008), Dinoflagellates (Naik et al., 2010) and Cyanobacteria (Devassy et al., 1978; Jyothibabu et al., 2003; Hegde et al., 2008). However till now no attempt has been made to map the inter and intra-annual trends and its adaptations in relation to the seasonally changing physico-chemical conditions. The Bay of Bengal is influenced by enormous freshwater discharge, monsoonal cloud cover, and seasonal reversal of currents influenced by monsoon that control the water column characteristics. Hence understanding of inter and intra-annual variations of microphytoplankton cell counts and its adaptations can provide a novel information on ecosystem characteristics.

The objective of this study was to map the microphytoplankton and to evaluate how the physico-chemical conditions influence its distribution.

2.2 Material and Methods

2.2.1 Study area and Sampling strategy

Surface water samples were collected from the Bay of Bengal, hereafter referred to as (BoB) along the shipping route viz: From Chennai to Port Blair (81°00’ E/ 13°00’ N to 92°00’ E/ 11°23’ N) and Port Blair to Kolkata (12°00' N / 93°14'E to 21°00'N / 88°23' E) (Fig.2.1). Samples were collected from 22 stations (separated by one-degree intervals) of which, 12 stations were located along the Chennai to Port

Blair transect (C-P) and 10 Station along the Port Blair to Kolkata transect (P-K). Sampling was carried out from October 2006 to September 2011(Appendix A1 and A2) on 48 and 38 occasions along both C-P and P-K transect respectively.

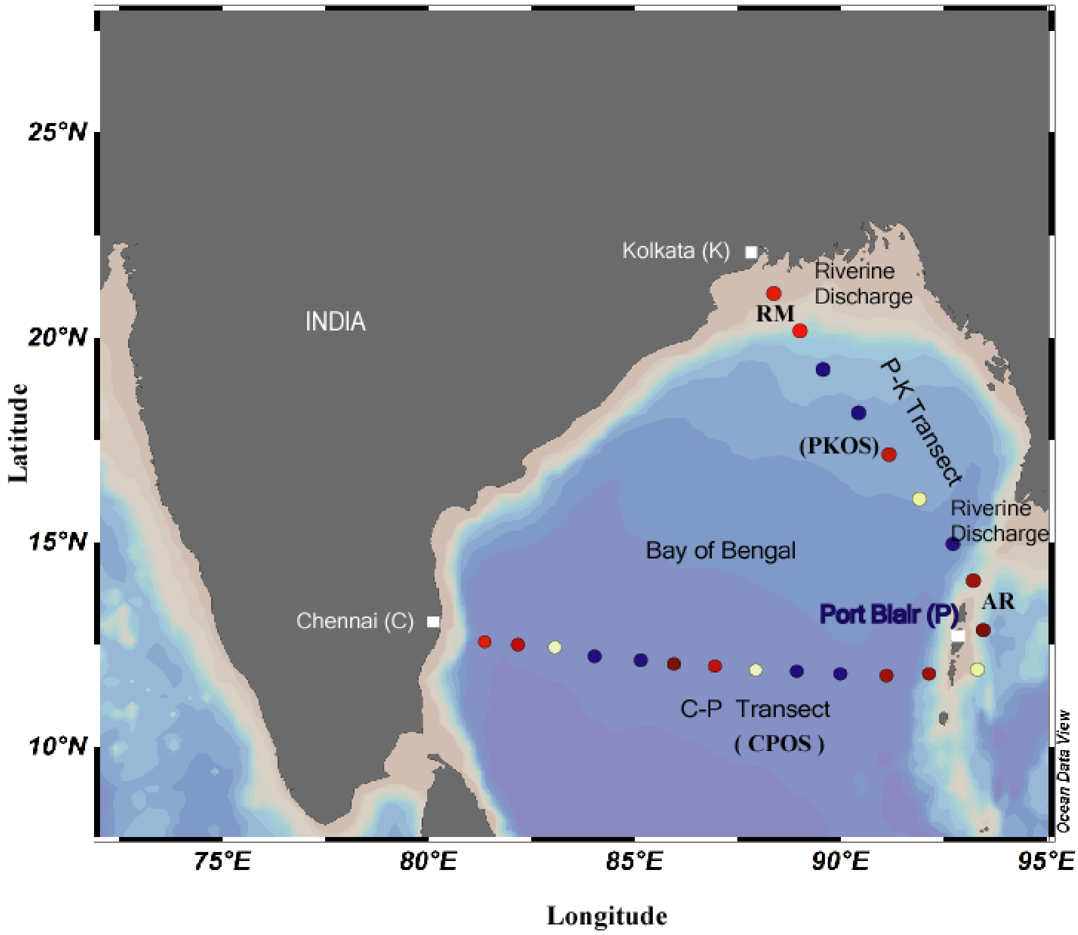

Fig. 2.1 Map of sampling area showing 12 stations along C-P and 10 stations along P-K transects. Circles with different colors denote sampling time. Red circle - night hours; (absence of sunlight), white circle - late evening and early morning; (faint sunlight), blue circle - day hours; (presence of sunlight).

The stations of the two transects are classified into four tracks based on the variations in water column conditions such as nutrients, chlorophyll *a*. The C-P transect also referred as Chennai to Port Blair Oceanic Stations (CPOS; Station 1 to 12) lies in the open ocean characterized by low nutrients, low chlorophyll. The P-K transect is partitioned into three tracks and referred as AR; Andaman Region were relatively higher nutrients, high chlorophyll and shallow bathymetry were noticed (AR; Station 13 to 15). The Port Blair to Kolkata Oceanic Stations (PKOS; Station16 to 21) is in the open ocean with low nutrients, low chlorophyll. The River Mouth (RM; Station 22) is a site which is influenced by fresh water influx by riverine discharges and the addition of nutrients. Here after, the regions will be referred using respective abbreviations. All the three regions inclusive (AR, PKOS, and RM) is also referred as P-K transect

To depict the influence of monsoons and wind stress, monthly datasets are categorized into seasons as Fall Intermonsoon (FIM; October), North East Monsoon (NEM; November to February), Spring Intermonsoon (SIM; March to May), and South West Monsoon (SWM; June to September). March to May and October both experience moderate winds; hence these months are termed as Intermonsoon (IM), Spring Intermonsoon and Fall Intermonsoon, respectively.

2.2.2 Environmental parameters

Sea Surface Temperature (SST) was obtained onboard by deploying XBT - MK21 - T7 Probes (Sippican Inc). The XBT data was further used to calculate Isothermal Layer Depth (ILD) [defined as ''the depth where the temperature is 0.5° C lower than the SST'']. The Sea Surface Salinity (SSS) were collected and stored in 200 ml bottles and analyzed using Guideline 8410A Autosal in the Laboratory. Nutrients (Dissolved Inorganic Nitrogen; DIN, Dissolved Inorganic Phosphate; DIP and Silicate), were analyzed using standard methods (Grassoff et al., 1983). For silicate, the samples were analysed from October 2006 to October 2009 following standard spectrophotometric procedures as that of DIN and DIP using Grasshoff et al (1983).

2.2.3 Atmospheric variables

The wind speed data were obtained from APDRC (Asia Pacific Data Research Centre) data access (http://apdrc.soest.hawaii.edu) for the grid area of 7°38'N-21°38'N and 74°38'E - 95°38'E. Rainfall data were obtained from NOAA (NOAA Earth System Research Laboratory), data access (http://www.esrl.noaa.gov/psd/data/gridded/data. unified.daily.conus.html) for the gridded area of 7°28' N – 25°88'N and 7° 88' E - 97° 28'E.

2.2.4 Remote sensing variables

The values of PAR were extracted from level-3 MODIS, 9 km resolution at each 1° interval from 10°95'E to 21′95°N and 80° 04'E to 95°04' E (http://oceandata.sci.gsfc.nasa.gov). For detection of eddies, SSHA images obtained from the 7-day snapshots of merged sea-level anomalies from live access server having a spatial resolution of 1/3 of a degree (http://las.aviso.oceanobs.com) during the period 2006–2008 coinciding with high microphytoplankton abundance.

2.2.5 Analysis of Microphytoplankton

The Plankton samples were collected from the moving ship at any given time. Two litres of water was collected from each station, and each one litre was fixed using acetic Lugol's (2%) iodine and buffered formaldehyde (0.6%). Samples were brought back to the laboratory, kept undisturbed for 48 h, concentrated to a final volume of 10 ml and stored in vials. The samples were analysed using an inverted microscope by placing 4 ml of preserved subsample each separately (2 ml of acetic Lugol's iodine and 2 ml of buffered formaldehyde) from the oceanic stations (stations 1–21), and 0.2–0.5 ml from RM in a petri dish of ×3.8 cm diameter, with phase contrast attachment at 100x and 200x magnification. Microphytoplankton cells were identified based on identification keys provided by Subrahmanyan, 1968; Taylor, 1976; Tomas, 1997 and Horner, 2002. Their abundance is expressed in terms of cells per litre (Cells L^{-1}).

2.2.6 Data Analysis

The inter- and intra-annual variations in the environmental, Atmospheric, Remote sensing and biological variables are depicted using SURFER 9 (developed by Golden Software Inc., USA).

2.3 Results

2.3.1 Hydrological variability

Along CPOS, low SST (26.1–29.9°C) was observed during monsoon (NEM and SWM) and relatively higher during SIM and FIM (28.2 - 31.0°C). Along the P–K transect (PKOS, AR and RM), low SST was observed during NEM (24.3 – 30.0°C) and relatively higher values during FIM, SIM and SWM (27.9 – 30.9°C). The SST was lowest during NEM (irrespective of the region), and this trend was observed in all the five years (Fig.2.2a and d; Appendix B1-B3) The CPOS comprises of stations that are away from riverine influence, whereas AR and RM are closer to the Irrawaddy and Ganges–Brahmaputra river basins. The SSS was relatively high in CPOS (29.2–34.4) when compared to P–K transect (25.7–34.4). Low SSS was observed during SWM, especially in RM and was relatively high during SIM and FIM (Fig. 2.2b and e; Appendix B1-B3). ILD ranged from 14 to 115 m along the CPOS and 7 to 104 m along the P-K transect. ILD was shallower and was in the range of 7 to 30 m during the SIM in all the four regions which indicate stable water column.

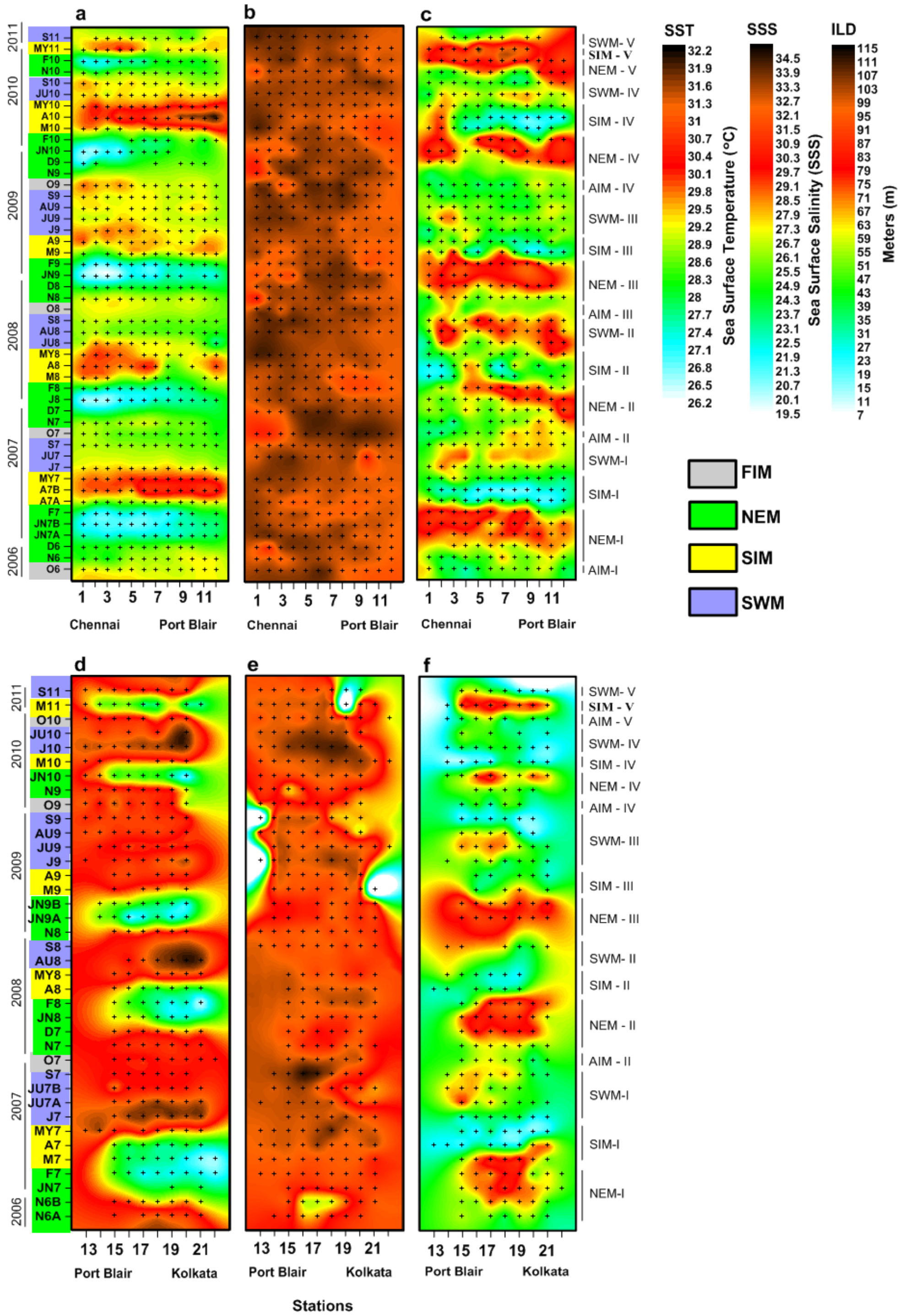

Fig 2.2 a-f Spatial and temporal variations in Sea Surface Temperature (SST; Fig. 2.2a and d), Sea Surface Salinity (SSS; Fig. 2.2b and e), and Isothermal Layer Depth (ILD; Fig. 2.2c and f) from the Chennai to Port Blair (CPOS) and Port Blair to Kolkata (AR, PKOS and RM) transect respectively. The colour code superimposed on the months denotes different seasons, grey - FIM, Green – NEM, Yellow – SIM, and Sky blue – SWM. The sampling months along with the respective codes are provided in the Appendix A1 and A2. The symbol (+) superimposed on the contours denotes sampled stations.

During the SWM and NEM increase in wind speed and water column mixing lead to deeper ILD in the open ocean stations (CPOS and PKOS). However, on some occasions, ILD was in the range of 40 to 50 m in the AR and RM during SWM and could be possibly due to the intrusion of freshwater by precipitation and freshwater riverine discharge. (Fig. 2.2c and f; Appendix B1-B3)

2.3.2 Nutrients

Dissolved Inorganic Nitrogen (DIN) concentration in the open ocean (CPOS and PKOS) was below detectable range for the most of the year especially, during the SIM. However, during monsoon 1 to 2.2 µmol $L^{-1}$of DIN was observed in the CPOS and PKOS (Fig. 2.3a and b; Appendix B1-B3). In the River Mouth, DIN concentration reached up to 4.23µmol L^{-1}, whereas in the Andaman Region it varied from 1 to 1.8µmol L^{-1}. High DIN concentration in the open ocean can be attributed to advective processes and wind-driven mixing, whereas in the coastal stations of AR and RM it could be due to precipitation and fresh water riverine discharge (Fig. 2.3b).

The Dissolved Inorganic Phosphate (DIP) was below the detectable level in the open ocean for most of the year. However, there were some occasions during the SWM where in concentration ranged from 0.12 to 0.7 µmol L^{-1}. In the Andaman Region and River Mouth, the DIP concentrations reached up to 1.44 and 3.02 µmolL^{-1} during the monsoon season (Fig. 2.4a and b).

Silicate concentration in the open ocean (CPOS and PKOS) were below detectable range for the most of the year especially, during the SIM. However, during monsoon silicate concentration reached upto 3.00 µmol L^{-1}. In the River Mouth, Silicate concentration reached up to 6.5 µ mol L^{-1}, whereas in the Andaman Region it varied from 2 to 4.00µ mol L^{-1} (Fig 2.5a and b). High concentration in the open ocean can be attributed to advective processes, and wind-driven mixing, whereas in the coastal stations of AR and RM it could be due to the precipitation and fresh water riverine discharge (Fig.2.5a and b).

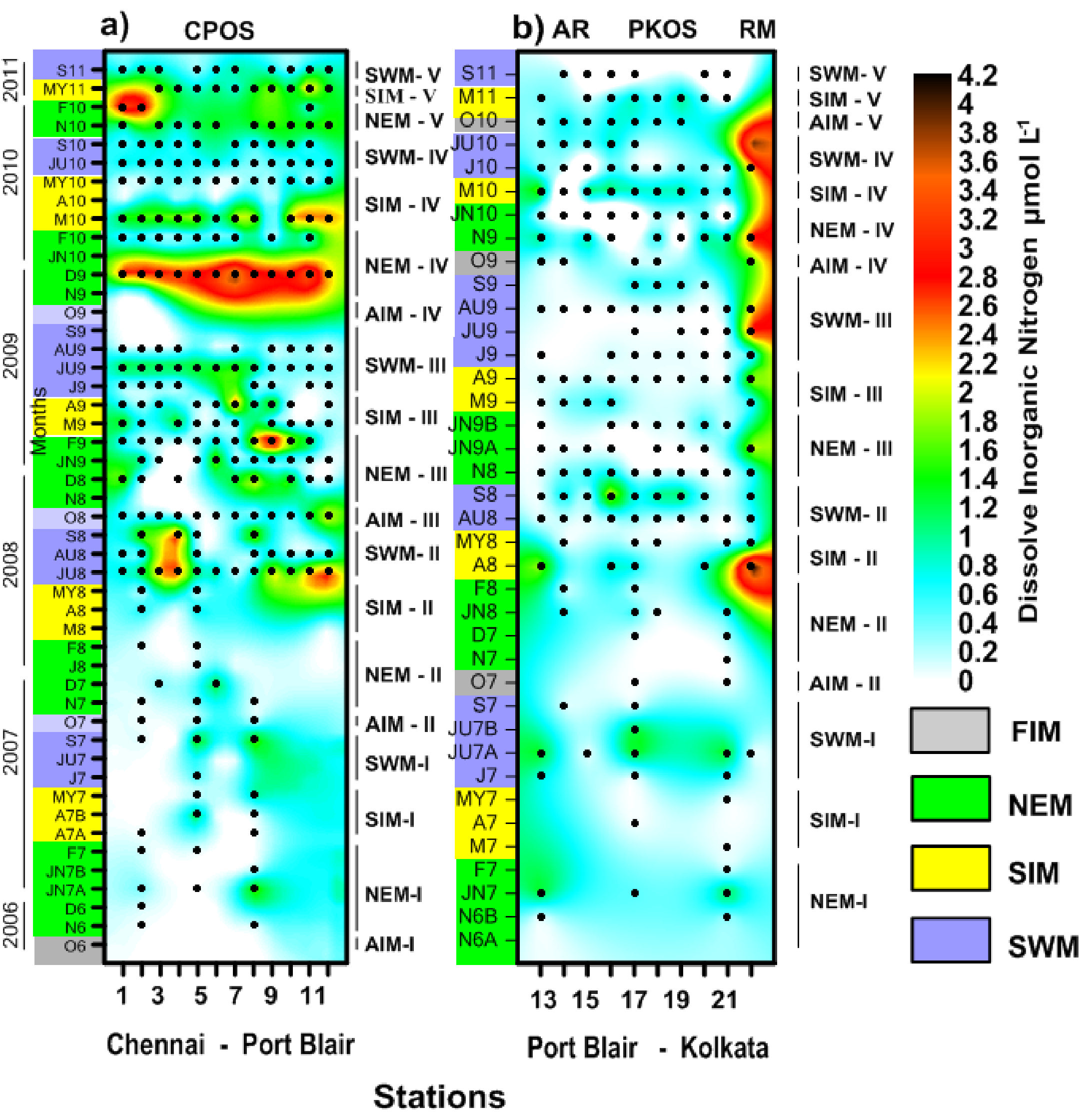

Fig. 2.3 a and b: Spatial and temporal variations in Dissolved Inorganic Nitrate (DIN) from four different tracks (Fig. 2.3a; CPOS), (Fig. 2.3b; AR, PKOS and RM) of Bay of Bengal. The colour code superimposed on the months denotes different seasons, grey - FIM, Green – NEM, Yellow – SIM, and Sky blue - SWM. The sampling months along with the respective codes are provided in the Appendix A1 and A2. The symbol (+) superimposed on the contours denotes sampled stations.

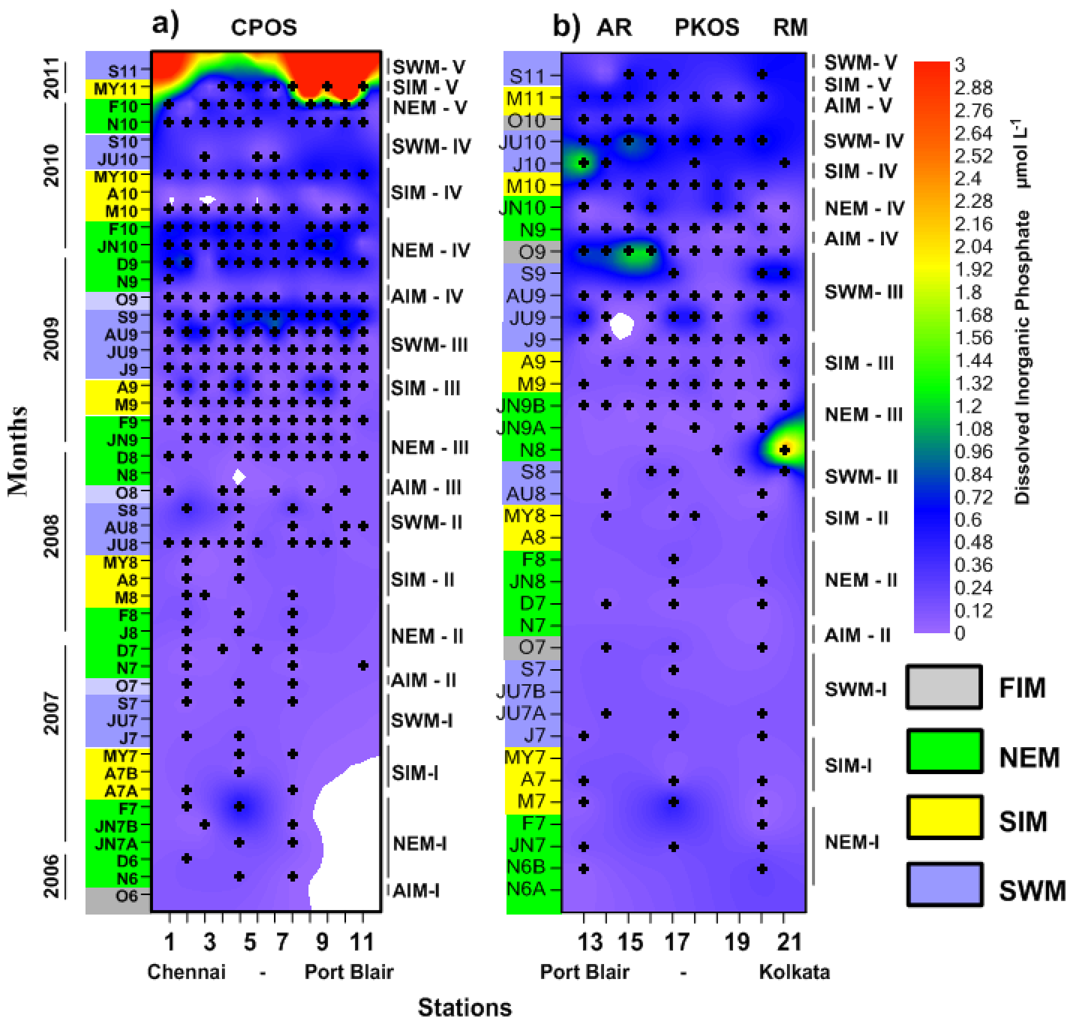

Fig. 2.4 a and b Spatial and temporal variations in Dissolved Inorganic Phosphate (DIP) from four different tracks (Fig. 2.4a; CPOS), (Fig.2.4b; AR, PKOS and RM) of Bay of Bengal. The colour code superimposed on the months denotes different seasons, grey - FIM, Green – NEM, Yellow – SIM, and Sky blue - SWM. The sampling months along with the respective codes are provided in the Appendix A1 and A2. The symbol (+) superimposed on the contours denotes sampled stations.

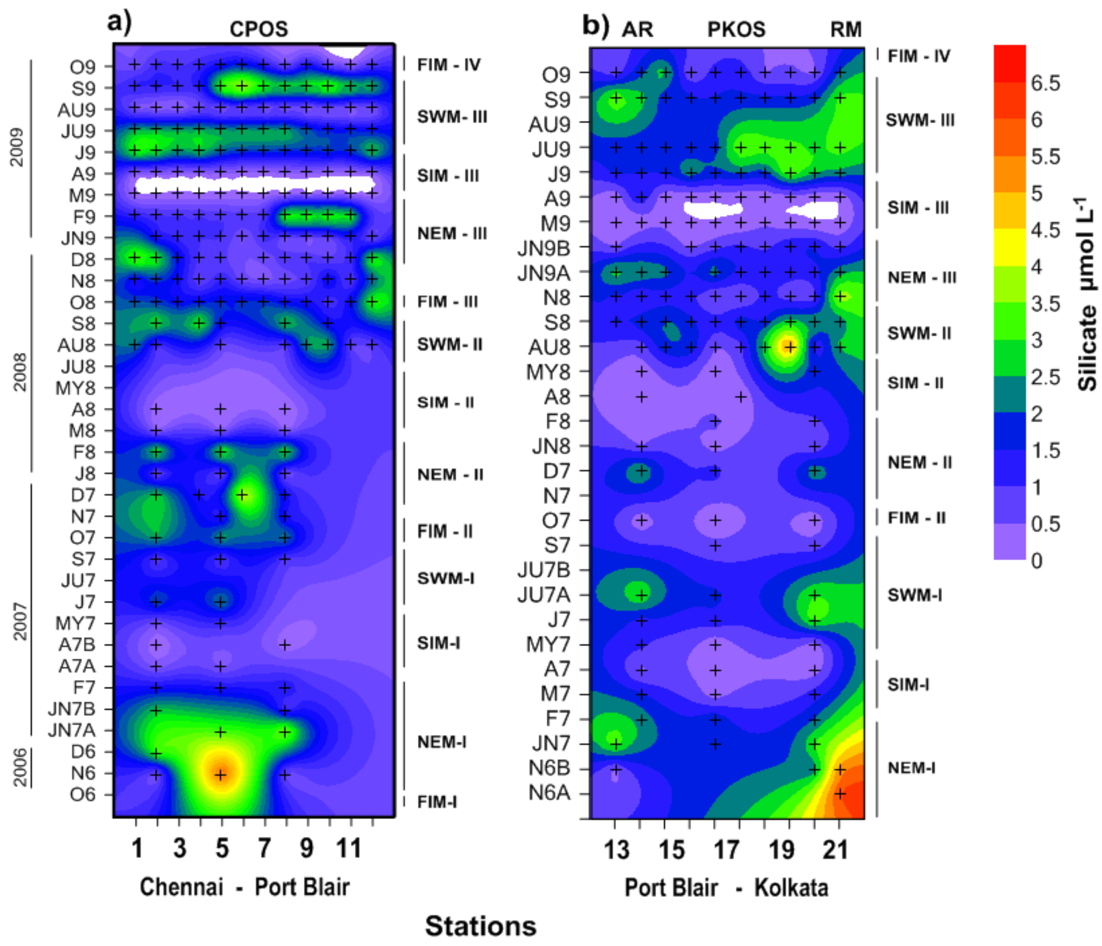

Fig. 2.5 a-b Spatial and temporal variations in Silicate from four different tracks (Fig.2.5a; CPOS), (Fig.2.5b; AR, PKOS and RM) of Bay of Bengal. The colour code superimposed on the months denotes different seasons, grey - FIM, Green – NEM, Yellow – SIM, and Sky blue - SWM. The sampling months along with the respective codes are provided in the Appendix A1 and A2. The symbol (+) superimposed on the contours denotes sampled stations.

2.3.3 Atmospheric variability

The Photosynthetically Active Radiation was higher during the SIM (43 to 57 mol quanta m^{-2} /day) and decreased during the Monsoon, SWM, and NEM (1.2 to 25.2 mol quanta m^{-2} /day) (Fig. 2.6a and b; Appendix B1-B3). In all the regions, high windspeed was recorded during the SWM, followed by NEM, whereas low windspeed was recorded during IM. PAR was also high during IM, and low during

SWM and NEM (Fig. 2.7a and b; Appendix B1-B3). Rainfall showed a different pattern. High precipitation was noticed during SWM and NEM in the entire CPOS, whereas during SWM it was observed in the P–K transect (Fig.2.8b).However, we could also see the intra-annual variation, where rainfall was also recorded during SIM in the stations of AR.

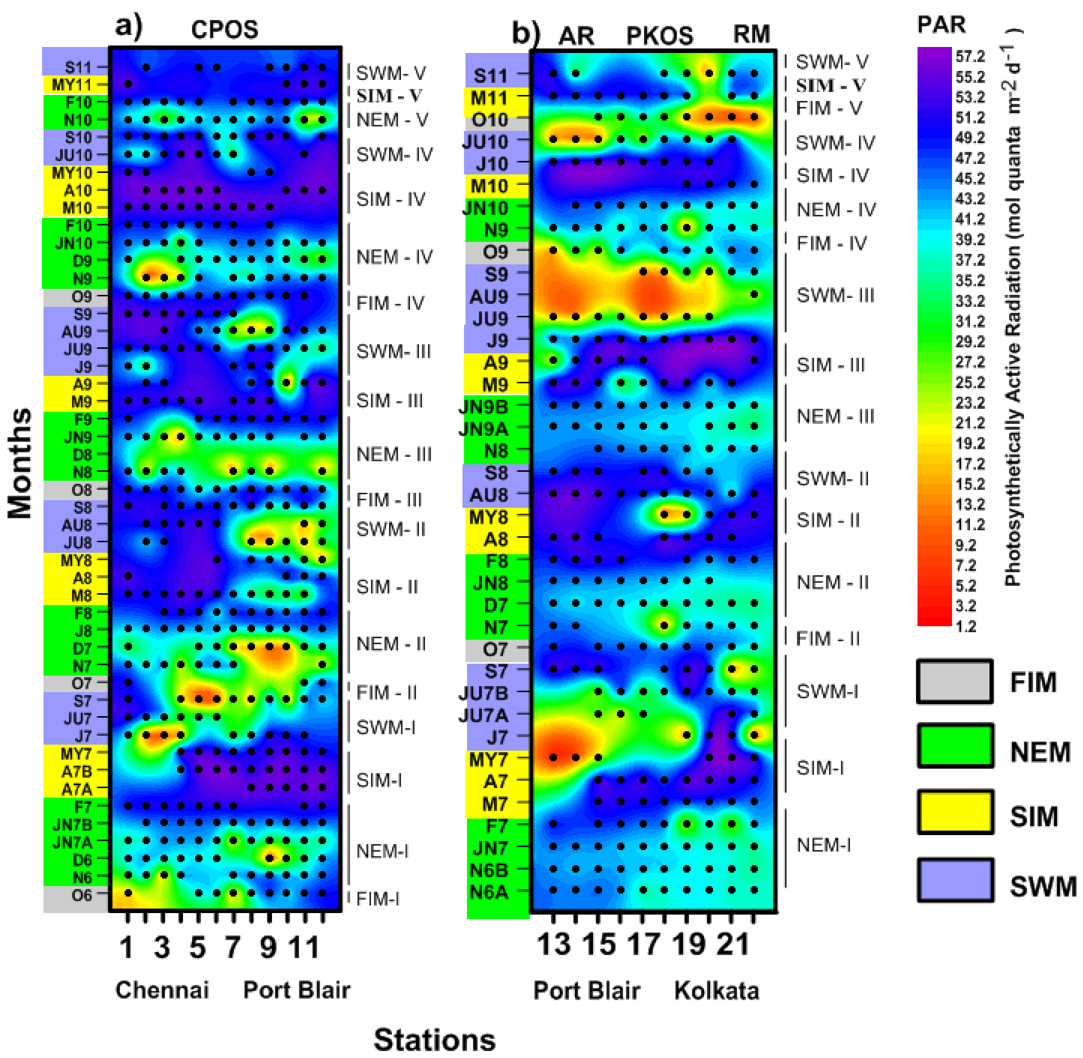

Figure 2.6 a and b: Spatial and temporal variations in Photosynthetically Active Radiation (PAR) from four different tracks (Fig. 2.6a; CPOS), (Fig.2.6b; AR, PKOS and RM) of Bay of Bengal. The colour code superimposed on the months denotes different seasons, grey - FIM, Green – NEM, Yellow – SIM, and Sky blue - SWM. The sampling months along with the respective codes are provided in the Appendix A1 and A2. The symbol (+) superimposed on the contours denotes sampled stations.

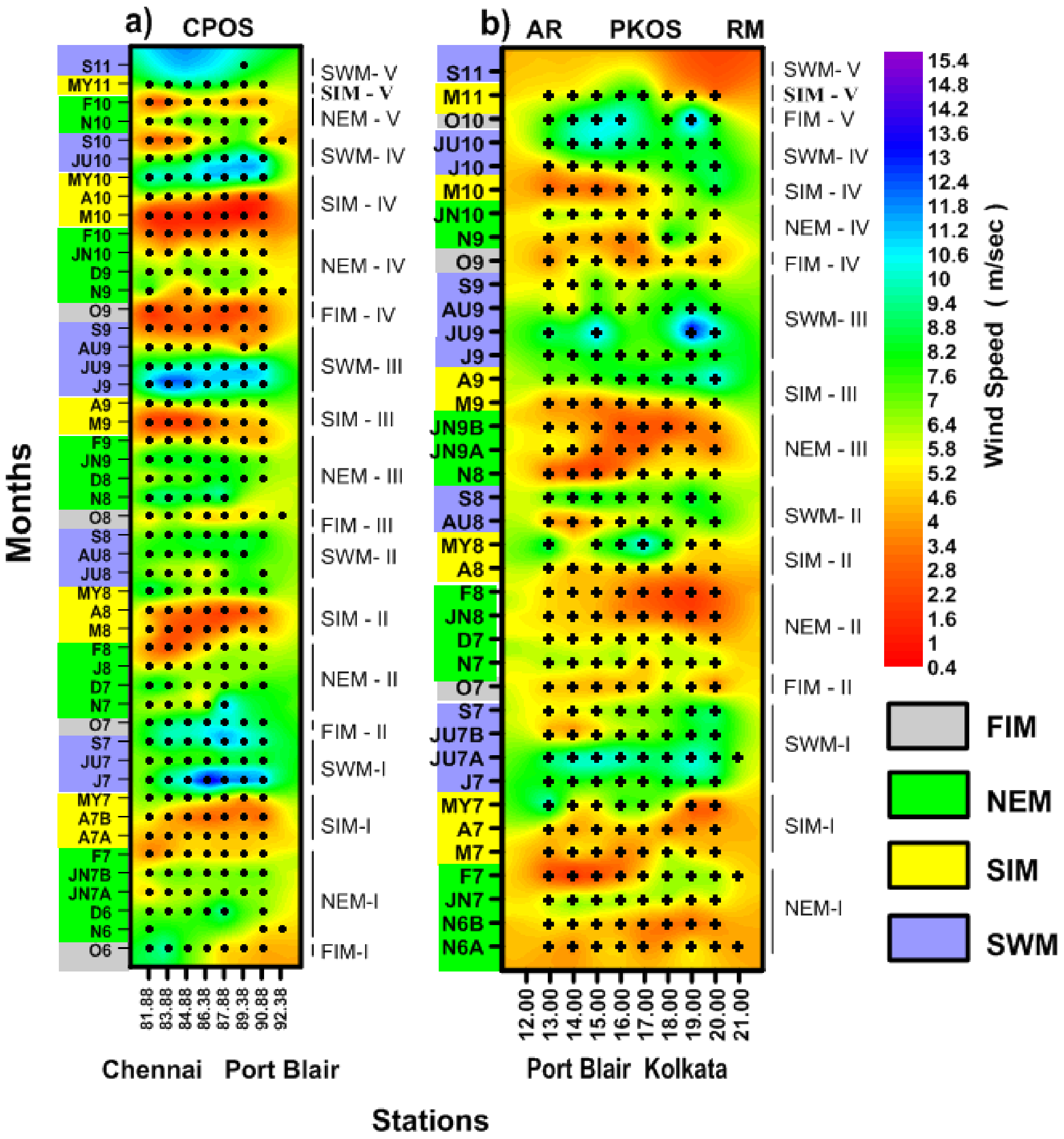

Fig. 2.7a and b: Spatial and temporal variations in wind speed from four different tracks (Fig. 2.7a CPOS), (Fig.2.7b; AR, PKOS and RM) of Bay of Bengal. The colour code superimposed on the months denotes different seasons, grey - FIM, Green – NEM, Yellow – SIM, and Sky blue - SWM. The sampling months along with the respective codes are provided in the Appendix A1 and A2. The symbol (+) superimposed on the contours denotes sampled stations.

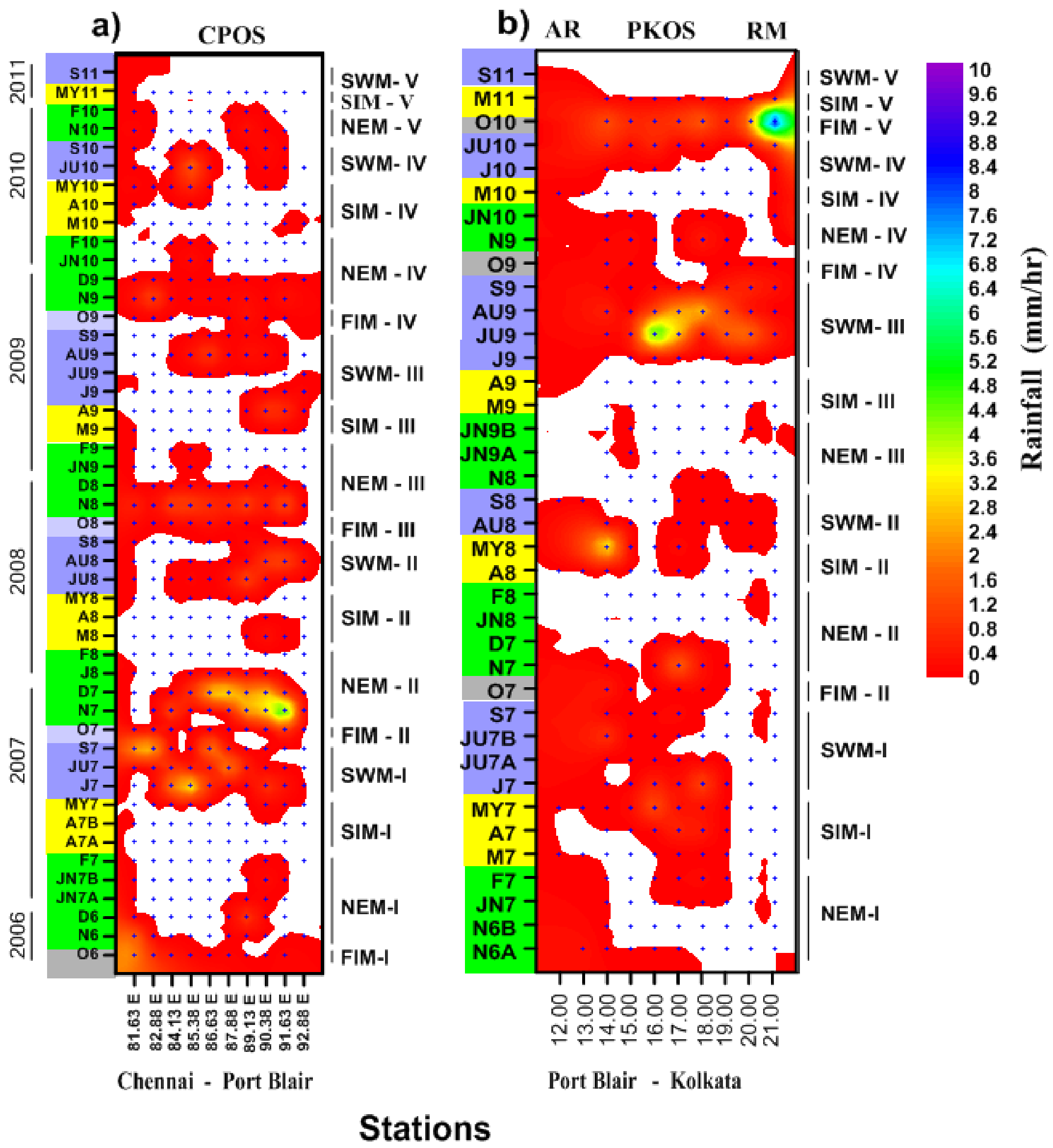

Fig. 2.8a and b: Spatial and temporal variations in rainfall from four different tracks (Fig. 2.8a CPOS), (Fig.2.8b; AR, PKOS and RM) of Bay of Bengal. The colour code superimposed on the months denotes different seasons, grey - FIM, Green – NEM, Yellow – SIM, and Sky blue - SWM. The sampling months along with the respective codes are provided in the Appendix A1 and A2. The symbol (+) superimposed on the contours denotes sampled stations.

Based on the SSHA mesoscale eddy was identifiable on 4 ocassions. The first eddy had a centre at 13.00'N lat. and 83°00'E long. The second eddy had a centre at 18°50' N and 87°00' E. The third and fourth had a centre at 16°00'N and 85°00' E and 13°00'N and 83°00'E (Fig. 2.9a to d; Appendix C)

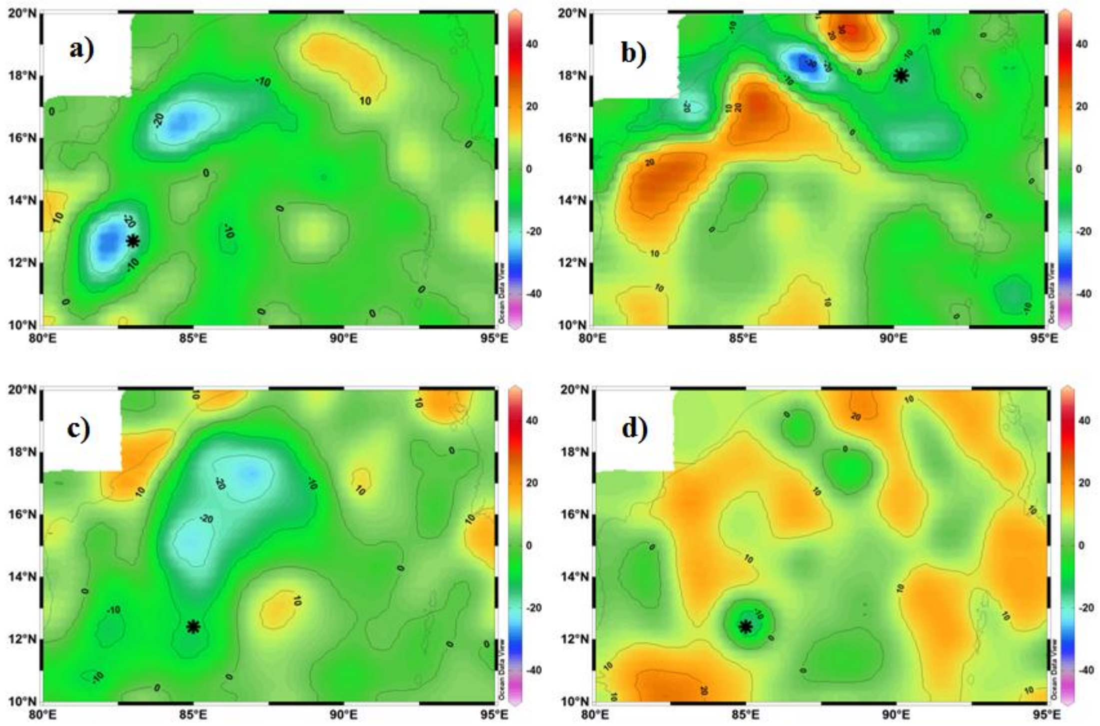

Fig. 2.9a to d. The contour map showing (a; 17th November 2006, b; 13th April 2007, c; 6th October 2007 and d; 8th May 2008) the presence of eddies identified based on the sea surface height anomalies in the Bay of Bengal. The symbol (*****) denotes the stations influenced by the eddy region. The details are provided in Appendix C.

2.3.4 Microphytoplankton assemblages

Microphytoplankton abundance varied from 25 to 63000 cells L^{-1} along the C-P transect and 30 to 276000 cells L^{-1} along the P–K transect (Fig. 2.10a; 2.11a). The highest abundance was observed during SWM followed by NEM. However, at AR and RM the abundance was also high during SIM and FIM (Fig. 2.10c; 2.11*c*). The trend was opposite in the case of dinoflagellates, except at RM and AR (Fig.

2.10c; 2.11*c*). Diatoms were the dominant group with respect to their numbers, whereas dinoflagellates was the highest with respect to its taxonomic composition (Appendix D, E, F and G).

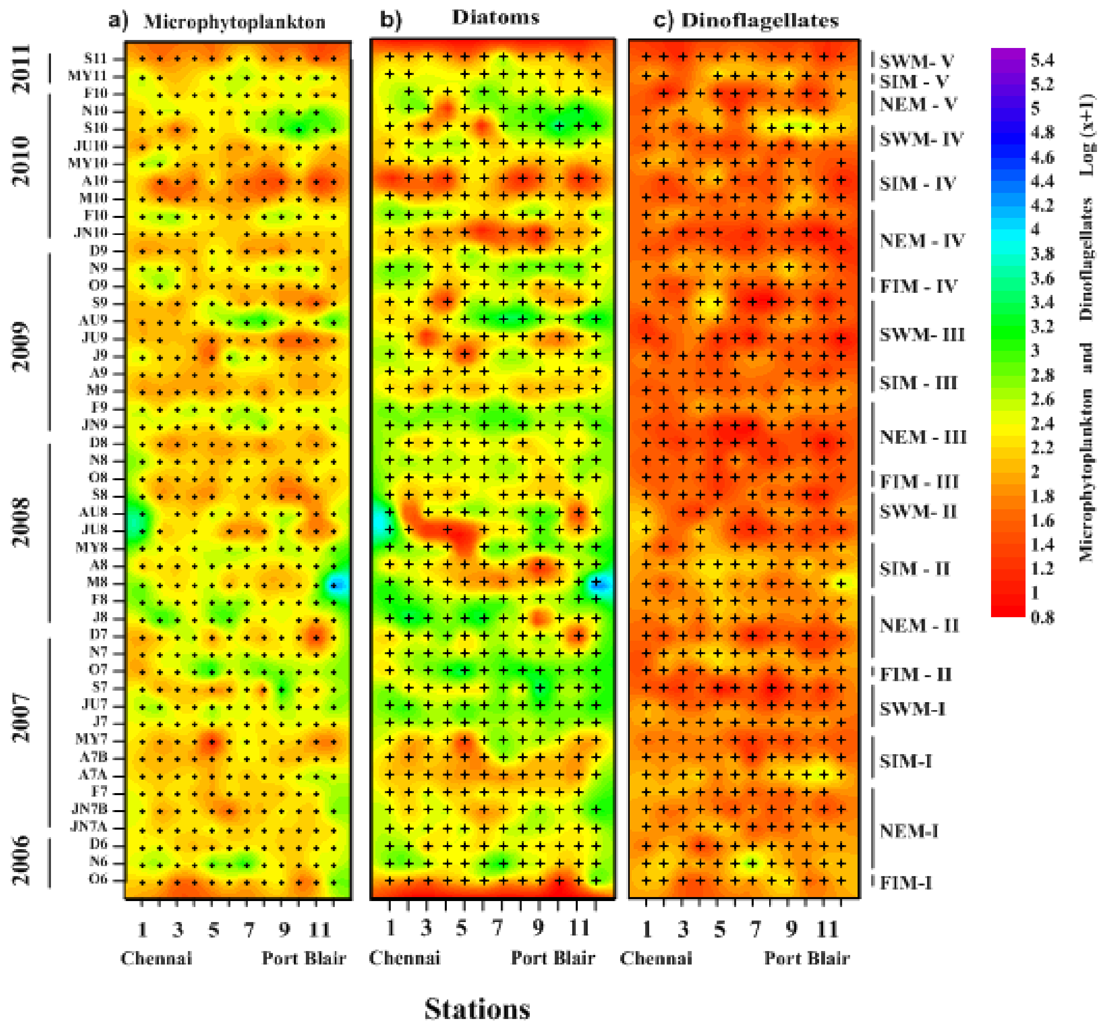

Fig. 2.10 a-c. Spatial and temporal variations of Microphytoplankton (**a**), Diatoms (**b**), and Dinoflagellates (**c**) along the C-P (CPOS) transects. The sampling dates with its respective codes are provided in Appendix A1 and A2.

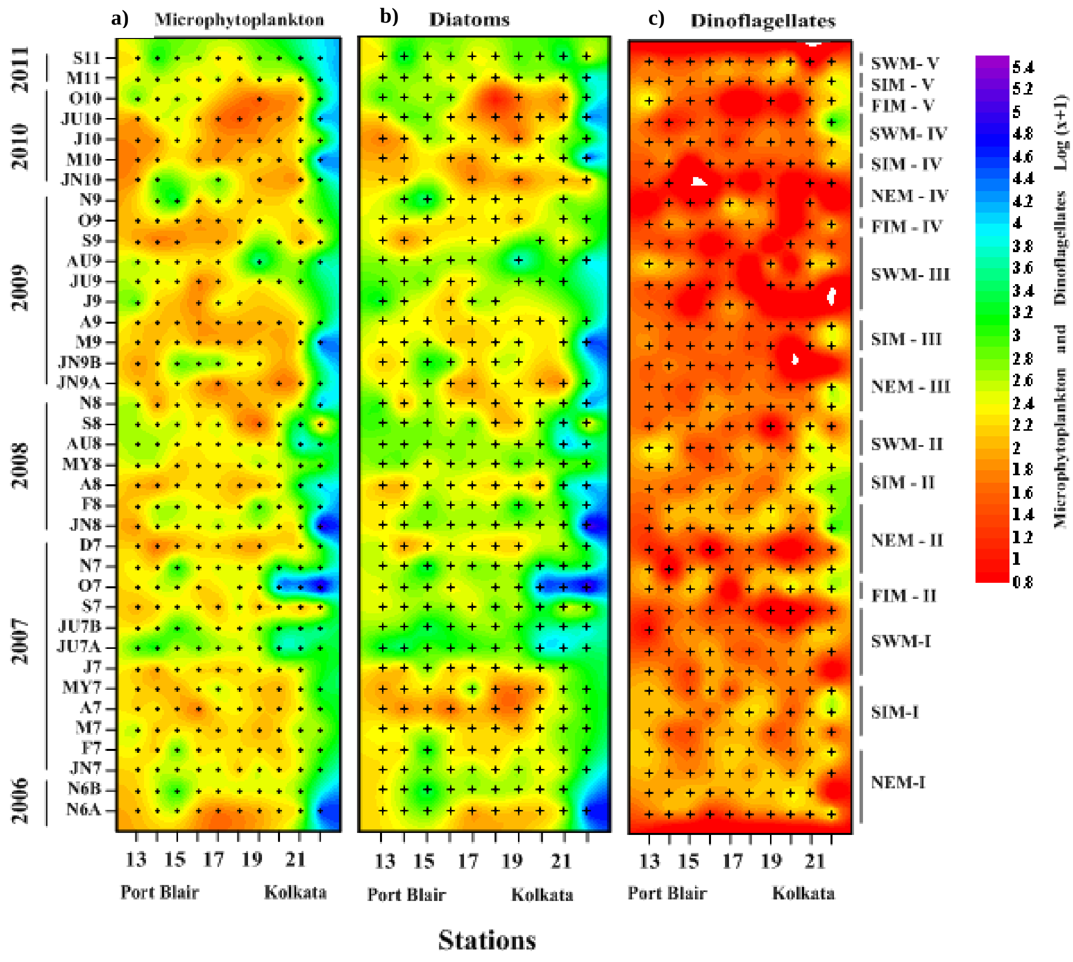

Fig. 2.11 a-c Spatial and temporal variations of Microphytoplankton (**a**), Diatoms (**b**), and Dinoflagellates (**c**) along the P-K transects (AR, PKOS and RM) respectively. The sampling dates with its respective codes are provided in Appendix A1 and A2.

2.4 Discussion

The study describes variations of environmental variables and its influence on the variability of microphytoplankton cell counts especially diatoms and dinoflagellates on inter and intra-annual scales. In several temperate waters a general trend with dominance of diatoms during spring, autumn, and dinoflagellates during summer can be observed (Ignatiades, 1969; Margalef, 1978; Gomez and Gorsky, 2003; Estrada and Berdalet, 1997; Barthon et al., 2013). The dominance of diatoms in the above studies was attributed to light peneteration and its availability to the euphotic zone, strength of solar radiation, cloudiness (most notably during the winter), and degree of mixing and amount of suspended matter in the water column (Edwards, 2000). In the late spring and summer the microphytoplankton community shifted from diatoms to dinoflagellates. This has been related to stratified water column and depleted nutrients, where flagellates (competitors) and dinoflagellates (stress tolerant) are known to flourish (Margalef, 1978; Holligan, 1987). In the surface waters of the CPOS a similar trend was observed and this can be attributed to the shifts in the changes in the environmental conditions. However, such a trend was not reflected in the near coastal regions (AR and RM). In the near coastal regions diatoms were also noticed during SIM. In the AR it could be due to rainfall and terrigenous discharges, whereas in the RM it could be due to the influence of fresh water riverine discharge.

In the NE Atlantic development of diatoms and bloom forming dinoflagellates is characterised due to bottom up effects of cooler water temperature, increased nutrients and decrease in stratification. However, in this study increased cell counts in the open ocean transects of CPOS during the SWM and NEM could be due to advective and vertical transport of nutrients from the subsurface to the surface.

However the mixing of water column can be evident from the variations observed in the ILD where it is seen to be deeper during monsoon (Fig. 2.2 c and f).

In the North Atlantic, during the spring increase in solar irradiance and decline in the input of turbulent energy is observed and the conditions are known to trigger photoautotrophic growth contributed by diatom blooms (Behernfield et al., 2006; Taylor and Ferrari, 2011). In this study high diatom cell counts observed in the River Mouth during SIM could be due to similar mechanisms. However, since the intensity of freshwater discharge in maximum in the RM then in any other tracks (CPOS, PKOS and AR) there are less chance for the RM to be nutrient limited and this could be the possible factor for the proliferation of diatoms that prevailed during most part of the year in the RM (Fig. 2.10c; 2.11c).

Several other physical factors are known to promote phytoplankton abundance in the oceanic waters. The satellite imageries showed enhanced phytoplankton production in the open ocean of southern Bay of Bengal, which is facilitated by Summer Monsoon current (Vinaychandran et al., 2009). The impact of the Summer Monsoon current intrusion was observed between 5° and 10° N along 85°E. (Jyotibabu et al., 2015). In this study increase in the microphytoplankton cell counts was observed at station 5 (Fig. 2.10a; 2.11a), and this can be attributed to the influence of SMC.

Chapter 3: Inter- and intra-annual variations in the population of *Tripos* from the Bay of Bengal.

3.1 Introduction

Dinoflagellates constitute one of the important groups of marine protists in all aquatic ecosystems and form the second most dominant group of the total of phytoplankton community (Schiller 1933, 1937). It comprises a wide range of genera with 117 genus and 1555 species (Gomez, 2007). Amongst them, *Tripos* is one of the important ubiquitous marine thecate genera, whose distribution ranges from polar to tropical environments (Dodge and Marshal 1994). The *Tripos* species are slow-growing, found round the year (Dodge and Marshal 1994; Grahm 1941; Elbrachter 1973; Weiler, 1980; Matrai 1986), and are known to be a model species within the dinoflagellates for biogeographic and global change studies (Okolodkov 2010). In relation to temperature some of its forms are referred as excellent water mass indicators, North Atlantic (Dodge and Marshal 1994; Raine et. al 2002), Mediterranean Sea (Dowidar 1973; Tunin-Ley et. al 2007), Pacific (Sanchez et. al 2000, Dodge 1993), Arctic (Okolodkov, 1996) and Indian Ocean (Subrahmanyan, 1968). Phytogeographical studies also showed close relationship of individual species with temperature, while some are fairly tolerant towards wide temperature range (Matrai, 1986). Recently, the taxonomy of this genus has been revised based on the numbers and arrangement of cingular plates. The freshwater species are referred to as *Ceratium* and the marine species renamed as *Neoceratium* (Gomez et al., 2010). Recently, Gómez (Gomez, 2013) has elaborated on nomenclature priority of this species and reinstated genus *Neoceratium* to *Tripos*. The genus is strong-armoured, large-sized cells (100–300 μm) that is readily identified and distinctly characterized when preserved in any of the common fixatives (Gomez, 2010). In the waters around the subcontinent of India, *Tripos* species have been documented from the east and west coasts of India (Devassy and Goes 1988; Madhu et al., 2006; D'Costa et al., 2008; Jyothibabu et al., 2008; Naik et al., 2011; Patil and Anil 2011). Taxonomic studies on dinoflagellates from the Indian Ocean date back to 1968 (Subrahmanyan, 1968), although there is information available on dinoflagellates from several international expeditions as well as those that have passed through waters along the Indian subcontinent. Most of the authors studied *Tripos* qualitatively by reporting the presence of species in the form of description and illustration (Taylor, 1976). Taylor (Taylor, 1976) pointed out that in the description of dinoflagellates, Matzenauer (1933) had also omitted genus *Tripos*. However, from the above literature, we can say that information on the abundance and diversity at the spatio-temporal scale is lacking. The only tropical ocean being bounded by a continent to the north, the Indian Ocean comprising of the Arabian Sea and Bay of Bengal, hereafter referred to as BoB (Chaitanya et al., 2014), is home for the semi-annually reversing monsoon wind system (Shankar et al., 2002). Changes in the environmental conditions (salinity, temperature, nutrients) driven by major riverine discharges and monsoon reversals (precipitation and wind) make the bay a unique system in the northern Indian Ocean. Given the understanding that the *Tripos* has been used as an indicator of water mass as stated above, a study was undertaken to map the distribution of *Tripos* in BoB for five years (October 2006 – September 2011).

3.2 Materials and method

3.2.1 Environmental Parameters

The Environmental parameters (SST-Sea Surface Temperature, SSS; Sea-Surface Salinity), Nutrients (DIN-Dissolved Inorganic Nitrogen, Dissolved Inorganic Phosphate), Wind speed, Rainfall and Photosynthetically Active Radiation (PAR) are provided in details in Chapter 2.

3.2.2 Study area and sampling strategy

The surface water was collected with a bucket from two different transects (Chennai to Port Blair (C-P) and Port Blair to Kolkata (P-K) from 22 stations using a passenger ship under the Indian Expendable Bathythermograph (XBT) Programme (Figure 3.1). The method for plankton collection and analysis is as followed in the materials and methods section described in Chapter 2.

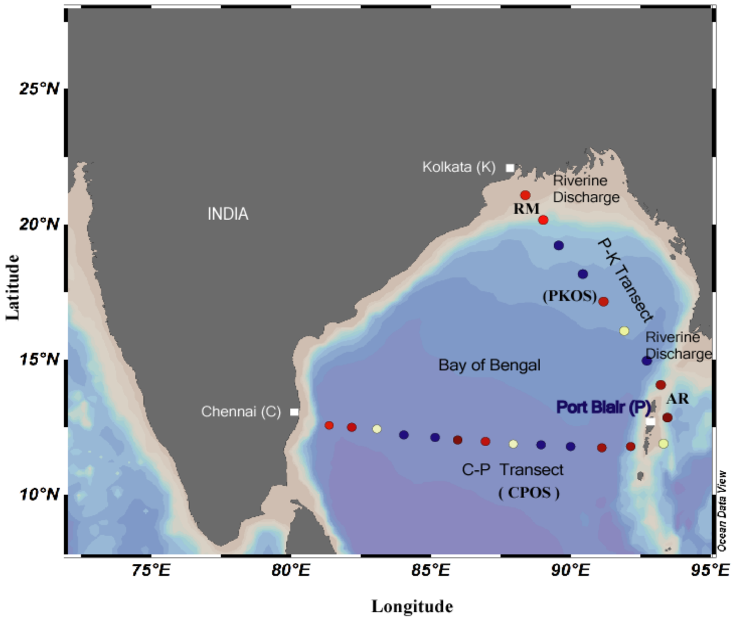

Fig. 3.1 Map of sampling area showing 12 stations along C-P and 10 stations along P-K transects. Circles with different colors denote sampling time. Red circle - night hours; (absence of sunlight), white circle - late evening and early morning; (faint sunlight), blue circle - day hours; (presence of sunlight)

3.2.3 Microscopic enumeration and analysis of Tripos and Ciliates

To study the *Tripos* species composition and distribution, samples preserved with acetic Lugol's iodine were used. We draw information of *Tripos* from the microphytoplankton population, since the sampling was carried out using the ships of opportunity. The *Tripos* abundance was further compared with other geographical regions. The abundance of ciliates (*Rhabdonellopsis*, *Albatrossiella*, *Eutintinnus*, *Ormosella*, *Salpingella*, *Steenstrupiella*, *Xystonella*, *Dictyocysta* and *Salpingacantha*) to genus level was also enumerated from 1 litre of water sample preserved separately with buffered formaldehyde (0.6%).

3.2.4 **Data analyses**

The *Tripos* species that contributed to more than 0.5% of the total *Tripos* population were subjected to ordination analysis. The relationship among *Tripos*, ciliates and environmental parameters (sea-surface temperature (SST), sea-surface salinity (SSS), DIN, DIP, wind speed, rainfall and PAR) was evaluated separately for CPOS, and P–K transect by performing canonical correspondence analysis (CCA), CANOCO version 4.5 (ter Braak and Smilauer 1998). An automatic selection, on seven environmental variables was performed, and using a Monte Carlo permutation test and statistical significance of each variable was tested under the reduced model with 999 permutations. Only those stations were considered for which physicochemical data was available.

3.3 Results

3.3.1 ***Tripos species composition and community structure***

Tripos abundance varied from 5 to 125 cells L^{-1} along the CPOS and up to 280 cells L^{-1} along the P–K transect (Figure 3.2 *a* and *b*). Altogether 40 species of *Tripos* were recorded, of which 29 were common to the two transect (Table 3.1). It was also noticed that 10 species were exclusively found along the C–P and 1 species along the P–K transect (Table 3.1). Along the CPOS, maximum abundance of *Tripos* was noticed at station 5 during FIM and SIM, and at station 7 during NEM, whereas along the P–K transect the highest abundance was observed in the RM during SWM–IV then followed by SIM. In addition, *T. furca*, *T. fusus*, *T. muelleri* and *T. lineatus* having the potential to form blooms were also encountered.

Table 3.1. List of *Tripos* species recorded along the C–P and P–K transects from October 2006 to September 2011

Sr No	Taxa	CCA Codes	C-P	P-K
1	*Tripos arietinus* (Cleve 1900)	ar	(5-10)(4)	5(3)
2	*Tripos azoricus*(Cleve 1900)	az	5(3)	5-10(4)
3	*Tripos belone* (Cleve 1900)*	be	5(1)	
4	*Tripos boehmii* (H. W. Grahm & Bronik 1944)	bh	5(1)	10(1)
5	*Tripos brevis*(Ostenf. & Johannes Schmidt 1901)	br	5-15(24)	5-10(5)
6	*Tripos candelabrus*(Ehrenb. 1859)	ca	5-20(4)	10(1)
7	*Tripos concilians* (Jorg. 1920)*	cc	5(2)	
8	*Tripos contortus* (Gourret 1883)	co	5(2)	5(1)
9	*Tripos declinatus* (G. Karst. 1911)	de	5-20 (75)	5-10(35)
10	*Tripos deflexus* (Kof. 1907)	df	5-10(10)	5-20(3)
11	*Tripos dens* (Ostenf. & Johannes Schmidt 1901)	dn	5-20(3)	5-15(7)
12	*Tripos digitatus* (F. Schutt 1895)*	di	5-10(3)	
13	*Tripos extensus* (Gourret 1883)	ex	5-20(14)	5-20(5)
14	*Tripos euarcuatus* (Jorg 1920)*	eu	5(1)	
15	*Tripos furca* (Ehrenb. 1834)	fr	5-40(76)	(5-240)65
16	*Tripos fusus* (Ehrenb. 1834)	fu	5-25(69)	5-40(47)
17	*Tripos hexacanthus* (Gourret 1883)*	hex	5(3)	
18	*Tripos horridus* (Cleve 1897)	hr	5-30(35)	5-60(23)

Continued……..

19	*Tripos incisus* (G. Karst. 1906)*	inc	5(1)	
20	*Tripos inflatus* (Kof. 1907)	inf	5-10(17)	5-15(14)
21	*Tripos karstenii* (Pavill. 1907)*	kar	5(5)	
22	*Tripos kofoidii* (Jorg. 1911)	kof	5(5)	20(1)
23	*Tripos lineatus* (Ehrenb.1854)	lin	5-20(17)	5-10(5)
24	*Tripos limulus* (C.H.G. Pouchet 1883)*	lim	5(1)	
25	*Tripos.longirostrus* (Gourret 1883)	lon	5-10(9)	5(3)
26	*Tripos lunula* (Schimper 1900 ex G. Karst 1906)	lu	5(1)	5(1)
27	*Tripos macroceros* (Ehrenb. 1840)	mac	5-10(13)	5-15(5)
28	*Tripos massiliense* (Gourret 1883)	mes	5-15(5)	5(2)
29	*Tripos minutus* (Jorg. 1920)*	min	5(2)	
30	*Tripos muelleri* (Bory 1825)	tri	5-20(21)	5-15(12)
31	*Tripos muelleri* var.*atlanticus* (Ostenf. 1903)	tra	5(4)	5-20(4)
32	*Tripos pentagonus* (Gourret 1883)	pen	5-15(26)	5-10(11)
33	*Tripos pulchellus* (Schrod. 1911)	pul	5(1)	5(2)
34	*Tripos ranipes* (Cleve 1900)*	ran	5-25(3)	
35	*Tripos schmidtii* (Jorg. 1911)	sc	5-20(18)	5-15(6)
36	*Tripos.setaceus* (Jorg. 1911) **	se		5(2)
37	*Tripos symmetricus* (Pavill 1905)	sy	5(1)	5(1)
38	*Tripos teres* (Kof. 1907)	te	5-15(61)	5-20(22)
39	*Tripos trichoceros* (Ehrenb. 1859)	trh	5-20(25)	5-100(18)
40	*Tripos vulture* (Cleve 1900)	vu	5-10(6)	5-80(10)

Note: Values outside the brackets indicate variation in cell numbers (cells L^{-1}) and those inside the Brackets indicate the number of occurrences. * and ** indicate species which were exclusively recorded in the C–P and P–K transects respectively. CCA codes for the species are also indicated.

3.3.2 Tripos distribution in the C–P and P–K transects

Tripos abundance along the CPOS showed inter- and intra-annual variations as illustrated in Figure 3.2*a* and *b*. The highest abundance (125 cells L^{-1}) was observed during FIM (October 2007 and October 2008), and the abundance was low during October 2006 and October 2009 (40 cells L^{-1}). During November, which is a northeast monsoon month, *Tripos* was widely distributed. During the later stage of SIM, abundance was high and reached up to 60 cells L^{-1}, and these high numbers continued in the initial stages of SWM and decreased at the end of SWM. On an inter-annual scale, September 2010 was an exception yielding high numbers.

Along the P–K transect, irrespective of the seasons, maximum abundance was recorded at RM ,followed by AR, and ranged from 100 to 280 cells L^{-1}. In PKOS, the cell abundance was on par with CPOS (Figure 3.2*b*).

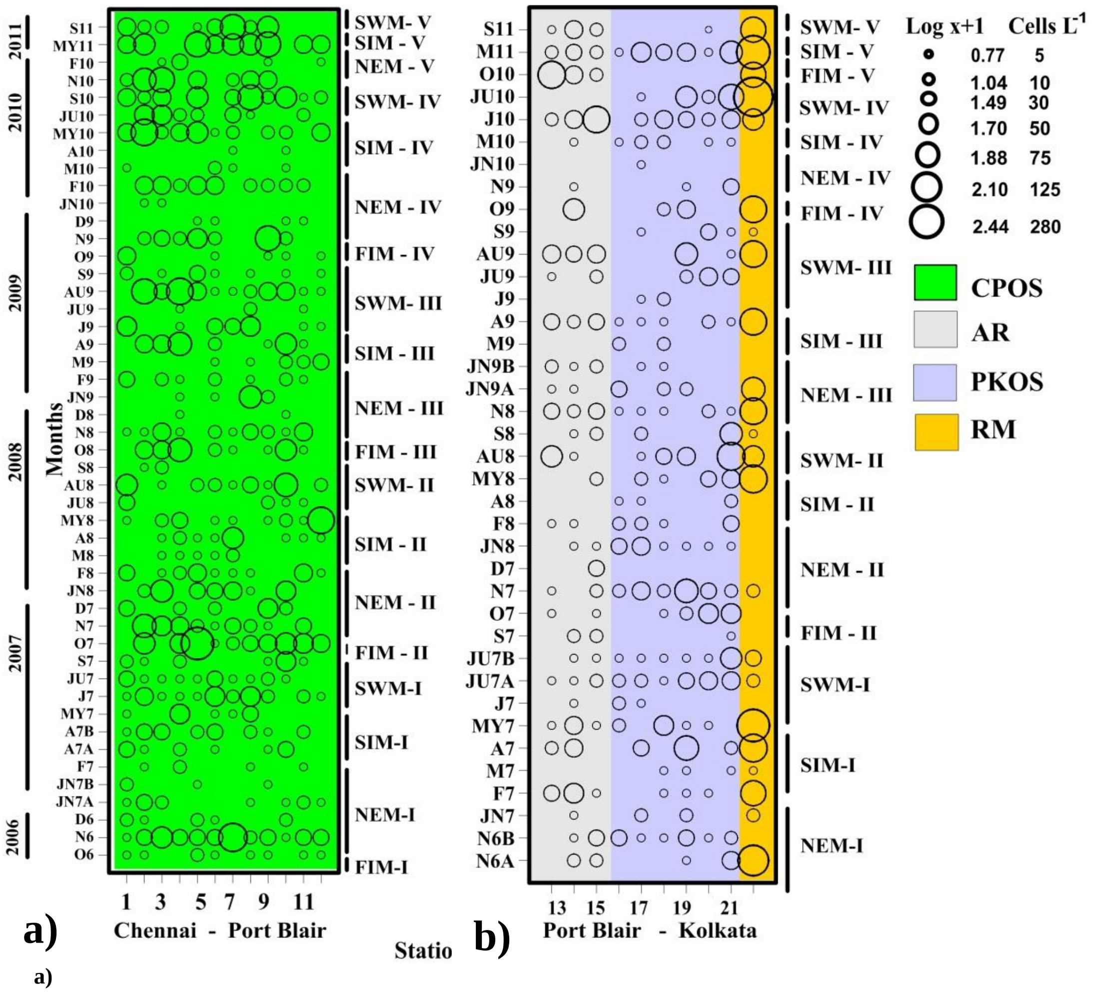

Fig 3.2 *a* and *b*. Spatio-temporal variation of *Tripos* along the CPOS (***a***) and P–K transect (***b***). The log(x + 1) transformed abundance values were used in the plot. The sampling dates with its respective codes along the CPOS and P–K transect are provided in Appendix A1 and A2.

3.3.3 *Comparison of Tripos with different biogeographical regions*

A comparison of the *Tripos* abundance in different regions of the oceans is provided in Table 3.2. In the open ocean the abundance is generally low. Higher abundance of *Tripos* population have been reported from the Sagami Bay, Buyukcekmece Bay and Chesapeake Bay and have been related to nutrient regeneration (decay of *Noctiluca scintillans*), higher DIN concentration (up to 10.79 μmol L^{-1}) and availability of feed *Strobilidium* spp. in the Chesapeake Bay.

Table 3.2 Comparison of *Tripos* abundance and the two most dominant forms (*T. furca* and *T. fusus*) from different geographical regions

Ocean/Sea	Locality	Cell abundance (cells m^{-3})			Reference
		***Tripos* spp.**	***Tripos furca***	***Tripos fusus***	
Indian	Bay of Bengal		0-2 x 10^4	0-2 x 10^4	Naik et al., 2010
Indian	Cochin backwaters	1.8-2 x 10^3			Qasim *et al*., 1973
Indian	Jakartha Bay	5.1 x 10^5			Thoha and Rachman, 2012
Indian	North Western Red Sea		70-100000		Nasser *et al*., 2014
Pacific	Sagamy Bay		7.5 x 10^7	1.1 x 10^7	Baek *et al*., 2007
Pacific	Sagamy Bay		1.4x 10^7	4.9 x 10^7	Baek *et al*., 2008
Pacific	North pacific central gyre	166-2399	0-38	0-5.5	Weiler, 1980
Pacific	Eastern north pacific	2000-22000			Matrai, 1986
Pacific	Tropical central pacific	48000-108000	12000-24000	40 x 10^3	Gomez *et al*., 2007
Mediteranean	Büyükçekmece Bay, Sea of Marmara		5000 x 10^3		Balkis, 2003
Mediterranean	East - West transects of the Mediterranean		1.4-1.6 x10^5	17000-230000	Ignatiades *et al*., 2009
Mediterranean	Mediterinean gulf of Kalloni		2.84 x10^6	2.1 x 10^6	Spatharis *et al*., 2009
Mediteranean	Ligurian sea	24000			Tunin-Ley et al., 2007
Mediteranean	North west Mediterranean	834-3734			Lasternas *et al*., 2008
Atlantic	Chesapeake Bay		7 - 480 x 10^6		Smalley and Coats, 2002
Atlantic	East coast of USA		10000	70000	Marshall, 1978
Atlantic	English channel and North sea	90 x 10^6			Masquelier *et al*., 2011
Arctic	Barent and Karas sea	10-500 x 10^3			Matishov *et al*., 2000
Atlantic	Brazil-Malvinas confluence region		0-20000	0-20000	Goncalves-Araujo *et al*., 2012

3.3.4 *Influence of environmental characteristics on the distribution of Tripos*

The CCA was used to link the distribution of *Tripos* species to environmental variables. The orientation and arrow lengths shown in Figure 3.3*a* and *b* (environmental variables) indicate their relative importance and approximate correlation to the axes. Arrows point in the direction of increase of the environmental gradient. Based on automatic selection and Monte Carlo permutation test of the total 7 environmental variables, SST and SSS was statistically significant in CPOS and P–K transect (Appendix H1 and I1). In the CPOS, CCA results showed that 10.74% of the total inertia (2.1%) in the species data could be explained by environmental variables (Figure 3.3*a*). The CCA axes1 and 2 (eigenvalues of 0.09 and 0.05 respectively) explained cumulative variance (49.5%) of the relation of species–environmental variables (Appendix H2). Based on the intersect correlation of environmental variables with the CCA axis, we could notice, *T. fusus*, *T. candelabrus* and *T. deflexus* preferred moderate to higher DIN concentration, whereas *T .trichoceros* preferred higher DIP. *T. karstenii* and *T. kofoidii* preferred higher rainfall, whereas *T. longirostrus*, *T. extensus* and *T. inflatus* preferred low SST. *T. furca* was not seen to be influenced by any of the environmental variables.

In the P–K transect, CCA results showed 3.9% of the total inertia (11.8%) in the *Tripos* was explained by environmental variables (Fig. 3.3*b*). The CCA axes 1 and 2 (eigenvalues of 0.27 and 0.09 respectively) explained 70.6% of the environmental variables (Appendix I2). Based on the intersect correlation of environmental variables with the CCA axis, we could notice that the cosmopolitan forms which are most dominant (*T. furca*, *T. fusus* and *T. horridus* preferred higher DIN, DIP, rainfall, photosynthetic active radiation and windspeed). The open ocean forms (T. *extensus, T. macroceros*, *T. schmidtii*, *T. inflatus* and *T. declinatus)* preferred higher SSS and SST.

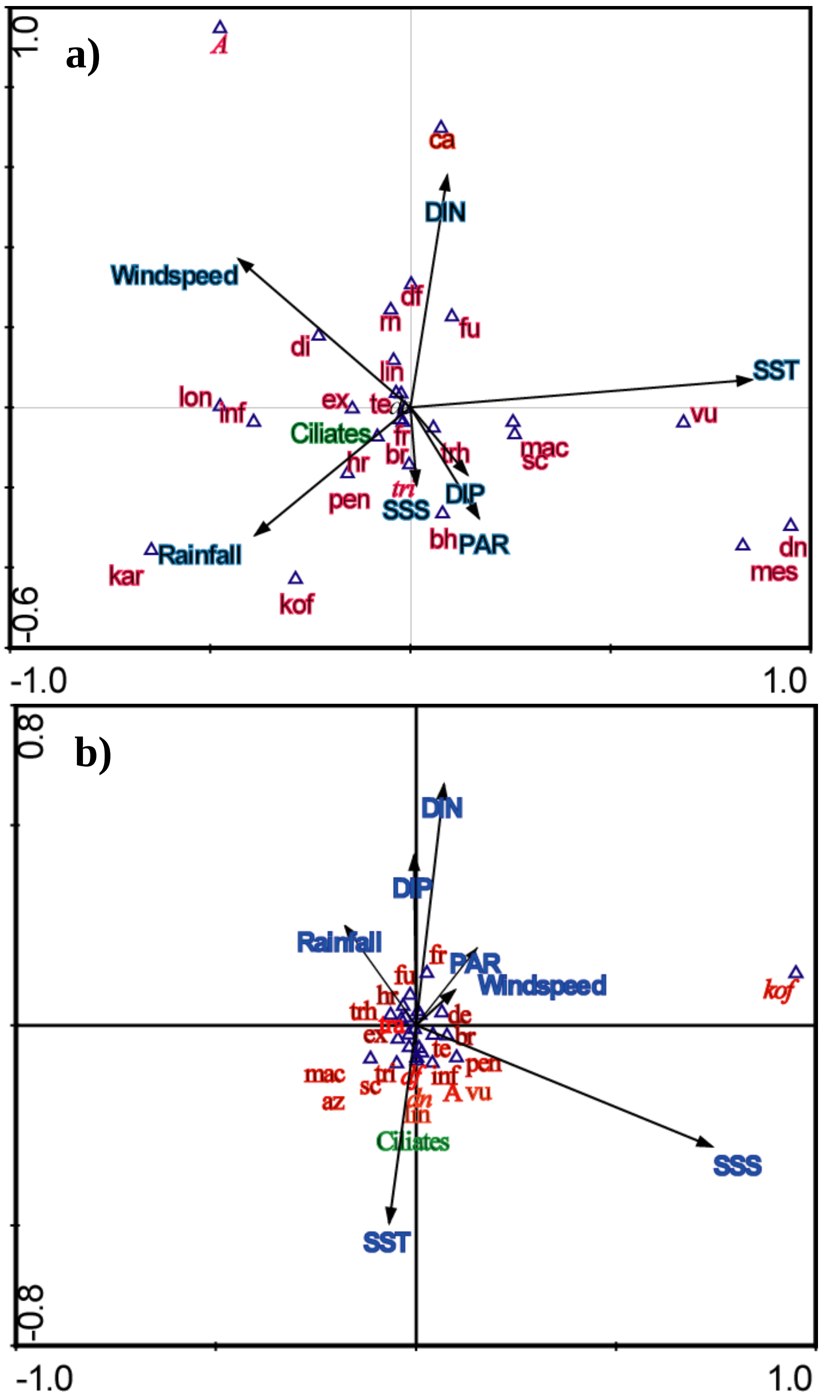

Fig 3.3 a and b Ordination diagrams for CPOS (**a**), P–K transect (**b**), based on canonical correspondence analysis of *Tripos* and ciliates. The physicochemical variables (temperature, salinity, dissolved inorganic nitrogen, dissolved inorganic phosphorus, rainfall and PAR) are indicated by arrows. Species abbreviations are listed in Table 3.1

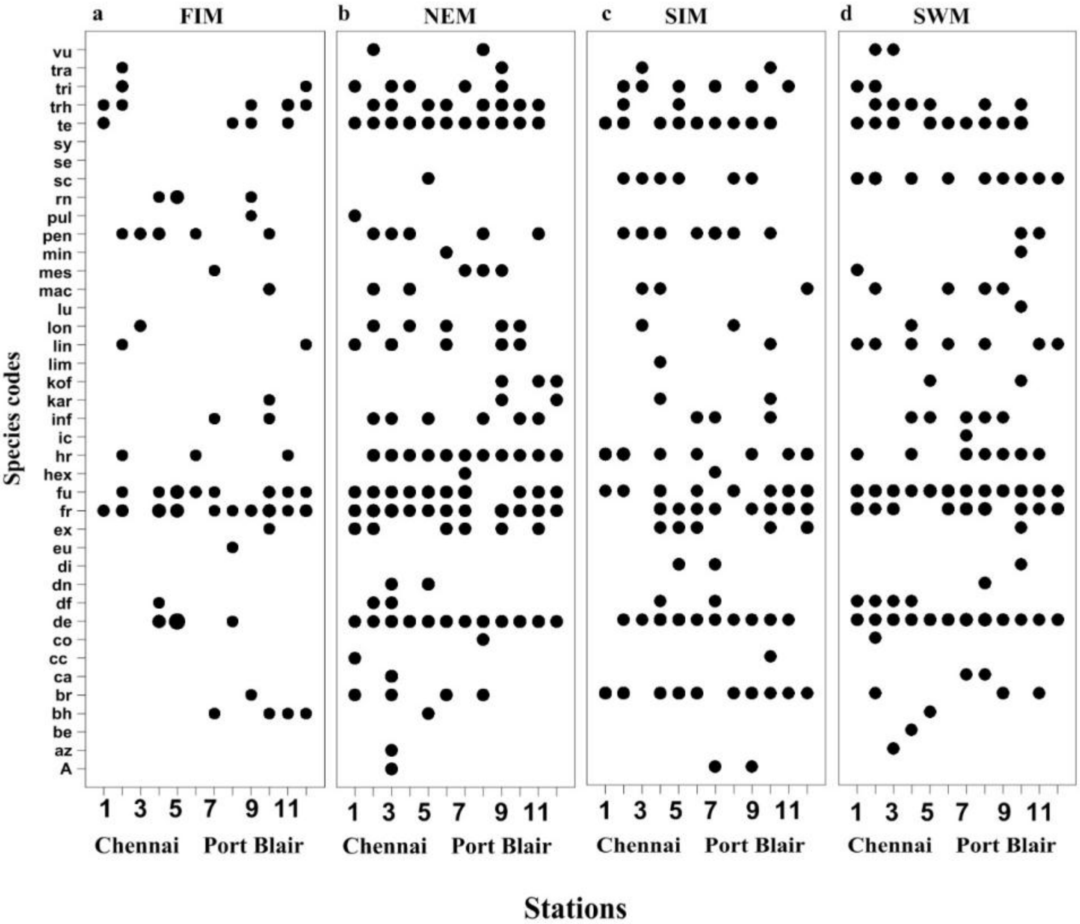

Fig. 3.4 a to d *Tripos community* composition based on cell abundance along the CPOS, (Seasonally averaged values) during different seasons, Fall Intermonsoon (FIM; **a**), North East Monsoon (NEM; **b**), Spring Intermonsoon (SIM; **c**), and South West Monsoon (SWM; **d**). The minimum diameter represents 0.03 $\times 10^{\mathbf{3}}$cells m^3 and maximum diameter represents 39 $\times 10^{\mathbf{3}}$ cells m^3. The species codes along with its respective names are provided in table 3.1.

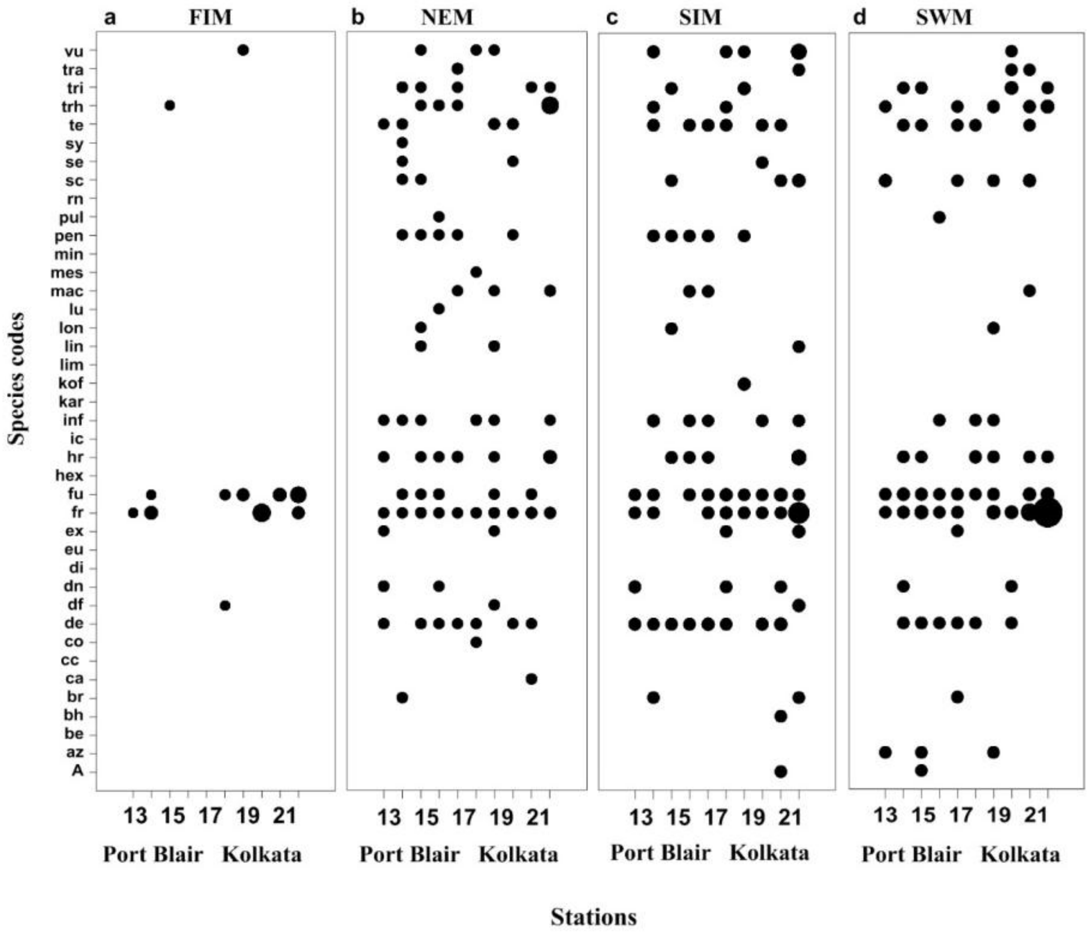

Fig. 3.5a to d *Tripos* community composition based on cell abundance along the P-K transect (PKOS, AR, RM), (Seasonally averaged values) during different seasons, Fall Intermonsoon (FIM; **a**), North East Monsoon (NEM; **b**), Spring Intermonsoon (SIM; **c**), and South West Monsoon (SWM; **d**). The minimum diameter represents 0.03×10^{3} cells m^{-3} and maximum diameter represents 39×10^{3} cells m^{-3}. The species codes along with their respective names are provided in table 3.1.

3.4 Discussion

The BoB is characterized by unique features such as seasonally reversing monsoon winds that blow during May – September from the southwest and during November – February from the northeast, March–April and October (IM) being the months of transition phase with weak winds (Shankar et al., 2002). The bay is also known for its enormous fresh water influx (riverine discharge and precipitation), vertical stratification, low light (due to cloud cover and silt), and low nutrients (Gomes et al., 2000; Madhupratap et al., 2003). Under such environmental settings, only those organisms that have developed an alternate mechanism for switching mode of nutrition have the efficiency to cope up in an oligotrophic environment. Studies indicate that dinoflagellates thrive well in low nutrient condition through a wide range of nutritional modes (Burkholder et al., 2008; Jeong, 2011). The present study revealed that in the BoB, genus *Tripos* is known to be wide spread in its distribution. In earlier studies (Pacific and NW Mediterranean) (Matrai, 1986; Tunin-Ley et al., 2007) large volume of water (~70 litre) was utilized to enumerate *Tripos* and their abundance quantified was in the range of 0–24 cells L^{-1}. In this study we utilized only one litre of surface water sample. Inspite of this limited volume the numbers are comparatively higher (5–280 cells L^{-1}) than that observed in the Pacific and Mediterranean. In this study, we covered spatial (CPOS, PKOS, AR and RM) and seasonal (FIM, NEM, SIM and SWM) variations in the distribution of *Tripos* species. The stations of CPOS and PKOS are in the open ocean, and the AR and RM are more restricted to riverine discharge. Though all the four regions are influenced by seasonally reversing monsoons, the hydrographic settings (changes brought by variations in SSS) in these transects are different. In AR and RM, the main factors are precipitation and riverine discharge; Irrawady basin and Hooghly–Ganga estuarine complex are the major sources of freshwater influx (UNESCO 1988). In the CPOS and PKOS, precipitation is the main source of salinity variation. The prevailing mesoscale eddies in the CPOS are also known for high biological production (Prasanna Kumar et al., 2004). Observations in this study indicate that the influence of eddies is restricted to upper 30 m of water column. Under such conditions, we observed distinct seasonality in the timing of occurrence of *Tripos*.

The number of species encountered was relatively higher along the CPOS than along the P–K transect. Most of the species recorded in the two transects (16 species; present during all four seasons) were widespread in the Bay, of which 15 species along C–P and four along P–K were noticed in all the four seasons. Among them, two species (*T. furca* and *T. fusus*) were dominant in both the transects (Fig.3.4 and 3.5). Their dominance in these two contrasting environmental settings indicates that they can also tolerate a wide range of salinity (25–34). Investigations from the Sagami Bay, Japan, also showed similar results (Baek et al., 2006, 2007, 2008a). For example, *T. furca* was observed in salinities varying from 17 to 34 and *T. fusus* from 24 to 30. It was also observed that apart from low salinity, rainfall results in nutrient loading especially DIN into the coastal waters. In both field and laboratory studies densities and specific growth rates tend to increase with higher N:P ratios (Baek et al.,. 2008a). In our studies as indicated in CCA biplot, high number of *T. furca* was related to high DIN concentration (Figure 3.3*b*). The species that formed the second dominant group are *T. vultur, T. trichoceros, T. muelleri, T. teres, T. pentagonus, T. macroceros, T. longirostrus, T. lineatus, T. inflatus, T. horridus*, *T. extensus*, *T. deflexus* and *T. brevis*. Although these species were not found in relatively high numbers (except *T. tricoceros*) they were present during SWM, NEM, SIM and were absent during FIM (Fig. 3.4a and 3.5a). In both the transects especially open ocean (CPOS and PKOS), the following species *T. lunula*, *T. contortus* and *T. candelabrus* were exclusively observed during the monsoon (SWM and NEM). The ten exclusive species observed along the C–P transect were found in very low numbers and occurrence (Table 3.1). These results indicate that they are purely oceanic forms with unique water mass characteristics and prevail mostly in less stratified water with a salinity range of 31 – 34. Dodge and Marshall (Dodge and Marshall, 1994) have observed tolerance of some of these species (*T. gracilis* var. *symmetricus*, *T. karstenii* and *T. ranipes*) to a maximum of 28°C. However, their occurrence in BoB indicates their tolerance to higher temperature (29 – 31°C). Several physical factors such as wind, current, tidal flow and density gradient have been suggested to concentrate phytoplankton in specific areas and play an important role in its regulation (Steidinger, 1973). Studies in the NE Atlantic Ocean have also shown distinct dinoflagellate community in two different current patterns (Raine et al., 2002). The current along the east coast of India (EICC; East India coastal current) reverses seasonally during the monsoon. Its pole ward phase is developed during March–April, and the equator phase begins as the SWM withdraws. The equator ward flow appears first in the north in September and by November it is present along the entire coast (Shetye et al., 1996). We could observe high wind speeds (11–15, 7–10m/s) during June and November in CPOS and during July in PKOS, AR and RM. Since high density of *T. furca* is usually found in the coastal waters, its widespread occurrence in November in CPOS can be related to the influence of the above monsoon events. During IM the nutrient concentrations were below detectable levels, whereas during SWM and NEM, they were in the detectable range which can be attributed to rainfall. The distribution of field population of *T. furca* and *T. fusus* was positively related with DIN, DIP and increased wind speed (Baek et al., 2008b). We could also observe a similar trend with *T. furca* in BoB. However, the level of enrichment was considerably lower than that reported in the Sagami Bay. It is also evident from the CCA biplots (Figure 3.3*a* and *b*), that one dominant form, i.e. *T. furca* persist under low DIN concentration, in the CPOS and the numbers tend to increase with elevated DIN in the stations of P–K transect. The low numbers sustained in the oceanic stations can be attributed to species-specific nutrient adaptation using half-saturation constant (*K*s) and have been evaluated by several authors (Eppley and Thomas, 1969; Qasim et al., 1973; Droop, 1973). K_s describes the ability of a species to take up low concentration of nutrients and thus determine the minimum nutrient concentration in which the species can grow. Dinoflagellates have low K_s compared with diatoms and raphidophytes. It has been reported that the half saturation constant for *T. furca* and *T. fusus* is low (0.15 μmol^{-1}) for phosphate and high for nitrate (0.44 μmol^{-1}) (Baek et al., 2008b). Field and laboratory results also suggested that *T. furca* and *T. fusus* have a competitive advantage against other algal species under low nutrient conditions because of their low K_s values.

Chapter 4: Estimation of diatoms and dinoflagellates cell volumes from the surface waters of the Northern Indian Ocean

4.1 Introduction

Trait-based characteristics are increasingly used to predict the phytoplankton community distribution along the environmental gradient (Margalef, 1978; Reynolds, 1988). They are not necessarily taxonomy related but determined based on size and the physiological processes such as growth (light and nutrient assimilation) and loss (sinking and grazing) (Morabito et al., 2007). The cell size is referred as a master trait which places important constraints on many key organismal characteristics and biotic interactions (Barton et al., 2013 and references therein). Smaller organisms have several advantages over large ones for e.g. a lower sinking rate, which is proportional to cell radius squared (Stokes law) (Smayda, 1970). Higher surface to volume ratio that helps efficient acquisition of limiting nutrients (Sherwood et al., 1975; Ploug et al., 1999) and higher maximum growth rates (Banse, 1976). In contrast, the large size organisms carry the advantage of motility, access nutrient resources unavailable to other organisms; avoid grazing and higher possibility of survival (Reynolds, 2006). The trade-off between these traits represents an ecological strategy to exploit better the available resources (Litchman et al., 2010). Since microphytoplankton exhibit a wide range in their size (20–200 mm) and shape, quantification of cell numbers only will not provide accurate information on carbon biomass. Hence, there is a need to convert cell count to cell volume since a large number of small cells are equivalent to few larger cells in terms of carbon biomass (Harrison et al., 2015). Cell size and its carbon content evaluations from cell volume can provide useful inputs to ecosystem applications, modelling and biogeochemistry studies. Phytoplankton cell volume and its associated parameters have been reported from Chinese Sea, Baltic Sea, Mediterranean Sea, Beagle Channel and North of Atlantic (Sarno et al., 1993; Sun et al., 2000; Olenina et al., 2006; Almandoz et al., 2011; Barton et al., 2013; Stanca et al., 2013). However, a similar kind of work from the waters surrounding the Indian subcontinent is lacking. Although Harrison (Harrison et al., 2015) has cited some of the references in this context, published literature is meager. In the Indian waters, the phytoplankton cell volume is measured in a few cases from the mangrove habitat and near coastal sites (Biswas et al., 2010; Mitra et al., 2012; Munir et al., 2015). This study provides information on cell volume and carbon per cell of diatoms and dinoflagellates from coastal and open ocean stations. The dataset is further compared for inter bioregional variations.

4.2 Material and methods

4.2.1 Study area

Surface water samples from the Bay of Bengal hereafter referred as “BoB” (XBT program using ships of opportunity) were collected from April 2008 to March 2010 on seven occasions along the Chennai–Port Blair ; 81°00 E, 13°00N to 92°00 E, 11°23 N, and on six occasions (April 2008 to March 2010) along Port Blair to Kolkata; 12°00 N, 93°14 E to 21°00 N, 88°23 E at 22 different stations. The stations are categorized into C-P open ocean (CPOS), Andaman Region (AR), P-K Open Ocean (PKOS) and River Mouth (RM) regions as shown in Fig. 4.1. From the northeastern Arabian Sea the surface water samples were collected while on a cruise SSK60 from 25th January 2014 to 1st February 2014 (40 stations covering 6 transects; 20°13 E, 68°90 N to 18°50 E, 69°99 N) and one coastal station located off Goa, Dona

Paula Bay (15°27 N, 73°48 E), weekly twice from 1st September to 24th December 2015 with a total 34 samples.

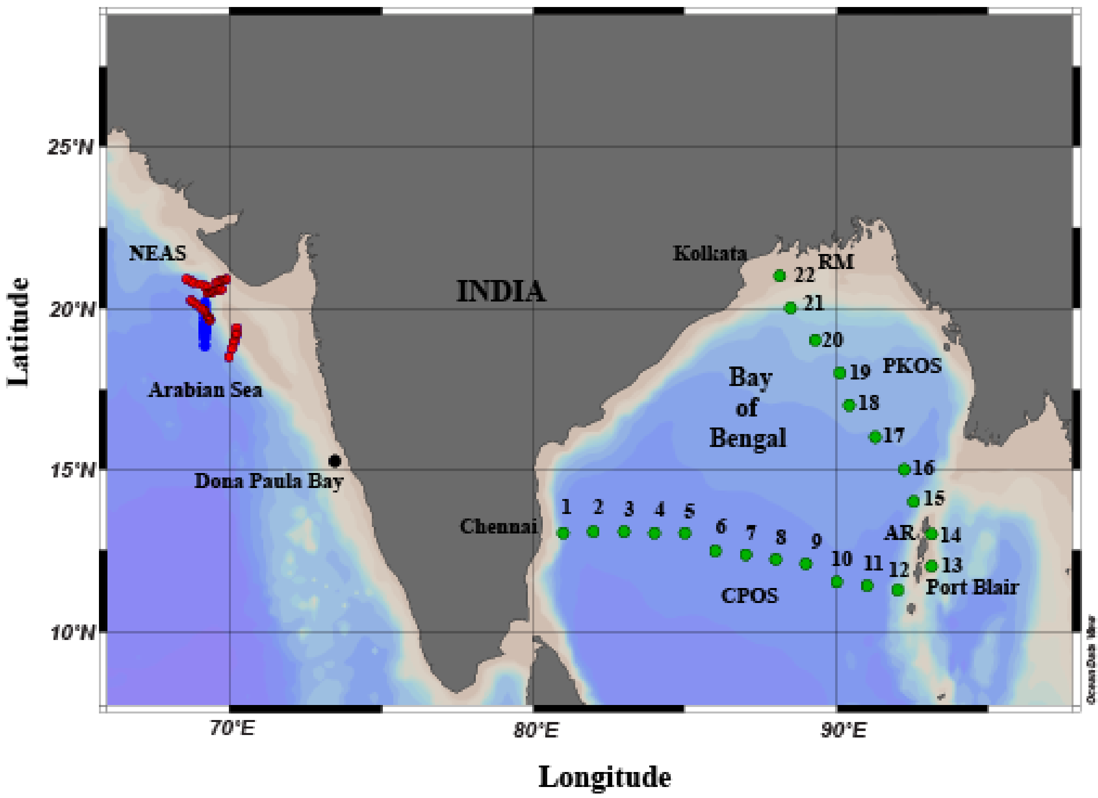

Fig. 4.1 Locations of sample collection from the northern Indian Ocean (Bay of Bengal, northeastern Arabian Sea, and Dona Paula Bay). In the Bay of Bengal, samples were collected from four different tracks (Chennai to Port Blair open ocean – CPOS; Andaman Region– AR; Port Blair to Kolkata open ocean – PKOS; and River Mouth – RM). From the northeastern Arabian Sea samples were collected from 40 stations and in the Dona Paula Bay from one station.

4.2.3 Hydrological parameters

From the BoB, vertical temperature profile of the water column was recorded by launching XBT-MK21-T7 probes (Sippican Inc.) at one-degree intervals. From the northeastern Arabian Sea, the temperature was recorded using CTD (Sea Bird Electronics, Inc.). In the Dona Paula Bay, surface water temperature was measured in situ. The conductivity of surface seawater from the Bay of Bengal and Dona Paula Bay was measured using Autosal and later converted into salinity (Guildline Autosal 8400B). From the northeastern Arabian Sea, the conductivity was measured using dual conductivity (SBE4) sensor fitted to CTD. In all regions, for nutrients, 10 ml of seawater samples were collected into 10 ml cryovials, immediately frozen in liquid nitrogen and then analyzed using Skylar, (San++ segmented flow analyzer) following the method of Grasshoff et al. (1983).

4.2.4 Estimation of microphytoplankton cell volume

From the BoB, three liters of surface water samples were collected separately and preserved with different preservatives. (0.40% of Lugol's iodine, 0.60% buffered formaldehyde and 0.20% glutaraldehyde).The samples were allowed to settle in the laboratory for quantification of diatoms and dinoflagellates through a microscope. From the northeastern Arabian Sea, only one liter of surface water samples was collected and fixed with 0.40% Lugol's iodine for the estimation of diatom cell volume and a similar procedure was followed as that of BoB. For the estimation of dinoflagellates, thirty-five liters of surface water samples were collected and concentrated to 50.0 ml, using 20 mm nylon mesh. The samples were immediately fixed with 0.40% Lugol's iodine. At the end of the cruise, the samples were brought to the laboratory and concentrated to 35.0 ml and 5.00 ml of this concentrated sample was analyzed for dinoflagellates. For the coastal station of Dona Paula Bay, one liter of surface water was concentrated to 20.0ml, of which 2.00 ml of sample was dispensed on a 3.80 cm petridish and measured for both diatoms and dinoflagellates. The cell dimensions of diatoms and dinoflagellates from the BoB were measured using an ocular micrometer, calibrated with a stage micrometer. From the northeastern Arabian Sea and Dona Paula Bay, the cells were measured using image analysis software (Q-Capture Pro 7, Olympus Inc). In all the three sites cells were observed using an inverted microscope (Olympus IX71) at 100 and 200 times magnification. The measured dimension for each taxon was calculated for its cell volume using assigned geometric shape (Hillebrand et al., 1999; Sun and Liu, 2003). The range of cell size and cell volume, its classification according to size classes, the median value of cell volume and the number of cells measured (N) from three different regions are provided in Appendix (J and K). A comparative analysis of the cell volume, 10 species of diatoms and dinoflagellates (which has a minimum number of 8 measurements) is presented in Fig. 4.2a–g. The rest of the species with cell volume are provided in Appendix J and K. The carbon per cell was calculated using the equation provided by Menden-Deuer and Lessard (2000). The median volume was converted to carbon per cell using the equation $C = aV^b$ where a and b are 0.288 and 0.811 for diatoms, 0.216 and 0.939 for other protists, and 0.003 and 1 for *Noctiluca scintillans*. We also measured cell volume of live and fixed cells. The data is provided in (Appendix L). Studies on phytoplankton cell volume have emphasized that at least a minimum of 10–50 randomly selected cells for each species should be measured. Although we have measured most of the cells up to 25 or more, it was not possible to measure all the taxa since some of them were rare forms and they are measured as they occurred in the samples. The dataset from three different sites of northern Indian Ocean is compared with the published literature from different bioregions to evaluate the variations in the cell size (Appendix M).

4.3 Results

4.3.1 Hydrological parameters

The BoB, (CPOS and PKOS) comprised of stations that are away from the riverine influence, whereas the AR and RM are closer to the Irrawaddy and Hooghly–Ganga river basins. The variations in Sea Surface Temperature (SST), Sea Surface Salinity (SSS) and nutrients during the observation period are provided in detail in another publication (Chitari et al., 2017). In brief, the SST was low during monsoon (NEM and SWM; 26.1–29.98 °C) and relatively higher during the intermonsoon (SIM and FIM; 28.2–31.0°C). The SSS was relatively high in CPOS (29.2–34.4) when compared to P-K (25.7–34.4). Low SSS, was observed during the SWM, especially in the RM and was relatively high during the SIM and FIM. Nutrient concentrations in the surface waters of the BoB were below detectable range for the most part of the year, especially during the SIM. In the CPOS, maximum concentrations of DIN and DIP were observed on some occasions during the monsoon and was up to 3.02 and 2.88 µmol L^{-1}.In the PKOS it was on par with CPOS. However, in the AR and RM, it was noticed that the concentration was up to 4.23µmol L^{-1} for DIN and 3.08 µmol L^{-1} for DIP. The relatively higher nutrient concentration can be attributed to freshwater discharge. The temperature in the northeastern Arabian Sea was observed to be low compared to BoB and Dona Paula Bay.

The nutrients were higher (Nitrate > 2.00 μmol^{-1}) compared to BoB and both are attributed to winter convective mixing. In the Dona Paula Bay high nitrate (0.40–8.00 µmol L^{-1}) and phosphate (0.01–0.68µmol L^{-1}) concentration was also observed. The details of hydrological parameters of the northeastern Arabian Sea (Roy et al., 2015;

Sarma et al., 2015) and Dona Paula Bay (Patil and Anil, 2011; 2015) are available in the published literature.

4.3.2 Microphytoplankton cell volume

A total of 219 micro-phytoplankton species, 90 diatoms, and 129 dinoflagellates were measured during the study period from three different sites of Indian Ocean (BoB, northeastern Arabian Sea, and Dona Paula Bay) (Appendix J and K). Regarding species composition, amongst the diatoms, *Chaetoceros* spp. followed by *Rhizosolenia* spp. were the dominant forms, whereas amongst the dinoflagellate, genus *Tripos* spp. was dominant and this was followed by *Protoperidinium* spp. The higher number of size classes was observed in diatoms especially in the Dona Paula Bay and River Mouth (Hooghly Estuary) when compared to dinoflagellates except for *Pyrocystis pseudonoctiluca* in the open ocean. The higher number of size classes observed in diatoms belonged to *Bacteriastrum furcatum*, *Ditylum brightwellii*, *Guinardia striata*, *Guinardia delicatula*, *Leptocylindrus danicus*, *Proboscia indica*, *Rhizosolenia hylina*, *Rhizosolenia hebetata* f. *Semispina*, *Rhizosolenia setigera*, *Proboscia alata*, and *Pseudo-solenia calcar-avis*. Such a size variation in the Dona Paula Bay and the River Mouth can be attributed to the nutrients and variation in salinity. Finenko et al., (2003) observed diatoms possess a greater degree of plasticity and are dependent on the growth conditions (mainly nutrients and irradiance). Patil and Anil (2015) also observed blooms of these forms in the Dona Paula Bay and are driven mainly by variation in salinity (14-30) and nutrients by freshwater discharge. Similarly, their variations in the Andaman Region can also be attributed to terrigenous inputs and rainfall. The cumulative variance in the cell volume between similar taxa measured by ocular micrometer and image analysis software showed maximum variations in most complex shapes. In the simplest forms having minimum line parameters, the CV was within a range of 2–3%. However, a maximum variation of 21% was observed in more complex shapes having multiple line parameters such as *Climacodium frauenfeldianum* and then followed by *Chaetoceros* spp. and *Thalassionema frauenfeldii* (Appendix L).

4.3.3 Seasonal and spatial variations in microphytoplankton cell volume in the Bay of Bengal

Seasonal variations in cell volume among the diatoms along the BoB was maximum during the SWM (July 2008, September 2008 and July 2009), and minimum during Intermonsoon (April 2008, March 2009 and March 2010). Among the diatoms, variations were observed in *Leptocylindrus. danicus*, *Guinardia. Striata Thalassionema nitzschoides*, *Proboscia alata*, *Rhizosolenia hebetata* f. *semispina*, *Rhizosolenia castracanii* and *Rhizosolenia bergonii* (Fig.4.2a–g). In some of the dinoflagellates, maximum variation was observed during the monsoon and minimum during Intermonsoon (*Pyrocystis pseudonoctulica*, *Tripos furca* and *Tripos fusus* and can be attributed due to wind-driven mixing (Fig. 4.2a–g). Irrespective to the seasons, the Andaman Region and River Mouth showed maximum variations in cell volume when compared to the open ocean sectors of C-P and P-K (Fig. 4.2a–g). Dinoflagellates are known to be a poor competitor for nitrates and half of them are heterotrophic. Vertical migration in the water column allows them to persist with non-competitive parameters for nitrogen uptake and growth (Eppley and Thomas, 1969; Smayda, 1997). The utilization of energy for mobility could be one of the reasons for minimum variation in cell volume.

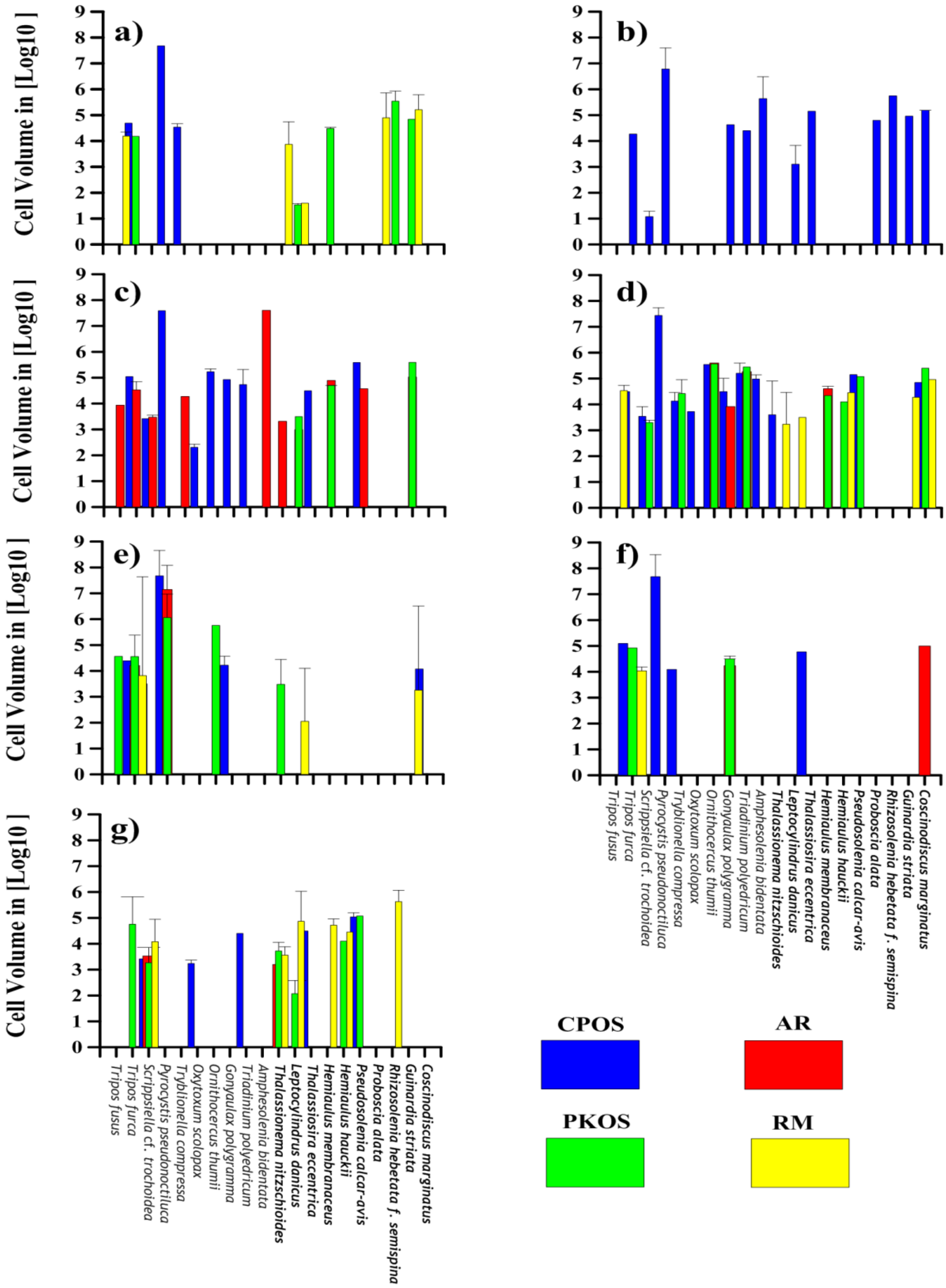

Fig. 4.2 (a–g) Intra- and inter-annual variations in the cell volume (log transformed values) of 10 diatoms and dinoflagellates species from the Bay of Bengal, which had minimum numbers of 8 measurements. The cells measured were from April 2008 to March 2010 (a: April 2008; b: July 2008; c: Sept 2008; d: March 2009; e: July 2009; f: Sept 2009; g: March 2010) along the 4 different tracks (Chennai to Port Blair open ocean – CPOS; Andaman Region – AR; Port Blair to Kolkata open ocean – PKOS; and River Mouth – RM). The regions are denoted in different shades. Species of Diatoms are indicated in bold and Dinoflagellates are indicated in regular font.

4.3.4 Comparison of cell volumes from the Indian ocean with different regions of the world

The cell volume data from this study is compared with the information available, from Atlantic (Olenina et al., 2006; Barton et al., 2013), Pacific (Sun et al., 2000), and the Mediterranean Sea (Kim and Travers, 1995) and is summarized in Fig. 4.3. Out of 219 species measured for cell volume from this study, we could compare only 8 species for which the reference data in all the regions were available (Fig. 4.3, Appendix M). The maximum cell volume was observed from the waters of North Atlantic and the minimum was observed from the Mediterranean Sea. Larger cell size observed in the northern Atlantic, compared to the Mediterranean could be due to variation in temperature, time of collection of the samples and site specific environmental characteristics. Smith and Reynolds (2003) observed annual mean SST within a range of 0 – 25 °C. In the Mediterranean waters, several authors (Sarno et al., 1993; Stanca et al., 2013) observed temperature variation from 3 to 30°C. All the above factors in the two different regions could be the reason for the variations in the cell volume.

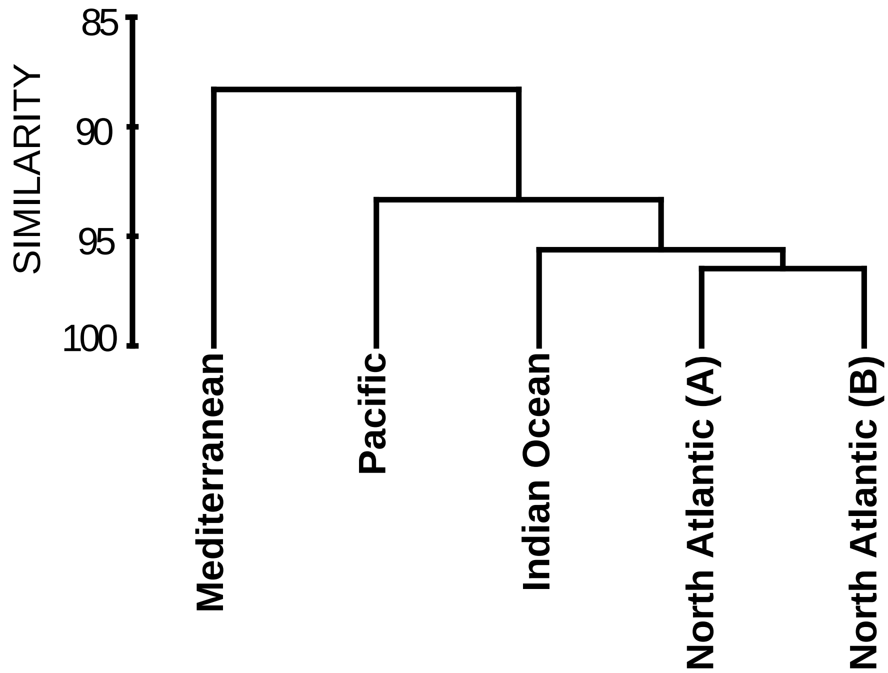

Fig. 4.3 Comparison of cell volume from 4 different geographical regions. These include present dataset, North Atlantic (Olenina et al., 2006; Barton et al., 2013), Pacific Ocean (Sun et al., 2000), and Mediterranean Sea (Kim and Travers, 1995). The eight species which are found to be common in all the 4 regions were clustered using the Bray–Curtis similarity coefficient and group average method (log transformed). The species used for clustering are marked by (*) and is provided in Appendix M.

4.4 Discussion

Till date, only 8% of the studies have estimated cell volume in the waters surrounding Indian subcontinent (Leblanc et al., 2012). In the Atlantic, Pacific and Arctic region several organized groups such as HELCOM (Helsinki Commission), PEG (Phytoplankton Expert Group), ECS (European Committee for Standardization) have setup standard protocols, to estimate biovolumes using recommended shapes of Hillebrand et al. (1999), and Sun and Liu (2003) for various phytoplankton species (Olenina et al., 2006; Harrison et al., 2015). In the Indian waters, although few datasets are available there is a need to follow the most simple and common protocol to facilitate inter bioregional comparison. According to Harrison et al. (2015), the diatom cell volumes and carbon estimates are a single largest source of uncertainty. Since larger diatoms are 20,000 times more in its cell volume than the small diatoms. Volumes of big dinoflagellates are 1500 times larger than small dinoflagellates. The ranges in diatom cell volumes are 10 times greater than across dinoflagellates (i.e. > 20,000 vs. 1500 times). The Information from the Indian Ocean region provided in this paper adds a number of species from the open ocean and provide their size ranges.

5.1 Introduction

Microphytoplankton species composition and their abundance vary mainly with light and nutrients (Reynolds, 1997). The observed variations in microphytoplankton cell size and shape indicate a direct relationship between morphology and physiology (Lewis, 1976; Sournia, 1982a). In the recent years due to global increase and geographic spread of HAB's, phytoplankton studies have attracted considerable attention in public health, aquaculture and sea food industry (Smayda, 2002a). Amongst the Harmful Algal Bloom species, dinoflagellates are the major contributors in species richness, morphological diversity and adaptive radiation in colonizing the diverse habitats found in the sea (Smayda and Reynolds, 2003).

Margalef (1978) conceived a model known as Margalef's Mandala or Margalef's elegant model, in which phytoplankton species composition are determined mainly by nutrients and turbulence. In phytoplankton succession, diatoms dominate during the periods of mixing at a high nutrient concentration ('r' strategies) and dinoflagellate prevail under oligotrophic and thermally stratified conditions ('K' strategies). Although Margalef's 'r' v/s 'K' adequately explained diatom to dinoflagellate successional stages in several temperate waters, some of the forms, do proliferate in high nutrient and stratified waters. Later based on the Grime's (Grime, 1979) model for terrestrial vegetation, Reynolds (Reynolds, 1988) divided r-K concept into three primary strategies known as Reynolds' C-S-R model. C-strategists (colonist-invasive) are small, fast-growing, high surface to volume ratio, susceptible to grazing and dominate in high nutrient and stratified waters. The S-strategists (stress-tolerance) are large species, low surface to volume ratios, slow growth rate and dominate in oligotrophic, high light conditions in which they can use strategies like mixotrophy and vertical migrations to obtain nutrients. The R-strategists (ruderal) are elongated in shape with high surface to volume ratio prevailing under high mixing conditions. The application of Margalefs Mandala ('r v/s K') and Reynolds Intaglio 'C-S-R' scheme has been applied to microphytoplankton population in several coastal upwelling systems (California, Peru, South and North Benguela) (Smayda, 2000) and also in the temperate waters for e.g fjords of southern Chile (Alves-D'Souza et al., 2008), northwestern Mediterranean Sea (Vila et al., 2005) and tropical waters (Leles et al., 2014; Moser et al., 2014; Nogueira and Figueiras, 2005). Through a series of review articles Smyada (2002b), Smyada and Reynolds (2001; 2003), applied the concept of C-S-R scheme exclusively for dinoflagellates from the waters of tropical and temperate regions. Wyatt (2014) in his recent review with reference to Margalef's model discussed the dynamic features and significance of bloom-forming species and attributed it to suites of traits which results in specific demographic strategies. Glibert et al. (2016) in a new conceptual model revisited Mandala and mapped twelve environmental characteristics or response traits and related them to different phytoplankton types.

The Bay of Bengal, receives an enormous volume of freshwater input from river discharge, is influenced by monsoonal clouds and seasonal reversal of winds and surface currents (Shetye et al., 1991; 1993; Subramanian, 1993; Gomes et al., 2000; Shankar et al., 2002; Madhupratap et al., 2003). Regardless of these, surface waters of the bay remain oligotrophic. Considering the above features, assemblages of microphytoplankton especially diatoms and dinoflagellates at different sites can be expected to adopt distinct strategies.

Till now no attempt has been made to apply these models towards microphytoplankton community from the waters of the Indian Ocean. Since the Bay of Bengal experiences variations in physico-chemical characteristics and changes also with seasons, it can be expected that microphytoplankton species with different size and shape can use their unique strategies and adapt towards the magnitude of nutrient and water column mixing. In this study, the variations in the microphytoplankton community and its associated environmental variables from October 2006 to September 2011 was evaluated. The two models (Margalef's elegant and Reynolds' C-S-R model) were applied to further identify whether the adaptations are influenced by the associated environmental features.

5.2 Materials and methods

5.2.1 Environmental Parameters

The Environmental parameters (SST; Sea Surface Temperature, SSS; Sea Surface Salinity), Nutrients (DIN; Dissolved Inorganic Nitrogen, Dissolved Inorganic Phosphate), Wind speed, Rainfall and Photosynthetically Active Radiation (PAR) are provided in details in **Chapter 2**.

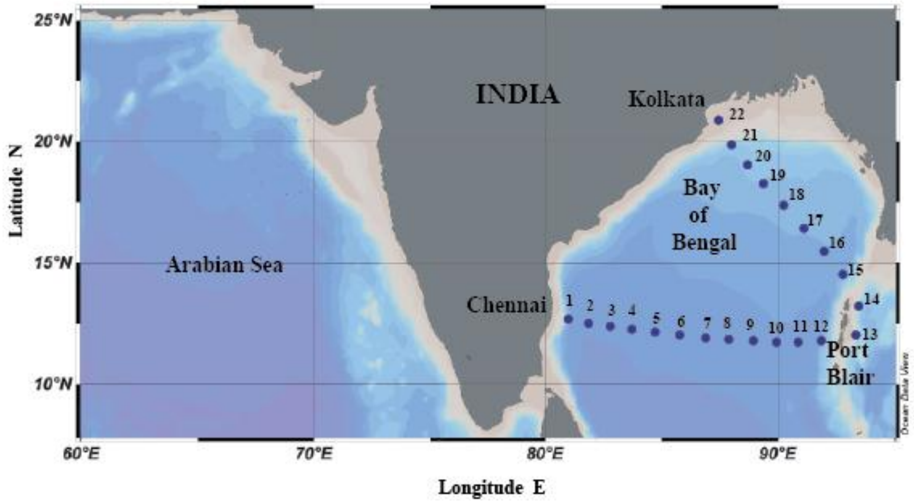

Fig. 5.1 Station map with sampling locations (circles) along the Chennai to Port Blair Oceanic Sectors (CPOS ; 12 stations) and Port Blair - Kolkata transect includes 10 stations comprising of three regions (Andaman Region-stations 13 to 15), Port Blair to Kolkata (Oceanic Stations-stations 16 to 21 and River Mouth region–station 22).

5.2.2 Study area and sampling strategy

The surface water was collected with a bucket at each of the 22 stations using a passenger ship under the Indian Expendable Bathythermography (XBT) Programmme (Fig. 5.1). The method for plankton collection and analysis followed is described in the materials and methods section of **Chapter 2**.

5.2.3 Data Processing

5.2.3a Identification of Habitat Types

The habitat is characterized based on the variations of the environmental variables along the four tracks of BoB (such as nutrients, Dissolved Inorganic Nitrogen and Silicate, Isothermal layer Depth (ILD), Photosynthetically Active Radiation (PAR), wind speed and Sea Surface Salinity (SSS)). The contour plots of each of the variable is provided in **Chapter 2**. The species assemblages and habitat types are mapped according to the classification of Smyada and Reynolds (2002) and is presented in the introduction.

5.2.3b Microphytoplankton assemblages based on life forms (r v/s K)

The microphytoplankton taxa used in the analysis were diatoms, dinoflagellates (with chloroplast) and dictyoca. The dinoflagellate with and without chloroplast were segregated based on the information provided by Tomas 1997; Loder et al. 2011; Barton et al. 2013; Steidinger and Williams 1970. The species were also assigned with ‘r,’ and ‘K’ strategies as described by Margalef (1978) and a detail list is provided in Appendix (F and G). For all the ordination analysis only those forms that most frequently occurred (0.7% and above) were used. The other morphological and ecophysiological traits such as size, shape, and affinity towards nutrient uptake rates, solitary and chain forms are also considered. Those forms without chloroplast were not considered in the ordination analysis as they were quantatively few.

5.2.3c 'C-S-R' Strategies

The species encountered were also assigned to four different adaptive strategies as classified by Smayda and Reynolds (2001; 2003). Since *Tripos* group is adapted to all forms of the environment, and appear to have characteristics of 'C', 'S' and 'R' species strategies (Smayda and Reynolds, 2003; Alves-D'souza et al. 2008), they were considered as a separate group and identified as 'C-S-R.'

5.2.3d Microphytoplankton assemblages using non-metric Multi dimensional Scaling (NMDS)

The abundance data of the respective seasons (FIM, NEM, SIM and SWM) and stations (1 to 22) were pooled to average numbers. The abundance data was converted into a lower triangular similarity matrix using Bray Curtis coefficients (Bray-Curtis, 1957) and subjected to ordination by non-metric multidimensional scaling. The analysis was performed using PRIMER ver. 6.

5.2.3e Spatial and seasonal patterns

The micro-phytoplankton abundance data was used to evaluate the possible association with the seasons of the year and or the geographical locations (Chennai to Port Blair; 12 stations and Port Blair to Kolkata; 10 stations). The cell abundance data was pooled to obain average numbers (Fall Intermonsoon; FIM, North East Monsoon; NEM, Spring Intermonsoon; SIM and South West Monsoon; SWM) respectively. The analysis was performed using Statistica 8.0 (StatSoft). The species which had chloroplast and that occurred very frequently (0.7% and above) were mapped into a matrix using Multiple Correspondence Analysis (MCA).

5.2.3f Factor analysis

Factor analysis was carried out to observe the relationship between micro-phytoplankton assemblages and its associated environmental variables. The analysis was performed using SPSS statistical package (Windows Ver. 16).

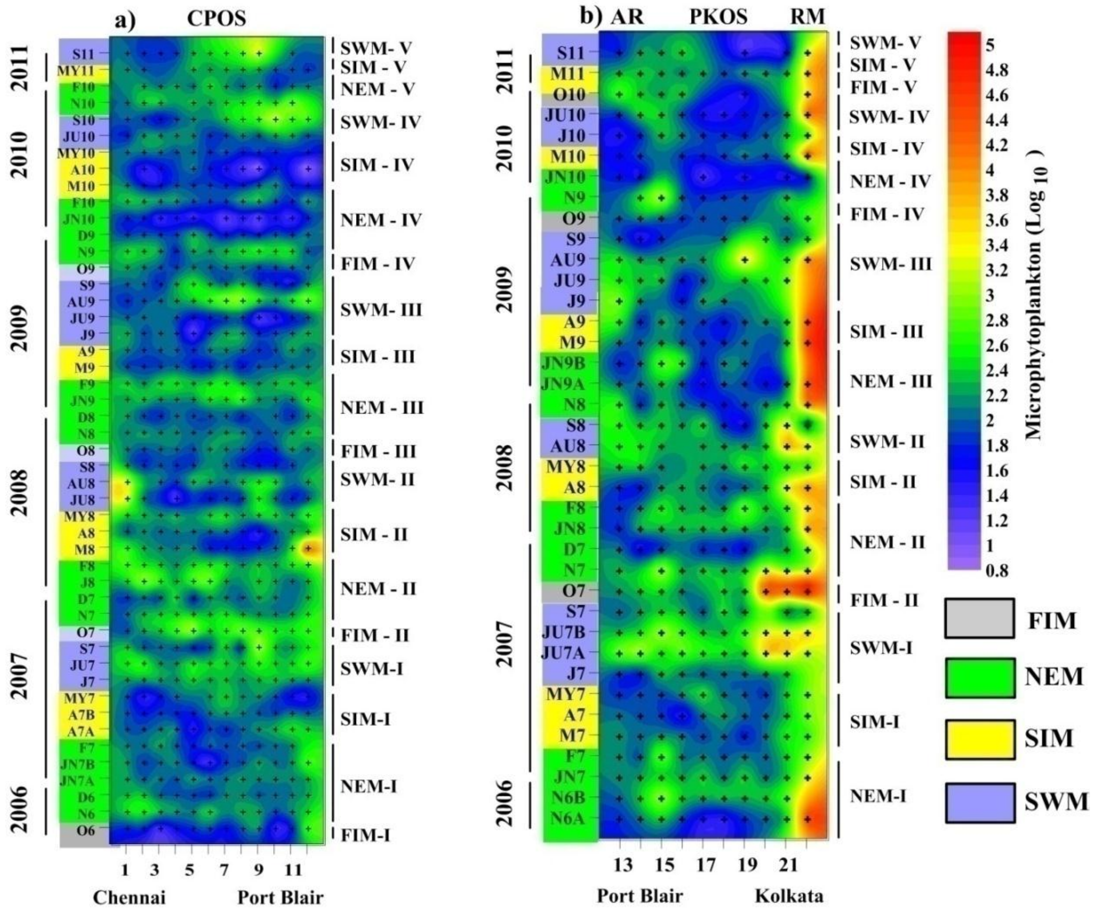

Fig. 5.2 a-b Spatial and temporal variations of microphytoplankton cell abundance which includes diatoms, dinoflagellates (species with chloroplast) and dictyoca (**a** and **b**), along the (C-P and P-K) respectively. Log transformed abundance values were used for the plot. The minimum value of 0.77 corresponds to 5 Cells L^{-1} and maximum value of 5.44 corresponds to 276400 Cells L^{-1}. The symbol (+) represents occasions of sample collection. The sampling dates with respective codes along the C-P and P-K transects are provided in Appendix A1 and A2.

5.3 Results

5.3.1 Microphytoplankton community

A total 423 microphytoplankton taxa were observed comprising 197 forms of diatoms, 225 forms of dinoflagellates and 1 form of dictyoca (Appendix D, E,F and G). Amongst these, 353 are chloroplast bearing (diatoms and dinoflagellates, dictyoca) and 70 non chloroplast bearing forms (dinoflagellates). Diatoms were the dominant group in terms of cell abundance compared to dinoflagellates. The maximum abundance of diatoms was observed in the River Mouth, and minimum was in the CPOS. In the open ocean stations of CPOS the highest abundance was noticed during the South West Monsoon (SWM), and the lowest was during the Spring Intermonsoon (Fig. 5.2 a and b).

5.3.2 Distribution of Microphytoplankton

The microphytoplankton community, when subjected to 2D ordination, showed two different groups (Fig. 5.3). Group 1 species consisted of diatoms which are chain forms, having relatively higher growth rates and known to form blooms (for e.g. *Chaetoceros peruvianus, Chaetoceros* spp. *Pseudo-nitzschia* spp. *Thalassiosira* spp. *Thalassionema nitzschoides, Bacteriastrum furcatum, Guinardia striata, Thalassionema frauenfeldii, Hemiulus huckii* and *Thalassionema* spp). However, there was only one dinoflagellate i.e. *Scrippsiella* cf. *trochoidea* in this group. Group 2 comprised of a mixed population of diatoms and dinoflagellates with relatively larger size and having slow growth rate compared to Group 1.

The distribution of micro-phytoplankton community using Multiple Correspondence Analysis (MCA) on a spatial and temporal scale is illustrated in Fig. 5.4. The Group 1 comprised of diatoms, (*Chaetoceros peruvianus, Chaetoceros* spp. *Pseudo-nitzschia* spp. *Thalassionema nitzschoides, Bacteriastrum furcatum, Guinardia striata,* *Thalassionema frauenfeldii*, and *Hemiulus huckii*). They were most dominant in the coastal stations (Station 22), especially during FIM and SIM. Amongst this *Guinardia striata* was also dominant in the CPOS at station 12. The Group 2 comprised a mixed population of relatively large diatoms and dinoflagellates. They were dominant in the open ocean and Andaman region especially during SWM and NEM. However there were some forms such as *Hemiaulus membranaeceus*, *Climacodium frauenfeldianum* and Dinoflagellates *Tripos furca*, *Tripos horridus* and *Prorocentrum micans* that also prevailed during spring intermonsoon (SIM).

5.3.3 Effect of environmental variables on microphytoplankton

The factor analysis performed using statistical package SPSS (Stastical Packages for Social Sciences) was used to relate different phytoplankton group with environmental variables (Fig. 5.5). In the factor analysis, the two factors together accounted for 26% of the variations in the dataset. The group 1 was dominated by *Chaetoceros peruvianus*, *Chaetoceros* spp, *Pseudo-nitzschia* spp. and *Thalassiosira* spp. *Bacteriastrum furcatum*, *Hemiaulus huckii Guinardia striata*, and *Thalassionema nitzschoides*. These forms were associated with low SSS, shallow ILD, Rainfall, moderate level of DIN and DIP. The Group 2a comprised of species such as *Mastogloia* spp. *Haslea trompii*, *Navicula* spp, *Nitzschia* spp, along with thecate dinoflagellates such as *Goniodoma polyedricum*, *Gonyaulax* spp. *Oxytoxum Scolopax Amphidinium* that is associated with higher DIN, DIP, SSS and shallower Isothermal Layer Depth and rainfall. The Group 2b comprised of species such as *Rhizosolenia*, *Thalassionema Pseudosolenia calcaravis Climacodinium frauenfeldianum* and occurred with high Silicate.

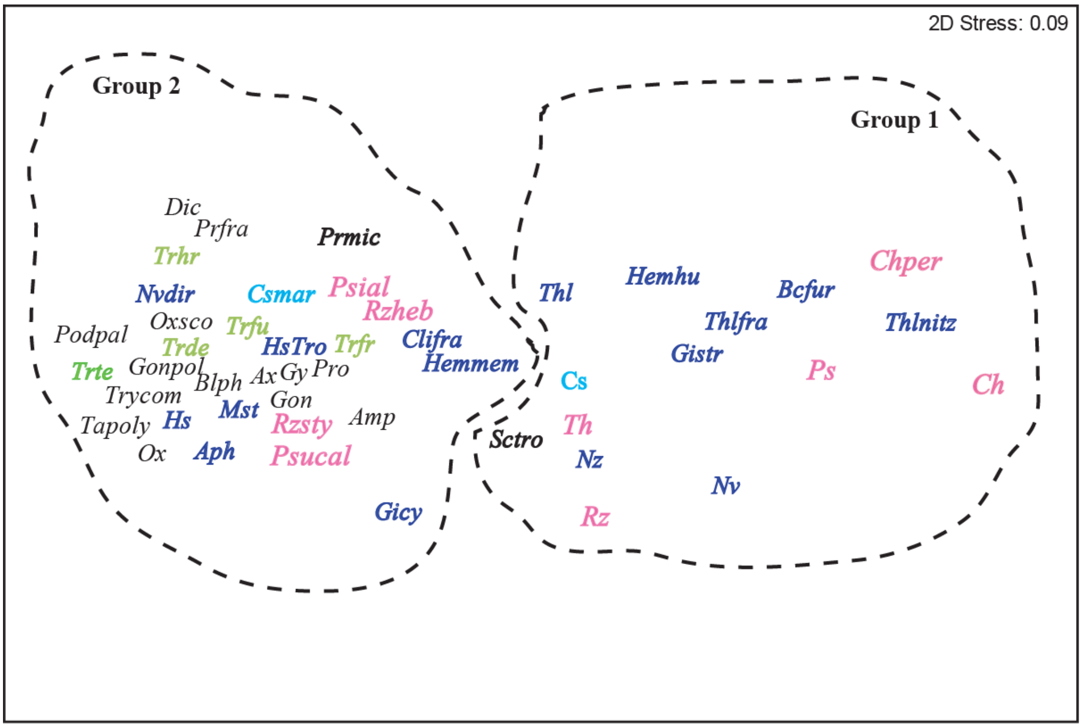

Fig. 5.3 Non-metric multidimensional (NMDS) scaling ordination based on the Bray-Curtis similarity coefficient of microphytoplankton from the surface waters of the Bay of Bengal. The figure denotes two groups. The **Group 1 -** Species proliferating in relatively high nutrient concentration and bloom forming species, **Group 2-** includes both diatoms and dinoflagellates that thrive mostly in the open ocean. Each species are assigned with different codes and are classified according to the life forms ('r' v/s 'K') forms and adaptive strategies (C, -S, -R and C-S-R) types proposed by Margalef (1978) and, Smyada and Reynolds (2001, 2003) respectively. Each codes represents unique life form and adaptive strategies and are denoted as follows (Appendix B). The pink colour (for e.g ***Chper***) depicts 'r' forms and 'R' type. The blue colour, (for e.g ***Thlnitz***) depicts only 'R' type. The black colour with bold font (for e.g ***Prmic*****)** denotes 'C' types. The green colour (for e.g. ***Trhr***) denotes 'K' form and C-S-R type. The species with sky blue (for e.g *Csmar*) denote 'S' type. Species with normal black colour font (for e.g *Podpal*) are not assigned to any form or type. The species names along with the respective codes are provided in Appendix D1.

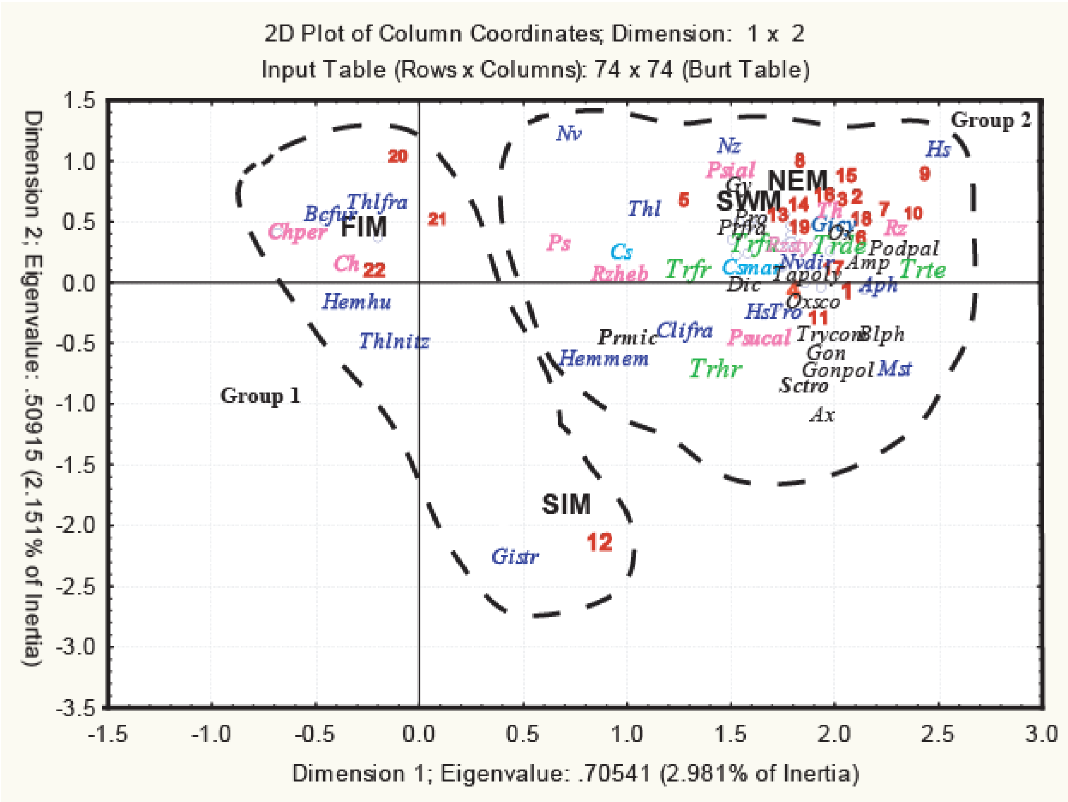

Fig. 5.4 Spatio-temporal ordination diagram of microphytoplankton, its life forms and adaptive strategies from the surface waters of the Bay of Bengal using Multiple Correspondence Analysis (MCA). The number 1 to 22 indicates stations. The seasons are abbreviated as follows Fall Intermonsoon - FIM, North East Monsoon - NEM, Spring Intermonsoon - SIM and South West Monsoon - SWM. The figure denotes 2 groups. Group 1 - species proliferating in relatively high nutrients and bloom forming species Group 2 – includes both diatoms and dinoflagellates that thrive mostly in the open ocean. Each species are assigned with different codes and are classified according to the life forms ('r' v/s 'K') forms proposed by Margalef (1978), and adaptive strategies (C,-S, -R and C-S-R) types proposed by Smyada and Reynolds (2001, 2003) respectively. Each codes represents unique life form and adaptive strategies and are denoted as follows (Appendix B). The pink colour (for e.g ***Chper***) depicts 'r' forms and 'R' type. The blue colour, (for e.g ***Thlnitz***) depicts only 'R' type. The black colour with bold font (for e.g ***Prmic***) denotes 'C' types. The green colour (for e.g. ***Trhr***) denotes 'K' form and C-S-R type. The species with sky blue (for e.g ***Csmar***) denote 'S' type. Species with normal black colour font (for e.g *Podpal*) are not assigned to any form or type. The species names along with the respective codes are provided in Appendix D1.

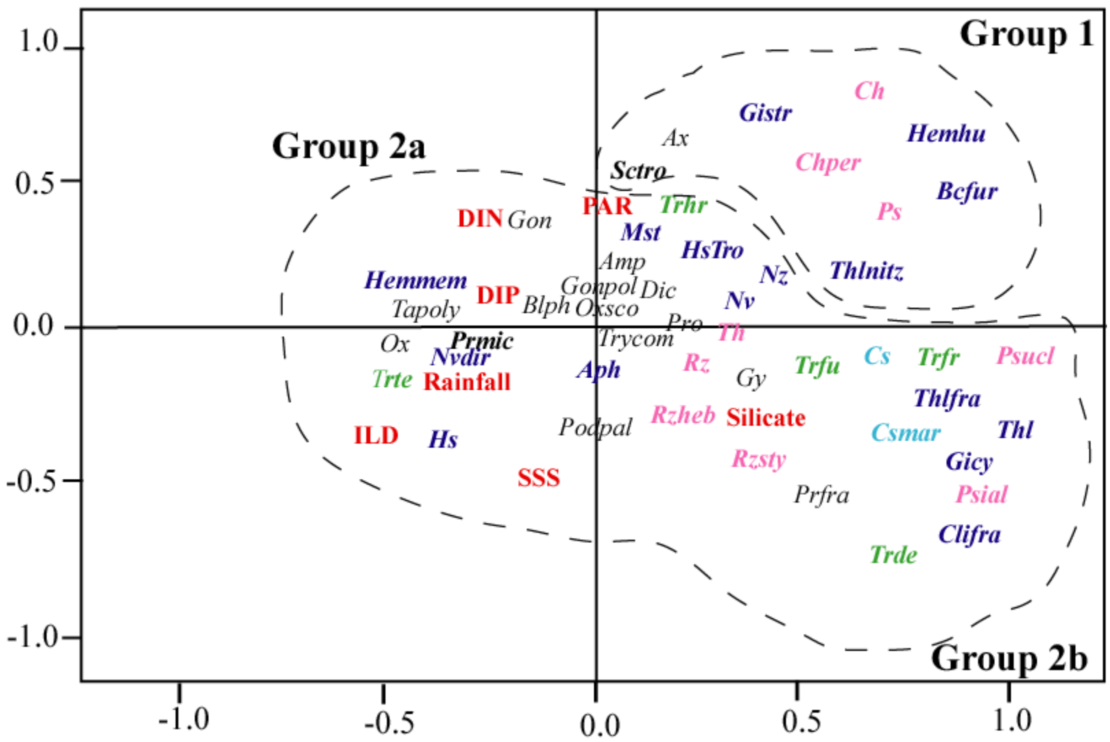

Fig. 5.5 Factor analysis biplot for surface waters of Bay of Bengal showing the relationship between microphytoplankton assemblages based on the life forms ('r' v/s 'K') and adaptive strategies (C,-S, -R and C-S-R) in association with its environmental variables (**SST**, **SSS**, **ILD, DIN**, **DIP**, **Silicate PAR** and **Rainfall**). The figure shows 2 groups. Group 1 - species that proliferate in relatively higher nutrient concentration and bloom forming species. Group 2a – includes both diatoms and dinoflagellates that thrive mostly in the open ocean. Group 2b–includes diatoms which are relatively larger than Group1 and Group2a. Each species are assigned with different codes and are classified according to the life forms ('r' v/s 'K') forms and adaptive strategies (C, -S, -R and C-S-R) types. Each codes represents unique life form and adaptive strategies and are denoted as follows (Appendix B). The pink colour (for e.g ***Chper***) depicts 'r' forms and 'R' type. The blue colour, (for e.g ***Thlnitz***) depicts only 'R' type. The black colour with bold font (for e.g ***Prmic***) denotes 'C' types. The green colour (for e.g. ***Trhr***) denotes 'K' form and C-S-R type. The species with sky blue (for e.g ***Csmar***) denote 'S' type. Species with normal black colour font (for e.g *Podpal*) are not assigned to any form or type. The species names along with the respective codes are provided in Appendix D1.

5.3.4 Microphytoplankton characterisation through life forms and adaptive strategies

Diatom and dinoflagellate community could be delineated through their life forms and adaptive strategies from the result of three different ordination analyses. The results revealed that Group 1 species which are smaller in size, fast growing, chain forming and known to bloom in elevated nutrients showing characteristics of (‘r’, ‘ R ‘) can be attributed to the nutrients brought in by freshwater discharge and fit well with the perspective of Margalefs elegant and Reynolds intaglio model. The ordination of group 2 species in association with its environmental conditions shows that they are ‘R’ type (Fig. 5.5). However, there were some ‘C’ forms in this group 2, which can be attributed to their adaptation to wide range of environmental conditions.

5.3.5 Identification of Habitat types in association with the environmental variables

Considering the reference of nine different habitat types described in the Reynolds Intaglio model and using three different ordination analysis and the species associated with the environment, we could categorize the Bay of Bengal into three different types of habitat (Type II, Type III and Type VI). The River Mouth (RM) region with characteristics such as low salinity, relatively high nutrients, and shallow ILD (influenced by riverine discharges during SWM and FIM) can be considered as Type II habitat. The same region during the NEM wherein the intensity of riverine influx decreases and exhibits higher salinity and low nutrients can be considered as Type III. The waters of Andaman Region (AR) which also is impacted by terrigenous discharge and a moderate level of ILD can be considered as Type II habitat. The CPOS during both SWM and NEM and PKOS during NEM where the deeper ILD and high wind speed was observed can be considered as TypeVI Habitat. Appendix (N,O,P,Q)

5.4 Discussion

The purpose of this study was to test the association of microphytoplankton community along the gradient of salinity, nutrients and water column mixing and to identify the species life forms, adaptive strategies in different habitat types described using the scheme proposed by Margalaf's Mandala (Margalef, 1978) and Reynolds intaglio (Smayda and Reynolds 2001). The results show the characterisation of specific forms of diatoms and dinoflagellates and their adaptations to three different habitat types in the Bay of Bengal.

The increase in the abundance of diatoms such as *Chaetoceros* (*C. peruvianus*, *Chaetoceros* spp.), *Pseudo-nitzschia* (*Pseudo-nitzschia* spp.), *Hemiaulus* (*Hemiaulus huckii*) and *Thalassionema* (*Thalassionema nitzschoides*, *Thalassionema frauenfeldii*, *Thalassionema* spp.) in the northernmost station i.e River Mouth (Station 22) can be attributed to the prevailing environmental conditions such as elevated nutrients and low salinity (influenced by freshwater discharge) (Fig. 5.5, Appendix B1 to B3(D)).

Diatoms are known to prevail in nutrient enriched turbulent conditions, whereas dinoflagellates are found in quiscent stable conditions (Barthon et al 2013, Thomas and Gibson 1990). The coastal and estuarine habitats characterised with low salinity and freshwater discharge are also known to be influenced by tidal turbulence that in turn has an impact on the variations of diatom community (Lauria et. al., 1999). Phytoplankton especially diatoms are known to respond towards sudden nutrient supply from rainfall and turbulence (Margalef 1978, Pearl et al., 1990, Thomas and Gibson 1990, Satoh et al., 2000). The dominance of diatoms in the RM could also be due to the tidal turbulence, a kind of disturbance with the interaction of two different water mass mixing (low saline water mass from riverine discharge and relatively high saline water mass from the open ocean). It is also possible that the RM and also to some extent in the PKOS is influenced by tidal turbulence and mixing of different watermass. Such physical disturbances can play a vital role in the proliferation of smaller size bloom forming diatoms and dinoflagellates. In the North Sea, it is also observed that diatoms are dominant in tidally mixed watermasses and the flagellate taxa increase its abundance in the sub surface in stratified conditions (Holligan et al., 1984).

Observation from this study in the Andaman Region showed that the ILD was in a moderate range (40 – 50 meters) and coincided with low diatom cell counts. In the previous study from same region Naik et al. (2011) observed dominance of flagellates. In several temperate waters it is also noticed that flagellates are the dominant group in stratified, nutrient enriched low turbulent conditions (Margalef, 1978).

In the RM, although high amount of silicate was observed during SWM (upto 6.5 µmol), increased turbidity by terrigenous fresh water runoff could be the factor for the low numbers of microphytoplankton population during the early phase of the SWM (see Chapter 2, Fig. 2.5b). Later on during the FIM, with improved light and changes in the water column conditions must have facilitated the occurence of Group 1 species (Fig. 5.5). In the Villefranche bay association of *Tripos* and *Prorocentrum* followed by the *Gyrodinium* and *Gymnodinium* were noticed and attributed it to the stratified conditions of the water column (Gomez and Gabriel, 2003). Later with the complete water column stratification species such as *Hemiaulus hauckii* and *Pseudosolenia calcar-avis* were dominant (Margalef 1967). The occurrence of these diatoms was attributed to its cyanobacterial endosymbiotic association (Taylor, 1982; Kimor et al., 1992). In this study associations of forms such as *Hemiaulus hauckii* and *Pseudosolenia calcar-avis* during the SIM (Appendex F) can be attributed to nutrient depleted water column conditions.

A typical succession in microphytoplankton community with the dominance of diatoms in turbulent, nutrient rich waters during the winter – spring period, and later on the dinoflagellates reaching its high numbers in stratified and depleted nutrient conditions especially during the summer is observed in several temperate waters of the North Atlantic (Barton et al., 2013), southern Bay of Biscay (Fernandez and Bode 1994). However, in the Bay of Bengal this trend could not be seen in the entire region. This could be due to the rainfall mediated changes. According to Lindenschmidt and Chorus (1998), even with the availability of silicate prolonged stratification (2-3 weeks) causes decline in the diatom biomass and hence frequent mixing events is required for the diatom to maintain its population.

There are also other physical processes such as mesoscale eddies that change the water column conditions. life forms is not seen to be closely related and could be due to the gradient in water column stratification observed along different habitats. The sources for silicate availability in the coastal (River Mouth and Andaman Region) and the open ocean tracks (CPOS and PKOS) is different, and the concenterations also varies with the habitats. In the RM and AR it is through freshwater riverine influx and terrigenous discharge respectively, whereas in the CPOS and PKOS it is through the wind driven mixing. However in the northern stations of PKOS (Station 20 and 21) the intensity of freshwater influx increased the microphytoplankton numbers during FIM (Fig. 5.2b). From the PCA biplot (Fig. 5.5) it is evident that silicate is closely associated with few of the forms such as *Rhizosolenia setigera*, *Rhizosolenia styliformis*, *Rhizosolenia* spp. (Fig. 5). Previous studies from the fjords of Southern Chile, three of the forms (*Skeletonema costatum*, *Talassionema nitzschioides*, *Rhizosolenia setigera*) were associated with high Silicate concentration and stratified water column. In the RM, presence of *Thalassionema nitzschoides* in association with shallow ILD could be due to its adaptation towards stable water column. The maximum intensity of riverine influx increased the availability of silicate concentration during the SWM and the diatom community ('r' forms) responded later with improved light conditions during the end of SWM and commencement of FIM. However, the nutrients are not the only prerequisite for the growth of diatoms, additional factors such as light intensity and low turbidity should also be considered for the development of ('r' forms) (see Chapter 2.6a and b). In a recent study Sarkar et.al (personal communication) observed estuarine fronts in the northern Bay of Bengal region influenced by Ganga – Brahmaputra estuarine system. Our result showed higher cell counts in the northern most stations of Ganga– Brahmaputra estuarine system during October – November months (Fig.5.2b) and that coincided with higher silicate concentration (see Chapter 2, Fig. 2.5b). A study from the Catalan coast of N W Mediterranean a permanent front is observed where nutrient enrichment, seaward spreading of coastal water are known to be the factors for the proliferation of diatom population (Estrada and Salat, 1989). In the Beagle channel of south Argentina, the blooms of *Chaetoceros* causes strong depletion of nitrate, phosphate and silicate with low concentration upto 0.10, 0.18, and 2.17 µmol L^{-1} respectively. (Almandoz et al., 2011). In our studies as the season progresses from SWM to FIM, with improved irradiance and the availability of nutrients, efficient absorption and its utilization could be the reason for the dominance of diatoms and decrease in nutrients during FIM. Several diatom species such as *Chaetoceros Thalassionema Rhizosolenia* and *Hemiaulus* are known to be influenced by fresh water inputs (Malej 1995). In the regions influenced by river runoff (Gulf of Trieste, Adriatic Sea, northern Adriatic Sea, Hong Kong waters with pearl river discharge, Irish coastal waters, The Galicianrıas (NW Iberian Peninsula), Bay of Calvi (NW Mediterranean) several authors observed blooms of *Chaetoceros* spp. and was most prominient during the winter-spring transition phase in response to major freshwater input in the surface layer (Malej et al., 1995; Bernardi et al., 2006; Revelante and Gilmartin, 1976; Goffart et al., 2002; Bernardez et al., 2010; Thompson, 1981; Boyle et al., 2010). In this study increase in the diatom cell counts during FIM could be due to similar mechanism wherein silicate is brought by river runoff that triggers the growth of Group 1 species. However the amount of silicate brought into the RM regions is relatively lesser (6.7 µmol L^{-1}), when compared to the temperate regions of North Western Adriatic (up to 67.7 µmol L^{-1}). The open ocean stations of the CPOS are characterised by deeper ILD and high wind speed during the SWM and NEM (see Chapter 2, Fig. 2.2b and 2.7a). The prevalence of the elongated pennate forms and medium sized thecate dinoflagellate (Group 2) such as *Gonyaulax polygramma*, *Goniodoma polydricum* are both 'R' types could be due to wind driven mixed water column conditions. The dinoflagellate *Gonyaulax polygramma*, *Goniodoma polydricum* are phylogenetically very closely related to *Gonyaulax polydera* and also share similar ecophysiological characteristics. The bloom forming *Gonyaulax polydera* are pravelent in the habitats of upwelling and bloom during upwelling relexations phase (Blasco, 1977). In this study occurrence of this 'R' type with relatively low density could be due to the tolerance towards shear/stress caused by deeper water mixing during SWM and NEM (Fig. 5.4 and 5.5). However, further increase in their numbers during the FIM could be due to the stabilization of water column and nutrient availability, a similar mechanism observed commonly during the upwelling relaxation.

There were several single-celled elongated diatoms such as *Navicula* spp., *Nitzschia* spp. *Pleurosigma elongatum*, *Pleurosigma angulatum Pleurosigma normanii*, *Pseudo-nitzschia delicatismma Pseudo-nitzschia seriata* and *Pseudo-nitzschia spp*. observed in the River Mouth during SIM. Species of the *Pseudo-nitzschia* group for e.g. *P. delicatismma*, P. *seriata*, *Pseudonitzschia* spp. were also noticed in the CPOS (Appendix F). The possible reason for their occurence could be a survival strategy in the stable water column condition. Evolution of multitude morphologies among the diatoms which includes elongated shape and chain formation have important ecological functions such as protection towards grazing and effects of sinking (Fryxell and Miller 1978, Pahlow et al., 1997). Using a diffusive and advective nutrient transport model (Pahlow et. al., 1997), observed that in a turbulent environment the potential diffusive nutrient supply is greater for elongated forms than for spherically shaped cells of similar volume, but lower for chains than for solitary cells. Compared to the spherical cells, elongated cells take up more nutrients in stagnant water due to larger surface-to-volume ratio (Pahlow et al., 1997, Litchman et al., 2010). Since diatoms possess higher specific density and sink rapidly, higher mixing conditions is required for the population to remain suspended in the water column (Harris, 1986). Diatoms sink during the SIM when the surface water is nutrient depleted, reduced water column mixing and low turbulence. Their high numbers could be a survival strategy for proliferation during favourable conditions.

The water column characteristics in the RM and to a certain extent the upper most stations of the PKOS (Station 21 and 22) are transformed during the NEM. During the NEM period the water column, is stable with a decrease in the intensity of riverine influx and depleted nutrients (Appendix B1-B3). Such conditions could be the reason for the proliferation of *Tripos* (*T. horridus, T. trichoceros*) (Appendix E). Several authors have observed blooms of *Tripos* from the habitats of German Bight, Kattegat Bay, and New York Bight and attributed it to nutrient loading, anoxic or hypoxic events (Edler, 1984, Hickel et al. 1989, Graneli, et al. 1989), especially during summer or autumn successional stages. In the above context occurrence of *Tripos* (T. *horridus*, T. *trichoceros*) during NEM could be the successional stage from FIM to NEM wherein ILD becomes shallower and nutrients gets depleted. (Appendix P and Q).

Smaller size bloom forming dinoflagellates of ‘C’ types (*Prorocentrum micans, Scrippsiella* cf. *trochoidea*) observed in the bay were not associated with any of the environmental characteristics. Their position in the PCA biplot at the centre of the axis indicates that they are adapted to the varying magnitude of environmental conditions especially nutrients and water column mixing (Fig. 5.5). Both these forms (*Prorocentrum micans, Scrippsiella* cf. *trochoidea*) are common in several coastal eutrophicated waters (Brarrud, 1945; Tangen, 1979) .Prodigious blooms of these forms in nutrient-enriched, non-upwelling coastal systems are also observed by Lackey and Glendenning (1963); Lasker and Zweifel (1978). Apart from the non-upwelling eutrophic regions, *Scrippsiella* cf. *trochoidea* are also known to proliferate in the stable water column (Alves De-Souza et al., 2008). In this study their dominance in the River Mouth and Andaman Region can also be attributed to relatively higher DIN observed during SWM and FIM. In a recent study from Hong Kong waters it is pointed out that, *Scrippsiella* cf. *trochoidea are* also influenced by high solar irradiance and availability of Iron (Zhuo-Ping et al., 2009).

It was also observed that during the SIM, increase in temperature thermally stratifies the waters of the Bay of Bengal and hence the water column is nutrient depleted with oligotrophic nature. Naik et al. (2011) using pigment indices observed the dominance of prokaryotic group in the depleted waters. Inspite of the dominance of prokaryotes, larger forms of highly ornamented, thecate dinoflagellate that are known to have cyanobacterial symbiotic association for e.g *Amphisolenia bidendata*, were also be seen in the open ocean of CPOS, PKOS and near coastal Andaman Region. The same region is later on transformed especially during the NEM with changes in the environmental characteristics such as deeper ILD and increased nutrients. However, in such conditions the shade adapted forms were prevalent. Though they are ecologically known to be most relevant at the base of the euphotic zone with high nutrients. In the present study, since microphytoplankton community are mapped only from the surface waters, characterization of such forms is not attempted. However, their abundance and occurrence is provided in the Appendix (D to F).

Performing the ordination analysis on this long-term data set, the study demonstrates that microphytoplankton community fits well based on different habitat template and species adaptive strategies. Though we classify microphytoplankton based on two different models (Margalef Elegant Model and Reynolds Intaglio Model), it is important to note that they are also differentiated as photoautotrophs, mixotrophs and heterotrophs. Amongst them mixotrophic forms are known to simultaneously perform both photosynthesis and phagocytosis (Zubkov et al., 2008; Flynn et al., 2013; Stoecker et al., 2017). In the temperate North Atlantic Ocean, 40-95% of total bacteriovery are performed by mixotrophic forms of 5µm in size range (Zubkov et al., 2008). The importance of mixotrophs in the food web dynamics has also been put forth by Mitra et al. (2014; 2016). An evaluation of the contribution of mixotrophs in the food web dynamics in this region is desirable.

Chapter 6: Microphytoplankton community from north eastern Arabian sea during early and peak winter monsoon

6.1 Introduction

The Northeastern Arabian Sea (NEAS) situated along the western side of the Indian subcontinent experiences seasonally variable surface circulation (Banse, 1968; Qasim, 1982; Schott and McCreary, 2001; Shankar et al., 2002; Shetye et al., 1994). NEAS exhibits upwelling during the SWM and convective mixing during winter (Madhupratap et al., 1996; Shetye, 1998). The physical process such as convective mixing and ventilation of the subsurface water in combination with irradiance is known to exert ecological pressure on phytoplankton (Roy et al. 2015). Nutrient transport from the upper thermocline to the surface layers due to winter convection triggers phytoplankton blooms (Madhupratap et al., 1996). The Arabian Sea is known to be highly productive region and also has a potentially significant impact on global carbon budget (Smith et al., 1991). Several cruises as a part of US Joint Global Ocean Flux Studies (JGOFS) were conducted in the northern Arabian Sea. However, these studies dealt with the distribution of specific forms of phytoplankton and their role in primary productivity. From the northwestern Arabian Sea (NWAS) Garrison et al (Garrison et al., 1998) determined the abundance of nanoplankton and microplankton using epiflouresence and light microscopy during the late South West Monsoon. One dimensional vertical hydrodynamic model showed classical food web dynamics predominated during the monsoon system and microbial loop with oligotrophic water column characteristics dominated during the intermonsoon (Blackford and Burkhill, 2002). Shakpyonok, et al. (2001) showed the dominance of *Prochlorococcus* in the oligotrophic stratified waters with low nutrient and higher temperature, whereas the increased numbers of *Synechococcus* and other eukaryotic phytoplankton cell was attributed to monsoon related intense mixing. Characterization of phytoplankton group through pigment analysis from the northern and southern Arabian sea were assessed during late South West Monsoon and spring intermonsoon (Latasa and Bidigrare, 1998). Tarran et al. (1999) compared phytoplankton communities quantified through microscopic analysis during the South West Monsoon and the following intermonsoon from the Arabian Sea. Caron and Dennett (Caron and Dennett, 1999) also measured phytoplankton growth and mortality rates during north east and spring intermonsoon. Goericke (2002) measured phytoplankton biomass using pigment based methods from High Nutrient Low Chlorophyll areas of Arabian Sea. In his study increase in the diatom biomass was observed and attributed to the absence of mesozooplankton population, rather than the availability of nutrients. The studies on microphytoplankton community and its distribution were restricted spatially towards the northern and central Arabian Sea and temporally during South West Monsoon and Spring Intermonsoon (Tarran et al., 1999). There are some reports of phytoplankton community observed from the central and eastern Arabian Sea (Sawant and Madhupratap, 1996) and from the NEAS by Madhupratap et al. (1996) at primary level.

Several cruises were undertaken in the NEAS by National Institute of Oceanography through the OCEAN FINDER program. Efforts in this program, (Roy et al., 2015; Roy and Anil, 2015; Bemal et al., 2018) described the role of picoplankton (< 2µm) quantified through marker pigments, flow cytometric analysis and their responses to the physico-chemical changes in the water column during different phases of winter convective mixing. Sarma et al. (2018) and Khandeparker et al., (2018) also observed response of different planktonic (Bacteria and Zooplankton) groups within the temperature gradient fronts.

In earlier studies from northeastern Arabian Sea, SST and Chlorophyll *a* were measured using satellite remote sensing to identify Potential Fishing Zone (PFZ) advisories. In addition to the satellite remote sensing data, Vipin et al. (2015) collected temperature salinity and chlorophyll *a* data using a suite of sensor system and CTD (Conductivity, Temperature, Depth) and observed the gradients within the parameters that characterized Filaments and Fronts.

Though there are descriptive information available on microphytoplankton composition and abundance from the northern Arabian Sea, its role in primary production and bloom formation, is not much known from the vicinity of the fronts. In a recent study, Roy et al. (2015) characterised phytoplankton pigments from the frontal regions and its surrounding proximity.

Traditional planktonic food web describes photoautotrophic forms that are known to utilize inorganic nutrients which further support zooplankton and higher trophic organisms. Mixotrophy a combined use of photosynthesis to obtain inorganic carbon and energy, and heterotrophy i.e feeding on organic carbon is known to provide a better advantage over strict phototrophs and heterotrophs (Bockstahler and Coats, 1993). Mitra et al. (2014) also emphasized that mixotrophy as an alternate new paradigm where bulk of the food web at the base is supported by microscopic organisms that combine phototrophic and phagotrophic activity within a single cell. Within the two extreme ends of spectrum i.e strict phototrophs and strich phagotrophs mixotrophs occupy an intermediate niche zone. Mixotrophy is a common phenomenon that occurs in a wide range of habitats from eutrophic, mesotrophic and oligotrophic, coastal to open ocean systems (Burkholder et al., 2008). However, information on phytoplankton taxonomic composition, species characterization and its appraisal based on trophic strategies from the frontal and non-frontal regions is lacking. In this study microphytoplankton community composition and abundance based on microscopic cell counts from filaments and fronts was mapped and the microphytoplankton were categorized based on their trophic strategies (Photoautotrophic, mixotrophic, and heterotrophic)

6.2 Methods

6.2.1 Study site and Sampling

Observations were made as a part of CSIR-NIO program OCEAN FINDER. Two cruises (ORV Sindhu Sankalp; SSK - 41 and SSK - 60) were conducted, the first was from 23rd November to 11th December 2012 (SSK41) during the period of early winter monsoon (EWM) and the second cruise (SSK-60) was between 22nd January to 3rd February 2014 during the peak winter monsoon (PWM) (Fig 6.1). Sea water samples were collected from total 61 stations, 21 and 40 from SSK-41 and SSK-60 respectively. Sub samples were collected at discrete depths from 0 to 100 meter and later used for the analysis of microphytoplankton species abundance and its composition. The details of other physico-chemical parameters such as nutrients, temperature, salinity, dissolved oxygen are published elsewhere (Roy et al., 2015; Roy and Anil, 2015; Sarma et al., 2015; Vipin et al., 2015).

For the quantification of microphytoplankton using light microscopic analysis, water samples from the surface and subsurface depth were collected using 10 L Niskin bottles fitted to the rosette frame (SBE32). A known volume (500 ml and 1000 ml) of water samples during two different cruises of SSK-41 and SSK-60 respectively were fixed with 4% of acidic lugols iodine. The samples were brought to the laboratory and allowed to settle for 48 hours. The samples were concentrated to a final volume of 10 ml and stored in the vials. An aliquot of 2 to 3 ml of the concentrated 10 ml samples were taken and dispensed into a petri dish of 3.8 cm diameter and enumerated under an inverted microscope with phase contrast attachment at 100x and 200x magnification. Microphytoplankton cells were identified using identification keys provided by Subrahmanyan, 1968; Taylor, 1976; Tomas, 1997; and Horner, 2002. The cell counts are expressed interms of cells L^{-1}.

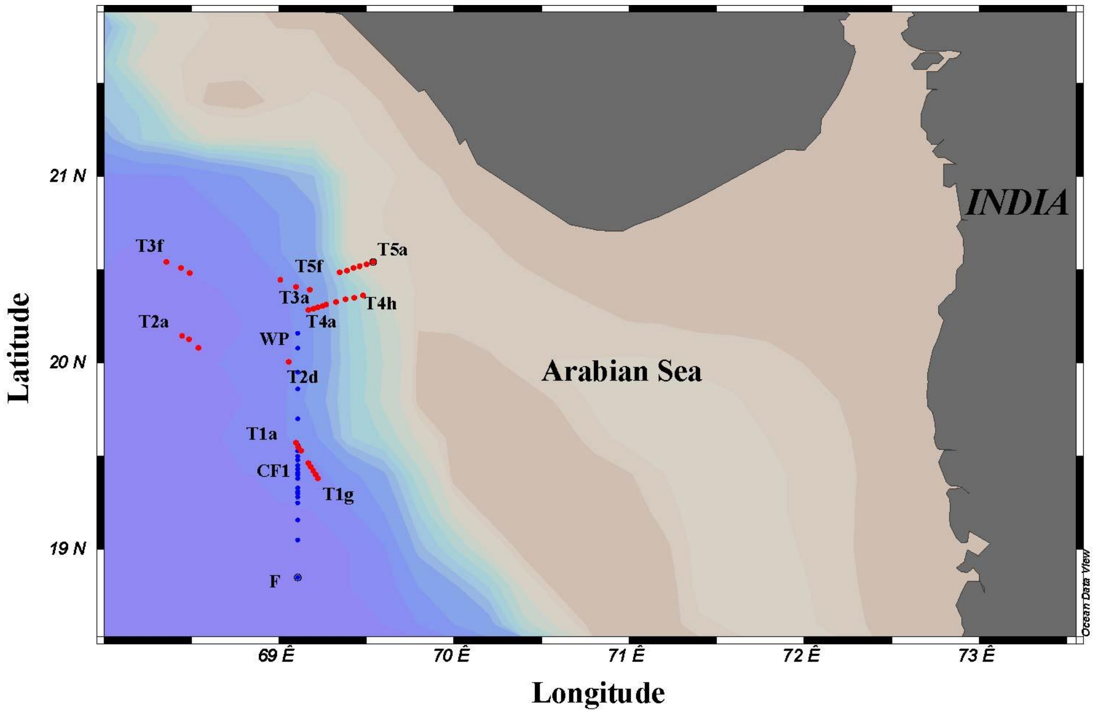

Fig. 6.1 Station map of the study site in the north eastern Arabian Sea. Blue circles denote stations sampled during SSK-41 (Early Winter Monsoon; EWM) and red circles denote stations sampled during SSK-60 (Peak Winter Monsoon; PWM).

During SSK 41 cruise, CTD data showed two cold parcels of water with in temperature difference of 0.5 to 1° C from 18.85 °N to 20.50 °N and along the 69.2 °E meridian. The cruise track is classified taking into consideration the gradients in Temperature, Salinity and Chlorophyll *a* as described in (Roy et al., 2015; Vipin et al., 2015) The zones are identified as Filament (CF1); 19.25 – 19.48 °N, Front (F); 19.95–20.20 °N, and Warm Patch (WP) 18.85–19.25 °N. During SSK-60 cruise samples were collected from 5 different transcets. The classification of fronts and non-fronts during the SSK-60 cruise is described with details in Sarma et al. (2018). In this study frontal (12) and non frontal (19) stations belonging to total 5 transects (Frontal - F1, F2, F3, F4, F5,) and (Non Frontal - NF1, NF2, NF3, NF4, NF5) are used. On some ocassions both the frontal and non frontal stations are referred as zones (Open Ocean, Transition and Shelf). Considering the spatial gradient and variations in chlorophyll *a* and nutrients the frontal (F) and non frontal (NF) zones are also classified as Open Ocean (F1, F2, NF1, NF2) Transistion (F3, NF3) and Shelf (F4, F5, NF4, NF5).

6.2.2 Data Processing

6.2.2a Cellular carbon content

The abundance value of diatoms and dinoflagellates was converted into carbon content. The mean value of carbon content (pg carbon per cell) was used in this computation. The details of carbon content per cell is provided in (Appendix J). The microphytoplankton carbon content is compared with the picophytoplankton carbon content (Bemal et al., 2018).

6.2.2b Trophic strategy

Diatom and dinoflagellate trophic strategies were categorised based on the information published by Barthon et al. (2013). Since all the diatoms contain plastids and photosynthetic pigments they are considered to be photoautotrophic. Those dinoflagellates that contain plastid, photosynthetic pigments and presence of consumed prey and other organic particles in its food vacuoles or presence of prey during feeding, were grouped as Mixotrophs. The heterotrophs were those forms where plastids or photosynthetic pigments are absent and with the presence of food vacuole (Hansen and Calado, 1999).

6.3 Results

6.3.1 Physico-chemical conditions during Early and Peak winter

The physico-chemical conditions observed during two different phases of winter monsoon (EWM and PWM) are provide in Table 1a and 1b. The low nutrient concentrations and shallow mixed layer depth observed during EWM indicates that the water is stable and oligotrophic. However, in the later stage during PWM nutrient injection from the sub surface to the surface and deepening of the mixed layer indicates intense convective mixing (Table 1a).

Table 1a Temperature, Salinity and Mixed Layer Depth observed during EWM (SSK-41) and PWM (SSK-60) in the North-eastern Arabian Sea (NEAS). The values outside the bracket indicates the range of variations and the values inside the bracket is the mean value The data is sourced from project OCEAN FINDER, Roy et al. (2015), Sarma et al. (2018).

Period and No of Stations	DIN µMol L^{-1}	Phosphate µMol L^{-1}	Silicate µMol L^{-1}	n
Early Winter Monsoon				
WP				
0-25 meters	0.48 - 1.75 (0.818)	0.41 - 1.05 (0.54)	2.79 - 4.55 (3.52)	9
26-50 meters	0.68 - 0.03 (0.766)	0.33 - 0.45 (0.39)	1.12 - 3.23 (2.43)	3
51-100 meters	1.67 - 20.89 (11.75)	0.78 - 2.34 (1.57)	0.15 - 23.11 (10.05)	8
CF1				
0-25 meters	0.17 - 8.11 (1.52)	0.09 - 2.39 (0.65)	0.1 - 21(2.78)	31
26-50 meters	0.35 - 20.14 (3.96)	0.43 - 3.18 (0.97)	0.72 - 16.86 (2.76)	23
51-100 meters	0.59 - 30.62 (13.35)	0.44 - 3.30 (1.76)	0.55 - 28.79	13
F				
0-25 meters	0.20 - 0.57 (0.39)	0.5 -0.9 (0.74)	1.29 - 4.62 (2.665)	6
26-50 meters	0.81 - 10.87 (5.84)	0.78 - 1.26 (1.02)	5.15 - 5.74 (5.44)	3
51-100 meters	11.45 - 25.8 (16.66)	1.39 - 2.47 (1.76)	7.37 - 16.40 (11.94)	4
Peak Winter Monsoon				
Open Ocean Front				
0-25 meters	1.77 - 3.74 (2.81)	0.91 - 1.21 (1.069)	0.47 - 2.82 (1.505)	19
26-50 meters	3.26 - 4.62 (4.05)	1.08 - 1.69 (1.33)	1.39 - 5.72 (2.94)	
51-100 meters	4.19 -5.85 (4.77)	1.86 - 2.99 (2.38)	8.85 - 17.46(12.64)	
Open Ocean non front				
0-25 meters	1.34 - 6.75(3.47)	0.89 - 2.41 (1.23)	0.78 - 12.73 (2.80)	35
26-50 meters	3.29 - 7.07 (4.31)	1.02 - 1.66 (1.238)	1.87 - 4.74(2.96)	
51-100 meters	3.09 - 7.28 (5.19)	1.09 - 3.69 (1.88)	2.13 - 25.09 (7.62)	
Shelf front				
0-25 meters	1.64 - 9.63 (3.81)	0.68 - 2.32 (1.11)	1.03 - 10.78 (4.25)	35
26-50 meters	3.18 - 5.94 (4.34)	0.82 - 1.47 (1.151)	3.34 -7.95 (4.46)	
51-100 meters	2.94 - 7.49 (4.96)	0.66 - 2.30 (1.24)	1.61 - 10.68 (4.72)	
Shelf non front				
0-25 meters	1.77 - 8.12 (3.603)	0.37 - 1.74 (0.901)	0.89 - 10.97 (2.67)	40
26-50 meters	3.09 - 9.69 (4.67)	0.58 - 1.64 (1.01)	1.77 - 8.73(3.33)	
51-100 meters	2.24 - 6.8 (4.61)	0.82 - 1.35 (1.060)	2.77 - 5.46 (3.712)	
Transition front				
0-25 meters	2.6 -6.12 (4.00)	0.64 - 1.66 (0.992)	0.87 - 3.33 (1.882)	20

Continued..

Period and No of Stations	**DIN µMol L^{-1}**	**Phosphate µMol L^{-1}**	**Silicate µMol L^{-1}**	**n**
26-50 meters	5.37 - 6.53 (5.80)	0.93 - 1.39 (1.103)	1.8 - 4.08 (2.88)	
51-100 meters	1.68 - 9.56 (5.53)	0.84 - 2.48 (1.31)	0.83 - 18.48 (6.14)	
Transition non front				
0-25 meters	2.42 - 5.19(3.95)	0.65 - 1.27 (0.878)	0.16 - 5.85 (2.35)	8
26-50 meters	3.35 - 6.37(4.96)	0.53 - 1.56 (0.962)	0.48 - 6.49 (2.69)	
51-100 meters	3.74 - 10.97 (6.76)	0.90 - 2.94 (1.68)	2.03 - 22.23(10.59)	

Table 1b Dissolved Inorganic Nitrogen (DIN), Phosphate and Silicate concentration observed at different depths during EWM (SSK-41) and PWM (SSK-60) from the Northeastern Arabian Sea (NEAS). The values outside the bracket indicates the range of variations and the values inside the bracket is the mean value The data is sourced from project OCEAN FINDER, Roy et al. (2015), Sarma et al. (2018).

Period and No of Stations	Temperature °C	Salinity	n	Mixed Layer Depth (m)	n
Early Winter Monsoon					
WP					
0-25 meters	26.69 - 27.97 (27.71)	36.05 - 36.59 (36.44)	12		
26-50 meters	27.65 - 27.84 (27.75)	36.39 - 36.60 (36.51)	4	54.8 - 71 (63.4)	4
51-100 meters	21.38 - 27.82 (24.67)	35.62 - 36.56 (36.20)	8		
CF1					
0-25 meters	26.74 - 26.72 (27.39)	35.37 - 36.59 (36.39)	25		
26-50 meters	26.89 - 27.63 (27.34)	36.39 - 36.60 (36.48)	14	47.5 - 64.1 (58.7)	10
51-100 meters	21.19 - 27.37 (27.34)	35.58 - 36.49 (35.97)	15		
F					
0-25 meters	26.49 - 27.65 (27.22)	35.47 - 36.58 (36.10)	8		
26-50 meters	26.84 - 27.64 (27.26)	36.15 - 36.58 (36.38)	4	9.67 - 63.1 (44.6)	3
51-100 meters	22.50 - 26.45 (23.92)	36.06 - 36.37 (36.19)	6		
Peak Winter Monsoon					
Open Ocean Front					
0-25 meters	23.2 - 25.34 (24.90)	36.2 - 26.63 (36.37)	25		
26-50 meters	24.38 - 24.86 (24.64)	36.38 - 36.58 (36.48)	5	46 - 82 (66)	4
51-100 meters	20.09 - 24.79 (22.80)	35.49 - 36.58 (36.02)	11		
Open Ocean non front					
0-25 meters	23.8 - 25.66 (25.01)	36.2 - 36.47 (36.37)	30		
26-50 meters	23.69 - 25.23 (24.37)	36.18 - 36.60 (36.41)	5	16 - 83 (44)	7
51-100 meters	20.35 - 24.6 (22.49)	35.50 - 36.49 (35.99)	13		
Shelf front					
0-25 meters	24.2 - 25.53 (24.84)	35.98 - 36.39 (36.18)	20		
26-50 meters	23.00 - 25.10 (23.97)	35.74 - 36.30 (35.99)	4	14 - 60 (39)	7
51-100 meters	24.02 - 25.31 (24.53)	36.09 - 36.86 (36.41)	3		
Shelf non front					
0-25 meters	24.30 - 27.17 (25.08)	36.09 - 36.39 (36.25)	55		
26-50 meters	23.92 - 25.20 (24.73)	36.03 - 36.44 (36.29)	10	26 - 54 (41)	8
51-100 meters	21.71 - 24.72 (23.90)	35.75 - 36.50 (36.23)	12		

Continued..

Period and No of Stations	Temperature °C	Salinity	N	Mixed Layer Depth (m)	n
0-25 meters	24.45 - 25.37 (24.90)	36.22 - 36.41 (36.35)	13		
26-50 meters	24.32 - 24.77 (24.49)	36.39 - 36.45 (36.41)	5	57 - 83 (71)	3
51-100 meters	20.98 - 24.83 (23.59)	35.65 - 36.48 (36.22)	5		
Transition non front					
0-25 meters	24.4 - 25.57 (24.98)	36.26 - 36.33 (36.30)	14		
26-50 meters	24.41 - 25.29 (24.86)	36.26 - 36.33 (36.30)	3	46 - 80 (63)	2
51-100 meters	22.46 - 25.02 (23.80)	35.83 - 36.37 (36.12)	7		

6.3.2 Variations in microphytoplankton abundance during EWM (CF1, F and WP)

The microphytoplankton cell counts were high in the CF1 (20–6060 Cells L^{-1}) followed by WP (40–1340 cells L^{-1}) in the subsurface up to 40 meters. Whereas, the abundance was relatively lower in the ‘F’ (70–1140 cells L^{-1}) and restricted up to 10 meters (Fig. 6.2a, b and c). A similar trend was also reflected in the diatom abundance. The dinoflagellate abundance was seen to be uniform from 0-80 meters in the CF1 and WP, whereas in the front high abundance was restricted up toz 10 meters and the abundance decreased thereafter.

6.3.3 Variations in microphytoplankton abundance within PWM (Open Ocean, transitional and Shelf fronts)

The microphytoplankton cell counts varied horizontally (open ocean, transition and shelf zones) and also vertically from surface to 100 meters of the water column during the PWM. Relatively high microphytoplankton cell counts were observed in the open ocean and was especially noticed at 0-20 meters (19–15020 cells L^{-1}), and the abundance decreased there after (20–100 m). The microphytoplankton distribution was observed to be in a uniform range and the trend was noticed up to 40 meters in the transition zone. Whereas in the shelf zone the uniform distribution was noticed up to 80 meters. The trend was similar for the diatom cell counts as that of microphytoplankton. However, among the dinoflagellate distribution trend was different. Relatively high number of dinoflagellates was observed in the open ocean up to a depth of 60 meters. Whereas in the transition and the shelf zones higher abundance was restricted up to 40 meters (Fig. 6.2d, e and f).

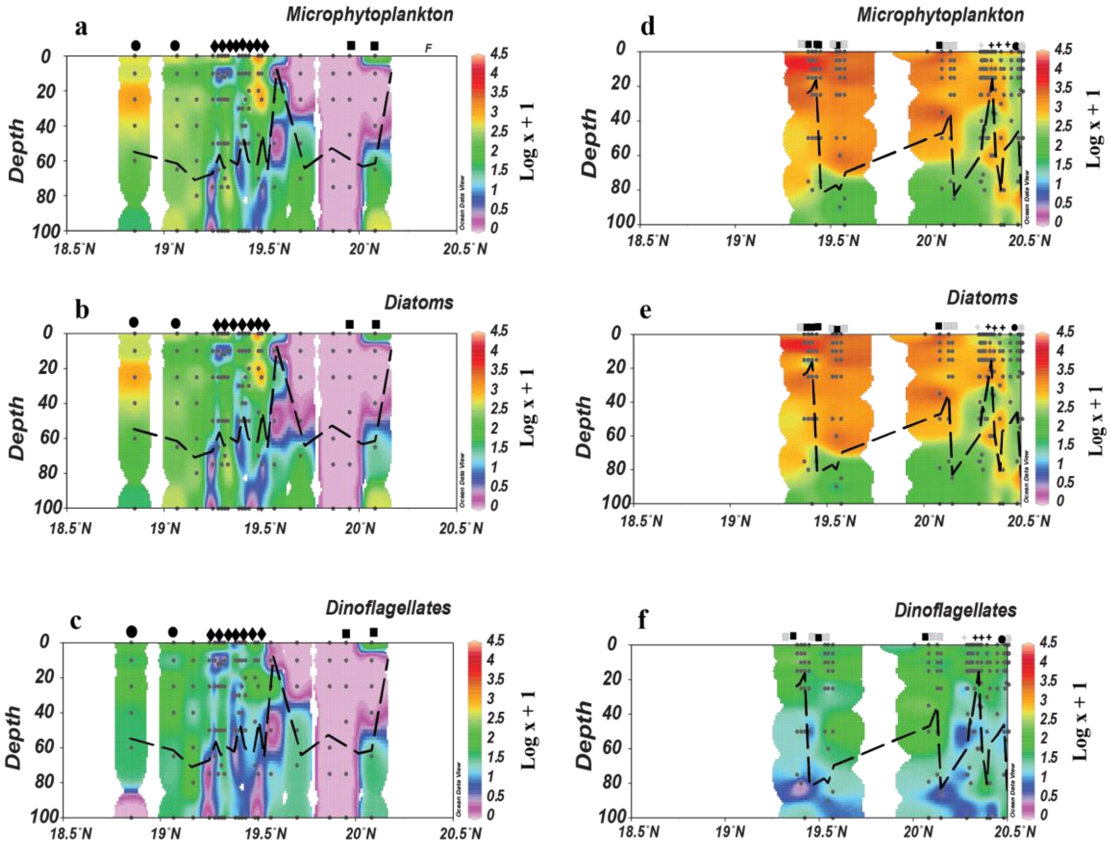

Fig. 6.2a-f Variations in microphytoplankton (a and d), diatoms (b and e) and dinoflagellates (c and f) cell counts observed during Early Winter Monsoon (EWM) and Peak Winter Monsoon (PWM) respectively. The cell counts for microphytoplankton, diatom and dinoflagellate are depicted using log transformed (log x + 1) values. The minimum value of 0.47 corresponds to 2 cells L^{-1} and the maximum value of 4.24 corresponds to 17500 cells L^{-1}. The respective symbols denotes frontal and non-frontal regions. Warm Patch (●) Filament (◆), Fronts (■), Open Ocean fronts (■), Open Ocean non fronts (■), transition fronts (✚), transition non fronts (✚), Shelf fronts (●), Shelf non fronts (◎).

6.3.4 Differences of microphytoplankton community between early and peak winter

The two way ANOVA indicated significant variations in the diatom cell counts from early to peak winter ($F = 9.85$, $p \leq 0.001$). However, a significant trend was not seen in any other group except for diatoms. During EWM, it was also observed that diatom and dinoflagellate community were dominated by few of its forms (Fig 6.3 a, b and c). Increase in the diatom and dinoflagellate species composition was noticed during PWM. (Fig. 6.3d to i).

6.3.5 Variations in Diatom and Dinoflagellate community during EWM

The diatom and dinoflagellate community during EWM comprised fewer forms as shown in (Appendix S, T, U). The most frequently occurring forms are shown in Fig. 6.3a, b and c. The dominant representative of diatoms comprised of genus *Chaetoceros*, *Navicula* and *Pseudo-nitzschia*. Relatively higher cell counts were noticed in the CF1 when compared to the 'F' and WP. Whereas, the species composition is seen to be high in the WP (80 species) when compared to CF1 (42 species) and 'F' (30 species) (Appendix S). A similar trend was also observed for dinoflagellate community with the dominance of *Tripos furca*, *Scrippsiella* cf. *trochoidea* and *Protoperidinium* spp.

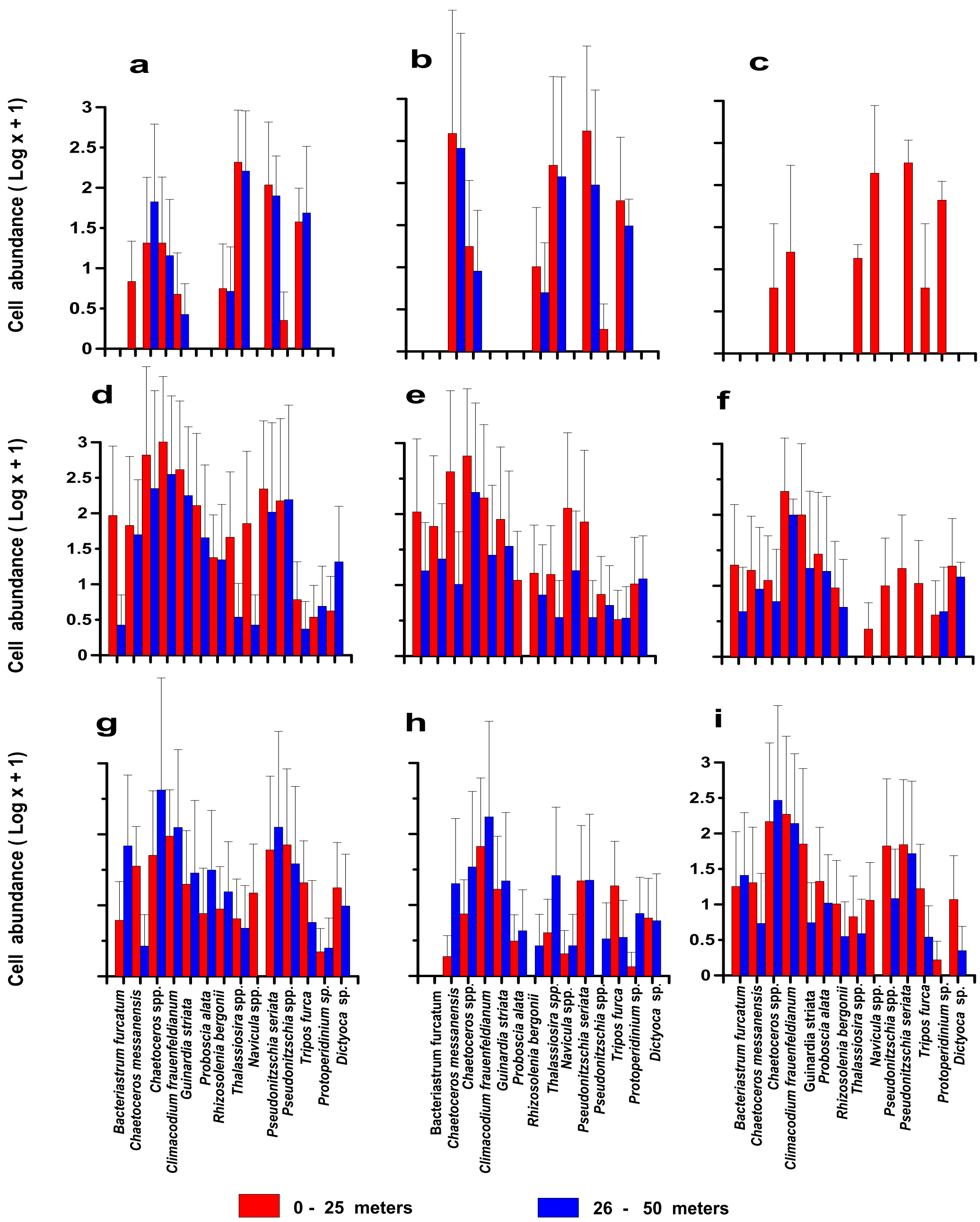

Fig. 6.3a-i. Variations in microphytoplankton community (Diatoms, Dinoflagellates and Dictyoca) observed during Early Winter Monsoon (EWM) and Peak Winter Monsoon (PWM). EWM includes stations sampled. **a** – Warm Patch (stations; 4, samples; 23, b - Filament (stations; 9, samples 36), **c** – Fronts (Stations; 3, samples 8). PWM includes station sampled **d** - Open Ocean fronts (stations ; 5, samples ; 38), **e** – Open Ocean non fronts (stations ; 6, samples ; 41), **f** - Transistion fronts (stations ; 3 , samples ; 23), **g** - Transistion non fronts (stations ; 3 , samples; 18), **h** - Shelf fronts (stations ; 4, samples 25), **i** - Shelf non fronts (stations ;10 samples ; 56) . The red and blue colour denotes different depths i.e. (0-25 meters) and (26–50 meters) respectively. The bars indicate standard deviation.

6.3.6 Variations in Diatom and Dinoflagellate community during PWM

During the PWM increase in species numbers with higher numbers of diatom and dinoflagellate taxa was noticed (Fig. 6.3d to i). The population was diverse and include species such as *Bacteriastrum furcatum*, *Chaetoceros messanensis*, *Chaetoceros* spp. *Climacodinium frauenfeldianum*, *Guinardia striata*, *Proboscia alata*, *Rhizosolenia bergonii*, *Thalassiosira* spp. *Navicula* spp. *Pseudo-nitzschia seriata*, and *Pseudo nitzschia* spp. Their abundance was four folds higher than that seen during EWM. In the open ocean diatoms such as *Chaetoceros* spp. *Climacodinum frauenfeldum Guinardia striata* were dominant when compared to transitional and shelf zones. Whereas the abundance of these forms was lower in transitional and shelf fronts (Fig. 6.3f and h). Relatively high numbers of *Chaetoceros* spp. and *Climacodium frauenfeldianum* was also noticed in the transitional non fronts and shelf non fronts (Fig. 6.3g and i). The heterotrophic forms for e.g. *Protoperidinium* spp. was observed at sub surface (26-50) meters depth in all the zones during PWM (Fig. 6.3d to i). The increased abundance upto fourfold was also contributed by several bloom forming dinoflagellates such as *Prorocentrum micans*, *Scrippsiella* cf. *trochoidea*, *Tripos furca* and *Tripos fusus* that were prevalent in the surface and subsurface waters of open ocean, shelf and transitional zones (Fig. 6.4a to h).

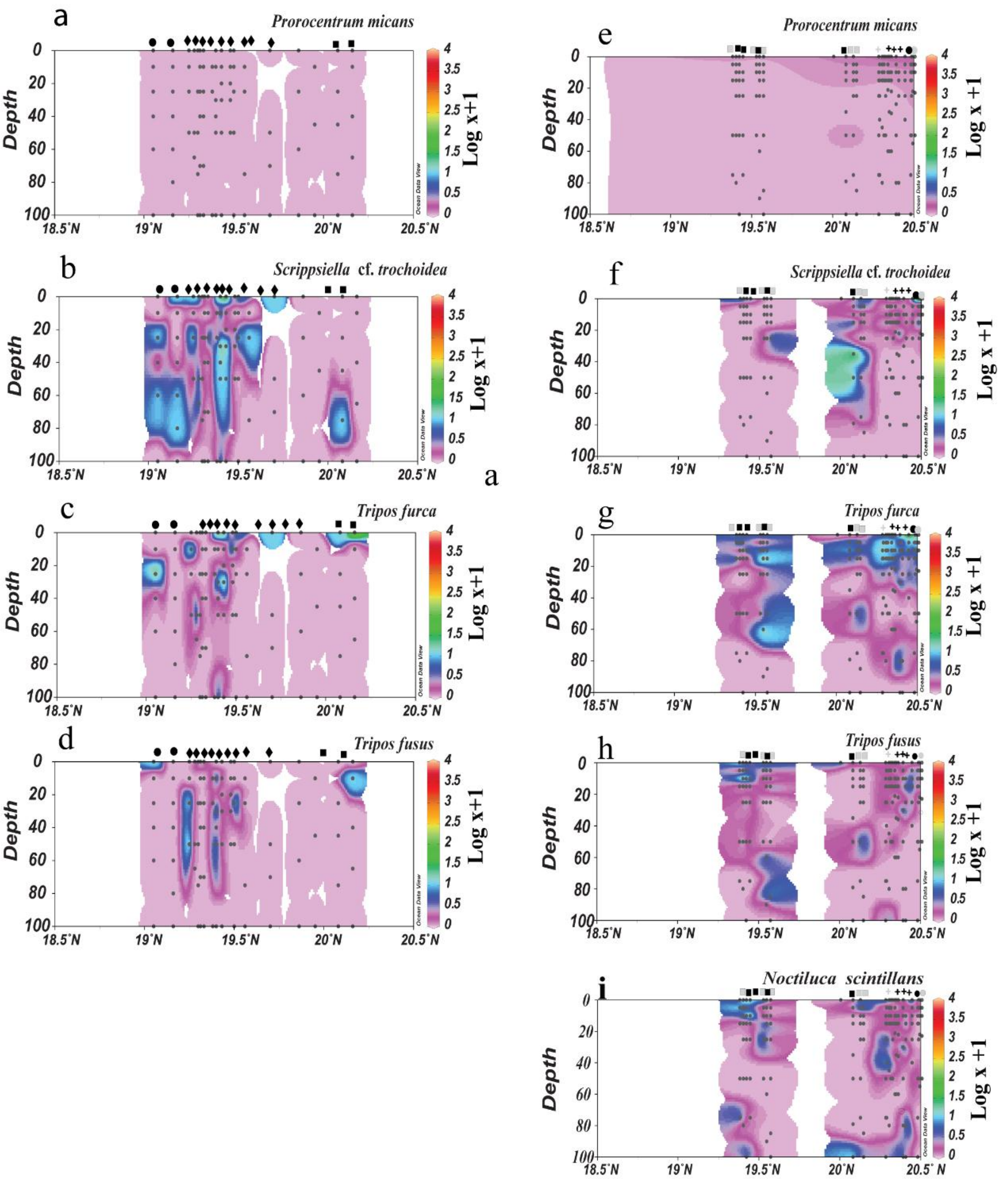

Fig. 6.4a-i Variations in bloom forming representative dinoflagellate species. *Prorocentrum micans* (a and e), *Scrippsiella trochoidea* (b and f), *Tripos furca* (c and g), *Tripos fusus* (d and h) observed during Early Winter Monsoon (EWM) and Peak Winter Monsoon (PWM). *Noctulica scintillians* was observed only during PWM (i). The cell counts are log transformed (log x + 1). The minimum value of 0.47 corresponds to 2 cells L^{-1} and the maximum value of 4.24 corresponds to 17500 cells L^{-1}. The respective symbols denotes frontal and non-frontal regions. Warm Parcel (●) Filaments (♦), Front (■), open ocean fronts (■), Open Ocean non fronts (■), transistion fronts (■), transistion non fronts (○), Shelf fronts (●, Shelf non fronts (○

6.3.7 Comparison of Dinoflagellate community during Early and Peak winter

Among the dinoflagellates species such as *Tripos furca*, *Tripos fusus*, *Scrippsiella* cf. *trochoidea*, were noticed during both EWM and PWM. However, some of the forms such as *Noctiluca scintillans* was observed exclusively during the Peak Winter Monsoon. All these species are known to form blooms and increased their numbers increased from EWM to PWM. Apart from its prevalence in the open ocean waters, *Noctiluca scintillans* was also found in the transistion zones. The other dinoflagellates such as *Tripos furca, Tripos fusus* and *Scrippsiella* cf. *trochoidea* were seen to be prevalent in the open ocean, transition and shelf zones.

During the EWM *Scrippsiella* cf. *trochoidea* was observed at the surface (0 meters) and the sub surface (20-80) meters in the CF1 and WP. However, in ‘F’ they were dominant in the sub surface (80 meters) (Fig. 6.4b). During the PWM *Scrippsiella* cf. *trochoidea* was prevalent only at the surface in the open ocean, whereas in the transition and shelf zone it was observed up to 30 meters (Fig. 6.4f). The *Tripos furca* another bloom forming species that thrived at the surface in the CF1 and ‘F’ and at the sub surface along the WP during EWM (Fig. 6.4c). During the PWM *Tripos furca* was prevalent at the surface and sub-surface (20 to 80) meters in the open ocean and transitional zones, whereas in the shelf zone their dominance was restricted upto 30 meters (Fig. 6.4g). *Tripos fusus* was another dominant bloom forming species observed along with *Tripos furca*. The vertical distribution of *Tripos fusus* also showed a different pattern. During the EWM dominance of *Tripos fusus* was observed up to 80 meters in the CF1, whereas in the ‘F’ it was observed within 0 to 20 meters. However in the WP it was prevalent only at the surface (fig. 6.4 d).

6.3.8 Variations in photoautotrophic, mixotrophic, heterotrophic and Harmful Bloom forming species during EWM and PWM.

Overall, 137, 135 and 62 of photoautotrophic, mixotrophic and heterotrophic forms were recorded. Their respective cell counts are provided in Appendix (S, T and U). Bloom forming and toxic forms (including diatoms and dinoflagellates) were also encountered (Appendix S, T and U). The most common occurring form of genera were *Rhizosolenia*, *Guinardia*, *Chaetoceros*, and *Pseudo-nitzschia*. Among the dinoflagellates, the community was dominated by mixotrophic forms *Tripos furca*, *Tripos fusus*, and *Scrippsiella* cf. *trochoidea*. Heterotrophic forms for e.g. *Noctiluca scintillans* was dominant during the PWM (Fig. 6.4i). Within the trophic category the majority of the species was dominated by photoautotrophs (Diatoms). The mixotrophic and heterotrophic forms contributed < 10% of the total microphytoplankton community.

6.3.9 Variations in Phytoplankton Carbon content

The variations in phytoplankton carbon content in the Warm Patch (WP), Filaments (CF1), and Front (F) is provided in Fig. 6.5 (a,b and c). The fourth bar in the figure (6.5 a,b and c) indicates an average value for the EWM. The WP had the highest carbon contribution of 6.23 µg $L^{-1.}$ This was followed by front 'F' (5.51 µg L^{-1}) and minimum in the CF1 (5.19 µg L^{-1}). The contribution of *Synechococcus* and *Prochlorococcus* accounted for (4µg C L^{-1}) (65.3%). In general the contribution from the diatoms was the least i.e. 0.50 to 7.3 % (0.03 to 0.40 µg L^{-1}).

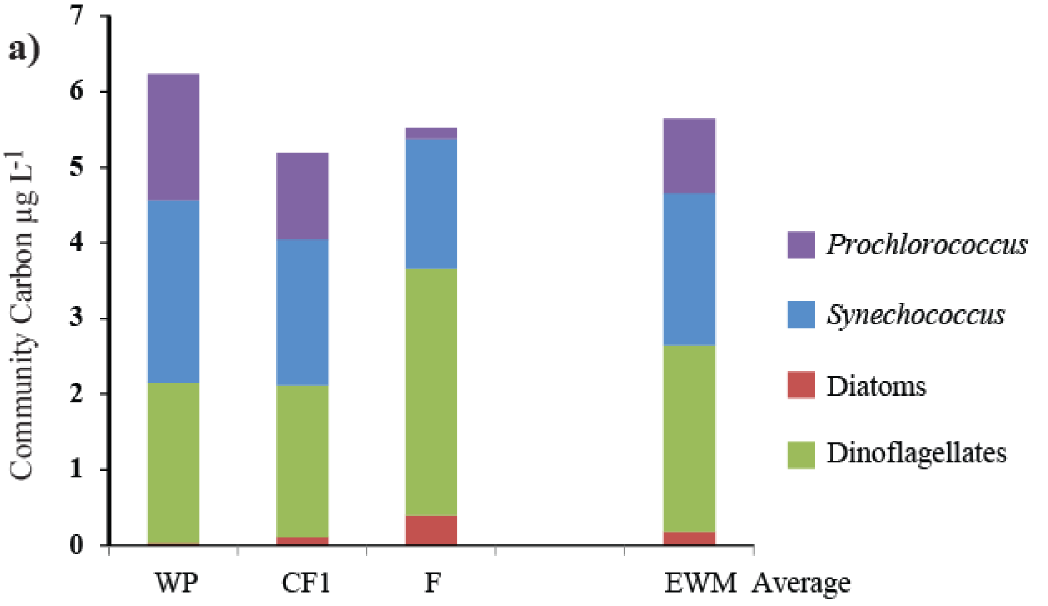

Fig. 6.5a Variations in phytoplankton carbon content (contribution of *Prochlorococcus*, *Synechococcus*, Diatoms and Dinoflagellates) during EWM (WP, CF1 and F, Average value for EWM)

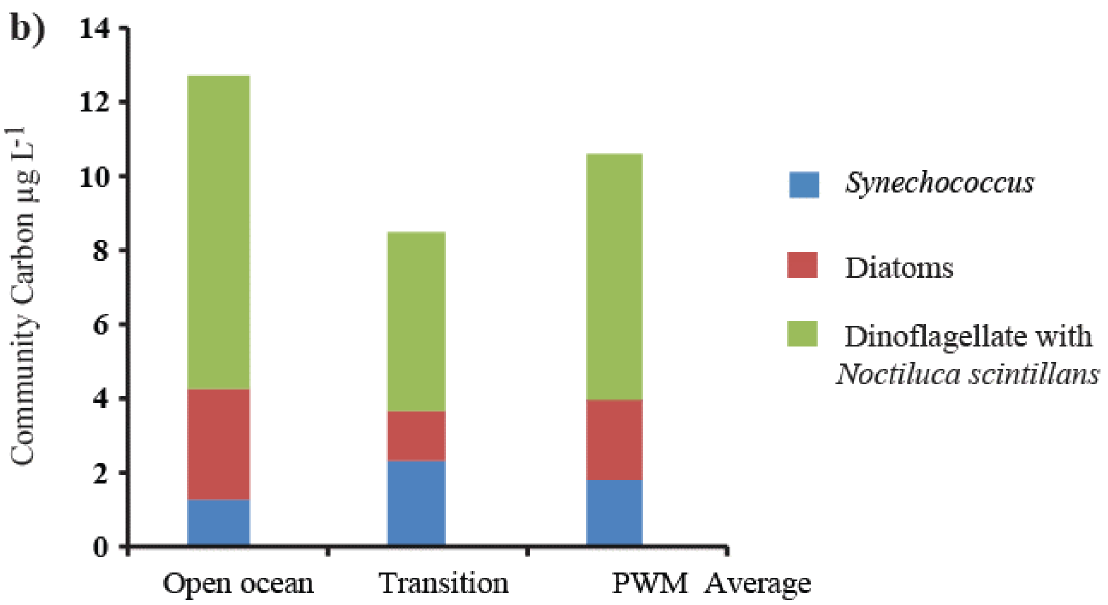

Fig. 6.5b Variations in phytoplankton carbon content (contribution of *Synechococcus*, Diatoms and Dinoflagellates) during PWM (open ocean and transition zone, Average value for PWM) with *Noctiluca scintillans*

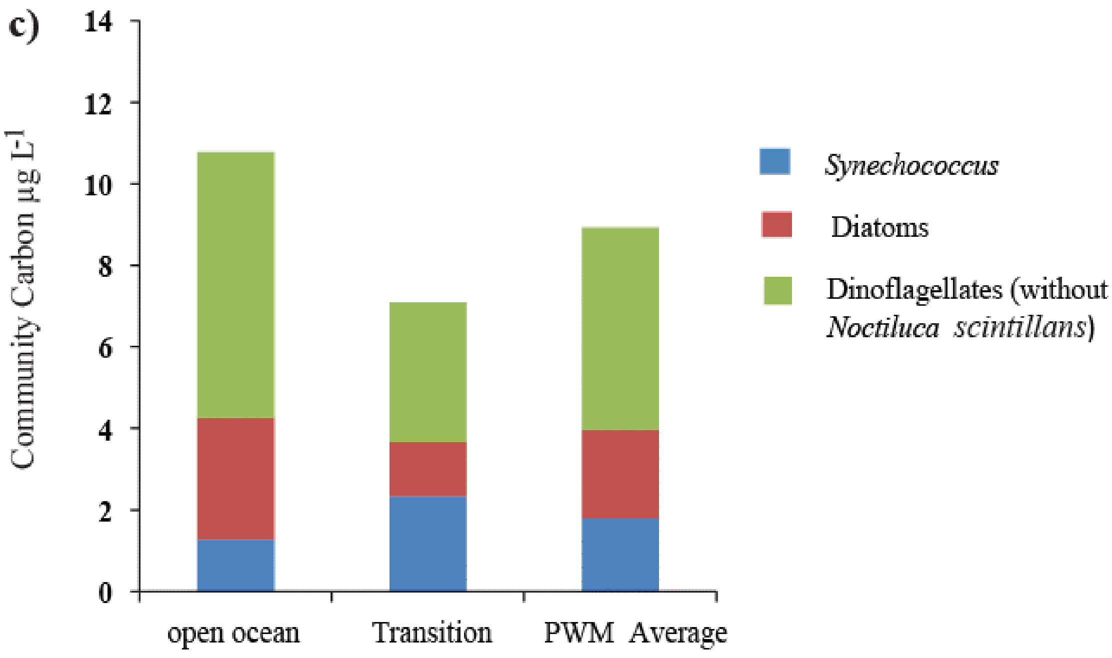

Fig. 6.5c Variations in phytoplankton carbon content (contribution of *Synechococcus*, Diatoms and Dinoflagellates) during PWM (open ocean and transition zone, Average value for PWM) without *Noctiluca scintillans*

During PWM the carbon content contributed by both picophytoplankton and microphytoplankton was 12.7 and 8.4 µg L^{-1} in the open ocean and transition zone respectively (Fig. 6.5b). The contribution of picophytoplankton came only from *Synechococcus*, whereas the dinoflagellates was the major contributor (open ocean; 8.43 µg L^{-1}, transition zone 4.82 µg L^{-1}) followed by the diatoms (open ocean; 3.0 µg L^{-1}). It is to be noted that the dinoflagellates was predominated by *Noctiluca scintillans* and their contribution to the carbon biomass was (2.5 µg L^{-1}). Overall during EWM, picophytoplankton contribution on an average was 3.00 µg L^{-1} (53.1 %) whereas during PWM dinoflagellates contributed a maximum up to 62.5 % (6.6 µg L^{-1}).

6.4 Discussion

A marked increase in microphytoplankton cell counts especially diatoms, and the species composition of diatoms and dinoflagellates from EWM to PWM can be attributed to the nutrient entrained from the sub surface to the surface by winter convective mixing (Fig. 6.2a-f). The results also highlights the dominance of specific diatom and dinoflagellate taxa at different water column depths during EWM and PWM (Fig. 6.3a – I; fig. 6.6, 6.7, 6.8). Chemotaxonomic studies from the NEAS showed increase in the marker pigment from EWM to PWM (Roy and Anil 2015). In the same region Bemal et al., 2018 observed threefold increase in the Chlorophyll concentration from EWM to Late Winter Monsoon (LWM).

Diatoms are known to dominate at intense turbulent mixing (Jones and Gowen 1990, Lauria et al., 1999, Irigoien et al., 2000). On the other hand, dinoflagellates peak mainly during summer and prefer warm water with low tolerance to turbulence and temperature changes (Silva et al., 2009). Species having similar morphology, phylogeny and physiology whether they are bloom forming or non-bloom forming, diatoms or dinoflagellates coexists with HAB species in different habitats along the gradient of water column mixing and nutrients (Smyada and Reynolds 2001). Several harmful dinoflagellates such as *Tripos furca*, *Scrippsiella* cf. *trochoidea* and *Prorocentrum micans* were found to be associated with the diatoms and this could be due to their cosmopolitan distribution. The other reason for the association of diatoms with bloom forming dinoflagellates during EWM and PWM could be due to their similar ecophysiological characteristics.

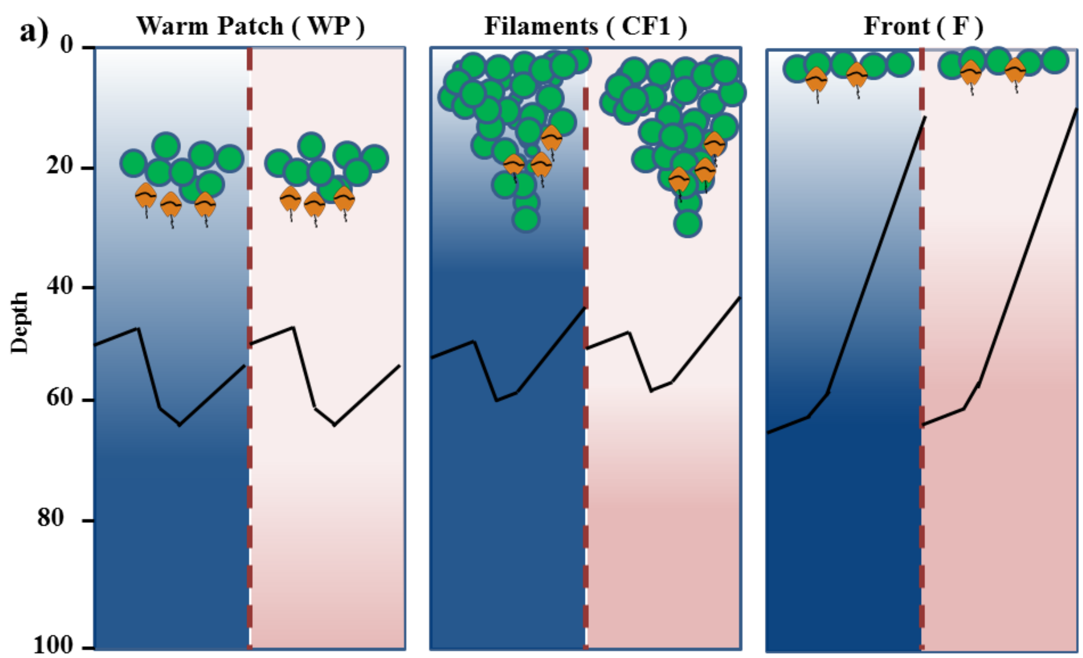

Fig. 6.6 Schematic diagram of microphytoplankton abundance (Diatoms and Dinoflagellates), Nutrients (Nitrate, Phosphate and Silicate) in the NEAS during EWM. The green and orange symbol represent maximum abundance of diatoms and dinoflagellates respectively. The background colour gradient denote variations in the nutrient (Blue colour denote silicate, Pink colour denotes Phosphate. The Black line indicates Mixed Layer Depth.

The small-scale turbulence, produced by changes in the wind-induced vertical mixing can modulate the relative abundance of diatoms and dinoflagellates (Acha et al., 2008). The increase in the species composition of several diatoms and dinoflagellate during the PWM could be due to the nutrient availability and its utilization facilitated by convective mixing.

EWM and PWM have different water column characteristics, with a lower concentration of nutrients and shallow MLD during EWM when compared to PWM. Distinct spatial variations during EWM was also noticed with relatively higher nutrients and deeper MLD in the Filments (CF1) and low nutrients with shallow MLD in the Warm Patch (WP) (Table 1a and b). According to (Cushing 1989), the chain forming cells do not grow well in the warm, stratified and nutrient poor waters. In this study we could also observe low cell counts of chain forming forms especially *Chaetoceros* spp. and high cell counts of elongated single cell forms for e.g *Navicula* spp. The environmental conditions that prevailed during EWM, could be the factor for the dominance of smaller size *Navicula* spp. in the WP and *Chaetoceros* spp. in the CF1 (Fig. 6.3 a and b).

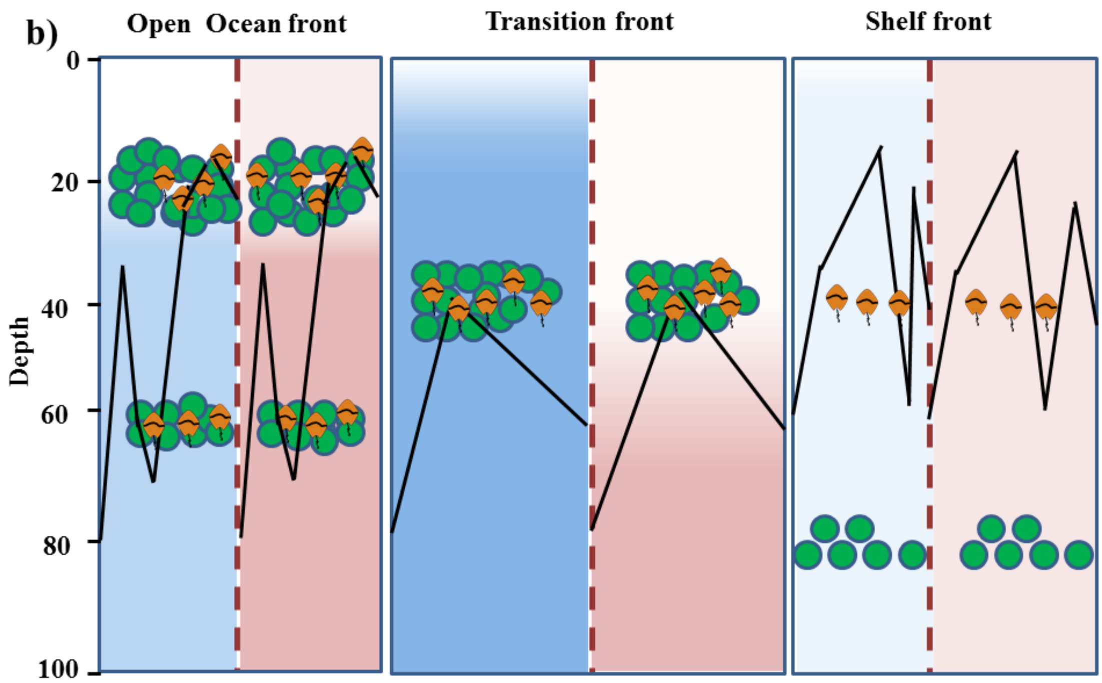

Fig. 6.7 Schematic diagram of microphytoplankton abundance (Diatoms and Dinoflagellates), Nutrients (Nitrate, Phosphate and Silicate) in the NEAS at frontal zones during PWM. The green and orange symbol represent maximum abundance of diatoms and dinoflagellates respectively. The background colour gradient denote variations in the nutrient (Blue colour denote silicate, Pink colour denotes Phosphate. The Black line indicates Mixed Layer Depth.

Diatom community is known to prevail in well mixed water column in the gulf of California (Lechuga-Devéze and Morquecho-Escamilla 1998*)* Later on a positive relationship is also seen between diatoms zooplankton and shellfish larvae (Martínez-

López and Gárate-Lizárraga, 1994) along with the blooms of *Noctiluca scintillans* (Gárate-Lizárraga, 1991). In the NEAS, Sarma et al. (2018) also observed high zooplankton biomass in the shelf fronts and that coincided with low *Chaetoceros* population. In the Sagami bay a positive relationship between diatoms and *Noctiluca scintillans* was also observed (Baek et al., 2006). The above observation point that the depletion of *Chaetoceros* abundance in this study along with increase in *Noctiluca scintillans* population can be attributed to grazing interaction could be one of the reason for the low *Chaetoceros* abundance.

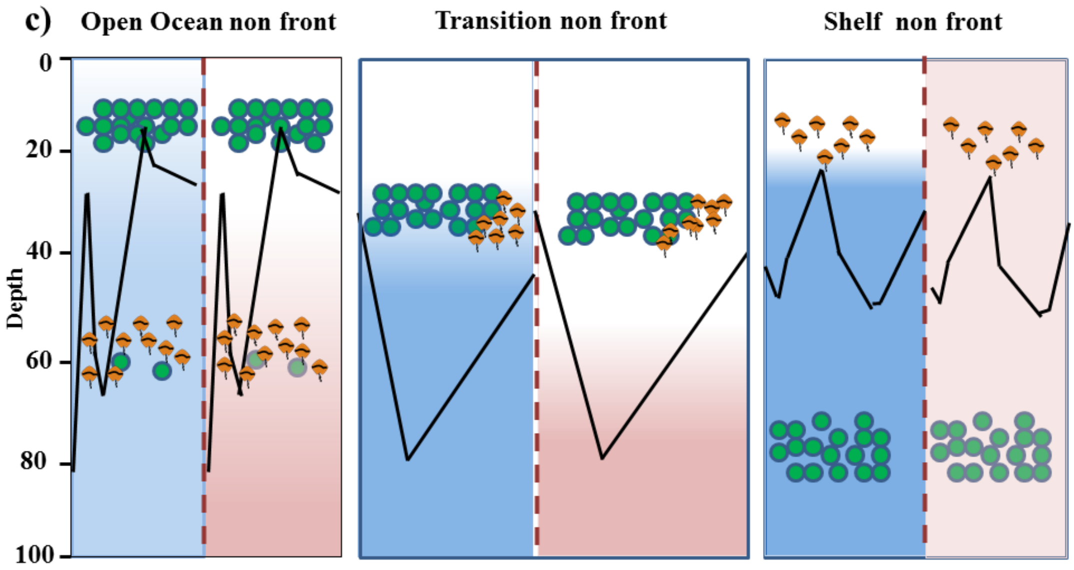

Fig. 6.8 Schematic diagram of microphytoplankton abundance (Diatoms and Dinoflagellates), Nutrients (Nitrate, Phosphate and Silicate) in the NEAS at non frontal zones during PWM. The green and orange symbol represent maximum abundance of diatoms and dinoflagellates respectively. The background colour gradient denote variations in the nutrient (Blue colour denote silicate, Pink colour denotes Phosphate. The Black line indicates Mixed Layer Depth.

In addition to diatoms that was the dominant group, few of the dinoflagellates known to form blooms were also encountered during EWM and PWM. Amongst them *Tripos* contributes with the maximum no of genera (Appendix S,T and U). Blooms of *Tripos* are also noticed in association with the anoxic or hypoxic conditions and is seen in the waters of German Bight, Kattegat bay and New York Bight (Smyada and Reynolds, 2001). In a recent study from the NEAS, Roy and Anil (Roy and Anil 2015) mapped latitudinal distribution of oxygen concentration during EWM and PWM. They noticed low oxygen concentration within the patch of 90 to 100 meters during EWM. Later during the PWM shoaling of this low oxygen patch was noticed gradually at 70 meters. Herein the population density of *Tripos furca* during EWM was encountered within the patch of 80 to 90 meters and later on during the PWM its subsequent increase at 60 to 80 meters can be attributed to the high nutrient and low oxygen levels. *Tripos furca* was previously thought to be photosynthetic (Bockstahler and Coats, 1993). Since they gain their nutrition both by photosynthetically and dissolved or organic material uptake (Stoecker, 1998), recently it is considered as mixotrophic (Li et al.,. 1996; Smalley et al., 1999; Smalley and Coats, 2002). Since increase in the concentration of bacteria, POC was observed during PWM (Sarma et al., 2018) and also the availability of prey species such as ciliates, increase in the abundance of *Tripos furca* during PWM can be attributed to the availability of nutrients, POC, bacteria and prey species such as ciliates.

Several authors observed that the Pycnocline is known to be a main factor for the development of dinoflagellate population (Morse, 1947, Donaghay and Osborn, 1997, Baek et al., 2006). Sub surface population of phytoplankton patchiness is also been attributed to the pycnocline (Rasmussen and Richardson, 1989). In the NEAS increase in the density of the upper ocean also ventilates the upper part of the permanent pycnocline (Roy and Anil, 2015). Pycnocline is also considered as a facilitating condition for the development of dinoflagellate population (Baek et al., 2006). *Tripos furca* is also known to prevail in high numbers above the pycnocline (Donaghay and Osborn, 1997). In the Sagami bay *Tripos furca* is observed frequently near the pycnocline during rainy season with stratified waters entailing with nutrients in the water column (Baek et al., 2006). In this study a similar phenomenon could be one of the reason for increase in the density of *Tripos furca.*

Another harmful bloom forming species also known to be mixotrophic is *Tripos fusus*. In the NEAS the cell counts of *T. fusus* were seen to be very low when compared to *Tripos furca*. In the Sagami Bay blooms of *Tripos fusus* are often noticed after heavy rainfall with low salinity (24 to 27 psu) and subsequent nutrient addition (Baek et al., 2008a). In the NEAS, prior to or during EWM high rainfall events are known to create a low salinity patch at 19.55 °N and 20.20 °N and is known to be advected by local currents (Vipin et al., 2015). In this study increase in the cell counts of *Tripos fusus* at 20.20 °N (F) during the EWM and one of the possible factors could be due to rainfall induced low salinity condition (Fig. 6.4d). *Prorocentrum micans* is another harmful bloom forming dinoflagellate commonly found in nutrient enriched coastal habitats. Earlier observation in Chilean water points out *Prorocentrum micans* can spread from the offshore frontal zone to the inshore region (Avaria, 1979). Naik et al. (2010) pointed out such a possibility in the Bay of Bengal as well. In this observation increase in the cell numbers of *Prorocentrum micans* during PWM was observed in the Shelf and transistion zone. According to Pitcher and Boyd (Pitcher and Boyd, 1996) blooms of *Prorocentrum* is transported from offshore to the inshore by wind driven coastal upwelling and accumulate in the regions of upwelling fronts. *Noctiluca scintillans* is another bloom forming heterotrophic dinoflagellate that acquired characteristics of omnivorous feeding on wide range of prey substances such as copepod nauplii, fish eggs, fecal pellates, marine snow and bacteria (Mikaelyan et al., 2014 and References therein). The occurrence of *Noctiluca scintillans* during PWM can be attributed to the two different mechanisms such as utilization of inorganic nutrients and also by grazing interaction on different prey such as diatoms, bacteria and POM. In the south east coast of Australia nutrient injection from the bottom are known to be main factor for the development of *Noctillica* population (Dela-Cruz et al., 2002). In the North West Bulgarian region high biomass of *Noctiluca scintillans* were related to both warmer and colder Sea Surface Temperature (Oguz and Velikova, 2010). Assumptions are also made where *Noctiluca scintillans* prefer diatoms as its food in both field populations and culture studies (Nakamura, 1998). In the Arabian Sea blooms of *Noctiluca scintillans* are observed from the coastal and open ocean (Prakash et al., 2008, Padmakumar et al., 2010) and attributed to upward movement of nutrient from the bottom to the surface. Gomes et al. (2014) observed the blooming of *Noctiluca scintillans* in the NEAS. Sarma et al. (personal communication) also observed blooms of *Noctiluca scintillans* during the late phase of the winter monsoon and attributed it to the nutrients brought up from the subsurface by vertical mixing. Sarma et al. (2018) also observed increase in the bacterial population and POM in the open ocean. Along with the *Noctulica scintillans* cells of *Pyrocystis pseudo-noctiluca, Pyrocystis lunula* were also encountered which share common ecophysiological characteristics with *Noctiluca scintillans*. They are capable of depth keeping and known to proliferate at the base of euphotic zone (Smyada and Reynolds, 2003).

In another observation, Sarma et al. (2018) noticed that the F_V/F_M ratio contributed by the microphytoplankton population varied from (0.43 to 0.49). However, the results of Sarma et al. (2018) indicates that the F_V/F_M ratio is low and the cells are physiologically inactive or must have reached its senescent stage. As stated earlier the observed increase in diatom numbers during PWM could be its senescent stage.

Studies from the Norwegian Sea (Erga et al., 2014), western Mediterranean Sea (Marty et al., 2002), Rio de La Plata marine time front (Carreto et al., 2003) observed dominance of Pryminesiophytes in association with diatoms through its diagonistic pigments. Along the continental shelf between the Rio de La plata and the open ocean waters of the sub-tropical convergence, Carreo et al. (2000) observed five different phytoplankton assemblages dominated by haptophytes and cryptophytes. Their bloom was also observed along with diatom population and attributed to the cold and nutrient rich waters. Increase in the phytoplankton concentrations as well as compositional shifts from smaller prokaryotic forms to a larger eukaryotic phytoplanktons have been reported in several frontal regions of trophic and sub trophic waters (Howell et al., 2017). In context to the waters of Arabian Sea similar features were also observed with reference to prokaryotic forms i.e shifts from *prochlorococcus* to *synechococcus* (Roy and Anil, 2015; Bemal et al., 2018). The uptake capability of nutrient by the phytoplankton is influenced by cell size, shape and Surface/Volume ratio. In the picophytoplankton community smaller size *prochlorococcus* are known to have better competitive advantage towards nutrient utilization in oligotrophic waters when compared to larger size *Synechoccus* (Mourino-Carballido et al., 2016). A similar trend can also be seen from the NEAS with diatoms as well as in the dinoflagellates. The relatively low diatom and dinoflagellate cell counts and smaller size forms such as *Navicula* spp. *Pseudo-nitzschia* spp. and *Chaetoceros* spp. *Scrippsiella* cf. *trochoidea*, *Prorocentrum micans Tripos furca Tripos fusus* observed during early winter could be due to the oligotrophic conditions. Whereas, increase numbers of larger size diatoms such as

Climacodinium frauenfeldianum, *Rhizosolenia* spp. and dinoflagellates *Noctiluca scintillans* and *Pyrocystis pseudo-noctiluca* could be due to elevated nutrients

In the North West Mediterranean region, Volpe et al., 2012, and Arin et al., 2013 observed a similar kind of mechanism where extraordinary nutrient enrichment in the surface water was induced by intense deep convection that triggered an increase in phytoplankton biomass. Siokou and Frangou (Siokou-Frangou et al., 2010) also noticed the proliferation of diatoms in the open ocean where processes like deep convection, fronts or gyres sufficiently enrich the surface waters. In the NEAS, Roy et al. (Roy et al., 2015) observed the dominance of *Pheocystis* in the warmer portion. According to Estrada (Estrada, 1991), *Pheocystis* is an important contributor to the winter-spring blooms in the north-west Mediterranean and may be the dominant taxon in regions where diatoms do not proliferate.

The present study concludes that changes in the water column with increase in the nutrients and increase convective mixing influence the microphytoplankton community with smaller size diatoms such as *Navicula* spp., *Pseudo-nitzschia* spp. and smaller size bloom forming dinoflagellates to four fold increase with the dominance of centric diatoms and larger size dinoflagellates such as *Noctiluca scintillans* and *Pyrocystis pseudo-noctiluca*.

The contribution of dinoflagellates was evident to the Phytoplankton carbon content irrespective of the seasons. In the PWM amongst the microphytoplankton dinoflagellate contributed maximum to the carbon content. Primarily dinoflagellate population was dominated by *Noctiluca scintillans* followed by diatoms. Earlier studies have shown that *Noctiluca scintillans* does not serve as a prey for higher trophic levels (Goes et al., 2018). Their senescence can lead to higher bacterial abundance leading to the fuelling of microbial loop. Though the diatom numbers were higher, their contribution to carbon pool was lesser then the dinoflagellates owing to their smaller size. Hence their contribution to higher trophic level directly will not be proportional to their numbers. The contribution of non thecate dinoflagellates and *Pheocystis* group which has not been accounted in this study should also be considered in future studies for a better understanding of the carbon flow and food web dynamics.

Summary

- Microphytoplankton community in the Bay of Bengal hasa distinct seasonal trend with dominance of diatoms during monsoons (South West Monsoon, North East Monsoons and Fall Intermonsoon) and Dinoflagellates during Spring Intermonsoon.

- The higher abundance of diatoms in the northernmost station (River Mouth) and Andaman Region during the monsoon can be attributed to the availability of silicate by freshwater and terrigenous discharges. In the open ocean (CPOS and PKOS) the maximum numbers encountered can be related to wind driven water column mixing.

- The dominance of diatoms in the Andaman Region during the Spring Intermonsoon could be related to the precipitation enabled nutrient enrichment and that from the terrigenous sources.

- Observation of spatio-temporal variation in the dinoflagellate community of BoB revealed that *Tripos* is present round the year and is widespread in occurrence. Amongst the *Tripos* population, *T. furca* was the dominant form. The high numbers of *T. furca* recorded in AR, RM and in the C–P transect relate to the influence of monsoon, freshwater discharge and mesoscale eddies respectively.

  Dominance of *T. furca* was also observed with an increase in the ciliates population in AR and RM. Further studies on this association elucidating the depth integrated information of *Tripos* community along with its environmental settings will be a step forward.

- From the three different regions of the Northern Indian Ocean (Bay of Bengal, northern Arabian Sea, and Dona Paula Bay Goa) changes in the cell size, cell volume and carbon per cell of diatoms and dinoflagellates are reported. The maximum variations in cell size and cell volume were observed in riverine and terrigenous discharge influenced regions.

- Comparison of the commonly available forms (8 species) from four different inter-regions (North Atlantic, Pacific Ocean, Mediterranean Sea and Indian Ocean points out that cell volumes are highest in the North Atlantic and lowest in the Mediterranean. The reason could be variations in temperature, time of collection and site specific environmental characteristics.

- Microphytoplankton community and species assemblages mapped along the four different tracks of Bay of Bengal (CPOS, AR, PKOS, and RM) was also evaluated from the perspective of Margalef's Mandala and Reynolds Intaglio. The results revealed fast growing smaller size diatoms such as *Chaetoceros* spp., *Pseudo-nitzschia* spp., dominated in terms of its abundance in the River Mouth. Their dominance could be due to its life form characteristics such as faster growth rate in high nutrient conditions facilitated by riverine discharge. Later with the changes in the water column wherein the nutrients are depletedand light conditions are improved larger size *Tripos* (*T. horridus*, *T. trichoceros*) dominated the niche. In the open ocean stations of the CPOS, the prevalence of some of relatively slow growing diatoms compared to those found in River Mouthand other medium size thecate dinoflagellates such as *Gonyaulax polygramma*, *Goniodomapolyedricum*canbe attributed to the mixed water column during Monsoon. The association of both diatoms and dinoflagellate species in the CPOS can be categorized as 'R' type in context to the classification of Reynolds 'C-S-R' model. The results indicate species association in the River Mouth and those in the CPOS fit well from the perspective of Margalef's Mandala and Reynolds Intaglio model respectively.

- Microphytoplankton community in the NEAS varied from early winter to Peak winter and were dominated by diatoms.

- Diatom abundance increased fourfold from early to peak winter. This can be attributed to the influence of convective mixing bringing in higher amount of silicate and nitrate to the surface.

- Dinoflagellate community was dominated by *Tripos furca*, *Tripos fusus*, *Scrippsiella* cf. *trochoidea*, and *Prorocentrum micans* during Early Winter Monsoon. Later during Peak Winter monsoon in addition to these forms (*Tripos furca*, *Tripos* *fusus*, *Scrippsiella* cf. *trochoidea*, and *Prorocentrum micans*) larger size dinoflagellates such as *Noctiluca scintillans*, *Pyrosystis pseudo-noctiluca*, *Pyrocystis lunula* dominant during Peak Winter Monsoon.

- Quantification of Carbon contribution by phytoplankton pointed out that picoplankton (Prochlorococcus) was a major contributor during EWM and least was contributed by diatoms.

- During Peak Winter Monsoon the carbon contribution from microphytoplankton (Diatoms and Dinoflagellates) is measured 83%. Here again the contribution of diatom was comparatively lesser (20.4 %).

- During Peak Winter Monsoon wherever *Noctiluca scintillans* proliferated, its contribution to the total carbon pool is increased up to 10.5 $\mu g l^{-1}$. However such contribution does not fuel the conventional grazing pathway as this bloom forming species is not readily available for higher trophic level. The decay of such blooms can enter the functioning of microbial loop.

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Appendix A1 and A2. Details of sampling dates (DD/MM/YYYY) with its respective codes sampled for 48 months along the Chennai to Port Blair (**a**) and for 38 months along the Port Blair to Kolkata (**b**) route, during October 2006 to September 2011.

APPENDIX A1

Sr. No	Chennai to Port Blair	Codes
1	25/10/2006 to 28/10/2006	O6
2	11/11/2006 to 16/11/2006	N6
3	07/12/2006 to 09/12/2006	D6
4	02/01/2007 to 04/01/2007	JN7A
5	27/01/2007 to 30/01/2007	JN7B
6	26/02/2007 to 01/03/2007	F7
7	04/04/2007 to 06/04/2007	A7A
8	25/04/2007 to 27/04/2007	A7B
9	28/05/2007 to 30/05/2007	MY7
10	26/06/2007 to 29/06/2007	J7
11	21/07/2007 to 23/07/2007	JU7
12	31/08/2007 to 03/09/2007	S7
13	05/10/2007 to 08/10/2007	O7
14	09/11/2007 to 12/11/2007	N7
15	14/12/2007 to 17/12/2007	D7
16	12/01/2008 to 14/01/2008	J8
17	24/02/2008 to 26/02/2008	F8
18	24/03/2008 to 26/03/2008	M8
19	14/04/2008 to 16/04/2008	A8
20	08/05/2008 to 09/05/2008	MY8
21	18/07/2008 to 21/07/2008	JU8
22	21/08/2008 to 23/08/2008	AU8
23	18/09/2008 to 20/09/2008	S8
24	27/10/2008 to 30/10/2008	O8
25	10/11/2008 to 13/11/2008	N8
26	25/12/2008 to 27/12/2008	D8
27	13/01/2009 to 16/01/2009	JN9
28	18/02/2009 to 21/02/2009	F9
29	18/03/2009 to 21/03/2009	M9
30	16/04/2009 to 19/04/2009	A9
31	06/06/2009 to 09/06/2009	J9
32	10/07/2009 to 12/07/2009	JU9
33	13/08/2009 to 16/08/2009	AU9
34	12/09/2009 to 13/09/2009	S9
35	14/10/2009 to 17/10/2009	O9
36	09/11/2009 to 12/11/2009	N9
37	26/12/2009 to 28/12/2009	D9
38	22/01/2010 to 25/01/2010	JN10
39	17/02/2010 to 20/02/2010	F10
40	20/03/2010 to 23/03/2010	M10
41	21/04/2010 to 23/04/2010	A10
42	24/05/2010 to 27/05/2010	MY10
43	21/07/2010 to 24/07/2010	JU10
44	22/09/2010 to 26/09/2010	S10
45	26/11/2010 to 29/11/2010	N10
46	16/02/2011 to 19/02/2011	F11
47	09/05/2011 to 12/05 2011	MY11
48	20/09/2011 to 23/09/2011	S11

APPENDIX A2

Sr. No	Port Blair to Kolkata	Codes
1	03/11/2006 to 05/11/2006	N6A
2	23/11/2006 to 25/11/2006	N6B
3	16/01/2007 to 19/01/2007	JN7
4	13/02/2007 to 15/02/2007	F7
5	02/03/2007 to 04/03/2007	M7
6	12/04/2007 to 14/04/2007	A7
7	02/05/2007 to 04/05/2007	MY7
8	05/06/2007 to 08/06/2007	J7
9	06/07/2007 to 10/07/2007	JU7A
10	24/07/2007 to 26/07/2007	JU7B
11	07/09/2007 to 09/09/2007	S7
12	20/10/2007 to 23/10/2007	O7
13	18/11/2007 to 21/11/2007	N7
14	19/12/2007 to 21/12/2007	D7
15	18/01/2008 to 21/01/2008	JN8
16	08/03/2008 to 11/03/2008	F8
17	18/04/2008 to 24/04/2008	A8
18	13/05/2008 to 16/05/2008	MY8
19	28/08/2008 to 30/08/2008	AU8
20	25/09/2008 to 28/09/2008	S8
21	05/11/2008 to 07/11/2008	N8
22	06/01/2009 to 08/01/2009	JN9A
23	26/01/2009 to 28/01/2009	JN9B
24	24/03/2009 to 27/03/2009	M9
25	20/04/2009 to 23/04/2009	A9
26	12/06/2009 to 14/06/2009	J9
27	17/07/2009 to 20/07/2009	JU9
28	20/08/2009 to 22/08/2009	AU9
29	21/09/2009 to 24/09/2009	S9
30	21/10/2009 to 24/10/2009	O9
31	19/11/2009 to 21/11/2009	N9
32	28/01/2010 to 31/01/2010	JN10
33	25/03/2010 to 27/03/2010	M10
34	31/05/2010 to 03/06/2010	J10
35	25/07/2010 to 27/07/2010	JU10
36	04/10/2010 to 07/10/2010	O10
37	28/02/2011 to 02/03/2011	M11
38	29/09/2011 to 01/10/2011	S11

Appendix B1: Shows variations in environmental variables observed along the respective regions (**A**; CPOS, **B**; AR, **C**; PK, and **D**; RP), from October 2006 to February 2008. The Environmental variables recorded were Sea Surface Temperature (SST ; °C), Sea Surface Salinity, Dissolve Inorganic Nitrogen (DIN ; µmol L^{-1}), Dissolved Inorganic Phosphate (DIP ; µmol L^{-1}), Wind Speed (m/s), Photosynthetic Active Radiation (PAR; mol quanta m^{-2} d^{-1}) and Rainfall (mm/hr). Each season are categorized as follows. FIM-I (October 2006), NEM-I (November 2006 to February 2007), SIM-I (April 2007 to May 2007), SWM-I (June 2007 to September 2007), FIM–II (October 2007), NEM-II (November 2007 to February 2008). The values outside the bracket indicates its range (Minimum – Maximum) and inside the bracket indicates number of occurrences.

		FIM-I	NEM-I	SIM-I	SWM-I	FIM-II	NEM-II
A	**SST**	28.9-29.3(12)	28.3-29.2(54)	28.6-31.0(36)	28.4-29.5(24)	28.2-28.9(12)	26.3-29.2(34)
	SSS	31.9-34.3(9)	30.0-34.4(60)	31.8-33.7(36)	30.0-34.1(24)	30.5-34.4(12)	31.5-34.1(36)
	DIN		0.02-1.43(9)	0.02-1.02(6)	0.09-1.30(4)	0.04-0.83(3)	0.04-1.03(8)
	DIP		0.01-0.14(7)	0.04-0.60(5)	0.03-0.10(7)	0.07-0.09(3)	0.01 0.13(13)
	Wind Speed	4.2-10(7)	4.2-10.08(23)	2.6-7(28)	6-15.4(21)	8.2-10.4(7)	2-12.2(26)
	PAR	13.2-49.2(9)	6.6-52.3(52)	40.0-56.1(23)	4.9-54.0(25)	35.1-50.7(3)	11.5-51.05(39)
	Rainfall	(6)0.1 - 2.1	(3)0.2 - 1.8	0.1(1)	0.1-3.6(16)	0.8(1)	0.3-5.9(11)
B	**SST**		26.8 - 29.1(3)	26.8 - 30.4(5)	28.1 - 30.0(4)	28.8(1)	27.6 - 29.2(6)
	SSS		30.03 - 31.7(7)	31.5 - 32.4(9)	32.18 - 33.07(7)	32.08(1)	31.07 - 32.18(3)
	DIN		0.02 - 1.33(2)		0.03 - 1.36(4)		0.64(1)
	DIP		0.02 -0.12(2)	0.03 - 0.15(2)	0.07 - 0.12(2)	0.11(1)	0.05(1)
	Wind Speed		0.4 - 6.8(8)	3.2 - 10.2(6)	2.8 - 10.2(8)	3.8 -6.2(4)	4.4 - 6.2(6)
	PAR		41.9 - 50.0(11)	3.5 - 55.0(5)	23.3 - 54.8(5)	45.2 - 45.06(2)	40.0 - 45.9(8)
	Rainfall		0.3(1)	0.1(1)	0.9(1)	0.5(1)	

Appendix B1 Continued

		FIM-I	NEM-I	SIM-I	SWM-I	FIM-II	NEM-II
C	**SST**		25.4 - 30.0(17)	25.0-29.6(17)	28.8-30.7(23)	28.6 - 29.2(6)	25.7 - 29.5(17)
	SSS		25.7 - 31.7(23)	29.9-33.9(18)	27.6-34.4(23)	31.9 - 32.7(5)	29.2 - 32.0(17)
	DIN		0.06 - 1.32(5)	0.02-0.06(3)	0.02-1.38(6)	0.02 - 0.03(2)	0.02 - 0.58(6)
	DIP		0.02 - 0.22(4)	0.01-0.47(4)	0.05-0.13(5)	0.04 - 0.13(2)	0.02 - 0.12(5)
	Wind Speed		1.4 - 6.6(24)	2-7.6(18)	4.2-10.4(24)	2.4 - 5.8(7)	1.8 - 6.4(18)
	PAR		19.35 - 47.7(24)	45.6 - 56.5(14)	11.4-55.2(15)	43.7 - 47.2(7)	11.91 - 43.07(15)
	Rainfall			0.1-0.2(2)	0.1-1.4(7)	0.1-1.3(6)	0.1(1)
D	**SST**		25.2(1)	24.7(1)		29.0(1)	
	SSS						
	DIN				0.04(1)		
	DIP						
	Wind Speed		3.6 - 4.6(2)		6(1)		
	PAR		35.4 - 42.9(4)	45.8 - 55.5(3)	4.2-49.4(4)	41.5(1)	34.3 - 37.5(2)
	Rainfall						

Appendix B2. Shows variations in environmental variables observed along the respective regions (**A**; CPOS, **B**; AR, **C**; PKOS, and **D**; RP), from March 2008 to September 2009. The environmental variables recorded were Sea Surface Temperature (SST ; °C), Sea Surface Salinity, Dissolve Inorganic Nitrogen (DIN ; µmol L^{-1}), Dissolved Inorganic Phosphate (DIP ; µmol L^{-1}), Wind Speed (m/s) Photosynthetic Active Radiation (PAR; mol quanta m^{-2} d^{-1}) and Rainfall (mm/hr). Each season are categorized as follows. SIM-II (March 2008 to May 2008), SWM-II (July 2008 to September 2008), FIM-III (October 2008), NEM – III (November 2008 to February 2009), SIM-III (March 2009 to April 2009), SWM-III (June 2009 to September 2009). The values outside the bracket indicates its range (Minimum – Maximum) and inside the bracket indicates number of occurrences.

		SIM-II	SWM-II	FIM-III	NEM-III	SIM-III	SWM-III
A	**SST**	28.3-30.3(28)	27.3 - 29.7(34)		26.1-29.2(46)	28.4-30.2(22)	28.8-29.9(46)
	SSS	31.7-34.4(33)	32.24 - 34.2(25)	32.04-34.04(12)	29.2-33.9(46)	31.9-33.8(24)	32.3-34.1(42)
	DIN	0.03 - 0.67(4)	0.02 - 2.25(24)	0.01-1.68(12)	0.01-2.93(30)	0.01-2.19(20)	0.01-3.02(30)
	DIP	0.02 - 0.11(7)	0.01 - 0.39(19)	0.01-0.07(5)	0.01-0.17(31)	0.02-0.69(23)	0.03-0.94(41)
	Wind Speed	1.6 - 9.8(21)	4.6 - 8.6(19)	3.6-6.2(8)	4-10.2(26)	1.2-7(14)	2.6-13.4(27)
	PAR	10.9 - 54.9(21)	10.6 - 53.3(24)	35.6-49.5(12)	9.9-50.9(28)	5.1-55.2(15)	15.65-55(31)
	Rainfall	0.3(1)	0.1-1.3(9)	0.1-0.3(5)	0.1-1.5(11)	0.8-0.9(2)	0.1-1.1(6)
B	**SST**	27.6 - 29.7(3)			26.9-28.7(5)	28.9-29.5(2)	28.8-29.8(10)
	SSS	32.19 - 32.6(3)	31.0 - 32.2(3)		29.4-31.7(7)	31.3-32.0(4)	31.4-32.3(10)
	DIN	0.02 - 1.88(3)	0.02 - 0.85(5)		0.02-0.51(7)	0.05-0.49(6)	0.01-0.12(3)
	DIP	0.04 - 0.09(2)			0.01-0.11(4)	0.01-0.65(4)	0.01-1.22(8)
	Wind Speed	4 - 9.6(5)	2.2 - 9(4)		1.2-5.4(6)	3.2-6.8(4)	4.6-9.2(7)
	PAR	48.0 - 53.4(6)	46.0 - 55.3(6)		42.4-46.0(7)	16.0-55.2(6)	12.0-50.9(6)
	Rainfall	3.7(1)					0.1-0.6(3)

Appendix B2. continued

		SIM-II	SWM-II	FIM-III	NEM-III	SIM-III	SWM-III
C	**SST**	24.3 - 29.8(17)	28.7 - 30.9(6)		24.8-29.3(15)	28.3-29.5(7)	28.4-30.5(20)
	SSS	29.8 - 32.8(18)	30.6 - 32.0(6)		29.9-32.03(16)	30.0-32.6(11)	25.6-33.3(21)
	DIN	0.04 - 0.93(7)	0.01 - 2.23(11)		0.02-0.71(15)	0.02-0.13(7)	0.02-0.75(20)
	DIP	0.01 - 0.12(5)	0.04 - 0.14(5)		0.01-0.09(12)	0.04-0.2(11)	0.04-0.76(19)
	Wind Speed	1.4 - 11.4(18)	3.4 - 8.8(12)		1.4-5.4(18)	2.8-11(12)	5.4-13.8(21)
	PAR	4.5 - 55.3(12)	36.6 - 52.1(10)		35.7-44.5(17)	27.6-54.8(8)	11.4-57.1(16)
	Rainfall	0.1-1.8(3)	0.2(1)	0.1(2)			0.2-5.5(14)
D	**SST**						
	SSS					27.3(1)	26.0-26.6(2)
	DIN	0.29 - 2.32(2)	0.59 - 0.79(2)		0.03-0.51(2)	0.48(1)	1.35-4.23(3)
	DIP		0.08(1)		0.08-0.12(2)	0.24(1)	0.09-0.78(4)
	Wind Speed						
	PAR	46.6 - 52.5(2)	51.9(1)		33.2-40.9(3)	52.7(1)	22.1-52.2(3)
	Rainfall						0.4-0.6(2)

Appendix B3. Shows variations in environmental variables observed along the respective regions (**A**; CPOS, **B**; AR, **C**; PKOS, and **D**; RP), from October 2009 to September 2011. The environmental variables recorded were Sea Surface Temperature (SST ; °C), Sea Surface Salinity, Dissolve Inorganic Nitrogen (DIN ; µmol L^{-1}), Dissolved Inorganic Phosphate (DIP ; µmol L^{-1}), Wind Speed (m/s) and Photosynthetic Active Radiation (PAR; mol quanta m^{-2} d^{-1}) and Rainfall (mm/hr). Each season are categorized as follows. FIM-IV (October 2009) NEM IV (November 2009 to February 2010), SIM – IV (March 2010 to May 2010), SWM-IV (July 2010 to September 2010), NEM – V (November 2010 to February 2011) SIM – V (May 2011) and SWM-V (September 2011). The values outside the bracket indicates its range (Minimum – Maximum) and inside the bracket indicates number of occurrences.

		FIM-IV	**NEM-IV**	**SIM-IV**	**SWM-IV**	**NEM-V**	**SIM-V**	**SWM-V**
A	**SST**	28.8-30.0(12)	26.3-29(21)	28.9-32.3(33)	28.9-29.8(24)	26.5-28.7(24)	29.3-30.4(11)	28.4-29.1(8)
	SSS	30.9-34.4(12)	30.2-34.1(46)	31.2-34.4(34)	32.8-34.2(24)	30.9-34.1(24)	32.55-33.8(10)	32.8-34.3(10)
	DIN		0.02-3.08(21)	0.02-2.04(21)	0.26-0.86(22)	0.38-2.54(15)	0.54-1.99(10)	0.17-0.74(10)
	DIP	0.03-0.16(11)	0.28-0.98(32)	0.08-0.71(17)	0.02-0.10(3)	0.28-0.61(22)	0.23-1.08(6)	3.92(1)
	Wind Speed	1-3.8(7)	2.2-8.6(28)	0.6-11.4(21)	2.2-11.2(14)	1.6-8.4(14)	7-9.6(7)	
	PAR	43.4-51.46(11)	5.6-50.28(39)	46.5-56.0(21)	31.1-54.4(19)	16.6-50.4(23)	51.8-55.8(4)	43.5-51.5(7)
	Rainfall	0.1(1)	0.1 - 1.3(8)	0.1-0.8(3)	0.1-1.7(4)	0.1-0.3(2)		
B	**SST**	28.6-30.4(3)	29.4-29.6(3)	28.7-29.6(2)	29.2-30.3(4)	29.1-29.6(3)	26.7-28.1(3)	28.2-28.6(3)
	SSS	28.6-30.4(3)	26.1-31.5(6)	31.3-32.1(3)	31.8-33.3(6)	31.0-32.2(3)	32.0-32.4(3)	31.4-32.0(3)
	DIN	0.04-0.19(2)	0.02-1.15(3)	1.35-1.74(3)	0.24-0.56(5)	0.27-0.78(3)	0.07-0.39(2)	0.23(1)
	DIP	0.04-0.20(3)	0.23-0.48(4)	0.45-1.42(5)	0.24-0.30(3)	0.56-0.64(3)	0.24-0.3(3)	0.54(1)
	Wind Speed	3-5.2(4)	2.2-6.4(6)	2.2-5.6(4)	4-9.2(4)	5-9(2)	5-5.2(2)	
	PAR	13.89-36.2(3)	42.7-45.85(5)		9.05-55.7(6)	33.44(1)	51.00-52.1(3)	30.60-51.9(2)
	Rainfall	0.2(1)	0.1(1)		0.7(1)	1.4(1)		

Appendix B3 continued

		FIM-IV	NEM-IV	SIM-IV	SWM-IV	NEM-V	SIM-V	SWM-V
C	**SST**	27.0-29.6(5)	24.3-29.5(10)	28.3-29.0(5)	29.0-30.0(8)	29.3-29.7 (4)	25.4-26.9 (5)	28.8-29.7(5)
	SSS	27.0-29.6(5)	28.8-32.3(10)	32.1-33.1(6)	27.3-33.8(11)	29.7-32.4 (5)	29.9-32.5 (5)	19.7-31.9(5)
	DIN	0.02-0.05(2)	0.03-1.20(6)	0.64-1.24(6)	0.03-1.20(6)	0.53-0.75 (4)	0.37-1.08 (5)	
	DIP	0.07-1.23(6)	0.01-0.60(10)	0.23-0.48(6)	0.37-0.72(7)	0.19-0.46 (6)	0.28-0.34 (2)	0.43-0.59(3)
	Wind Speed	3.4-5.2(6)	3-8.4(12)	1.8-8.6(7)	5.8-9.8(12)	6.8-12.8(5)	2.8-7.8(6)	
	PAR	40.1-47.8(5)	10.6-44.1(12)	49.0-52.2(8)	21.77-55.4(11)	1.2-38.1(6)	11.1-50.7(5)	11.13-43.7(4)
	Rainfall	0.1(1)	0.1-0.5(3)		0.2-0.7(3)	0.6-2.1(6)		
D	**SST**							
	SSS			28.0(1)	25.1(1)	26.7(1)		
	DIN	1.45(1)	0.93(1)		1.07(1)	1.23(1)		
	DIP	0.10(1)						
	Wind Speed							
	PAR	43.3(1)	37.5-39.1(2)	46.2(1)		5.5(1)	46.2(1)	42.7(1)
	Rainfall				1(1)	9.6(1)		

Appendix C Details of eddies centered on 4 occasion listed along with its date (DD/MM/YY) and positions

Eddies	Dates	Latitude	Longitude
1	17th November 2006	13° 00' N	83° 00' E
2	13th April 2007	18° 50' N	87° 00' E
3	6th October 2007	16° 00' N	85° 00' E
4	17th November 2007	13° 00' N	83° 00' E

Appendix D1: The checklist of microphytoplankton species comprising diatoms, dinoflagellates and Dictyochales (Dictyocha) used in the ordination analysis (**Chapter 5**; Fig. 5.3, 5.4, and 5.5). The list provides species which were the most dominant in terms of occurrence (above 0.7%) and the abbreviation used.

	Taxa
Bcfur	*Bacteriastrum furcatum* Shadbolt, 1854
Chper	*Chaetoceros peruvianus* Brightwell, 1856
Ch	*Chaetoceros* spp.
Clifra	*Climacodium frauenfeldianum* Grunow, 1868
Csmar	*Coscinodiscus marginatus* Ehrenberg, 1844
Cs	*Coscinodiscus* spp.
Gicy	*Guinardia cylindrus* (Cleve) Hasle, 1996
Gistr	*Guinardia striata* (Stolterfoth) Hasle, 1996
Hemhu	*Hemiaulus hauckii* Grunow ex Van Heurck, 1882
Hemmem	*Hemiaulus membranaceus* Cleve
Psucal	*Pseudosolenia calcar-avis* B.G.Sundström, 1986
Psial	*Proboscia alata* (Brightwell) Sundström, 1986
Rzheb	*Rhizosolenia hebetata* (Hensen) Gran, 1908
Rzsty	*Rhizosolenia styliformis* T.Brightwell, 1858
Rz	*Rhizosolenia* spp.
Th	*Thalassiosira* spp.
Aph	*Amphora* spp.
HsTro	*Haslea trompii* (Cleve) Simonsen, 1974
Hs	*Haslea* spp.
Mst	*Mastogloia* spp.
Nvdir	*Navicula directa* (W.Smith) Ralfs, 1861
Nv	*Navicula* spp.
Nz	*Nitzschia* spp.
Ps	*Pseudo-nitzschia* spp.
Thlfra	*Thalassionema frauenfeldii* Tempère & Peragallo, 1910
Thlnitz	*Thalassionema nitzschioides* Mereschkowsky, 1902
Thl	*Thalassionema* sp.
Ax	*Alexandrium* spp.
Amp	*Amphidinium* sp.
Blph	*Blepharocysta* sp.?
Tapoly	*Triadinium polyedricum* (Pouchet) Dodge, 1981
Gonpol	*Gonyaulax polygramma* Stein, 1883
Gon	*Gonyaulax* sp
Gy	*Gymnodinium* spp.
Oxsco	*Oxytoxum scolopax* Stein, 1883
Ox	*Oxytoxum* sp
Podpal	*Podolampas palmipes* Stein, 1883
Trde	*Tripos declinatus* (G.Karsten) F.Gómez, 2013
Trfr	*Tripos furca* (Ehrenberg) F.Gómez, 2013
Trfu	*Tripos fusus* (Ehrenberg) F.Gómez, 2013
Trhr	*Tripos horridus* (Cleve) F.Gómez, 2013
Trte	*Tripos teres* (Cleve) F.Gómez, 2013
Trycom	*Tryblionella compressa* (J.W.Bailey) M.Poulin, 1990
Prfra	*Prorocentrum gracile* Schütt, 1895
Prmic	*Prorocentrum micans* Ehrenberg, 1834
Pro	*Prorocentrum* sp..
Sctro	*Scrippsiella trochoidea* (Stein) Loeblich III, 1976
Dic	*Dictyocha* spp.

Appendix D : Checklist of Microphytoplankton comprising Diatoms, Dinoflagellates and Dictyoca from the four different tracks of the Bay of Bengal (BoB) observed during the Fall Intermonsoon (FIM). The column from left to right denotes, **A** - Serial no, **B** - codes used in the ordination analysis. **C** - Microphytoplankton species comprised of Diatoms, Dinoflagellates and Dictyoca. **D** - Cell abundance (cells L^{-1}), values outside the bracket denotes minimum to maximum variations in cell counts and values inside the brackets denotes number of occurrences. The codes D1 to D4 depicts variations in cell abundance observed along the four different tracks CPOS, AR, PKOS and RM respectively.

		Seasons	FIM	FIM	FIM	FIM
		Region (Tracks)	CPOS	AR	PKOS	RM
A	B	C	D1	D2	D3	D4
sr no	codes	**Diatoms**				
1	AcSe	*Actinocyclus senarius* Ehrenberg, 1843				
2	Ac	*Actinocyclus* sp				
3	Amar	*Asterolampra marylandica* Ehrenberg, 1844	10(1)	10(1)		
4	A	*Asterolampra* spp.	5(2)			
5	Auar	*Asteromphalus arachne* Ralfs, 1861				
6	Auhep	*Asteromphalus heptactis* Ralfs, 1861				
7	Aupet	*Asteromphalus pettersonii* Thorrington-Smith 1970				
8	Au	*Asteromphalus* spp.		5(2)		50(1)
9	Aznod	*Azpeitia nodulifera* G.A.Fryxell & P.A.Sims, 1996				
10	Bcdel	*Bacteriastrum delicatulum* Cleve, 1897	5(1)		15-100(3)	380(1)
11	Bcel	*Bacteriastrum elongatum* Cleve, 1897	10(1)			20(1)
12	Bcfur	***Bacteriastrum furcatum*** Shadbolt, 1854 *	5-100(8)	10-30(4)	1900 -2575(2)	120 -8800(3)
13	Bchya	*Bacteriastrum hyalinum* Lauder, 1864			100-150(2)	40 -900(2)
14	Bc	*Bacteriastrum* spp.		5(1)		

15	Bid	*Biddulphia* sp
16	Cam	*Campylodiscus* sp
17	Cerbi	*Cerataulina bicornis* (Ehrenberg) Hasle, 1985

Appendix D continued

		Seasons Region (Tracks) C	FIM CPOS D1	FIM AR D2	FIM PKOS D3	FIM RM D4
A	B					
18	Cerden	*Cerataulina dentata* Hasle				
19	Cerpel	*Cerataulina pelagica* (Cleve) Hendey, 1937	10-50(3)			
20	Cer	*Cerataulina* sp.			1575(1)	
21	Chae	*Chaetoceros aequatorialis* Cleve, 1873				
22	Chaf	*Chaetoceros affinis* Lauder, 1864	5-30(4)	5-45(5)	3200 -3550(2)	1500 -17600(2)
23	Chat	*Chaetoceros atlanticus* Cleve, 1873	5-50(5)	40(1)	10 -20(3)	100 -860(2)
24	Chco	*Chaetoceros coarctatus* Lauder, 1864	5-30(3)	30(1)	25(1)	
25	Chcom	*Chaetoceros compressus* Lauder, 1864			275-450(2)	6100(1)
26	Chcon	*Chaetoceros concavicornis* Mangin, 1917				
27	Chcon	*Chaetoceros constrictus* Gran, 1897			525(1)	
28	Chcov	*Chaetoceros convolutus* Castracane, 1886				
29	Chcos	*Chaetoceros costatus* Pavillard, 1911			100(1)	1800(1)
30	Chcur	*Chaetoceros curvisetus* Cleve, 1889	5-90(3)		25-5200(2)	3260 -41100(2)
31	Chdad	*Chaetoceros dadayi* Pavillard, 1913				
32	Chdan	*Chaetoceros danicus* Cleve, 1889				60 (1)
33	Chdeb	*Chaetoceros debilis* Cleve, 1894				2300 (1)
34	Chdec	*Chaetoceros decipiens* Cleve, 1873	5-25(4)	10(2)	675 -2075(2)	640 -14800(3)

35	Chdia	*Chaetoceros diadema* (Ehrenberg) Gran, 1897				1800 (1)
36	Chdic	*Chaetoceros dichaeta* Ehrenberg, 1844				180 -400(2)
37	Chdid	*Chaetoceros didymus* Ehrenberg, 1845	10-50(3)		550-750(2)	
38	Chdiv	*Chaetoceros diversus* Cleve, 1873	5(1)		25(1)	950 -2200(2)
39	Chei	*Chaetoceros eibenii* Grunow, 1882				

Appendix D continued

		Seasons Region (Tracks) C	FIM CPOS D1	FIM AR D2	FIM PKOS D3	FIM RM D4
A	B					
40	Chfur	*Chaetoceros furcellatus* Yendo, 1911				
41	Chlac	*Chaetoceros laciniosus* F.Schütt, 1895	25(1)		10-75(2)	
42	Chlau	*Chaetoceros lauderi* Ralfs, 1864				
43	Chlor	*Chaetoceros lorenzianus* Grunow, 1863	5-250(6)	5(1)	5 -4900(4)	340 -24700(3)
44	Chmess	*Chaetoceros messanense* Castracane, 1875	5-15(4)	20(1)		
45	Chper	***Chaetoceros peruvianus*** Brightwell, 1856 *	5-50(7)	5-20(2)	5 -2450(3)	2050 -22200(2)
46	Chpscur	*Chaetoceros pseudocurvisetus* Mangin, 1910	30(1)		300-1525(2)	140 -150(2)
47	Chsim	*Chaetoceros simplex* Ostenfeld, 1902				
48	Chsub	*Chaetoceros subtilis* Cleve, 1896				
49	Chwig	*Chaetoceros wighamii* Brightwell, 1856				
50	Ch	***Chaetoceros* spp. ***	5-145(15)	5-50(7)	5 -8000(6)	200 -62900(4)
51	Clifra	***Climacodium frauenfeldianum*** Grunow, 1868 *	15-275(11)		30(1)	40(1)
52	Clma	*Climacosphenia* spp.				
53	Cocri	*Corethron criophilum* (Grunow) Ostenfeld, 1909				
54	Cohy	*Corethron hystrix* Hensen, 1887				

55	Co	*Corethron* sp.				
56	Cscen	*Coscinodiscus centralis* Ehrenberg, 1844	5-10(3)	5(1)	5 -15(3)	100(1)
57	Csgra	*Coscinodiscus granii* Gough, 1905				
58	Cslin	*Coscinodiscus lineatus* Ehrenberg				
59	Csmar	***Coscinodiscus marginatus*** Ehrenberg, 1844 *	5-25(13)	5-10(3)	5 (4)	
60	Csocc	*Coscinodiscus oculus-iridis* Ehrenberg, 1840				
61	Csrad	*Coscinodiscus radiatus* Ehrenberg, 1840	10(1)		5(1)	

Appendix D continued

		Seasons Region (Tracks) C	FIM CPOS D1	FIM AR D2	FIM PKOS D3	FIM RM D4
A	B					
62	Cswei	*Coscinodiscus wailesii* Gran & Angst, 1931				
63	Cs	***Coscinodiscus* spp**. *	5-75(27)	10-75(7)	5 -25(10)	100 -1050(4)
64	Cystr	*Cyclotella striata* (Kützing) Grunow, 1880				
65	Cy	*Cyclotella* sp.			5(1)	
66	Dctfra	*Dactyliosolen fragilissimus* (Bergon) Hasle, 1996	5-25(4)			
67	Dct	*Dactyliosolen* sp?			6825(1)	
68	Ditbri	*Ditylum brightwellii* (T.West) Grunow, 1885	15(1)		100-125(2)	1920 -8600(3)
69	Ditsol	*Ditylum sol* (Grunow) De Toni, 1894			10-525(2)	70 -100(2)
70	Dit	*Ditylum* sp.			15(1)	
71	Eucor	*Eucampia cornuta* (Cleve) Grunow, 1883				
72	Eugeo	*Eucampia geolandrica* Cleve, 1896				
73	Euzod	*Eucampia zodiacus* Ehrenberg, 1839				
74	Eu	*Eucampia* sp.			40-75(2)	

75	Csjoh	*Eupodiscus johneius* (Greville) J.Rattray				
76	Gicy	***Guinardia cylindrus*** (Cleve) Hasle, 1996 *	15-75(4)	5-10(3)	10 -15(2)	
77	Gidel	*Guinardia delicatula* (Cleve) Hasle, 1997	5(1)	20(1)	75(1)	1120 (1)
78	Giflac	*Guinardia flacida* (Castracane) H.Peragallo, 1892				
79	Gistr	***Guinardia striata*** (Stolterfoth) Hasle, 1996 *	5-35(8)	10-165(4)	10 -575(4)	1220 (1)
80	Gi	*Guinardia* spp.		5-25(2)	5 -325(2)	
81	Hltem	*Helicotheca tamesis* (Shrubsole) M.Ricard, 1987				
82	Hemhu	***Hemiaulus hauckii*** Grunow ex Van Heurck, 1882 *	5-25(3)	5-15(2)	150 -325(2)	80 -2400(4)
83	Hemind	*Hemiaulus indicus* Karsten, 1907				

Appendix D continued

		Seasons Region (Tracks)	FIM CPOS	FIM AR	FIM PKOS	FIM RM
A	B	C	D1	D2	D3	D4
84	Hemmem	***Hemiaulus membranaceus*** Cleve *	5-25(5)	5(1)	5 -100(6)	180 -750(2)
85	Hemsin	*Hemiaulus sinensis* Greville, 1865				100 (1)
86	Hem	*Hemiaulus* sp.			50(1)	
87	Hmcun	*Hemidiscus cuneiformis* Wallich, 1860				40 (1)
88	Hm	*Hemidiscus* sp.	10(1)			
89	Luan	*Lauderia annulata* Cleve, 1873				200 -11200(2)
90	lu	*Lauderia* sp.	5(1)			
91	Lpdan	*Leptocylindrus danicus* Cleve, 1889	10-150(5)		50-75(2)	
92	Lpmed	*Leptocylindrus mediterraneus* Hasle, 1975	15(1)	15-20(2)		
93	Lpmin	*Leptocylindrus minimus* Gran, 1915			150(1)	

94	Lp	*Leptocylindrus* sp.	5(1)			50 (1)
95	NeoRob	*Neocalyptrella robusta* Meave del Castillo, 1997				
96	Osin	*Odontella sinensis* (Greville) Grunow, 1884		25(1)	15 -25(2)	40 -1500(5)
97	O	*Odontella* sp.				
98	Pal	*Palmerina hardmaniana* (Greville) G.R.Hasle, 1996				400 (1)
99	Pksol	*Planktoniella sol* (C.G.Wallich) Schütt, 1892	5(1)	5(1)		
100	Psial	***Proboscia alata*** (Brightwell) Sundström, 1986 *	5-125(11)	5(1)		150(1)
101	Psiain	*Proboscia indica* Hernández-Becerril, 1995	20(1)		10(1)	
102	Pgurec	*Pseudoguinardia recta* von Stosch, 1986	5-15(2)		25(1)	520 (1)
103	Pgu	*Pseudoguinardia* spp.		15(1)		
104	Psucal	***Pseudosolenia calcar-avis*** B.G.Sundström, 1986 *	10-100(9)	5(1)	10(1)	
105	Rzac	*Rhizosolenia accuminata* H.Peragallo, 1907				

Appendix D continued

		Seasons Region (Tracks)	FIM CPOS	FIM AR	FIM PKOS	FIM RM
A	B	C	D1	D2	D3	D4
106	Rzaci	*Rhizosolenia acicularis* B.G.Sundström, 1986				
107	Rzbeg	*Rhizosolenia bergonii* H.Peragallo, 1892				
108	Rzbor	*Rhizosolenia borealis* B.G.Sundström, 1986		20(1)	5 (2)	
109	Rzcas	*Rhizosolenia castracanei* H.Peragallo, 1888			50(1)	
110	Rzcle	*Rhizosolenia clevei* Ostenfeld, 1902	5(1)			
111	Rzcra	*Rhizosolenia crassa* Schimper, 1905	10(1)			
112	Rzcur	*Rhizosolenia curvata* Zacharias, 1905	10(1)			

113	Rzdeb	*Rhizosolenia debyana* H.Peragallo, 1892	20(1)	5(1)	15(1)	
114	Rzdec	*Rhizosolenia decipiens* B.G.Sundström, 1986			5(2)	
115	Rzfor	*Rhizosolenia formosa* H.Peragallo, 1888		10(1)		
116	Rzheb	***Rhizosolenia hebetata*** (Hensen) Gran, 1908 *	5-40(8)		25-50(3)	400(1)
117	Rzheb	*Rhizosolenia hebetata* f. *semispina* Gran, 1908				
118	Rzhya	*Rhizosolenia hyalina* Ostenfeld, 1901				
119	Rzimb	*Rhizosolenia imbricata* Brightwell, 1858		20(1)		
120	Rzsetg	*Rhizosolenia setigera* Brightwell, 1858	5-10(5)		25-425(2)	1400 -13300(2)
121	Rzsetp	*Rhizosolenia setigera* f. *pungens* Brunel, 1962		15(1)		
122	Rzsty	***Rhizosolenia styliformis*** T.Brightwell, 1858 *	5-25(11)	5-20(5)	15 -20(6)	
123	Rz	***Rhizosolenia* spp. ***	5-225(20)	5-45(9)	5 -15(6)	90 -150(2)
124	SkeCos	*Skeletonema costatum*(Greville) Cleve, 1873	40(1)	80(1)		1780 -10300(2)
125	Ske	*Skeletonema* sp			175(1)	500 -1580(2)
126	Ste	*Stephanopyxis* sp.				
127	Stri	*Striatella* spp.				

Appendix D continued

		Seasons	FIM	FIM	FIM	FIM
		Region (Tracks)	CPOS	AR	PKOS	RM
A	B	C	D1	D2	D3	D4
128	Thang	*Thalassiosira angulata* (W.Gregory) Hasle, 1978	10(1)			
129	Thecc	*Thalassiosira eccentrica* (Ehrenberg) Cleve, 1904				
130	Thex	*Thalassiosira excentrica* (Ehrenberg) Cleve, 1904				
131	Thgra	*Thalassiosira gravida* Cleve, 1896				

132	Thpun	*Thalassiosira punctigera* (Castracane) Hasle, 1983				
133	Th	***Thalassiosira* spp.** *	5-75(32)	5-20(8)	5 -75(14)	50 -100(3)
134	Tmob	*Trieres mobiliensis* Ashworth & Theriot, 2013	5(1)			50(1)
135	Tgia	*Trieres regia* M.P.Ashworth & E.C.Theriot, 2013				
136	Anan	*Achnanthes* sp.	10(1)			
137	Amphh	*Amphiprora* spp.				
138	Aph	***Amphora* spp. ***	5-10(3)	30(1)	20(1)	
139	Asterio	*Asterionellopsis* sp?				
140	CccSC	*Cocconeis scutellum* Ehrenberg, 1838				
141	Ccc	*Cocconeis* sp.				20(1)
142	CyClo	*Cylindrotheca closterium* Reimann & J.C.Lewin, 1964	20-35(3)	5(1)		
143	Dip	*Diploneis* sp.				
144	Fgcyl	*Fragilariopsis cylindrus* (Grunow) Krieger, 1954	35(1)	15-35(4)	15 -75(2)	
145	Fgdol	*Fragilariopsis doliolus* Medlin & P.A.Sims, 1993		15(1)		
146	Fgoce	*Fragilariopsis oceanica* (Cleve) Hasle, 1965				
147	Fg	*Fragilariopsis* spp.	5-40(4)		10(1)	
148	Gmma	*Grammatophora* sps				
149	Gyro	*Gyrosigma* sp.		5(1)		

Appendix D continued

		Seasons Region (Tracks) C	FIM CPOS D1	FIM AR D2	FIM PKOS D3	FIM RM D4
A	B					
150	Hsgig	*Haslea gigantea* (Hustedt) Simonsen, 1974				

151	HsTro	***Haslea trompii*** (Cleve) Simonsen, 1974 *	5-50(12)		5-10(5)	80(1)
152	Hswaw	*Haslea wawrikae* (Hustedt) Simonsen, 1974	5-55(6)			
153	Hs	***Haslea* spp**. *	5-15(5)	5(3)	5(2)	
154	Lioelo	*Lioloma elongatum* (Grunow) Hasle, 1997	5-5(2)			
155	Liopac	*Lioloma pacificum* (Cupp) Hasle, 1996	5-10(3)	5(1)	75(1)	400(1)
156	Lio	*Lioloma* sp.	5-50(8)		3275(1)	40(1)
157	Mstros	*Mastogloia rostrata* (Wallich) Hustedt, 1933	20(1)			
158	Mstspl	*Mastogloia splendida* Cleve & Möller, 1879				
159	Mst	***Mastogloia* spp.** *	5-10(7)	5-15(3)	5 -10(4)	
160	Mmem	*Meuniera membranacea* (Cleve) P.C.Silva, 1996	15-175(5)		50-100(2)	640(1)
161	Mm	*Meuniera* spp.				
162	Nvdir	***Navicula directa*** (W.Smith) Ralfs, 1861 *	5-10(3)			60(1)
163	Nvdis	*Navicula distans* (W.Smith) Ralfs, 1861	5-5(3)			
164	Nvsep	*Navicula septantronalis* (Grunow) Gran, 1908				
165	Nvsub	*Navicula subinflata* Cleve & Möller, 1882				
166	Nvdel	*Navicula transitans* f. *delicatula* Heimdal, 1970	10(1)		5(1)	
167	NvDer	*Navicula transitans* var. *derasa* Cleve, 1883	5-25(5)		5-10(3)	
168	Nv	***Navicula* spp**. *	5-140(23)	5-180(11)	5 -6725(15)	20 -100(2)
169	Nzang	*Nitzschia angularis* W.Smith, 1853				
170	Nzlong	*Nitzschia longissima* (Brébisson) Ralfs, 1861	30(1)		5-50(2)	
171	Nzsig	*Nitzschia sigma* (Kützing) W.Smith, 1853			475(1)	

Appendix D continued

Seasons	FIM	FIM	FIM	FIM
Region (Tracks)	CPOS	AR	PKOS	RM

A	B	C	D1	D2	D3	D4
172	Nz	***Nitzschia* spp. ***	5-30(10)	5-115(6)	5 -1075(2)	40(1)
173	Phae	*Phaeodactylum tricornutum* Bohlin, 1897				
174	Pin	*Pinnularia* sps	5(1)			
175	PluAng	*Pleurosigma angulatum* W.Smith, 1852	5-10(2)			
176	Pludir	*Pleurosigma directum* Grunow, 1880				
177	Pluelo	*Pleurosigma elongatum* W.Smith, 1852				50(1)
178	Plunor	*Pleurosigma normanii* Ralfs, 1861				
179	Plusim	*Pleurosigma simonsenii* Hasle, 1990				
180	Plu	*Pleurosigma* spp.	5-10(3)	5(1)		20(1)
181	Psdel	*Pseudonitzschia delicatissima* Heiden, 1928				30000 (1)
182	Psfra	*Pseudonitzschia fraudulenta* Hasle, 1993		10(1)		
183	Pslin	*Pseudonitzschia lineola* (Cleve) Hasle, 1965	10(1)			
184	Psser	*Pseudonitzschia seriata* (Cleve) H.Peragallo, 1899				
185	Pssufra	*Pseudonitzschia subfraudulenta* G.R.Hasle, 1993		25(1)		
186	Ps	***Pseudonitzschia* spp. ***	5-425(7)	10-15(3)	5 -1775(4)	300 -1800(3)
187	Sur	*Surirella* sp?			5(1)	
188	Syne	*Synedropsis* sp.	5-5(2)		5(1)	
189	Thlbac	*Thalassionema bacillare* (Heiden) Kolbe, 1955	10-25(5)		125(1)	
190	Thlfra	***Thalassionema frauenfeldii*** Tempère & Peragallo, 1910 *	5-75(5)	30(1)	300 -2200(2)	720 -3300(2)
191	Thljav	*Thalassionema javanicum* (Grunow) G.R.Hasle	5-10(3)		10(1)	20(1)
192	Thlnitz	*Thalassionema nitzschioides* Mereschkowsky, 1902	5-25(10)	10-20(2)	3725 -4400(2)	1050 -8200(3)
193	Thlpsnitz	*Thalassionema pseudonitzschioides* G.R.Hasle				

Appendix D continued

A	B	Seasons Region (Tracks) C	FIM CPOS D1	FIM AR D2	FIM PKOS D3	FIM RM D4
194	Thl	***Thalassionema* sp. ***	5-275(6)	5-15(3)	300 (1)	20(1)
195	Txlon	*Thalassiothrix longissima* Cleve & Grunow, 1880	15(1)			
196	Tx	*Thalassiothrix* sp.	5-10(3)			40(1)
197	Ticer	*Triceratium* sp	5(1)			20(1)
		Dinoflagellates				
198	Acgon	*Acanthogonyaulax spinifera* H.W.Graham, 1942		5(1)		
199	Aksn	*Akashiwo sanguinea* G.Hansen & Ø.Moestrup, 2000		5(1)		
200	Acat	*Alexandrium catenella* (Whedon & Kofoid) Balech, 1985			10(1)	
201	Acon	*Alexandrium concavum* (Gaarder) Balech, 1985				
202	Amin	*Alexandrium minutum* Halim, 1960				
203	Atam	*Alexandrium tamerense* (Lebour, 1925) Balech, 1995				
204	Ax	***Alexandrium* spp. ***	5-15(9)	5(2)	5 -15(4)	10(1)
205	AmpCar	*Amphidinium cartere* Hulburt, 1957				
206	Ampsph	*Amphidinium sphaenoides* WüIff, 1916	5(1)			
207	Amp	***Amphidinium* sp. ***	5-30(11)	5-55(7)	5 -40(4)	
208	Amdp	*Amphidoma* sp.				
209	Apsolast	*Amphisolenia astragalus* Kofoid & Michener, 1911				
210	Apsolbid	*Amphisolenia bidentata* Schröder, 1900	5-10(2)		10(1)	
211	Apsolglo	*Amphisolenia globifera* Stein, 1883				
212	Apsoltri	*Amphisolenia thrinax* Schütt, 1893				
213	Apsol	*Amphisolenia* spp.	5(1)		10(1)	
214	Azcau	*Azadinium caudatum* (Halldal) Nézan & Chomérat, 2012				

Appendix D continued

		Seasons Region (Tracks)	FIM CPOS	FIM AR	FIM PKOS	FIM RM
A	B	C	D1	D2	D3	D4
215	Blph	***Blepharocysta* sp.? ***	5-10(8)		5-15(6)	
216	Craar	*Ceratocorys armata* (Schütt) Kofoid, 1910				
217	Cragou	*Ceratocorys gourretii* Paulsen, 1931				
218	Crahor	*Ceratocorys horrida* Stein, 1883	5-5(2)	5(1)	5(3)	
219	Craret	*Ceratocorys reticulata* H.W.Graham, 1942				
220	Cra	*Ceratocorys* sp.	5(1)			
221	Coc	*Cochlodinium* sp.				
222	Crydip	*Corythodinium diploconus* F.J.R.Taylor, 1976				
223	Cryglo	*Corythodinium globosum* F.J.R.Taylor, 1976				
224	Crytes	*Corythodinium tesselatum* Loeblich III, 1966	5(4)	5(1)	10(1)	
225	Cry	*Corythodinium* sp.	5(1)	5(1)		
226	Dinacu	*Dinophysis acuminata* Claparède & Lachmann, 1859				
227	Dinac	*Dinophysis acuta* Ehrenberg, 1839				
228	Dincau	*Dinophysis caudata* Saville-Kent, 1881	5(2)	5-20(3)	25 (1)	40 -50(2)
229	Dinexi	*Dinophysis exigua* Kofoid & Skogsberg, 1928				
230	Dinfor	*Dinophysis fortii* Pavillard, 1923				
231	Dinhas	*Dinophysis hastata* Stein, 1883	5(1)			
232	Dinmil	*Dinophysis miles* Cleve, 1900				
233	Dinpar	*Dinophysis parvula* (Schütt) Balech, 1967				
234	Dinsch	*Dinophysis schuettii* Murray & Whitting, 1899				
235	Din	*Dinophysis* spp.		5(1)		

236	Ens	*Ensiculifera*?	5(1)	5(1)		

Appendix D continued

		Seasons Region (Tracks)	FIM CPOS	FIM AR	FIM PKOS	FIM RM
A	B	C	D1	D2	D3	D4
237	Gmb	*Gambierdiscus* sp?				
238	GnSph	*Goniodoma sphaericum* Murray & Whitting, 1899		5(1)	5(2)	
239	Gn	*Goniodoma* sps				
240	Gonbi	*Gonyaulax birostris*? Stein, 1883				
241	Gondi	*Gonyaulax digitale* (Pouchet) Kofoid, 1911				
242	Gonfra	*Gonyaulax fragilis* (Schütt) Kofoid, 1911				
243	Gonfus	*Gonyaulax fusiformis* H.W.Graham, 1942				
244	Gonhya	*Gonyaulax hyalina*? Ostenfeld & Schmidt, 1901			10(1)	
245	Gonkof	*Gonyaulax kofoidii* Pavillard, 1909	10(1)	5-10(2)		
246	Gonmin	*Gonyaulax minuta* Kofoid & Michener, 1911				
247	Gonmo	*Gonyaulax monospina* Rampi, 1951	5(2)		10(1)	50(1)
248	Gonpac	*Gonyaulax pacifica* Kofoid, 1907				
249	Gonpol	***Gonyaulax polygramma*** Stein, 1883 *	5(3)	5(2)	10 -15(2)	10(1)
250	Gonrot	*Gonyaulax rotundata*? Rampi, 1951				
251	Gonscr	*Gonyaulax scrippsae* Kofoid, 1911		5(1)		
252	Gonspi	*Gonyaulax spinifera* Diesing, 1866	5(3)	5-20(2)		10(1)
253	Gonsub	*Gonyaulax subulata* Kofoid & Michener, 1911				
254	Gon	***Gonyaulax* sp** *	5-10(12)	5(4)	5 -25(4)	50(1)
255	Gymbic	*Gymnodinium bicorne* Kofoid & Swezy, 1921				

256	Gyct	*Gymnodinium catenatum* H.W.Graham, 1943				
257	Gy	***Gymnodinium* spp.** *	5-25(9)	10(1)	20 -100(2)	
258	Ha	*Heteraulacus* spp.			5(1)	

Appendix D continued

		Seasons Region (Tracks) C	FIM CPOS D1	FIM AR D2	FIM PKOS D3	FIM RM D4
A	B					
259	Htni	*Heterocapsa niei* Morrill & Loeblich III, 1981		5(1)		
260	Httr	*Heterocapsa triquetra* Stein, 1883	5-60(8)	5-20(2)	5 -10(3)	50(1)
261	KrBr	*Karenia brevis* Gert Hansen & Ø.Moestrup, 2000			15(1)	
262	LinPoly	*Lingulodinium polyedrum* J.D.Dodge, 1989	5(1)			
263	Oxcu	*Oxytoxum caudatum* Schiller, 1937				
264	Oxco	*Oxytoxum constrictum* (Stein) Bütschli, 1885				
265	Oxglo	*Oxytoxum globosum* Schiller				
266	Oxlat	*Oxytoxum laticeps* Schiller, 1937	40(1)			
267	Oxmil	*Oxytoxum milneri* Murray & Whitting, 1899		5(1)		
268	Oxpar	*Oxytoxum parvum* Schiller, 1937	5(1)			
269	Oxret	*Oxytoxum reticulatum* (Stein) Schütt, 1899				
270	Oxsce	*Oxytoxum sceptrum* (F.Stein) Schröder, 1906				
271	Oxsco	***Oxytoxum scolopax*** Stein, 1883 *	5-10(14)	5(2)	5 (2)	20(1)
272	Oxse	*Oxytoxum semicollatum* F.J.R.Taylor, 1976				
273	Oxsub	*Oxytoxum subulatum* Kofoid, 1907	5(1)			
274	Oxvar	*Oxytoxum variabile* Schiller, 1937				
275	Ox	***Oxytoxum*** sp *	5(1)		5-25(3)	

276	Podbi	*Podolampas bipes* Stein, 1883	5(1)		5(1)	
277	Podele	*Podolampas elegans* Schütt, 1895	10(1)			
278	Podpal	***Podolampas palmipes*** Stein, 1883 *	5-10(7)		5(2)	
279	Podspi	*Podolampas spinifera* Okamura, 1912	5(2)			
280	Pod	*Podolampas* spp.				

Appendix D continued

		Seasons Region (Tracks) C	FIM CPOS D1	FIM AR D2	FIM PKOS D3	FIM RM D4
A	B					
281	Prmin	*Prorocentrum balticum* J.D.Dodge, 1975				
282	Prbel	*Prorocentrum belizeanum* M.A.Faust, 1993				
283	Prcon	*Prorocentrum concavum* Y.Fukuyo, 1981				
284	Prden	*Prorocentrum dentatum* Stein, 1883				
285	Premr	*Prorocentrum emarginatum* Y.Fukuyo, 1981				
286	Prfra	***Prorocentrum gracile*** Schütt, 1895 *	5-55(5)	5-10(2)	10 (1)	40(1)
287	Prlen	*Prorocentrum lenticulatum* F.J.R.Taylor, 1976	5(1)	5(1)		
288	Prlim	*Prorocentrum lima* (Ehrenberg) F.Stein, 1878				
289	Prmex	*Prorocentrum mexicanum* Osorio-Tafall, 1942				
290	Prmic	***Prorocentrum micans*** Ehrenberg, 1834 *	5(5)	5-10(2)	5 -10(4)	20 -100(2)
291	Prmin	*Prorocentrum minimum* (Ostenfeld) J.D.Dodge, 1975				
292	Probl	*Prorocentrum oblongum* (Schiller) Ab~				
293	Probu	*Prorocentrum obtusum* Ostenfeld, 1908	5-10(4)		5-10(2)	
294	Prscu	*Prorocentrum scutellum* Schröder, 1900		5(1)		
295	Pro	***Prorocentrum* sp**. *	5-20(14)	5-10(6)	5 -75(9)	50(1)

296	Pyrsele	*Pyrocystis elegans*				
297	Pyrfus	*Pyrocystis fusiformis* C.W.Thomson, 1876		10(1)		
298	Pyrger	*Pyrocystis gerbaultii*				
299	Pyrlun	*Pyrocystis lunula* Swift ex Elbrächter & Drebes, 1978				
300	Pyrpsnoc	*Pyrocystis pseudonoctiluca* Wyville-Thompson, 1876	5(1)		5-10(2)	20(1)
301	Pyrrhom	*Pyrocystis rhomboides* (Matzenauer) Schiller, 1937				
302	Pyrrob	*Pyrocystis robusta* Kofoid, 1907	5-15(2)			

Appendix D continued

		Seasons Region (Tracks) C	FIM CPOS D1	FIM AR D2	FIM PKOS D3	FIM RM D4
A	B					
303	Pyr	*Pyrocystis* spp.	5(2)			20(1)
304	PyroHo	*Pyrophacus horologium* Stein, 1883				
305	Pyroste	*Pyrophacus steinii* (Schiller) Wall & Dale, 1971	5-15(2)			
306	Pyro	*Pyrophacus* spp.		5(1)	25(1)	
307	Scspi	*Scrippsiella spinifera* G.Honsell & M.Cabrini, 1991				
308	Sctro	***Scrippsiella trochoidea*** (Stein) Loeblich III, 1976 *	5-55(19)	5-100(7)	5 -175(12)	30(1)
309	Tapoly	*Triadinium polyedricum* (Pouchet) Dodge, 1981	5(5)	5(1)	5 -15(7)	
310	Trar	*Tripos arietinus* (Cleve) F.Gómez, 2013				
311	Traz	*Tripos azoricus* (Cleve) F.Gómez, 2013				
312	Trbe	*Tripos belone* (Cleve) F.Gómez, 2013				
313	Trbh	*Tripos boehmii* (Graham & Bronikovsky) F.Gómez, 2013	5(4)			
314	Trbr	*Tripos brevis* (Ostenfeld & Johannes) F.Gómez, 2013	5(1)	5(1)		
315	Trca	*Tripos candelabrus* (Ehrenberg) F.Gómez, 2013				

Appendix D continued

A	B	C	D1	D2	D3	D4
		Seasons	FIM	FIM	FIM	FIM
		Region (Tracks)	CPOS	AR	PKOS	RM
316	Trcc	*Tripos concilians* (Jørgenen) F.Gómez, 2013				
317	Trco	*Tripos contortus* (Gourret) F.Gómez, 2013				
318	Trde	***Tripos declinatus*** (G.Karsten) F.Gómez, 2013 *	5-50(4)	10(1)		
319	Trdf	*Tripos deflexus* (Kofoid) F.Gómez, 2014	5(1)		5(1)	
320	Trdn	*Tripos dens*(Ostenfeld & Johannes) F.Gómez, 2013				
321	Trdi	*Tripos digitatus* (F.Schütt) F.Gómez, 2013		15(1)		
322	Trex	*Tripos extensus* (Gourret) F.Gómez, 2013	5(1)			
323	Treu	*Tripos euarcatus* (Jørg.1920) F. Gómez, 2013	5(1)			
324	Trfr	***Tripos furca*** (Ehrenberg) F.Gómez, 2013	5-25(17)	5-35(5)	5 -25(5)	20 -40(2)
325	Trfu	***Tripos fusus*** (Ehrenberg) F.Gómez, 2013	5-25(9)	5-10(3)	5 -25(5)	40(1)
326	Trhr	***Tripos horridus*** (Cleve) F.Gómez, 2013	5(3)			10 -60(2)
327	Trinc	*Tripos incisus* (Karsten) F.Gómez, 2013				
328	Trinf	*Tripos inflatus* (Karsten) F.Gómez, 2013				
329	Trkar	*Tripos karstenii* (Pavillard) F.Gómez, 1907	5(1)			
330	Trkof	*Tripos kofoidii* (Jörgenen) F.Gómez, 2013				
331	Trlim	*Tripos limulus* (Pouchet) F.Gómez, 2013				
332	Trlin	*Tripos lineatus* (Ehrenberg) F.Gómez, 2013	5(2)	10(1)	5 (1)	
333	Trlnf	*Tripos linflatus* (Karsten) F.Gómez, 2013	5(2)			
334	Trlon	*Tripos longirostrus* (Gourret) F.Gómez, 2013	10(1)	5(1)		

335	Trlu	*Tripos lunula* (Schimper ex Karsten) F.Gómez, 2013				
336	Trmac	*Tripos macroceros* (Ehrenberg) F.Gómez, 2013	10(1)			
337	Trmes	*Tripos massiliensis* (Gourret) F.Gómez, 2013				
338	Trmin	*Tripos minutus* (Jörgensen) F.Gómez, 2013				
339	Trtri	*Tripos muelleri* Bory de Saint-Vincent, 1824	5(3)	5(1)	10(1)	
340	Trtra	*Tripos muelleri* f. *atlanticus* F.Gómez, 2013	5(1)			
341	Trpen	*Tripos pentagonus* (Gourret) F.Gómez, 2013	5-15(5)	5(2)	5(2)	
342	Trpul	*Tripos pulchellus* (Schröder) F.Gómez, 2013			5(1)	
343	Trran	*Tripos ranipes* (Cleve) F.Gómez, 2013	5-25(3)			
344	Trsc	*Tripos schmidtii* (Jørgesen) F.Gómez, 2013		10(1)		
345	Trse	*Tripos setaceus* (Jørgesen) F.Gómez, 2013			5(1)	

Appendix D continued

A	B	Seasons Region (Tracks) C	FIM CPOS D1	FIM AR D2	FIM PKOS D3	FIM RM D4
346	Trsy	*Tripos symmetricus* (Pavillard) F.Gómez, 2013				
347	Trte	***Tripos teres*** (Kof. 1907) F. Gómez, 2013 *	5-10(4)		5(1)	
348	Trtrh	*Tripos trichoceros* (Ehrenberg) Gómez, 2013	5-15(5)	5(1)		100 (1)
349	Trvu	*Tripos vultur* (Cleve) F.Gómez, 2013			10(1)	
350	Trycom	***Tryblionella compressa*** (J.W.Bailey) M.Poulin, 1990 *	5-10(9)	5-10(4)	5(1)	
1	Apermin	*Archaeperidinium minutum* (Kofoid) Jørgensen, 1912	5(1)			50 -100(2)
2	Blcoe	*Balechina coerulea* (Dogiel) F.J.R.Taylor, 1976			5(1)	
3	Bl	*Balechina* sps ?	5(4)	10(1)	5 (1)	
4	Citreg	*Citharistes regius* Stein, 1883				

5	Dino	*Dinophysis argus* (Stein) Abé				20(1)
6	Diplen	*Diplopsalis lenticula* Bergh, 1881				
7	Dip	*Diplopsalis* sp.	5(2)		20-20(2)	
8	Got	*Gotoius* sps		5(1)		
9	Gyr	*Gyrodinium* sp.				
10	Hetdnmi	*Heterodinium milneri* (Murray & Whitting) Kofoid, 1906				
11	Hetdn	*Heterodinium* spp.	10(1)			
12	Hiscar	*Histioneis carinata* Kofoid, 1907				
13	His	*Histiones* spp.				
14	Noctsci	*Noctiluca scintillans*(Macartney) Kofoid & Swezy, 1921				
15	Noct	*Noctiluca* spp.				
16	Orfor	*Ornithocercus formosus* Kofoid & Michener, 1911			5(1)	
17	Orhet	*Ornithocercus hetroporus* Kofoid, 1907				

Appendix D continued

		Seasons Region (Tracks) C	FIM CPOS D1	FIM AR D2	FIM PKOS D3	FIM RM D4
A	B					
18	Ormag	*Ornithocercus magnificus* Stein, 1883	5(1)			
19	Orqad	*Ornithocercus quadratus* Schütt, 1900				
20	Orste	*Ornithocercus steinii* Schütt, 1900	5(1)			
21	Orthu	*Ornithocercus thumii* Kofoid & Skogsberg, 1928	5(1)	5(1)	5 (1)	
22	Orn	*Ornithocercus* spp.	5(1)	5(1)		
23	Pphae	*Paleophalacroma*??				
24	Pent	*Pentapharsodinium tyrrhenicum* Marino, 1993				

25	Phacir	*Phalacroma circumcinctum* Kofoid & Michener, 1911				
26	Phacun	*Phalacroma cuneus* F.Schütt, 1895				
27	Phador	*Phalacroma doryphorum* Stein, 1883				
28	Phafav	*Phalacroma favus* Kofoid & Michener, 1911				
29	Phloxy	*Phalacroma oxytoxoides* D.Moreira, 2011				
30	Pharap	*Phalacroma rapa* Jorgensen, 1923				
31	Pharot	*Phalacroma rotundatum* Kofoid & Michener, 1911	5(2)			
32	Pha	*Phalacroma* spp.	5(5)	5(2)	5 (1)	
33	Pnocac	*Pronoctiluca acuta* (Lohmann) Schiller, 1933				
34	Pnocpel	*Pronoctiluca pelagica* Fabre-Domergue, 1889				
35	Pnocros	*Pronoctiluca rostrata* F.J.R.Taylor, 1976				
36	Pnocspi	*Pronoctiluca spinifera* (Lohmann) Schiller, 1932				
37	Pnoc	*Pronoctiluca* spp.	5(2)			
38	Proabi	*Protoperidinium abei*(Paulsen, 1931) Balech, 1974				

Appendix D continued

		Seasons Region (Tracks)	FIM CPOS	FIM AR	FIM PKOS	FIM RM
A	B	C	D1	D2	D3	D4
39	Proacb	*Protoperidinium achromaticum* Balech 1974				
40	Probicon	*Protoperidinium biconicum* Balech, 1974	5(1)			
41	Probre	*Protoperidinium brevipes* Balech, 1974				
42	Procla	*Protoperidinium claudicans* Balech, 1974				60(1)

43	Procon	*Protoperidinium conicum* f. *quardafuiana* Balech, 1974			5(1)	80(1)
44	Procra	*Protoperidinium crassipes* Balech, 1974				20(1)
45	Procur	*Protoperidinium curvipes* (Ostenfeld) Balech, 1974				40(1)
46	Prodiv	*Protoperidinium divergens* Balech, 1974	5(3)	5(2)	5(1)	20 -50(2)
47	Proele	*Protoperidinium elegans* (Cleve, 1900) Balech, 1974	5(1)			
48	Prohet	*Protoperidinium heteracanthum* (Dangeard) Balech			5(1)	
49	Proinf	*Protoperidinium inflatum* (Okamura, 1912) Balech, 1974				
50	Prolat	*Protoperidinium latispinum* Balech, 1974			5(1)	
51	Proleo	*Protoperidinium leonis* Balech, 1974	5(1)	5-10(2)	5 -10(3)	20(1)
52	Prolon	*Protoperidinium longicollum* Pavillard 1916	5(3)	5(1)	20(1)	
53	Proobl	*Protoperidinium oblongum* Parke & Dodge, 1976				50(1)
54	Prooce	*Protoperidinium oceanicum* Balech, 1974				
55	Proova	*Protoperidinium ovatum* Pouchet, 1883				
56	Propac	*Protoperidinium pacificum* Balech ex Balech, 1988	5(3)	5(1)		
57	Propall	*Protoperidinium pallidum* Balech, 1973	5-10(4)		5-5(1)	
58	Proped	*Protoperidinium pedunculatum* Balech, 1974				100(1)
59	Propell	*Protoperidinium pellucidum* Bergh, 1881				

Appendix D continued

		Seasons	FIM	FIM	FIM	FIM
		Region (Tracks)	CPOS	AR	PKOS	RM
A	B	C	D1	D2	D3	D4

60	Propen	*Protoperidinium pentagonum* Balech, 1974	10(1)	5-10(2)		
61	Propon	*Protoperidinium ponticum* Vershinin & Morton, 2005			25(1)	
62	Propun	*Protoperidinium punctulatum* Balech, 1974				
63	Propyr	*Protoperidinium pyriforme* Balech, 1974				
64	Prosou	*Protoperidinium sourniae* Balech, 1994		10(1)	10(1)	
65	Proste	*Protoperidinium steinii* Balech, 1974	5(1)	10(1)		
66	Prosub	*Protoperidinium subinerme* Loeblich III, 1969	5(1)			
67	Protri	*Protoperidinium tristylum* Balech, 1974				
68	Protub	*Protoperidinium tuba* Balech, 1974				50(1)
69	Pro	*Protoperidinium* sp.	5-25(11)	5-190(9)	5 -50(11)	100 -200(2)
70	Zyg	*Zygabikadonium lenticulatum* Loeblich III, 1970	5-10(2)	5(2)	5(1)	120(1)
1	Dic	*Dictyocha*	5-40(4)	5(2)	15(1)	

Appendix E : Checklist of Microphytoplankton comprising Diatoms, Dinoflagellates and Dictyoca from the four different tracks of the Bay of Bengal (BoB) observed during the North East Monsoon (NEM). The column from left to right denotes, **A** - Serial no, **B** - codes used in the ordination analysis. **C** - Microphytoplankton species comprised of Diatoms, Dinoflagellates and Dictyoca. **E** - Cell abundance (cells L^{-1}), values outside the bracket denotes minimum to maximum variations in cell counts and values inside the brackets denotes number of occurrences. The codes **E1** to **E4** depicts variations in cell abundance observed along the four different tracks CPOS, AR, PKOS and RM respectively.

		Seasons Region (Tracks)	NEM CPOS	NEM AR	NEM PKOS	NEM RM
A	B	C	E1	E2	E3	E4
sr no	codes	Taxa				
1	AcSe	*Actinocyclus senarius* Ehrenberg, 1843	5(1)		5 (1)	
2	Ac	*Actinocyclus* sp	5(1)	5 (1)		
3	Amar	*Asterolampra marylandica* Ehrenberg, 1844	5 -10(8)	5 -15(2)		
4	A	*Asterolampra* spp.	5 -5(2)		5 -10(3)	
5	Auar	*Asteromphalus arachne* Ralfs, 1861	5(1)			
6	Auhep	*Asteromphalus heptactis* Ralfs, 1861			5 (1)	10 (1)
7	Aupet	*Asteromphalus pettersonii* Thorrington-Smith 1970				
8	Au	*Asteromphalus* spp.	5 -5(6)		5 -15(3)	10(1)
9	Aznod	*Azpeitia nodulifera* G.A.Fryxell & P.A.Sims, 1996	10 (1)			
10	Bcdel	*Bacteriastrum delicatulum* Cleve, 1897	5 -4(4)			
11	Bcel	*Bacteriastrum elongatum* Cleve, 1897	30 (1)			
12	Bcfur	*Bacteriastrum furcatum* Shadbolt, 1854	5 -185(18)	5 -110(2)	5 -10(4)	15 - 45(2)
13	Bchya	*Bacteriastrum hyalinum* Lauder, 1864	5 -55(5)	5 (1)		
14	Bc	*Bacteriastrum* spp.	5 -50(18)	15 -95(4)	5 -45(5)	5 (1)

15	Bid	*Biddulphia* sp				
16	Cam	*Campylodiscus* sp			65(1)	

Appendix E continued

		Seasons Region (Tracks)	NEM CPOS	NEM AR	NEM PKOS	NEM RM
A	B	C	E1	E2	E3	E4
17	Cerbi	*Cerataulina bicornis* (Ehrenberg) Hasle, 1985				
18	Cerden	*Cerataulina dentata* Hasle & Syvertsen, 1980				
19	Cerpel	*Cerataulina pelagica* (Cleve) Hendey, 1937		5 (1)		
20	Cer	*Cerataulina* sp.				
21	Chae	*Chaetoceros aequatorialis* Cleve, 1873		45 (1)		
22	Chaf	*Chaetoceros affinis* Lauder, 1864	5 -80(6)	15 (1)	10(1)	5 - 1080(3)
23	Chat	*Chaetoceros atlanticus* Cleve, 1873	10 -135(9)		10(1)	
24	Chco	*Chaetoceros coarctatus* Lauder, 1864	10 -90(10)	20 -50(2)	10 -45(2)	40 (1)
25	Chcom	*Chaetoceros compressus* Lauder, 1864	5 -30(3)	5 (1)		
26	Chcon	*Chaetoceros concavicornis* Mangin, 1917	40 (1)			
27	Chcon	*Chaetoceros constrictus* Gran, 1897				
28	Chcov	*Chaetoceros convolutus* Castracane, 1886	5 -10(4)			
29	Chcos	*Chaetoceros costatus* Pavillard, 1911	10(1)			
30	Chcur	*Chaetoceros curvisetus* Cleve, 1889	5 -145(17)	25(1)		210(1)
31	Chdad	*Chaetoceros dadayi* Pavillard, 1913				
32	Chdan	*Chaetoceros danicus* Cleve, 1889	10 -30(2)			
33	Chdeb	*Chaetoceros debilis* Cleve, 1894				

34	Chdec	*Chaetoceros decipiens* Cleve, 1873	5 -90(8)		10 (1)	105 - 2800(2)
35	Chdia	*Chaetoceros diadema* (Ehrenberg) Gran, 1897				
36	Chdic	*Chaetoceros dichaeta* Ehrenberg, 1844				
37	Chdid	*Chaetoceros didymus* Ehrenberg, 1845	5 -30(3)			
38	Chdiv	*Chaetoceros diversus* Cleve, 1873	5 -35(8)	5 -15(2)	30(1)	

Appendix E continued

		Seasons	NEM	NEM	NEM	NEM
		Region (Tracks)	CPOS	AR	PKOS	RM
A	B	C	E1	E2	E3	E4
39	Chei	*Chaetoceros eibenii* Grunow, 1882	5 -20(3)	65 (1)	5 -15(3)	
40	Chfur	*Chaetoceros furcellatus* Yendo, 1911		10 (1)	10(1)	
41	Chlac	*Chaetoceros laciniosus* F.Schütt, 1895		5 -20(2)		
42	Chlau	*Chaetoceros lauderi* Ralfs, 1864		20 (1)		
43	Chlor	*Chaetoceros lorenzianus* Grunow, 1863	10 -60(5)	20(1)	5 -10(2)	45 - 2800(2)
44	Chmess	*Chaetoceros messanense* Castracane, 1875	5 -50(7)		5(1)	
45	Chper	*Chaetoceros peruvianus* Brightwell, 1856	5 -85(43)	5 -20(4)	5 -10(3)	15(1)
46	Chpscur	*Chaetoceros pseudocurvisetus* Mangin, 1910	5 -20(3)	40 (1)	5(1)	
47	Chsim	*Chaetoceros simplex* Ostenfeld, 1902	20(1)	10 (1)		
48	Chsub	*Chaetoceros subtilis* Cleve, 1896				
49	Chwig	*Chaetoceros wighamii* Brightwell, 1856	20(1)			
50	Ch	*Chaetoceros* spp.	5 -140(73)	5 -985(8)	5 -60(19)	35 - 155(4)
51	Clifra	*Climacodium frauenfeldianum* Grunow, 1868	5 -80(33)	15 -30(3)	15 -30(3)	

52	Clma	*Climacosphenia* spp.				
53	Cocri	*Corethron criophilum* (Grunow) Ostenfeld, 1909	5 -10(6)			5 (1)
54	Cohy	*Corethron hystrix.* Hensen, 1887		5(1)	5 (1)	
55	Co	*Corethron* sp.	5 -25(2)		5 (1)	
56	Cscen	*Coscinodiscus centralis* Ehrenberg, 1844	5 -30(12)	5(1)	5 -10(3)	
57	Csgra	*Coscinodiscus granii* Gough, 1905	5 -15(3)			
58	Cslin	*Coscinodiscus lineatus* Ehrenberg	5 (1)			
59	Csmar	*Coscinodiscus marginatus* Ehrenberg, 1844	5 -10(17)	5(2)	5 -15(7)	360 (1)
60	Csocc	*Coscinodiscus oculus-iridis* Ehrenberg, 1840				5(1)

Appendix E continued

		Seasons	NEM	NEM	NEM	NEM
		Region (Tracks)	CPOS	AR	PKOS	RM
A	B	C	E1	E2	E3	E4
61	Csrad	*Coscinodiscus radiatus* Ehrenberg, 1840	5 -10(4)	5(1)	5 -10(3)	
62	Cswei	*Coscinodiscus wailesii* Gran & Angst, 1931				
63	Cs	*Coscinodiscus* spp.	5 -80(109)	5 -40(15)	5 -220(28)	10 - 30(5)
64	Cystr	*Cyclotella striata* (Kützing) Grunow, 1880				
65	Cy	*Cyclotella* sp.	5 -25(8)	10 (1)	5 -20(2)	10 (1)
66	Dctfra	*Dactyliosolen fragilissimus* (Bergon) Hasle, 1996	5 -45(4)	5(1)		220(1)
67	Dct	*Dactyliosolen* sp?				
68	Ditbri	*Ditylum brightwellii* (T.West) Grunow, 1885	5 -30(4)	10 (2)	5 (1)	120 - 320(2)
69	Ditsol	*Ditylum sol* (Grunow) De Toni, 1894	5 -30(10)	5 (1)	5 -10(6)	5 - 140(2)
70	Dit	*Ditylum* sp.	5(1)			
71	Eucor	*Eucampia cornuta* (Cleve) Grunow, 1883	10(1)			

72	Eugeo	*Eucampia groenlandica* Cleve, 1896			5 (1)	
73	Euzod	*Eucampia zodiacus* Ehrenberg, 1839	15 -30(3)			5 - 240(3)
74	Eu	*Eucampia* sp.				
75	Csjoh	*Eupodiscus johneius* (Greville) J.Rattray				280(1)
76	Gicy	*Guinardia cylindrus* (Cleve) Hasle, 1996	5 -165(26)	65(1)	5 -10(2)	
77	Gidel	*Guinardia delicatula* (Cleve) Hasle, 1997	5 -75(3)			5 (1)
78	Giflac	*Guinardia flaccida* (Castracane) H.Peragallo, 1892				
79	Gistr	*Guinardia striata* (Stolterfoth) Hasle, 1996	5 -370(18)	10 -120(4)	5 (2)	35 - 120(2)
80	Gi	*Guinardia* sp.	5 -110(7)	15 -280(2)		15(1)
81	Hltem	*Helicotheca tamesis* (Shrubsole) M.Ricard, 1987	30 -70(2)			35 (1)
82	Hemhu	*Hemiaulus hauckii* Grunow ex Van Heurck, 1882	5 -45(17)	5 -35(8)	5 -10(6)	10(1)

Appendix E continued

		Seasons Region (Tracks)	NEM CPOS	NEM AR	NEM PKOS	NEM RM
A	B	C	E1	E2	E3	E4
83	Hemind	*Hemiaulus indicus* Karsten, 1907				
84	Hemmem	*Hemiaulus membranaceus* Cleve	5 -80(45)	5 -55(7)	5 -50(10)	15 - 20(2)
85	Hemsin	*Hemiaulus sinensis* Greville, 1865	5 -40(12)	20 (1)	5(1)	25 (1)
86	Hem	*Hemiaulus* sp.	5 -35(10)		10 -15(2)	
87	Hmcun	*Hemidiscus cuneiformis* Wallich, 1860	5(1)			
88	Hm	*Hemidiscus* sp.	5(1)		10(1)	5 - 25(2)
89	Luan	*Lauderia annulata* Cleve, 1873				2470 (1)
90	lu	*Lauderia* sp.	5(1)			
91	Lpdan	*Leptocylindrus danicus* Cleve, 1889	40 (1)			65 - 1880(2)

92	Lpmed	*Leptocylindrus mediterraneus* Hasle, 1975				195 (1)
93	Lpmin	*Leptocylindrus minimus* Gran, 1915				
94	Lp	*Leptocylindrus* sp.	5 -70(3)	5 -50(3)	5 -10(2)	20 - 95(3)
95	NeoRob	*Neocalyptrella robusta* Meave del Castillo, 1997	5 -30(5)			
96	Osin	*Odontella sinensis* (Greville) Grunow, 1884			5(1)	15 - 325(3)
97	O	*Odontella* sp.	5(5)			
98	Pal	*Palmeria hardmaniana* (Greville) G.R.Hasle, 1996				15 - 4200(2)
99	Pksol	*Planktoniella sol* (C.G.Wallich) Schütt, 1892	5(7)			
100	Psial	*Proboscia alata* (Brightwell) Sundström, 1986	5 -35(25)	5 -15(2)	5 -15(2)	
101	Psiain	*Proboscia indica* Hernández-Becerril, 1995	5 -100(9)	20(1)	5 (1)	5 (1)
102	Pgurec	*Pseudoguinardia recta* von Stosch, 1986		20 (1)		15 (1)
103	Pgu	*Pseudoguinardia* spp.		5 (1)		
104	Psucal	*Pseudosolenia calcar-avis* B.G.Sundström, 1986	5 -25(26)	15 -35(3)	5 -40(5)	

Appendix E continued

		Seasons Region (Tracks)	NEM CPOS	NEM AR	NEM PKOS	NEM RM
A	B	C	E1	E2	E3	E4
105	Rzac	*Rhizosolenia acuminata* H.Peragallo, 1907	10(1)			
106	Rzaci	*Rhizosolenia acicularis* B.G.Sundström, 1986	5(2)		20 -20(1)	
107	Rzbeg	*Rhizosolenia bergonii* H.Peragallo, 1892	5 -10(2)			
108	Rzbor	*Rhizosolenia borealis* B.G.Sundström, 1986			85 (1)	

109	Rzcas	*Rhizosolenia castracanei* H.Peragallo, 1888	5 -25(2)	10(1)	5 -20(3)	120 (1)
110	Rzcle	*Rhizosolenia clevei* Ostenfeld, 1902	10(1)			
111	Rzcra	*Rhizosolenia crassa* Schimper, 1905				
112	Rzcur	*Rhizosolenia curvata* Zacharias, 1905	5(1)			
113	Rzdeb	*Rhizosolenia debyana* H.Peragallo, 1892	10 (1)			
114	Rzdec	*Rhizosolenia decipiens* B.G.Sundström, 1986	30(1)	5 (1)		
115	Rzfor	*Rhizosolenia formosa* H.Peragallo, 1888	10(1)	15(1)	5 -10(3)	
116	Rzheb	*Rhizosolenia hebetata* (Hensen) Gran, 1908	5 -235(25)	10 -20(4)	5 -20(6)	40 (1)
117	Rzheb	*Rhizosolenia hebetata* f. *semispina* Gran, 1908	10(1)	10(1)		
118	Rzhya	*Rhizosolenia hyalina* Ostenfeld, 1901	5(1)			
119	Rzimb	*Rhizosolenia imbricata* Brightwell, 1858	5 -70(10)			
120	Rzsetg	*Rhizosolenia setigera* Brightwell, 1858	5 -10(3)	5 -20(2)		25 (1)
121	Rzsetp	*Rhizosolenia setigera* f. *pungens* Brunel, 1962				
122	Rzsty	*Rhizosolenia styliformis* T.Brightwell, 1858	5 -125(38)		5 -30(3)	
123	Rz	*Rhizosolenia* spp.	5 -180(123)	5 -115(13)	5 -150(30)	5 - 80(5)
124	SkeCos	*Skeletonema costatum* (Greville) Cleve, 1873	5 -90(3)	45(1)	15(1)	10 - 475(2)
125	Ske	*Skeletonema* sp	25(1)			180(1)

Appendix E continued

		Seasons Region (Tracks) C	NEM CPOS E1	NEM AR E2	NEM PKOS E3	NEM RM E4
A	B					
126	Ste	*Stephanopyxis* sp.				
127	Stri	*Striatella* spp.	5 -30(2)			

128	Thang	*Thalassiosira angulata* (W.Gregory) Hasle, 1978				
129	Thecc	*Thalassiosira eccentrica* (Ehrenberg) Cleve, 1904	5 -15(7)		5(1)	25 (1)
130	Thex	*Thalassiosira excentrica* (Ehrenberg) Cleve, 1904	5(2)		10 (1)	
131	Thgra	*Thalassiosira gravida* Cleve, 1896	35(1)			
132	Thpun	*Thalassiosira punctigera* (Castracane) Hasle, 1983			35(1)	
133	Th	*Thalassiosira* spp.	5 -80(111)	5 -2780(16)	5 -40(30)	35 - 200(5)
134	Tmob	*Trieres mobiliensis* Ashworth & Theriot, 2013				5 - 70 (4)
135	Tgia	*Trieres regia* M.P.Ashworth & E.C.Theriot, 2013				
136	Anan	*Achnanthes* sp.	5 -20(3)		15 (1)	
137	Amphh	*Amphiprora* spp.			5(1)	5(2)
138	Aph	*Amphora* spp.	5 -160(24)	30(1)	5 -50(5)	5(2)
139	Asterio	*Asterionellopsis* sp?	5 -20(2)	20(1)		
140	CccSC	*Cocconeis scutellum* Ehrenberg, 1838	5(1)			
141	Ccc	*Cocconeis* sp.	5(2)		25 (1)	
142	CyClo	*Cylindrotheca closterium* Reimann & J.C.Lewin, 1964	5 -30(10)	5 -20(4)	5 -725(8)	5 (1)
143	Dip	*Diploneis* sp.	5(1)			
144	Fgcyl	*Fragilariopsis cylindrus* (Grunow) Krieger, 1954	5 -30(9)	20(1)	25 (1)	
145	Fgdol	*Fragilariopsis doliolus* Medlin & P.A.Sims, 1993	5 -110(15)	25(1)	10 -15(2)	
146	Fgoce	*Fragilariopsis oceanica* (Cleve) Hasle, 1965	20(1)			
147	Fg	*Fragilariopsis* spp.	5 -50(12)		15 -50(4)	

Appendix E continued

Seasons	NEM	NEM	NEM	NEM
Region (Tracks)	CPOS	AR	PKOS	RM

A	B	C	E1	E2	E3	E4
148	Gmma	*Grammatophora* sps	5(1)			
149	Gyro	*Gyrosigma* sp.				
150	Hsgig	*Haslea gigantea* (Hustedt) Simonsen, 1974				
151	HsTro	*Haslea trompii* (Cleve) Simonsen, 1974	5 -65(45)	5 -10(3)	5 -15(2)	
152	Hswaw	*Haslea wawrikae* (Hustedt) Simonsen, 1974	5 -50(13)	5(2)		
153	Hs	*Haslea* spp.	5 -55(31)	5(2)	5 -15(9)	
154	Lioelo	*Lioloma elongatum* (Grunow) Hasle, 1997	5 -30(5)			
155	Liopac	*Lioloma pacificum* (Cupp) Hasle, 1996	5 -40(9)		5 (2)	
156	Lio	*Lioloma* sp.	5 -45(10)		5 -45(5)	
157	Mstros	*Mastogloia rostrata* (Wallich) Hustedt, 1933	5 -15(10)	5(1)	5(1)	
158	Mstspl	*Mastogloia splendida* Cleve & Möller, 1879				
159	Mst	*Mastogloia* spp.	5 -30(32)	5 -35(6)	5(4)	
160	Mmem	*Meuniera membranacea* (Cleve) P.C.Silva, 1996	5 -130(11)	15 -125(2)	20(1)	10 - 25(2)
161	Mm	*Meuniera* spp.	5(1)			
162	Nvdir	*Navicula directa* (W.Smith) Ralfs, 1861	5 -20(28)	5(5)	5 -10(3)	
163	Nvdis	*Navicula distans* (W.Smith) Ralfs, 1861	5 -20(6)	5 -10(2)	15(1)	
164	Nvsep	*Navicula septentrionalis* (Grunow) Gran, 1908				
165	Nvsub	*Navicula subinflata* Cleve & Möller, 1882				
166	Nvdel	*Navicula transitans* f. *delicatula* Heimdal, 1970	5(2)			15(1)
167	NvDer	*Navicula transitans* var. *derasa* Cleve, 1883	5 -30(14)	5(1)	5 -15(3)	5 (1)
168	Nv	*Navicula* spp.	5 -190(157)	5 -115(23)	5 -115(39)	30 - 160(5)

Appendix E continued

		Seasons	NEM	NEM	NEM	NEM
		Region (Tracks)	CPOS	AR	PKOS	RM
A	B	C	E1	E2	E3	E4
169	Nzang	*Nitzschia angularis* W.Smith, 1853	5(1)			
170	Nzlong	*Nitzschia longissima* (Brébisson) Ralfs, 1861	5 -95(6)			10 - 25(2)
171	Nzsig	*Nitzschia sigma* (Kützing) W.Smith, 1853				
172	Nz	*Nitzschia* spp.	5 -135(88)	5 -150(10)	5 -175(17)	25(3)
173	Phae	*Phaeodactylum tricornutum* Bohlin, 1897	5 -25(2)			
174	Pin	*Pinnularia* sps	10(2)	5(1)	5(2)	
175	PluAng	*Pleurosigma angulatum* W.Smith, 1852				
176	Pludir	*Pleurosigma directum* Grunow, 1880	5 -20(7)			
177	Pluelo	*Pleurosigma elongatum* W.Smith, 1852				40 (1)
178	Plunor	*Pleurosigma normanii* Ralfs, 1861				10 (1)
179	Plusim	*Pleurosigma simonsenii* Hasle, 1990				10(1)
180	Plu	*Pleurosigma* spp.	5 -20(16)		5 -20(5)	5 - 35(5)
181	Psdel	*Pseudonitzschia delicatissima* Heiden, 1928	5 -70(5)		5 -15(3)	525 - 2800(2)
182	Psfra	*Pseudonitzschia fraudulenta* Hasle, 1993	30 (1)	20(1)		
183	Pslin	*Pseudonitzschia lineola* (Cleve) Hasle, 1965				65(1)
184	Psser	*Pseudonitzschia seriata* (Cleve) H.Peragallo, 1899	10 -70(4)			20 - 6080(2)
185	Pssufra	*Pseudonitzschia subfraudulenta* G.R.Hasle, 1993				
186	Ps	*Pseudonitzschia* spp.	5 -235(44)	5 -570(5)	5 -895(12)	15 - 455(3)
187	Sur	*Surirella* sp?				20 (2)
188	Syne	*Synedropsis* sp.	5 -10(9)	5(2)	5 -15(6)	

189	Thlbac	*Thalassionema bacillare* (Heiden) Kolbe, 1955	5 -10(14)	30(1)		35 - 55(3)
190	Thlfra	*Thalassionema frauenfeldii* Tempère & Peragallo, 1910	5 -70(17)	5 -95(5)	5 -155(8)	70 - 360(5)
191	Thljav	*Thalassionema javanicum* (Grunow) G.R.Hasle	5 -40(5)	10(1)		220 (1)

Appendix E continued

		Seasons Region (Tracks) C	NEM CPOS E1	NEM AR E2	NEM PKOS E3	NEM RM E4
A	B					
192	Thlnitz	*Thalassionema nitzschioides* Mereschkowsky, 1902	5 -105(12)	10 -85(5)	10 -20(4)	5 - 1965(6)
193	Thlpsnitz	*Thalassionema pseudonitzschioides* G.R.Hasle	5(1)	40(1)		
194	Thl	*Thalassionema* sp.	5 -45(29)	5 -150(7)	5 -10(2)	5 - 300(2)
195	Txlon	*Thalassiothrix longissima* Cleve & Grunow, 1880	5 -30(8)			
196	Tx	*Thalassiothrix* sp.	5 -90(2)			
197	Ticer	*Triceratium* sp				
198	Acgon	*Acanthogonyaulax spinifera* H.W.Graham, 1942	5(2)			
199	Aksn	*Akashiwo sanguinea* G.Hansen & Ø.Moestrup, 2000	5 -10(2)			
200	Acat	*Alexandrium catenella* (Whedon & Kofoid) Balech, 1985	5 -10(2)		5 -20(2)	
201	Acon	*Alexandrium concavum* (Gaarder) Balech, 1985	5(1)			
202	Amin	*Alexandrium minutum* Halim, 1960			5(1)	
203	Atam	*Alexandrium tamarense* (Lebour, 1925) Balech, 1995	5(1)	5 (1)	5(1)	
204	Ax	*Alexandrium* spp.	5 -65(32)	5 (4)	5 -10(11)	5(1)
205	AmpCar	*Amphidinium carterae* Hulburt, 1957				
206	Ampsph	*Amphidinium sphenoides* WüIff, 1916	10 -20(2)			
207	Amp	*Amphidinium* sp.	5 -65(97)	5 -50(8)	5 -55(21)	
208	Amdp	*Amphidoma* sp.	5(2)			
209	Apsolast	*Amphisolenia astragalus* Kofoid & Michener, 1911	5(1)			

210	Apsolbid	*Amphisolenia bidentata* Schröder, 1900	5 -10(13)	5 (1)	5 -10(4)	
211	Apsolglo	*Amphisolenia globifera* Stein, 1883				
212	Apsoltri	*Amphisolenia thrinax* Schütt, 1893	5(1)			
213	Apsol	*Amphisolenia* spp.	5 -10(8)		5(2)	
214	Azcau	*Azadinium caudatum* (Halldal) Nézan & Chomérat, 2012	5 -5(2)		5(1)	
215	Blph	*Blepharocysta* sp.?	5 -10(27)	5 -15(5)	5 -15(12)	
216	Craar	*Ceratocorys armata* (Schütt) Kofoid, 1910				

Appendix E continued

		Seasons Region (Tracks) C	NEM CPOS E1	NEM AR E2	NEM PKOS E3	NEM RM E4
A	B					
217	Crahor	*Ceratocorys horrida* Stein, 1883	5(4)	5 (1)	5(4)	
218	Cragou	*Ceratocorys gourretii* Paulsen, 1931				
219	Craret	*Ceratocorys reticulata* H.W.Graham, 1942	5(1)			
220	Cra	*Ceratocorys* sp.	5(1)			
221	Coc	*Cochlodinium* sp.	5(1)			
222	Crydip	*Corythodinium diploconus* F.J.R.Taylor, 1976				
223	Cryglo	*Corythodinium globosum* F.J.R.Taylor, 1976	10(1)			
224	Crytes	*Corythodinium tesselatum* Loeblich III, 1966	5 -15(15)	5 (1)	5(3)	
225	Cry	*Corythodinium* sp.	5(2)			
226	Dinacu	*Dinophysis acuminata* Claparède & Lachmann, 1859	5 -10(3)		5(1)	10(1)
227	Dinac	*Dinophysis acuta* Ehrenberg, 1839	5(3)			
228	Dincau	*Dinophysis caudata* Saville-Kent, 1881	5 -20(9)	5 (1)		120(1)
229	Dinexi	*Dinophysis exigua* Kofoid & Skogsberg, 1928				

230	Dinfor	*Dinophysis fortii* Pavillard, 1923		5 (1)		
231	Dinhas	*Dinophysis hastata* Stein, 1883	5(1)			
232	Dinmil	*Dinophysis miles* Cleve, 1900				
233	Dinpar	*Dinophysis parvula* (Schütt) Balech, 1967	10 -10(1)			
234	Dinsch	*Dinophysis schuettii* Murray & Whitting, 1899				
235	Din	*Dinophysis* spp.	5 -10(10)	5 (2)	5 (1)	
236	Ens	*Ensiculifera*?	5 -10(10)	5 -10(3)	5 -25(7)	
237	Gmb	*Gambierdiscus* sp?	5(1)			5(1)
238	GnSph	*Goniodoma sphaericum* Murray & Whitting, 1899	5 -10(8)	5 (1)	5(2)	

Appendix E continued

		Seasons	NEM	NEM	NEM	NEM
		Region (Tracks)	CPOS	AR	PKOS	RM
A	B	C	E1	E2	E3	E4
239	Gn	*Goniodoma* sps	5(1)		5(1)	
240	Gonbi	*Gonyaulax birostris*? Stein, 1883	10(1)			
241	Gondi	*Gonyaulax digitale* (Pouchet) Kofoid, 1911			5(1)	
242	Gonfra	*Gonyaulax fragilis* (Schütt) Kofoid, 1911	5(1)			
243	Gonfus	*Gonyaulax fusiformis* H.W.Graham, 1942	5(1)			
244	Gonhya	*Gonyaulax hyalina*? Ostenfeld & Schmidt, 1901	5(1)			
245	Gonkof	*Gonyaulax kofoidii* Pavillard, 1909	10(1)		5(1)	
246	Gonmin	*Gonyaulax minuta* Kofoid & Michener, 1911	5(1)			
247	Gonmo	*Gonyaulax monospina* Rampi, 1951	5 -10(6)			
248	Gonpac	*Gonyaulax pacifica* Kofoid, 1907				
249	Gonpol	*Gonyaulax polygramma* Stein, 1883	5 -15(21)		5 -10(4)	

250	Gonrot	*Gonyaulax rotundata*? Rampi, 1951	10(1)			
251	Gonscr	*Gonyaulax scrippsae* Kofoid, 1911	5 -15(13)	5(3)	5 -10(2)	
252	Gonspi	*Gonyaulax spinifera* Diesing, 1866	5 -10(7)		5(3)	
253	Gonsub	*Gonyaulax subulata* Kofoid & Michener, 1911	10(1)			
254	Gon	*Gonyaulax* sp	5 -40(56)	5 -20(7)	5 -25(23)	
255	Gymbic	*Gymnodinium bicorne* Kofoid & Swezy, 1921	5(1)			
256	Gyct	*Gymnodinium catenatum*? H.W.Graham, 1943	10 -20(2)			
257	Gy	*Gymnodinium* spp.	5 -20(33)	5 -15(9)	5 -25(15)	5(1)
258	Ha	*Heteraulacus* spp.				
259	Htni	*Heterocapsa niei* Morrill & Loeblich III, 1981	5(3)		5(1)	
260	Httr	*Heterocapsa triquetra* Stein, 1883	5 (10)	10 (1)	5 -15(4)	
261	KrBr	*Karenia brevis* Gert Hansen & Ø.Moestrup, 2000				
262	LinPoly	*Lingulodinium polyedrum* J.D.Dodge, 1989	5(1)			

Appendix E continued

		Seasons Region (Tracks) C	NEM CPOS E1	NEM AR E2	NEM PKOS E3	NEM RM E4
A	B					
263	Oxcu	*Oxytoxum caudatum* Schiller, 1937	5(1)			
264	Oxco	*Oxytoxum constrictum* (Stein) Bütschli, 1885	5(2)			
265	Oxglo	*Oxytoxum globosum* Schiller	10(1)			
266	Oxlat	*Oxytoxum laticeps* Schiller, 1937	5 -25(8)	5 (1)	5(2)	
267	Oxmil	*Oxytoxum milneri* Murray & Whitting, 1899	5 (7)	5 (2)	5(2)	
268	Oxpar	*Oxytoxum parvum* Schiller, 1937	5(3)	5 (4)		

269	Oxret	*Oxytoxum reticulatum* (Stein) Schütt, 1899	5(1)			
270	Oxsce	*Oxytoxum sceptrum* (F.Stein) Schröder, 1906			5 (1)	
271	Oxsco	*Oxytoxum scolopax* Stein, 1883	5 -30(38)	5 (2)	5 -10(4)	
272	Oxse	*Oxytoxum semicollatum* F.J.R.Taylor, 1976				
273	Oxsu	*Oxytoxum subulatum* Kofoid, 1907				
274	Oxvar	*Oxytoxum variabile* Schiller, 1937	5(1)			
275	Ox	*Oxytoxum* sp	5 -10(28)	5 -15(4)	5 -20(10)	
276	Podbi	*Podolampas bipes* Stein, 1883	5 -10(4)	5 (1)		
277	Podele	*Podolampas elegans* Schütt, 1895	5 (1)	5 (1)		
278	Podpal	*Podolampas palmipes* Stein, 1883	5 -10(23)	5 (4)	5(2)	
279	Podspi	*Podolampas spinifera* Okamura, 1912	5 -10(12)		5(1)	
280	Pod	*Podolampas* spp.	5 (4)			
281	Prmin	*Prorocentrum balticum* J.D.Dodge, 1975		10 (1)		
282	Prbel	*Prorocentrum belizeanum* M.A.Faust, 1993	5(2)		5 (1)	
283	Prcon	*Prorocentrum concavum* Y.Fukuyo, 1981	5(3)	5 (1)		
284	Prden	*Prorocentrum dentatum* Stein, 1883			5(1)	

Appendix E continued

		Seasons Region (Tracks) C	NEM CPOS E1	NEM AR E2	NEM PKOS E3	NEM RM E4
A	B					
285	Premr	*Prorocentrum emarginatum* Y.Fukuyo, 1981	5(1)			
286	Prfra	*Prorocentrum gracile* Schütt, 1895	5 -40(17)	10(1)	5 -10(2)	25 - 40(2)
287	Prlen	*Prorocentrum lenticulatum* F.J.R.Taylor, 1976	5(1)	5 (1)		

288	Prlim	*Prorocentrum lima* (Ehrenberg) F.Stein, 1878		5(1)		
289	Prmex	*Prorocentrum mexicanum* Osorio-Tafall, 1942	10(1)			
290	Prmic	*Prorocentrum micans* Ehrenberg, 1834	5 -15(20)	5 -15(6)	5 -10(6)	5 - 165(3)
291	Prmin	*Prorocentrum minimum* (Ostenfeld) J.D.Dodge, 1975				
292	Probl	*Prorocentrum oblongum* (Schiller) Ab~			5 (1)	
293	Probu	*Prorocentrum obtusum* Ostenfeld, 1908	5 -15(4)		5(1)	
294	Prscu	*Prorocentrum scutellum* Schröder, 1900	5 -30(8)	5(1)	5 (1)	5(1)
295	Pro	*Prorocentrum* sp.	5 -30(52)	5 -30(7)	5 -90(12)	5 - 60(3)
296	Pyrsele	*Pyrocystis elegans* Pavillard, 1931	10(1)	5 (1)		
297	Pyrfus	*Pyrocystis fusiformis* C.W.Thomson, 1876	10(1)			
298	Pyrger	*Pyrocystis gerbaultii* Pavillard, 1935		5 (1)		
299	Pyrlun	*Pyrocystis lunula* Swift ex Elbrächter & Drebes, 1978	5 -10(5)			
300	Pyrpsnoc	*Pyrocystis pseudonoctiluca* Wyville-Thompson, 1876	5 -20(4)	5 -10(2)	5 -10(4)	5(1)
301	Pyrrhom	*Pyrocystis rhomboides* (Matzenauer) Schiller, 1937	5(2)			
302	Pyrrob	*Pyrocystis robusta* Kofoid, 1907	5(1)			
303	Pyr	*Pyrocystis* spp.	5 -40(13)		5 (3)	
304	PyroHo	*Pyrophacus horologium* Stein, 1883	5 (3)			
305	Pyroste	*Pyrophacus steinii* (Schiller) Wall & Dale, 1971				
306	Pyro	*Pyrophacus* spp.	5 (2)	5 (1)		

Appendix E continued

		Seasons	NEM	NEM	NEM	NEM
		Region (Tracks)	CPOS	AR	PKOS	RM
A	B	C	E1	E2	E3	E4

307	Scspi	*Scrippsiella spinifera* G.Honsell & M.Cabrini, 1991	5 -15(3)			
308	Sctro	*Scrippsiella trochoidea* (Stein) Loeblich III, 1976	5 -95(108)	5 -20(14)	5 -60(32)	10 - 120(3)
309	Tapoly	*Triadinium polyedricum* (Pouchet) Dodge, 1981	5 -15(24)	5 (2)	5 -10(6)	
310	Trar	*Tripos arietinus* (Cleve) F.Gómez, 2013	10(1)	5 (1)		
311	Traz	*Tripos azoricus* (Cleve) F.Gómez, 2013	5 (1)			
312	Trbe	*Tripos belone* (Cleve) F.Gómez, 2013				
313	Trbh	*Tripos boehmii* (Graham & Bronikovsky) F.Gómez, 2013	5(1)			
314	Trbr	*Tripos brevis* (Ostenfeld & Johannes) F.Gómez, 2013	5 -10(5)	5 (1)		
315	Trca	*Tripos candelabrus* (Ehrenberg) F.Gómez, 2013	20(1)		10 (1)	
316	Trcc	*Tripos concilians* (Jørgenen) F.Gómez, 2013	5(1)			
317	Trco	*Tripos contortus* (Gourret) F.Gómez, 2013	5 (1)		5 (1)	
318	Trde	*Tripos declinatus* (G.Karsten) F.Gómez, 2013	5 -15(30)	5 -10(3)	5 (5)	
319	Trdf	*Tripos deflexus* (Kofoid) F.Gómez, 2014	5 -10(2)		10 (1)	
320	Trdn	*Tripos dens* (Ostenfeld & Johannes) F.Gómez, 2013				
321	Trdi	*Tripos digitatus* (F.Schütt) F.Gómez, 2013	10 -20(2)		5 (1)	
322	Trex	*Tripos extensus* (Gourret) F.Gómez, 2013	5(7)	5(1)	5 (1)	
323	Treu	*Tripos euarcatus* F. Gómez, 2013				
324	Trfr	*Tripos furca* (Ehrenberg) F.Gómez, 2013	5 -40(30)	5(4)	5 -15(7)	5 - 20(2)
325	Trfu	*Tripos fusus* (Ehrenberg) F.Gómez, 2013	5 -15(19)	5(2)	5 -10(5)	
326	Trhr	*Tripos horridus* (Cleve) F.Gómez, 2013	5 -20(14)	5(2)	5 -10(5)	5-80(2)
327	Trinc	*Tripos incisus* (Karsten) F.Gómez, 2013				
328	Trinf	*Tripos inflatus* (Karsten) F.Gómez, 2013	5 -10(6)	5 (2)	5 -10(3)	5 (1)

Appendix E continued

A	B	Seasons Region (Tracks) C	NEM CPOS E1	NEM AR E2	NEM PKOS E3	NEM RM E4
329	Trkar	*Tripos karstenii* (Pavillard) F.Gómez, 1907	5 -5(2)			
330	Trkof	*Tripos kofoidii* (Jörgenen) F.Gómez, 2013	5 -5(3)			
331	Trlim	*Tripos limulus* (Pouchet) F.Gómez, 2013				
332	Trlin	*Tripos lineatus* (Ehrenberg) F.Gómez, 2013	5 -20(7)	10 (1)	10 (1)	
333	Trlnf	*Tripos linflatus* (Pouchet) F.Gómez, 2013		5 (1)		
334	Trlon	*Tripos longirostrus* (Gourret) F.Gómez, 2013	5 -10(5)			
335	Trlu	*Tripos lunula* (Karsten) F.Gómez, 2013			5 (1)	
336	Trmac	*Tripos macroceros* (Ehrenberg) F.Gómez, 2013	5 -10(4)		5(2)	15(1)
337	Trmes	*Tripos massiliensis* (Gourret) F.Gómez, 2013	15 -15(1)		5(1)	
338	Trmin	*Tripos minutus* (Jörgensen) F.Gómez, 2013	5 (1)			
339	Trtri	*Tripos muelleri* Bory de Saint-Vincent, 1824	5 -10(6)	15 (1)	5 (1)	10(1)
340	Trtra	*Tripos muelleri* f. *atlanticus*(Ostenf. 1903) F. Gómez, 2013	5(1)		20 (1)	
341	Trpen	*Tripos pentagonus* (Gourret) F.Gómez, 2013	5 -10(8)		5(1)	
342	Trpul	*Tripos pulchellus* (Schröder) F.Gómez, 2013	5(1)			
343	Trran	*Tripos ranipes* (Cleve) F.Gómez, 2013				
344	Trsc	*Tripos schmidtii* (Jørgesen) F.Gómez, 2013	5(1)	5 (2)		
345	Trse	*Tripos setaceus* (Jørgesen) F.Gómez, 2013				
346	Trsy	*Tripos symmetricus* (Pavillard) F.Gómez, 2013	5(1)		5 (1)	
347	Trte	*Tripos teres* (Kofoidii) F. Gómez, 2013	5 -10(23)	5 (3)	5 -20(4)	
348	Trtrh	*Tripos trichoceros* (Ehrenberg) Gómez, 2013	5 -10(12)	5 (1)	5 -10(3)	5 - 40(2)
349	Trvu	*Tripos vultur* (Cleve) F.Gómez, 2013	10 -10(3)	5 (1)	5(2)	
350	Trycom	*Tryblionella compressa* (J.W.Bailey) M.Poulin, 1990	5 -20(22)	5 -10(4)	5 -15(4)	

1	Apermin	*Archaeperidinium minutum* (Kofoid) Jørgensen, 1912	5 -10(10)	5 -10(2)	5 -10(3)	
2	Blcoe	*Balechina coerulea* (Dogiel) F.J.R.Taylor, 1976	5 (2)			

Appendix E continued

		Seasons	NEM	NEM	NEM	NEM
		Region (Tracks)	CPOS	AR	PKOS	RM
A	B	C	E1	E2	E3	E4
3	Bl	*Balechina* sps ?	5 (1)		5 (1)	
4	Citreg	*Citharistes regius* Stein, 1883	5(1)			
5	Dino	*Dinophysis argus* (Stein) Abé	5(1)			
6	Diplen	*Diplopsalis lenticula* Bergh, 1881				
7	Dip	*Diplopsalis* sp.	5 -10(3)	5 (1)	5 -10(2)	
8	Got	*Gotoius* sps				
9	Gyr	*Gyrodinium* sp.	5 -25(29)	5 (1)	5(3)	
10	Hetdnmi	*Heterodinium milneri* (Murray & Whitting) Kofoid, 1906	5 (1)			
11	Hetdn	*Heterodinium* spp..				
12	Hiscar	*Histioneis carinata* Kofoid, 1907	5(2)			
13	His	*Histioneis* spp.				
14	Noctsci	*Noctiluca scintillans* (Macartney) Kofoid & Swezy, 1921	5 -20(6)			
15	Noct	*Noctiluca* spp.				
16	Orfor	*Ornithocercus formosus* Kofoid & Michener, 1911				
17	Orhet	*Ornithocercus hetroporus* Kofoid, 1907	5 (1)			
18	Ormag	*Ornithocercus magnificus* Stein, 1883	5 (2)	5 (1)	5 -10(4)	
19	Orqad	*Ornithocercus quadratus* Schütt, 1900	5 -10(2)		10 (1)	
20	Orste	*Ornithocercus steinii* Schütt, 1900	5(2)			

21	Orthu	*Ornithocercus thumii* Kofoid & Skogsberg, 1928	5(1)	5 (3)	5(5)	
22	Orn	*Ornithocercus* spp.	5 -10(9)			
23	Pphae	*Paleophalacroma*??	5 (1)			
24	Pent	*Pentapharsodinium tyrrhenicum* Marino, 1993	5(2)			
25	Phacir	*Phalacroma circumcinctum* Kofoid & Michener, 1911				

Appendix E continued

		Seasons Region (Tracks)	NEM CPOS	NEM AR	NEM PKOS	NEM RM
A	B	C	E1	E2	E3	E4
26	Phacun	*Phalacroma cuneus* F.Schütt, 1895				
27	Phador	*Phalacroma doryphorum* Stein, 1883	5(2)		5 (1)	
28	Phafav	*Phalacroma favus* Kofoid & Michener, 1911	5 (1)			
29	Phloxy	*Phalacroma oxytoxoides* D.Moreira, 2011	5(1)		5 (1)	
30	Pharap	*Phalacroma rapa* Jorgensen, 1923	5 (1)		5(1)	
31	Pharot	*Phalacroma rotundatum* Kofoid & Michener, 1911	5 (6)	5(1)		
32	Pha	*Phalacroma* spp.	5 (9)	5 (1)	5 -10(2)	
33	Pnocac	*Pronoctiluca acuta* (Lohmann) Schiller, 1933	5 (1)			
34	Pnocpel	*Pronoctiluca pelagica* Fabre-Domergue, 1889			5(1)	
35	Pnocros	*Pronoctiluca rostrata* F.J.R.Taylor, 1976	5 (1)			
36	Pnocspi	*Pronoctiluca spinifera* (Lohmann) Schiller, 1932				
37	Pnoc	*Pronoctiluca* spp.	5 (1)	5(1)		
38	Proabi	*Protoperidinium abei* (Paulsen, 1931) Balech, 1974	5 -10(2)			
39	Proacb	*Protoperidinium achromaticum* Balech 1974				
40	Probicon	*Protoperidinium biconicum* Balech, 1974				
41	Probre	*Protoperidinium brevipes* Balech, 1974	5 (1)			

42	Procla	*Protoperidinium claudicans* Balech, 1974	5 (1)		5 -10(2)	
43	Procon	*Protoperidinium conicum* f. *quardafuiana* Balech, 1974	5 (4)			
44	Procra	*Protoperidinium crassipes* Balech, 1974	10 (1)			
45	Procur	*Protoperidinium curvipes* (Ostenfeld) Balech, 1974				
46	Prodiv	*Protoperidinium divergens* Balech, 1974	5 -10(17)	5 (4)	5 -10(5)	5 - 10(2)
47	Proele	*Protoperidinium elegans* (Cleve, 1900) Balech, 1974	5 (2)		5(1)	
48	Prohet	*Protoperidinium heteracanthum* (Dangeard) Balech				
49	Proinf	*Protoperidinium inflatum* (Okamura, 1912) Balech, 1974				

Appendix E continued

		Seasons	NEM	NEM	NEM	NEM
		Region (Tracks)	CPOS	AR	PKOS	RM
A	B	C	E1	E2	E3	E4
50	Prolat	*Protoperidinium latispinum* Balech, 1974	10 (1)			
51	Proleo	*Protoperidinium leonis* Balech, 1974	10 (4)		5 (1)	
52	Prolon	*Protoperidinium longicollum* Pavillard, 1916	5 -10(4)	5 (1)	5 (1)	
53	Proobl	*Protoperidinium oblongum* Parke & Dodge, 1976	5 (1)			
54	Prooce	*Protoperidinium oceanicum* Balech, 1974	5 (1)			
55	Proova	*Protoperidinium ovatum* Pouchet, 1883		5 (1)		
56	Propac	*Protoperidinium pacificum* Balech ex Balech, 1988	5 -10(7)	5 (2)	5 (5)	
57	Propall	*Protoperidinium pallidum* Balech, 1973	5 (1)	5 (2)		5(1)
58	Proped	*Protoperidinium pedunculatum* Balech, 1974	5 -10(3)	5 (1)		40(1)
59	Propell	*Protoperidinium pellucidum* Bergh, 1881	5 -10(10)	5 (1)		
60	Propen	*Protoperidinium pentagonum* Balech, 1974	10 (2)	5 (2)		

61	Propon	*Protoperidinium ponticum* Vershinin & Morton, 2005				
62	Propun	*Protoperidinium punctulatum* Balech, 1974			10 (1)	
63	Propyr	*Protoperidinium pyriforme* Balech, 1974	10 (1)			
64	Prosou	*Protoperidinium sourniae* Balech, 1994				
65	Proste	*Protoperidinium steinii* Balech, 1974	5 -10(6)		10 (2)	
66	Prosub	*Protoperidinium subinerme* Loeblich III, 1969				
67	Protri	*Protoperidinium tristylum* Balech, 1974				
68	Protub	*Protoperidinium tuba* Balech, 1974				
69	Pro	*Protoperidinium* sp.	5 -35(93)	5 -15(14)	5 -35(33)	5 - 255(5)
70	Zyg	*Zygabikadonium lenticulatum* Loeblich III, 1970	5 -10(4)		5 -10(2)	40(1)
1	Dic	*Dictyocha*	5 -10(17)		5 -20(2)	35 - 40(2)

Appendix F Checklist of Microphytoplankton comprising Diatoms, Dinoflagellates and Dictyoca from the four different tracks of the Bay of Bengal (BoB) observed during the Spring Intermonsoon (SIM). The column from left to right denotes, **A** - Serial no, **B** – Species with Chloroplast (C) and Non Chloroplast (NC). **C** - Species comprised of those forms that is assigned according to Margalef's Mandala (Margalef 1978), D - column depicts species assigned to 'C-S-R' strategies. E – column depicts habitat types of the respective taxa according to Smyada and Reynolds (2001). F – Microphytoplankton species comprised of Diatoms, Dinoflagellates and Dictyoca. **G** – column denotes Cell abundance (cells L^{-1}), values outside the bracket denotes minimum to maximum variations in cell counts and values inside the brackets denotes number of occurrences. The codes **G1** to **G4** depicts variations in cell abundance observed along the four different tracks CPOS, AR, PKOS and RM respectively.

					Seasons Region (Tracks)	SIM CPOS	SIM AR	SIM PKOS	SIM RM
A	B	C	D	E	C	G1	G2	G3	G4
sr no					Taxa				
					Diatoms				
1	C		R		*Actinocyclus senarius* Ehrenberg, 1843				
2	C		R		*Actinocyclus* sp				
3	C		R		*Asterolampra marylandica* Ehrenberg, 1844	5(2)	10 (1)	5(3)	60 (2)
4	C		R		*Asterolampra* spp.		5 (1)	5(1)	
5	C		R		*Asteromphalus arachne* Ralfs, 1861				
6	C		R		*Asteromphalus heptactis* Ralfs, 1861				
7	C		R		*Asteromphalus pettersonii* Thorrington-Smith 1970				
8	C		R		*Asteromphalus* spp.	5 (2)	5(2)	5 -15(3)	20 - 100(3)
9	C		S		*Azpeitia nodulifera* G.A.Fryxell & P.A.Sims, 1996				
10	C		R		*Bacteriastrum delicatulum* Cleve, 1897	5 -10(3)		15(1)	380 (1)

11	C		R		*Bacteriastrum elongatum* Cleve, 1897		5(1)		
12	C		R		***Bacteriastrum furcatum*** Shadbolt, 1854 *	5 -1250(7)	5 -25(3)	10 -150(4)	80 - 120(2)

Appendix F continued

					Seasons	SIM	SIM	SIM	SIM
					Region (Tracks)	CPOS	AR	PKOS	RM
A	B	C	D	E	C	G1	G2	G3	G4
13	C		R		*Bacteriastrum hyalinum* Lauder, 1864	5 -10(2)		15(1)	160 (1)
14	C		R		*Bacteriastrum* spp.	5 -15(2)	5(2)	5 -20(3)	120 (1)
15	C		R		*Biddulphia* sp				
16	C		R		*Campylodiscus* sp				
17	C		R		*Cerataulina bicornis* (Ehrenberg) Hasle, 1985				15 (1)
18	C		R		*Cerataulina dentata* Hasle			5(1)	
19	C		R		*Cerataulina pelagica* (Cleve) Hendey, 1937				
20	C		R		*Cerataulina* sp.			5 (1)	
21	C	r	R		*Chaetoceros aequatorialis* Cleve, 1873				
22	C	r	R		*Chaetoceros affinis* Lauder, 1864	5 -1100(4)	5 -45(3)	40(1)	10 - 40(2)
23	C	r	R		*Chaetoceros atlanticus* Cleve, 1873	5 -50(5)	40(1)	15 -20(2)	860 (1)
24	C	r	R		*Chaetoceros coarctatus* Lauder, 1864	5 -200(6)	15 -45(2)	5 -25(2)	
25	C	r	R		*Chaetoceros compressus* Lauder, 1864	3300 (1)		60 (1)	
26	C	r	R		*Chaetoceros concavicornis* Mangin, 1917				
27	C	r	R		*Chaetoceros constrictus* Gran, 1897				
28	C	r	R		*Chaetoceros convolutus* Castracane, 1886				
29	C	r	R		*Chaetoceros costatus* Pavillard, 1911	700(1)			480 (1)
30	C	r	R		*Chaetoceros curvisetus* Cleve, 1889	5 -12250(3)	5(1)	35(1)	440 - 3260(4)

31	C	r	R		*Chaetoceros dadayi* Pavillard, 1913				
32	C	r	R		*Chaetoceros danicus* Cleve, 1889				600 (1)
33	C	r	R		*Chaetoceros debilis* Cleve, 1894				
34	C	r	R		*Chaetoceros decipiens* Cleve, 1873	15 -1150(3)	10(1)	15 -40(2)	120 - 1600(5)

Appendix F continued

					Seasons Region (Tracks)	SIM CPOS	SIM AR	SIM PKOS	SIM RM
A	B	C	D	E	C	G1	G2	G3	G4
35	C	r	R		*Chaetoceros diadema* (Ehrenberg) Gran, 1897				
36	C	r	R		*Chaetoceros dicatea* Ehrenberg, 1844				180 (1)
37	C	r	R		*Chaetoceros didymus* Ehrenberg, 1845			10(1)	
38	C	r	R		*Chaetoceros diversus* Cleve, 1873	5 -700(3)		10 -15(2)	
39	C	r	R		*Chaetoceros eibenii* Grunow, 1882	5 -15(2)			
40	C	r	R		*Chaetoceros furcellatus* Yendo, 1911				
41	C	r	R		*Chaetoceros laciniosus* F.Schütt, 1895	5(3)	15(1)		
42	C	r	R		*Chaetoceros lauderi* Ralfs, 1864				
43	C	r	R		*Chaetoceros lorenzianus* Grunow, 1863	2750(1)	30(1)	5 -95(4)	340 - 1120(4)
44	C	r	R		*Chaetoceros messanense* Castracane, 1875	5 (3)	20(1)		
45	C	r	R		***Chaetoceros peruvianus*** Brightwell, 1856 *	5 -850(4)	5(4)	5 -15(8)	80 - 320(2)
46	C	r	R		*Chaetoceros pseudocurvisetus* Mangin, 1910	5 (1)			140 (1)
47	C	r	R		*Chaetoceros simplex* Ostenfeld, 1902				
48	C	r	R		*Chaetoceros subtilis* Cleve, 1896			30(1)	
49	C	r	R		*Chaetoceros wighamii* Brightwell, 1856				

50	C	r	R		***Chaetoceros* spp. ***	5-12150(26)	5 -70(10)	5 -360(18)	70 - 1280(5)
51	C		R		***Climacodium frauenfeldianum* Grunow, 1868 ***	10 -80(10)		5 -35(2)	840 (1)
52	C		R		*Climacosphenia* spp.				
53	C		R		*Corethron criophilum* (Grunow) Ostenfeld, 1909				
54	C		R		*Corethron hystrix.* Hensen, 1887				40 (1)
55	C		R		*Corethron* sp.			5(1)	
56	C		S		*Coscinodiscus centralis* Ehrenberg, 1844	5 -10(8)	5(1)	5 -15(3)	15 - 100(2)

Appendix F continued

					Seasons Region (Tracks)	SIM CPOS	SIM AR	SIM PKOS	SIM RM
A	B	C	D	E	C	G1	G2	G3	G4
57	C		S		*Coscinodiscus granii* Gough, 1905	5 -15(2)			
58	C		S		*Coscinodiscus lineatus* Ehrenberg				
59	C		S		***Coscinodiscus marginatus*** Ehrenberg, 1844 *	5 -20(10)	5(2)	5 -15(10)	100 (1)
60	C		S		*Coscinodiscus oculus-iridis* Ehrenberg, 1840				
61	C		S		*Coscinodiscus radiatus* Ehrenberg, 1840	5 -10(5)		5 -10(2)	
62	C		S		*Coscinodiscus wailesii* Gran & Angst, 1931				80 (2)
63	C		S		***Coscinodiscus* spp**. *	5 -100(51)	5 -40(16)	5 -80(22)	10 - 580(7)
64	C		R		*Cyclotella striata* (Kützing) Grunow, 1880			10(1)	5(1)
65	C		R		*Cyclotella* sp.			5(1)	10 - 50(3)
66	C		R		*Dactyliosolen fragilissimus* (Bergon) Hasle, 1996	15 -1350(2)		60(1)	200 (1)
67	C		R		*Dactyliosolen* sp?				
68	C		R		*Ditylum brightwellii* (T.West) Grunow, 1885			10 (2)	80 - 1920(5)

69	C		R		*Ditylum sol* (Grunow) De Toni, 1894	5 -10(2)		220 (1)	
70	C		R		*Ditylum* sp.			15(1)	
71	C		R		*Eucampia cornuta* (Cleve) Grunow, 1883	5 -30(5)			
72	C		R		*Eucampia geolandrica* Cleve, 1896				
73	C		R		*Eucampia zodiacus* Ehrenberg, 1839	5(1)			
74	C		R		*Eucampia* sp.				
75	C		S		*Eupodiscus johneius* (Greville) J.Rattray				40 (1)
76	C		R		***Guinardia cylindrus*** (Cleve) Hasle, 1996 *	5 -25(10)	5 -70(6)	5 -15(8)	20 (1)
77	C		R		*Guinardia delicatula* (Cleve) Hasle, 1997	750 -750(1)	20(1)		520 - 1120(2)
78	C		R		*Guinardia flacida* (Castracane) H.Peragallo, 1892	400 -400(1)			100 - 1200(3)

Appendix F continued

					Seasons	SIM	SIM	SIM	SIM
					Region (Tracks)	CPOS	AR	PKOS	RM
A	B	C	D	E	C	G1	G2	G3	G4
79	C		R		***Guinardia striata*** (Stolterfoth) Hasle, 1996 *	10 -1950(7)	10 -110(4)	10 -285(4)	40 - 5560(5)
80	C		R		*Guinardia* spp.	5 -15(5)	10(1)	5 -45(3)	40(1)
81	C		R		*Helicotheca tamesis* (Shrubsole) M.Ricard, 1987				
82	C		R		***Hemiaulus hauckii*** Grunow ex Van Heurck, 1882 *	5 -450(11)		15 -50(4)	5 - 740(5)
83	C		R		*Hemiaulus indicus* Karsten, 1907			15 (1)	320 - 320(1)
84	C		R		***Hemiaulus membranaceus*** Cleve *	5 -175(31)	5 -25(4)	5 -95(16)	5 - 400(5)
85	C		R		*Hemiaulus sinensis* Greville, 1865	5 (1)			
86	C		R		*Hemiaulus* sp.	10 (1)			
87	C		R		*Hemidiscus cuneiformis* Wallich, 1860				40 (1)

88	C		R		*Hemidiscus* sp.			20(1)	20 (1)
89	C		R		*Lauderia annulata* Cleve, 1873	15 -1650(2)		50(1)	720 - 3160(4)
90	C		R		*Lauderia* sp.			20(1)	
91	C		R		*Leptocylindrus danicus* Cleve, 1889	3600 -3600(1)	15(1)	560 (1)	20 - 1400(4)
92	C		R		*Leptocylindrus mediterraneus* Hasle, 1975	10 (1)	15(1)		
93	C		R		*Leptocylindrus minimus* Gran, 1915				
94	C		R		*Leptocylindrus* sp.	15 -35(2)		5 -100(2)	5 (1)
95	C	r	R		*Neocalyptrella robusta* Meave del Castillo, 1997				
96	C		R		*Odontella sinensis* (Greville) Grunow, 1884		25(1)	5 -15(2)	50 - 1500(3)
97	C		R		*Odontella* sp.		5(1)		20 (1)
98	C		R		*Palmerina hardmaniana* (Greville) G.R.Hasle, 1996				80 - 180(3)
99	C		R		*Planktoniella sol* (C.G.Wallich) Schütt, 1892		5(1)		
100	C		R		***Proboscia alata*** (Brightwell) Sundström, 1986 *	5 -30(5)	5 -10(2)	10 -30(2)	40 (2)

Appendix F continued

					Seasons	SIM	SIM	SIM	SIM
					Region (Tracks)	CPOS	AR	PKOS	RM
A	B	C	D	E	C	G1	G2	G3	G4
101	C		R		*Proboscia indica* Hernández-Becerril, 1995	5 -600(2)		5 -65(3)	80 - 400(3)
102	C		R		*Pseudoguinardia recta* von Stosch, 1986	5 -200(3)		20 (1)	100 - 1360(4)
103	C		R		*Pseudoguinardia* spp.				
104	C		R		***Pseudosolenia calcar-avis*** B.G.Sundström, 1986 *	5 -150(12)	30 (1)	5 -20(7)	20 (2)
105	C	r	R		*Rhizosolenia accuminata* H.Peragallo, 1907				
106	C	r	R		*Rhizosolenia acicularis* B.G.Sundström, 1986				

107	C	r	R		*Rhizosolenia bergonii* H.Peragallo, 1892		5(1)		
108	C	r	R		*Rhizosolenia borealis* B.G.Sundström, 1986		20(1)	5(2)	
109	C	r	R		*Rhizosolenia castracanei* H.Peragallo, 1888	5 (2)	5 -10(3)	5(3)	
110	C	r	R		*Rhizosolenia clevei* Ostenfeld, 1902	5 (1)			
111	C	r	R		*Rhizosolenia crassa* Schimper, 1905				
112	C	r	R		*Rhizosolenia curvata* Zacharias, 1905	10 (1)			
113	C	r	R		*Rhizosolenia debyana* H.Peragallo, 1892	10 (1)	5(1)	10 -15(2)	10 (1)
114	C	r	R		*Rhizosolenia decipiens* B.G.Sundström, 1986			5 (2)	
115	C	r	R		*Rhizosolenia formosa* H.Peragallo, 1888		10(1)		
116	C	r	R		***Rhizosolenia hebetata*** (Hensen) Gran, 1908 *	5 -20(12)	5(2)	5 -15(8)	400(1)
117	C	r	R		*Rhizosolenia hebetata* f. *semispina* Gran, 1908				
118	C	r	R		*Rhizosolenia hyalina* Ostenfeld, 1901				
119	C	r	R		*Rhizosolenia imbricata* Brightwell, 1858	15 -250(2)	10(1)	5 -15(3)	40 (1)
120	C	r	R		*Rhizosolenia setigera* Brightwell, 1858	5 -400(2)		115 (1)	80 - 120(3)
121	C	r	R		*Rhizosolenia setigera* f. *pungens* Brunel, 1962		15(1)		
122	C	r	R		***Rhizosolenia styliformis*** T.Brightwell, 1858 *	5 -40(20)	5 -10(2)	10 -15(5)	30 (1)

Appendix F continued

					Seasons Region (Tracks)	SIM CPOS	SIM AR	SIM PKOS	SIM RM
A	B	C	D	E	C	G1	G2	G3	G4
12 3	C	r	R		***Rhizosolenia* spp. ***	5 -105(36)	5 -70(10)	5 -170(27)	10 - 800(4)
12	C		R		*Skeletonema costatum* (Greville) Cleve, 1873	5 -1350(3)	80(1)	30(1)	30 - 1780(2)

4								
125	C		R	*Skeletonema* sp			65(1)	1580 (1)
126	C		R	*Stephanopyxis* sp.	850 (1)			
127	C		R	*Striatella* spp.				
128	C	r	R	*Thalassiosira angulata* (W.Gregory) Hasle, 1978	10 (1)			
129	C	r	R	*Thalassiosira eccentrica* (Ehrenberg) Cleve, 1904	5 -10(4)	5 -10(2)	5 (7)	
130	C		R	*Thalassiosira excentrica*(Ehrenberg) Cleve, 1904				
131	C	r	R	*Thalassiosira gravida* Cleve, 1896				
132	C	r	R	*Thalassiosira punctigera* (Castracane) Hasle, 1983	5(1)			
133	C	r	R	***Thalassiosira* spp.** *	5 -150(61)	5 -60(16)	5 -30(41)	10 - 1240(7)
134	C		R	*Trieres mobiliensis* Ashworth & Theriot, 2013	5 -150(3)	5(1)	70(1)	160 - 200(2)
135	C		R	*Trieres regia* M.P.Ashworth & E.C.Theriot, 2013	20 (1)			
136	C		R	*Achnanthes* sp.	10 (1)			
137	C		R	*Amphiprora* spp.				160 (1)
138	C		R	***Amphora* spp.** *	5 -15(7)	5 -10(3)	5 -20(4)	10 - 100(2)

139	C		R		*Asterionellopsis* sp?				120 (1)
140	C		R		*Cocconeis scutellum* Ehrenberg, 1838				
141	C		R		*Cocconeis* sp.				20(1)
142	C		R		*Cylindrotheca closterium* Reimann & J.C.Lewin, 1964	5 -35(6)	5(1)	5(1)	5 - 80(2)
143	C		R		*Diploneis* sp.	5(1)		5(1)	

Appendix F continued

					Seasons	SIM	SIM	SIM	SIM
					Region (Tracks)	CPOS	AR	PKOS	RM
A	B	C	D	E	C	G1	G2	G3	G4
144	C		R		*Fragilariopsis cylindrus* (Grunow) Krieger, 1954		10 -15(3)	5(2)	
145	C		R		*Fragilariopsis doliolus* Medlin & P.A.Sims, 1993	25 (1)	15(1)	40 (1)	
146	C		R		*Fragilariopsis oceanica* (Cleve) Hasle, 1965				
147	C		R		*Fragilariopsis* spp.	10 (1)	5(1)		
148	C		R		*Grammatophora* sps				
149	C		R		*Gyrosigma* sp.				
150	C		R		*Haslea gigantea* (Hustedt) Simonsen, 1974			5(1)	
151	C		R		***Haslea trompii*** (Cleve) Simonsen, 1974 *	5 -50(19)	5 -95(7)	5 -20(16)	

152	C		R		*Haslea wawrikae* (Hustedt) Simonsen, 1974	5 -250(5)	5 -10(3)	5 -10(4)	
153	C		R		***Haslea* spp.** *	5 (1)	10 -20(2)	5(2)	
154	C		R		*Lioloma elongatum* (Grunow) Hasle, 1997	5(1)		10 (1)	
155	C		R		*Lioloma pacificum* (Cupp) Hasle, 1996	5 -400(4)	5(1)	5 -50(3)	
156	C		R		*Lioloma* sp.	5 -15(5)	5(1)	5 -20(3)	40 (1)
157	C		R		*Mastogloia rostrata* (Wallich) Hustedt, 1933	5 -10(3)	5 (5)	5 -30(11)	
158	C		R		*Mastogloia splendida* Cleve & Möller, 1879	5 -30(9)			
159	C		R		***Mastogloia* spp. ***	5 -50(25)	5 -10(5)	5 -40(10)	
160	C		R		*Meuniera membranacea* (Cleve) P.C.Silva, 1996	200 (1)		10 -35(3)	480 - 640(2)
161	C		R		*Meuniera* spp.				
162	C		R		***Navicula directa*** (W.Smith) Ralfs, 1861 *	5 -10(5)	5 -35(4)	5 -20(5)	
163	C		R		*Navicula distans* (W.Smith) Ralfs, 1861	5 -5(4)		10(1)	
164	C		R		*Navicula septantronalis* (Grunow) Gran, 1908				

Appendix F continued

A	B	C	D	E	Seasons Region (Tracks) C	SIM CPOS G1	SIM AR G2	SIM PKOS G3	SIM RM G4
165	C		R		*Navicula subinflata* Cleve & Möller, 1882	40 (1)		5 (1)	
166	C		R		*Navicula transitans* f. *delicatula* Heimdal, 1970	10(1)		5(2)	
167	C		R		*Navicula transitans* var. *derasa* Cleve, 1883	5 -20(7)	5(1)	5 -20(4)	
168	C		R		***Navicula* spp**. *	5 -400(86)	5 -60(24)	5 -125(47)	10 - 960(8)

169	C		R		*Nitzschia angularis* W.Smith, 1853				
170	C		R		*Nitzschia longissima* (Brébisson) Ralfs, 1861	5 (1)			
171	C		R		*Nitzschia sigma* (Kützing) W.Smith, 1853	5(1)			
172	C		R		***Nitzschia* spp**.*	5 -195(23)	5 -120(8)	5 -215(16)	10 - 200(5)
173	C		R		*Phaeodactylum tricornutum* Bohlin, 1897		105(1)		
174	C		R		*Pinnularia* sps				
175	C		R		*Pleurosigma angulatum* W.Smith, 1852				5 - 160(4)
176	C		R		*Pleurosigma directum* Grunow, 1880			5(2)	
177	C		R		*Pleurosigma elongatum* W.Smith, 1852		5(1)		200(2)
178	C		R		*Pleurosigma normanii* Ralfs, 1861				120 (1)
179	C		R		*Pleurosigma simonsenii* Hasle, 1990			10 (1)	
180	C		R		*Pleurosigma* spp.	5 -10(3)	5(1)	5 -15(3)	5 - 200(5)
181	C		R		*Pseudonitzschia delicatissima* Heiden, 1928	5 -2500(8)		40 -285(3)	100 - 14280(3)
182	C		R		*Pseudonitzschia fraudulenta* Hasle, 1993		10(1)		
183	C		R		*Pseudonitzschia lineola* (Cleve) Hasle, 1965				
184	C		R		*Pseudonitzschia seriata* (Cleve) H.Peragallo, 1899	10 -2800(2)			400 - 7560(3)
185	C		R		*Pseudonitzschia subfraudulenta* G.R.Hasle, 1993		25(1)		

Appendix F continued

					Seasons	SIM	SIM	SIM	SIM
					Region (Tracks)	CPOS	AR	PKOS	RM
A	B	C	D	E	C	G1	G2	G3	G4

186	C	R	***Pseudonitzschia* spp.** *	5 -4100(9)		5 -300(6)	5 - 1580(6)
187	C	R	*Surirella* sp?			5(1)	5 - 160(3)
188	C	R	*Synedropsis* sp.	5 -5(6)	5(3)	5 -10(4)	
189	C	R	*Thalassionema bacillare* (Heiden) Kolbe, 1955		5(1)	5 -30(4)	75 - 80(2)
190	C	R	***Thalassionema frauenfeldii*** Tempère & Peragallo, 1910 *	5 -15(3)	5(1)	45 (1)	10 - 1300(6)
191	C	R	*Thalassionema javanicum* (Grunow) G.R.Hasle	5 -10(3)	120 (1)		50 (1)
192	C	R	*Thalassionema nitzschioides* Mereschkowsky, 1902 *	5 -650(4)	5 -10(3)	5 -165(4)	40 - 18640(11)
193	C	R	*Thalassionema pseudonitzschiodes* G.R.Hasle				15(1)
194	C	R	***Thalassionema* sp.** *	5 -20(4)	5 -10(3)	5 -155(5)	20 - 300(5)
195	C	R	*Thalassiothrix longissima* Cleve & Grunow, 1880	5 -15(4)			
196	C	R	*Thalassiothrix* sp.	10 -15(2)	5(1)		40 (1)
197	C	R	*Triceratium* sp				
			Dinoflagellates				
198	C		*Acanthogonyaulax spinifera* H.W.Graham, 1942				
199	C		*Akashiwo sanguinea* G.Hansen & Ø.Moestrup, 2000	5 (2)	5 (1)	5(1)	
200	C		*Alexandrium catenella* (Whedon & Kofoid) Balech, 1985				
201	C		*Alexandrium concavum* (Gaarder) Balech, 1985				
202	C		*Alexandrium minutum* Halim, 1960				
203	C		*Alexandrium tamerense* (Lebour, 1925) Balech, 1995	5 -5(2)	5(1)	5 (1)	
204	C		***Alexandrium* spp.** *	5 -150(30)	5 -15(7)	5 -25(11)	10 - 100(3)
205	C		*Amphidinium cartere* Hulburt, 1957		15(1)		
206	C		*Amphidinium sphaenoides* WüIff, 1916	10 -30(3)			

Appendix F continued

					Seasons	SIM	SIM	SIM	SIM
					Region (Tracks)	CPOS	AR	PKOS	RM
A	B	C	D	E	C	G1	G2	G3	G4
207	C				***Amphidinium* sp. ***	5 -35(52)	5 -30(13)	5 -40(25)	5 - 80(4)
208	C				*Amphidoma* sp.			45(1)	
209	C		S		*Amphisolenia astragalus*Kofoid & Michener, 1911				
210	C		S		*Amphisolenia bidentata* Schröder, 1900	5 -20(12)		5(3)	
211	C		S		*Amphisolenia globifera* Stein, 1883				
212	C		S		*Amphisolenia thrinax* Schütt, 1893				
213	C		S		*Amphisolenia* spp.	5 -10(2)		10 (1)	
214	C				*Azadinium caudatum* (Halldal) Nézan & Chomérat, 2012				
215	C				***Blepharocysta* sp.? ***	5 -20(43)	5(2)	5 -15(15)	35(1)
216	C				*Ceratocorys armata* (Schütt) Kofoid, 1910	5(1)			
217	C				*Ceratocorys gourretii* Paulsen, 1931	10 (1)			
218	C				*Ceratocorys horrida* Stein, 1883	5 -10(4)	5 (1)	5 (3)	
219	C				*Ceratocorys reticulata* H.W.Graham, 1942				

220	C				*Ceratocorys* sp.	5(1)			
221	C				*Cochlodinium* sp.				
222	C				*Corythodinium diploconus* F.J.R.Taylor, 1976	5(1)			
223	C				*Corythodinium globosum* F.J.R.Taylor, 1976				
224	C				*Corythodinium tesselatum* Loeblich III, 1966	5(4)		5(6)	
225	C				*Corythodinium* sp.		5(1)	5(1)	
226	C			VII	*Dinophysis acuminata* Claparède & Lachmann, 1859	10(2)			
227	C			VII	*Dinophysis acuta* Ehrenberg, 1839			5 (1)	
228	C				*Dinophysis caudata* Saville-Kent, 1881	5 -10(4)	5 (3)	5 -20(3)	10 - 40(3)

Appendix F continued

A	B	C	D	E	Seasons Region (Tracks) C	SIM CPOS G1	SIM AR G2	SIM PKOS G3	SIM RM G4
229	C				*Dinophysis exigua* Kofoid & Skogsberg, 1928	10(1)			
23	C				*Dinophysis fortii* Pavillard, 1923	10(1)			

0						
231	C	*Dinophysis hastata* Stein, 1883	10 (1)			
232	C	*Dinophysis miles* Cleve, 1900			5(1)	10 (1)
233	C	*Dinophysis parvula* (Schütt) Balech, 1967	5(1)			
234	C	*Dinophysis schuettii* Murray & Whitting, 1899		5 (1)		
235	C	*Dinophysis* spp.	5 -10(5)		5 -10(6)	15 (1)
236	C	*Ensiculifera*?	5 -15(6)			35(1)
237	C	*Gambierdiscus* sp?		5 (1)		
238	C	*Goniodoma sphaericum* Murray & Whitting, 1899	5 -15(10)			
239	C	*Goniodoma* sps	5(1)		5(1)	
240	C	*Gonyaulax birostris*? Stein, 1883				
241	C	*Gonyaulax digitale* (Pouchet) Kofoid, 1911	10(1)	5(1)		
242	C	*Gonyaulax fragilis* (Schütt) Kofoid, 1911				
243	C	*Gonyaulax fusiformis* H.W.Graham, 1942				
244	C	*Gonyaulax hyalina*? Ostenfeld & Schmidt, 1901	5(1)			

245	C				*Gonyaulax kofoidii* Pavillard, 1909	10(3)		5(1)	
246	C				*Gonyaulax minuta* Kofoid & Michener, 1911	5 -25(3)		5(1)	
247	C				*Gonyaulax monospina* Rampi, 1951	5 -10(2)	5(2)	5 -10(4)	
248	C				*Gonyaulax pacifica* Kofoid, 1907			5(1)	
249	C				***Gonyaulax polygramma*** Stein, 1883 *	5 -10(21)	5 (4)	5 -20(16)	
250	C				*Gonyaulax rotundata*? Rampi, 1951				

Appendix F continued

					Seasons Region (Tracks)	SIM CPOS	SIM AR	SIM PKOS	SIM RM
A	B	C	D	E	C	G1	G2	G3	G4
251	C				*Gonyaulax scrippsae* Kofoid, 1911	5(1)	5(1)		
252	C				*Gonyaulax spinifera* Diesing, 1866	5 -10(3)	5 (1)	5(1)	
253	C				*Gonyaulax subulata* Kofoid & Michener, 1911	5(1)			
254	C				***Gonyaulax* sp** *	5 -30(40)	5 -15(16)	5 -95(22)	5 - 10(3)
255	C				*Gymnodinium bicorne* Kofoid & Swezy, 1921				
256	C			V	*Gymnodinium catenatum*? H.W.Graham, 1943				
257	C			I	***Gymnodinium* spp**. *	5 -20(12)	5 -25(6)	5 -20(10)	100 (1)
258	C				*Heteraulacus* spp.	5(1)			

259	C				*Heterocapsa niei* Morrill & Loeblich III, 1981	5 (1)		5(1)	
260	C			II	*Heterocapsa triquetra* Stein, 1883	5 -10(5)	5(2)	5(4)	
261	C				*Karenia brevis* Gert Hansen & Ø.Moestrup, 2000				
262	C			V	*Lingulodinium polyedrum* J.D.Dodge, 1989	10 (1)	5(1)		
263	C				*Oxytoxum caudatum* Schiller, 1937				
264	C				*Oxytoxum constrictum* (Stein) Bütschli, 1885				
265	C				*Oxytoxum globosum* Schiller	5 -10(2)			
266	C				*Oxytoxum laticeps* Schiller, 1937	5 -40(6)	5 -10(2)	5 -25(2)	
267	C				*Oxytoxum milneri* Murray & Whitting, 1899			5(3)	
268	C				*Oxytoxum parvum* Schiller, 1937	5 -50(3)	5(1)	5(4)	
269	C				*Oxytoxum reticulatum* (Stein) Schütt, 1899				
270	C				*Oxytoxum sceptrum* (F.Stein) Schröder, 1906				
271	C				***Oxytoxum scolopax*** Stein, 1883 *	5 -15(18)	5 -10(4)	5(10)	
272	C				*Oxytoxum semicollatum* F.J.R.Taylor, 1976	10(1)			

Appendix F continued

					Seasons Region (Tracks)	SIM CPOS	SIM AR	SIM PKOS	SIM RM
A	B	C	D	E	C	G1	G2	G3	G4
27 3	C				*Oxytoxum subulatum* Kofoid, 1907	5(1)			
27 4	C				*Oxytoxum variabile* Schiller, 1937				
27	C				***Oxytoxum* sp** *	5 -15(17)		5(5)	

5						
276	C	*Podolampas bipes* Stein, 1883	5 -5(2)	5(2)		
277	C	*Podolampas elegans* Schütt, 1895	10(1)		5 -10(2)	
278	C	***Podolampas palmipes*** Stein, 1883 *****	5 -10(5)	5 -10(2)	5 -10(5)	
279	C	*Podolampas spinifera* Okamura, 1912	5 -10(10)	10 (1)	5(1)	
280	C	*Podolampas* spp.	5(2)	10 (1)		
281	C	*Prorocentrum balticum* J.D.Dodge, 1975	5(1)			
282	C	*Prorocentrum belizianum* M.A.Faust, 1993	5(1)			
283	C	*Prorocentrum concavum* Y.Fukuyo, 1981	5(3)			
284	C	*Prorocentrum dentatum* Stein, 1883				
285	C	*Prorocentrum emarginatum* Y.Fukuyo, 1981				
286	C	***Prorocentrum gracile*** Schütt, 1895 *	5(2)	5(4)	5 -10(6)	20 (2)
287	C	*Prorocentrum lenticulatum* F.J.R.Taylor, 1976	5 -10(3)			
288	C	*Prorocentrum lima* (Ehrenberg) F.Stein, 1878				
289	C	*Prorocentrum mexicanum* Osorio-Tafall, 1942				

290	C			II	***Prorocentrum micans*** Ehrenberg, 1834 *	5 -10(12)	5 -15(4)	5 -15(6)	10 - 80(7)
291	C				*Prorocentrum minimum* (Ostenfeld) J.D.Dodge, 1975				
292	C				*Prorocentrum oblongum* (Schiller) Ab~				
293	C				*Prorocentrum obtusum* Ostenfeld, 1908			5(1)	
294	C				*Prorocentrum scutellum* Schröder, 1900			5(1)	

Appendix F continued

					Seasons	SIM	SIM	SIM	SIM
					Region (Tracks)	CPOS	AR	PKOS	RM
A	B	C	D	E	C	G1	G2	G3	G4
295	C				***Prorocentrum* sp.** *	5 -50(24)	5 -20(8)	5 -15(17)	10 - 35(3)
296	C				*Pyrocystis elegans* Pavillard, 1931				
297	C				*Pyrocystis fusiformis* C.W.Thomson, 1876	5 -20(5)	5 -10(2)		
298	C				*Pyrocystis gerbaultii* Pavillard, 1935				
299	C				*Pyrocystis lunula* Swift ex Elbrächter & Drebes, 1978	10(1)			
300	C			IX	*Pyrocystis pseudonoctiluca* Wyville-Thompson, 1876	5 -55(10)	5 (1)	5 -10(2)	20 (1)
301	C				*Pyrocystis rhomboides* (Matzenauer) Schiller, 1937				
302	C				*Pyrocystis robusta* Kofoid, 1907	15(1)			
303	C				*Pyrocystis* spp.	5(1)		15(1)	20(1)
304	C				*Pyrophacus horologium* Stein, 1883	5(3)			

305	C				*Pyrophacus steinii* (Schiller) Wall & Dale, 1971	5 -10(3)	10 (1)		
306	C				*Pyrophacus* spp.			5(1)	120 (1)
307	C				*Scrippsiella spinifera* G.Honsell & M.Cabrini, 1991				
308	C			II	***Scrippsiella trochoidea*** (Stein) Loeblich III, 1976 *	5 -450(71)	5 -70(20)	5 -255(40)	10 - 300(6)
309	C				*Triadinium polyedricum* (Pouchet) Dodge, 1981	5 -10(17)	5(5)	5 -10(16)	10 (1)
310	C	R		III, VIII	*Tripos arietinus* (Cleve) F.Gómez, 2013	5 -10(2)		5(2)	
311	C	R		III, VIII	*Tripos azoricus* (Cleve) F.Gómez, 2013				
312	C	R		III, VIII	*Tripos belone* (Cleve) F.Gómez, 2013				
313	C	R		III, VIII	*Tripos boehmii* (Graham & Bronikovsky) F.Gómez, 2013			10(2)	
314	C	R		III, VIII	*Tripos brevis* (Ostenfeld & Johannes) F.Gómez, 2013	5 -20(15)	5(1)	10(1)	5(1)
315	C	R		III, VIII	*Tripos candelabrus* (Ehrenberg) F.Gómez, 2013				
316	C	R		III, VIII	*Tripos concilians* (Jørgenen) F.Gómez, 2013	5 -20(4)			
317	C	R		III, VIII	*Tripos contortus* (Gourret) F.Gómez, 2013				

Appendix F continued

					Seasons Region (Tracks)	SIM CPOS	SIM AR	SIM PKOS	SIM RM
A	B	C	D	E	C	G1	G2	G3	G4
318	C	R		III, VIII	***Tripos declinatus*** (G.Karsten) F.Gómez, 2013 *	5 -10(10)	5 -10(6)	5 -10(13)	
319	C	R		III, VIII	*Tripos deflexus* (Kofoid) F.Gómez, 2014	5 (3)			20 (2)
320	C	R		III, VIII	*Tripos dens* (Ostenfeld & Johannes) F.Gómez, 2013	10 (2)		10(1)	
321	C	R		III, VIII	*Tripos digitatus* (F.Schütt) F.Gómez, 2013		15 (1)	5(1)	
322	C	R		III, VIII	*Tripos extensus* (Gourret) F.Gómez, 2013	5 -20(5)		5(1)	20 (1)
323	C	R		III, VIII	*Tripos euarcatus* (Jørg.1920) F. Gómez,2013				

324	C	R	III, VIII	***Tripos furca*** (Ehrenberg) F.Gómez, 2013 *	5 -10(12)	5 -40(3)	5 -10(12)	5 - 110(6)
325	C	R	III, VIII	***Tripos fusus*** (Ehrenberg) F.Gómez, 2013 *	5 -10(13)	5 -20(5)	5 -10(17)	5 (1)
326	C	R	III, VIII	***Tripos horridus*** (Cleve) F.Gómez, 2013 *	5 -30(11)	5 -5(2)	5 -10(2)	10 - 60(2)
327	C	R	III, VIII	*Tripos incisus* (Karsten) F.Gómez, 2013				
328	C	R	III, VIII	*Tripos inflatus* (Karsten) F.Gómez, 2013	5(1)	15 (1)	5(2)	5 (1)
329	C	R	III, VIII	*Tripos karstenii* (Pavillard) F.Gómez, 1907	5(2)			
330	C	R	III, VIII	*Tripos kofoidii* (Jörgenen) F.Gómez, 2013			20 (1)	
331	C	R	III, VIII	*Tripos limulus* (Pouchet) F.Gómez, 2013	5(1)			
332	C	R	III, VIII	*Tripos lineatus* (Ehrenberg) F.Gómez, 2013	5(1)			5(1)
333	C	R	III, VIII	*Tripos linflatus* (Karsten) F.Gómez, 2013	5(3)			
334	C	R	III, VIII	*Tripos longirostrus* (Gourret) F.Gómez, 2013	5 -10(2)	5(1)	5(1)	
335	C	R	III, VIII	*Tripos lunula* (Karsten) F.Gómez, 2013				
336	C	R	III, VIII	*Tripos macroceros* (Ehrenberg) F.Gómez, 2013	5 -10(3)		5 -5(2)	
337	C	R	III, VIII	*Tripos massiliensis* (Gourret) F.Gómez, 2013				
338	C	R	III, VIII	*Tripos minutus* (Jörgensen) F.Gómez, 2013				
339	C	R	III, VIII	*Tripos muelleri* Bory de Saint-Vincent, 1824	5 -20(8)	5 -10(2)	20(1)	

Appendix F continued

A	B	C	D	E	Seasons Region (Tracks) C	SIM CPOS G1	SIM AR G2	SIM PKOS G3	SIM RM G4
340	C	R		III, VIII	*Tripos muelleri f.atlanticus* (Ostenf. 1903) F. Gómez, 2013	5(2)			10 (1)
341	C	R		III, VIII	*Tripos pentagonus* (Gourret) F.Gómez, 2013	5 -25(10)	5(2)	5 -10(4)	

342	C	R	III, VIII	*Tripos pulchellus* (Schröder) F.Gómez, 2013	5(6)	5(1)	10(1)	10 - 20(2)
343	C	R	III, VIII	*Tripos ranipes* (Cleve) F.Gómez, 2013				
344	C	R	III, VIII	*Tripos schmidtii* (Jørgesen) F.Gómez, 2013				
345	C	R	III, VIII	*Tripos setaceus* (Jørgesen) F.Gómez, 2013			5(1)	
346	C	R	III, VIII	*Tripos symmetricus* (Pavillard) F.Gómez, 2013				
347	C	R	III, VIII	***Tripos teres*** (Kofoidii) F. Gómez, 2013 *	5 -15(19)	5 (2)	5 -10(8)	
348	C	R	III, VIII	*Tripos trichoceros* (Ehrenberg) Gómez, 2013	5(3)	5 (1)	5(1)	
349	C	R	III, VIII	*Tripos vultur* (Cleve) F.Gómez, 2013		15(1)	5 -10(2)	80 (2)
350	C			***Tryblionella compressa*** (J.W.Bailey) M.Poulin, 1990 *	5 -20(14)	5 -10(2)	5 -10(6)	
1	NC			*Archaeperidinium minutum* (Kofoid) Jørgensen, 1912	5 -10(9)	5(5)	5(4)	10(1)
2	NC			*Balechina coerulea* (Dogiel) F.J.R.Taylor, 1976				
3	NC			*Balechina* sps ?	5(4)		5 (1)	
4	NC			*Citharistes regius* Stein, 1883			5(1)	
5	NC			*Dinophysis argus* (Stein) Abé				
6	NC			*Diplopsalis lenticula* Bergh, 1881	10(1)		5 -25(2)	
7	NC			*Diplopsalis* sp.	5 -15(8)	10(2)	10(1)	5(1)
8	NC			*Gotoius* sps				
9	NC			*Gyrodinium* sp.	5(4)	5(3)	5 -15(6)	
10	NC			*Heterodinium milneri* (Murray & Whitting) Kofoid, 1906	5(1)	5 (1)		
11	NC			*Heterodinium* spp..			5(1)	

Appendix F continued

Seasons	SIM	SIM	SIM	SIM
Region (Tracks)	CPOS	AR	PKOS	RM

A	B	C	D	E	C	G1	G2	G3	G4
12	NC		S		*Histioneis carinata* Kofoid, 1907				
13	NC		S		*Histioneis* spp.	5 (1)	5(1)		
14	NC				*Noctiluca scintillans* (Macartney) Kofoid & Swezy, 1921	10 -10(2)	5 -10(2)		
15	NC				*Noctiluca* spp.				
16	NC	K	S		*Ornithocercus formosus* Kofoid & Michener, 1911			5(1)	
17	NC	K	S		*Ornithocercus hetroporus* Kofoid, 1907	5(1)			
18	NC	K	S		*Ornithocercus magnificus* Stein, 1883	5 -10(6)	5 -10(4)	5(3)	
19	NC	K	S		*Ornithocercus quadratus* Schütt, 1900			5(2)	
20	NC	K	S		*Ornithocercus steinii* Schütt, 1900	5 (1)		5(1)	
21	NC	K	S		*Ornithocercus thumii* Kofoid & Skogsberg, 1928	5 -10(16)	5 -10(4)	5 -10(4)	
22	NC	K	S		*Ornithocercus* spp.	5 -10(2)	5(1)	5(1)	
23	NC				*Paleophalacroma*??	5(1)			
24	NC				*Pentapharsodinium tyrrhenicum* Marino, 1993				
25	NC				*Phalacroma circumcinctum* Kofoid & Michener, 1911	10 (1)			
26	NC				*Phalacroma cuneus* F.Schütt, 1895			5(1)	
27	NC				*Phalacroma doryphorum* Stein, 1883	5 -20(8)	5 (1)		
28	NC				*Phalacroma favus* Kofoid & Michener, 1911				
29	NC				*Phalacroma oxytoxoides* D.Moreira, 2011				
30	NC				*Phalacroma rapa* Jorgensen, 1923	5 (2)			
31	NC				*Phalacroma rotundatum* Kofoid & Michener, 1911	5 -10(3)		5 -10(3)	
32	NC				*Phalacroma* spp.	5 -10(7)	5 -15(3)	5 -15(3)	
33	NC				*Pronoctiluca acuta* (Lohmann) Schiller, 1933				

Appendix F continued

A	B	C	D	E	Seasons Region (Tracks) C	SIM CPOS G1	SIM AR G2	SIM PKOS G3	SIM RM G4
34	NC				*Pronoctiluca pelagica* Fabre-Domergue, 1889	20 (1)			
35	NC				*Pronoctiluca rostrata* F.J.R.Taylor, 1976				
36	NC				*Pronoctiluca spinifera* (Lohmann) Schiller, 1932	5(1)			
37	NC				*Pronoctiluca* spp.				
38	NC				*Protoperidinium abei* (Paulsen, 1931) Balech, 1974				
39	NC				*Protoperidinium achromaticum*	10(1)			
40	NC				*Protoperidinium biconicum* Balech, 1974	5(1)			
41	NC				*Protoperidinium brevipes* Balech, 1974				
42	NC				*Protoperidinium claudicans* Balech, 1974		5 (1)		10 (1)
43	NC				*Protoperidinium conicum* f. *quardafuiana* Balech, 1974	5 -10(3)	5 (1)	10(1)	5 - 80(2)
44	NC				*Protoperidinium crassipes* Balech, 1974	10(1)			
45	NC				*Protoperidinium curvipes* (Ostenfeld) Balech, 1974				40 (1)
46	NC				*Protoperidinium divergens* Balech, 1974	5 -10(13)	5 -10(5)	5 -10(5)	80 (3)
47	NC				*Protoperidinium elegans* (Cleve, 1900) Balech, 1974			5 (1)	10(1)
48	NC				*Protoperidinium heteracanthum* (Dangeard) Balech			5(1)	
49	NC				*Protoperidinium inflatum* (Okamura, 1912) Balech, 1974	10(1)			
50	NC				*Protoperidinium latispinum* Balech, 1974	15 -20(2)		5(1)	
51	NC				*Protoperidinium leonis* Balech, 1974	5 -15(5)	5(2)	5 -10(3)	20 (1)
52	NC				*Protoperidinium longicollum* Pavillard, 1916	5 -35(6)		5 -20(4)	10 (1)
53	NC				*Protoperidinium oblongum* Parke & Dodge, 1976	5(1)	5(1)		5 - 40(2)
54	NC				*Protoperidinium oceanicum* Balech, 1974	5 (1)			

Appendix F continued

					Seasons Region (Tracks)	SIM CPOS	SIM AR	SIM PKOS	SIM RM
A	B	C	D	E	C	G1	G2	G3	G4
55	NC				*Protoperidinium ovatum* Pouchet, 1883				
56	NC				*Protoperidinium pacificum* Balech ex Balech, 1988	5 -10(3)	5(2)	5(1)	
57	NC				*Protoperidinium pallidum* Balech, 1973	5 -10(5)		5(1)	15 (1)
58	NC				*Protoperidinium pedunculatum* Balech, 1974	5(4)		5 (1)	
59	NC				*Protoperidinium pellucidum* Bergh, 1881	5(4)			
60	NC				*Protoperidinium pentagonum* Balech, 1974	5 -10(2)	5 (2)	5(1)	10 (1)
61	NC				*Protoperidinium ponticum* Vershinin & Morton, 2005				
62	NC				*Protoperidinium punctulatum* Balech, 1974				
63	NC				*Protoperidinium pyriforme* Balech, 1974	10 (1)			
64	NC				*Protoperidinium sourniae* Balech, 1994				
65	NC				*Protoperidinium steinii* Balech, 1974	5 -10(3)	5 (1)	5(3)	
66	NC				*Protoperidinium subinerme* Loeblich III, 1969	5 -10(2)			
67	NC				*Protoperidinium tristylum* Balech, 1974	10(1)			
68	NC				*Protoperidinium tuba* Balech, 1974		5 -10(2)		
69	NC				*Protoperidinium* sp.	5 -100(53)	5 -20(8)	5 -220(21)	15 - 90(6)
70	NC				*Zygabikadonium lenticulatum* Loeblich III, 1970	5 -20(19)	5 -10(3)	5 -30(14)	5 - 320(4)
1	C				*Dictyocha*	5 -40(8)	10 -15(3)	15(1)	10(1)

Appendix G Checklist of microphytoplankton comprising Diatoms, Dinoflagellates and Dictyoca from the four different tracks of the Bay of Bengal (BoB) observed during the South West Monsoon (SWM). The column from left to right denotes, **A** - Serial no, **B** – Species with Chloroplast (C) and Non Chloroplast (NC). **C** - Species comprised of those forms that is assigned according to Margalef's Mandala (Margalef 1978), D - column depicts species assigned to 'C-S-R' strategies. E – column depicts habitat types of the respective taxa according to Smyada and Reynolds (2001). F – Microphytoplankton species comprised of Diatoms, Dinoflagellates and Dictyoca. **G** – column denotes Cell abundance (cells L^{-1}), values outside the bracket denotes minimum to maximum variations in cell counts and values inside the brackets denotes number of occurrences. The codes **G1** to **G4** depicts variations in cell abundance observed along the four different tracks CPOS, AR, PKOS and RM respectively. The species with bold italic font and marked with symbol (*****) are used in the ordination analysis.

A	B	C	D	E	Seasons Region (Tracks) C	SWM CPOS H1	SWM AR H2	SWM PKOS H3	SWM RM H4
sr no					Taxa				
1	C		R		*Actinocyclus senarius* Ehrenberg, 1843			5 (1)	10(1)
2	C		R		*Actinocyclus* sp				
3	C		R		*Asterolampra marylandica* Ehrenberg, 1844	5 -10(2)	5(1)		
4	C		R		*Asterolampra* spp.	5(3)			
5	C		R		*Asteromphalus arachne* Ralfs, 1861				
6	C		R		*Asteromphalus heptactis* Ralfs, 1861				
7	C		R		*Asteromphalus pettersonii* Thorrington-Smith 1970	5 (1)			
8	C		R		*Asteromphalus* spp.	5 -15(11)	5 (2)	5 - 80(5)	15 -30(2)
9	C		S		*Azpeitia nodulifera* G.A.Fryxell & P.A.Sims, 1996				
10	C		R		*Bacteriastrum delicatulum* Cleve, 1897				

11	C		R		*Bacteriastrum elongatum* Cleve, 1897				
12	C		R		***Bacteriastrum furcatum*** Shadbolt, 1854 *	5 -20(9)	5 -15(2)	5 - 200(5)	10 (2)
13	C		R		*Bacteriastrum hyalinum* Lauder, 1864	5(1)			

					Seasons	SWM	SWM	SWM	SWM
					Region (Tracks)	CPOS	AR	PKOS	RM
A	B	C	D	E	C	H1	H2	H3	H4
14	C		R		*Bacteriastrum* spp.	5 -280(7)	10 -45(3)	5 - 80(7)	90 -180(2)
15	C		R		*Biddulphia* sp	10(1)		5(1)	
16	C		R		*Campylodiscus* sp				
17	C		R		*Cerataulina bicornis* (Ehrenberg) Hasle, 1985				
18	C		R		*Cerataulina dentata* Hasle				
19	C		R		*Cerataulina pelagica* (Cleve) Hendey, 1937		5(1)	5(1)	160(1)
20	C		R		*Cerataulina* sp.			80 - 100(2)	20 (1)
21	C	r	R		*Chaetoceros aequatorialis* Cleve, 1873				
22	C	r	R		*Chaetoceros affinis* Lauder, 1864		5 -15(3)	10 - 70(3)	10(1)
23	C	r	R		*Chaetoceros atlanticus* Cleve, 1873	10(1)			
24	C	r	R		*Chaetoceros coarctatus* Lauder, 1864	10(1)	10 -50(2)	10 (1)	
25	C	r	R		*Chaetoceros compressus* Lauder, 1864	10 -20(2)		20(1)	
26	C	r	R		*Chaetoceros concavicornis* Mangin, 1917				
27	C	r	R		*Chaetoceros constrictus* Gran, 1897				
28	C	r	R		*Chaetoceros convolutus* Castracane, 1886				
29	C	r	R		*Chaetoceros costatus* Pavillard, 1911	15(1)	15 -15(1)		
30	C	r	R		*Chaetoceros curvisetus* Cleve, 1889	5 -45(5)	60 -105(2)	15 - 720(4)	
31	C	r	R		*Chaetoceros dadayi* Pavillard, 1913	110(1)			

32	C	r	R		*Chaetoceros danicus*				
33	C	r	R		*Chaetoceros debilis*				
34	C	r	R		*Chaetoceros decipiens*	5 -25(4)	10 -115(4)	5 - 105(7)	
35	C	r	R		*Chaetoceros diadema* (Ehrenberg) Gran, 1897				
36	C	r	R		*Chaetoceros dicatea* Ehrenberg, 1844				

					Seasons Region (Tracks)	SWM CPOS	SWM AR	SWM PKOS	SWM RM
A	B	C	D	E	C	H1	H2	H3	H4
37	C	r	R		*Chaetoceros didymus* Ehrenberg, 1845	10(1)		440(1)	
38	C	r	R		*Chaetoceros diversus* Cleve, 1873	5 -30(5)	10 -55(5)		
39	C	r	R		*Chaetoceros eibenii* Grunow, 1882	5 -35(14)	5 -10(3)	5(3)	
40	C	r	R		*Chaetoceros furcellatus* Yendo, 1911				
41	C	r	R		*Chaetoceros laciniosus* F.Schütt, 1895		5 -20(2)	375 - 375(1)	
42	C	r	R		*Chaetoceros lauderi* Ralfs, 1864				
43	C	r	R		*Chaetoceros lorenzianus* Grunow, 1863	5 -15(4)	5 -55(5)	40 - 145(5)	
44	C	r	R		*Chaetoceros messanense* Castracane, 1875	10 -25(2)		20(1)	
45	C	r	R		***Chaetoceros peruvianus*** Brightwell, 1856 *	5 -15(8)	5 -65(6)	5 - 90(7)	
46	C	r	R		*Chaetoceros pseudocurvisetus* Mangin, 1910			30(1)	
47	C	r	R		*Chaetoceros simplex* Ostenfeld, 1902				
48	C	r	R		*Chaetoceros subtilis* Cleve, 1896				
49	C	r	R		*Chaetoceros wighamii* Brightwell, 1856				
50	C	r	R		***Chaetoceros* spp. ***	5 -780(53)	5 -430(17)	5 - 1190(25)	300 -1000(4)
51	C		R		***Climacodium frauenfeldianum* Grunow, 1868 ***	5 -55(13)	25 -30(2)	5 - 30(5)	

					Seasons Region (Tracks) C	SWM CPOS H1	SWM AR H2	SWM PKOS H3	SWM RM H4
A	B	C	D	E					
52	C		R		*Climacosphenia* spp.	5(1)			
53	C		R		*Corethron criophilum* (Grunow) Ostenfeld, 1909	5 -15(3)		5(1)	
54	C		R		*Corethron hystrix.* Hensen, 1887				
55	C		R		*Corethron* sp.	20(1)	10 (1)		10(1)
56	C		S		*Coscinodiscus centralis* Ehrenberg, 1844				
57	C		S		*Coscinodiscus granii* Gough, 1905	5(2)			10 -200(2)
58	C		S		*Coscinodiscus lineatus* Ehrenberg				
59	C		S		***Coscinodiscus marginatus*** Ehrenberg, 1844 *	5 -35(23)	5 -25(4)	5 - 20(10)	
60	C		S		*Coscinodiscus oculus-iridis* Ehrenberg, 1840				
61	C		S		*Coscinodiscus radiatus* Ehrenberg, 1840	5(1)		20 - 60(2)	
62	C		S		*Coscinodiscus wailesii* Gran & Angst, 1931	10(1)		5(2)	20(1)
63	C		S		***Coscinodiscus* spp**. *	5 -130(84)	5 -35(18)	5 - 120(35)	20 -1050(8)
64	C		R		*Cyclotella striata* (Kützing) Grunow, 1880				
65	C		R		*Cyclotella* sp.	5 -15(3)	5 (1)	5(1)	5 -10(2)
66	C		R		*Dactyliosolen fragilissimus* (Bergon) Hasle, 1996	5 -25(3)	10(1)	25(1)	
67	C		R		*Dactyliosolen* sp?	10 -15(3)	5(1)	5(1)	
68	C		R		*Ditylum brightwellii* (T.West) Grunow, 1885	5(1)	5 -10(2)	5 - 180(5)	15 -600(3)
69	C		R		*Ditylum sol* (Grunow) De Toni, 1894	5 -10(5)	5 -25(3)	5 - 830(6)	20 -220(4)

70	C		R		*Ditylum* sp.				
71	C		R		*Eucampia cornuta* (Cleve) Grunow, 1883	10 -120(8)			
72	C		R		*Eucampia geolandrica* Cleve, 1896				
73	C		R		*Eucampia zodiacus* Ehrenberg, 1839	5 (2)	55(1)		
74	C		R		*Eucampia* sp.		5 (1)		
75	C		S		*Eupodiscus johneius* (Greville) J.Rattray			5 - 135(2)	
76	C		R		***Guinardia cylindrus*** (Cleve) Hasle, 1996 *	5 -1040(23)	5 -35(4)	5 - 55(9)	15 -510(3)
77	C		R		*Guinardia delicatula* (Cleve) Hasle, 1997	240 (1)		20(1)	20 (1)
78	C		R		*Guinardia flacida* (Castracane) H.Peragallo, 1892	55(1)			
79	C		R		***Guinardia striata*** (Stolterfoth) Hasle, 1996 *	5 -1165(10)	10 -60(8)	10 - 120(8)	45 -90(2)
80	C		R		*Guinardia* spp.	5 -25(10)	10 -25(2)	40 - 100(2)	20(1)
81	C		R		*Helicotheca tamesis* (Shrubsole) M.Ricard, 1987				

Appendix G continued

					Seasons	SWM	SWM	SWM	SWM
					Region (Tracks)	CPOS	AR	PKOS	RM
A	B	C	D	E	C	H1	H2	H3	H4
82	C		R		***Hemiaulus hauckii*** Grunow ex Van Heurck, 1882 *	5 -25(8)	5 -30(3)	5 - 110(9)	5 -100(4)
83	C		R		*Hemiaulus indicus* Karsten, 1907				
84	C		R		***Hemiaulus membranaceus*** Cleve *	5 -20(39)	5 -25(9)	5 - 40(15)	
85	C		R		*Hemiaulus sinensis* Greville, 1865			15 - 115(2)	
86	C		R		*Hemiaulus* sp.	5 -15(4)	5 -10(3)	25 - 40(2)	
87	C		R		*Hemidiscus cuneiformis* Wallich, 1860			395(1)	
88	C		R		*Hemidiscus* sp.			5 - 180(5)	20 -80(3)
89	C		R		*Lauderia annulata* Cleve, 1873	285(1)	5(1)	5 - 1620(4)	40 (1)

90	C		R		*Lauderia* sp.			60 (1)	
91	C		R		*Leptocylindrus danicus* Cleve, 1889	20 -890(3)	10(1)	10 - 60(2)	960 (1)
92	C		R		*Leptocylindrus mediterraneus* Hasle, 1975	15 (1)			
93	C		R		*Leptocylindrus minimus* Gran, 1915	5(1)			
94	C		R		*Leptocylindrus* sp.	5 -380(11)	10(1)	25 - 60(2)	50(1)
95	C	r	R		*Neocalyptrella robusta* Meave del Castillo, 1997	5(1)		15(2)	
96	C		R		*Odontella sinensis* (Greville) Grunow, 1884		5 -10(3)	5 - 100(3)	5 -150(3)
97	C		R		*Odontella* sp.	5 (1)	5(1)	20 - 180(3)	
98	C		R		*Palmerina hardmaniana* (Greville) G.R.Hasle, 1996			5 - 15(2)	30 -13280(2)
99	C		R		*Planktoniella sol* (C.G.Wallich) Schütt, 1892				
100	C		R		***Proboscia alata*** (Brightwell) Sundström, 1986 *	5 -75(22)	5 -190(5)	5 - 35(7)	
101	C		R		*Proboscia indica* Hernández-Becerril, 1995	5 -25(9)	10(1)	15 (1)	30(1)
102	C		R		*Pseudoguinardia recta* von Stosch, 1986	15(1)	15 -95(2)	40 - 560(2)	
103	C		R		*Pseudoguinardia* spp.				
104	C		R		***Pseudosolenia calcar-avis*** B.G.Sundström, 1986 *	5 -40(17)	5 -15(4)	5 - 25(11)	
105	C	r	R		*Rhizosolenia accuminata* H.Peragallo, 1907				

					Seasons	SWM	SWM	SWM	SWM
					Region (Tracks)	CPOS	AR	PKOS	RM
A	B	C	D	E	C	H1	H2	H3	H4
106	C	r	R		*Rhizosolenia acicularis* B.G.Sundström, 1986				
107	C	r	R		*Rhizosolenia bergonii* H.Peragallo, 1892	5 -10(5)	15(1)		
108	C	r	R		*Rhizosolenia borealis* B.G.Sundström, 1986				
109	C	r	R		*Rhizosolenia castracanei* H.Peragallo, 1888	5(1)	10 -15(2)	5(1)	400 (1)
110	C	r	R		*Rhizosolenia clevei* Ostenfeld, 1902				

111	C	r	R	*Rhizosolenia crassa* Schimper, 1905	15(1)		5 - 5(1)	
112	C	r	R	*Rhizosolenia curvata* Zacharias, 1905	10 (1)			
113	C	r	R	*Rhizosolenia debyana* H.Peragallo, 1892			5(2)	
114	C	r	R	*Rhizosolenia decipiens* B.G.Sundström, 1986	35(1)			
115	C	r	R	*Rhizosolenia formosa* H.Peragallo, 1888				
116	C	r	R	***Rhizosolenia hebetata*** (Hensen) Gran, 1908 *	5 -30(14)	5 -65(6)	10 - 20(3)	10(1)
117	C	r	R	*Rhizosolenia hebetata* f. *semispina* Gran, 1908	15 (1)	10(1)		
118	C	r	R	*Rhizosolenia hyalina* Ostenfeld, 1901				
119	C	r	R	*Rhizosolenia imbricata* Brightwell, 1858	5 -50(5)	10(1)	10(1)	
120	C	r	R	*Rhizosolenia setigera* f. *pungens* Brunel, 1962				
121	C	r	R	*Rhizosolenia setigera* Brightwell, 1858	5 -10(2)	60 -140(2)	5 - 600(7)	10 (1)
122	C	r	R	***Rhizosolenia styliformis*** T.Brightwell, 1858 *	5 -35(5)	10 -35(3)	15 - 25(2)	
123	C	r	R	***Rhizosolenia* spp. ***	5 -2515(93)	5 -390(23)	5 - 255(31)	30 -265(5)
124	C		R	*Skeletonema costatum* (Greville) Cleve, 1873	40 -220(2)		60 - 565(2)	680 (1)
125	C		R	*Skeletonema* sp		25(1)	35 - 360(4)	165 -330(2)
126	C		R	*Stephanopyxis* sp.				
127	C		R	*Striatella* spp.				
128	C	r	R	*Thalassiosira angulata* (W.Gregory) Hasle, 1978				
129	C	r	R	*Thalassiosira eccentrica* (Ehrenberg) Cleve, 1904	5 -15(13)	15(1)	5(1)	
130	C		R	*Thalassiosira excentrica* (Ehrenberg) Cleve, 1904	5 -10(9)	5 -10(2)	5 - 5(2)	

Appendix G continued

Seasons	SWM	SWM	SWM	SWM
Region (Tracks)	CPOS	AR	PKOS	RM

A	B	C	D	E	C	H1	H2	H3	H4
131	C	r	R		*Thalassiosira gravida* Cleve, 1896	15(1)			
132	C	r	R		*Thalassiosira punctigera* (Castracane) Hasle, 1983				
133	C	r	R		***Thalassiosira* spp.** *	5 -2550(58)	5 -70(20)	5 - 380(32)	5 -200(7)
134	C		R		*Trieres mobiliensis* Ashworth & Theriot, 2013	20 (1)	5(1)	5 - 140(5)	15 -20(2)
135	C		R		*Trieres regia* M.P.Ashworth & E.C.Theriot, 2013				
136	C		R		*Achnanthes* sp.				
137	C		R		*Amphiprora* spp.				
138	C		R		***Amphora* spp.** *	5 -25(17)	5 -15(4)	5 - 15(5)	
139	C		R		*Asterionellopsis* sp?	5(2)	5(1)	10 (1)	50 -100(2)
140	C		R		*Cocconeis scutellum* Ehrenberg, 1838				
141	C		R		*Cocconeis* sp.				
142	C		R		*Cylindrotheca closterium* Reimann & J.C.Lewin, 1964	5 -335(6)	5 -10(4)	15 (2)	25 -30(2)
143	C		R		*Diploneis* sp.			5(1)	
144	C		R		*Fragilaria doliolus* Medlin & P.A.Sims, 1993	5 -25(4)	10 -20(4)	10 - 40(5)	
145	C		R		*Fragilariopsis cylindrus* (Grunow) Krieger, 1954	5 -30(5)	10 -125(2)	15 - 30(3)	
146	C		R		*Fragilariopsis oceanica* (Cleve) Hasle, 1965				
147	C		R		*Fragilariopsis* spp.	5 -20(5)	5(1)	25 (1)	20 (1)
148	C		R		*Grammatophora* sps				210(1)
149	C		R		*Gyrosigma* sp.	5(1)			
150	C		R		*Haslea gigantea* (Hustedt) Simonsen, 1974				
151	C		R		***Haslea trompii*** (Cleve) Simonsen, 1974 *	5 -20(21)	70(1)	5 - 50(11)	5(1)

Appendix G continued

					Seasons Region (Tracks)	SWM CPOS	SWM AR	SWM PKOS	SWM RM
A	B	C	D	E	C	H1	H2	H3	H4
152	C		R		*Haslea wawrikae* (Hustedt) Simonsen, 1974	5 -30(15)	5 -35(6)	5 - 15(6)	5 (1)
153	C		R		***Haslea* spp.** *	5 -25(17)	5 -15(4)	5 - 25(5)	5 (1)
154	C		R		*Lioloma elongatum* (Grunow) Hasle, 1997				
155	C		R		*Lioloma pacificum* (Cupp) Hasle, 1996	10 -65(3)	5 (1)	5 - 15(3)	
156	C		R		*Lioloma* sp.	5 -25(10)	5 -20(5)	5(2)	
157	C		R		*Mastogloia rostrata* (Wallich) Hustedt, 1933	5 -85(5)	5(1)	10 - 15(2)	
158	C		R		*Mastogloia splenoides*				
159	C		R		***Mastogloia* spp. ***	5 -30(31)	5 -10(2)	5 - 15(9)	
160	C		R		*Meuniera membranacea* (Cleve) P.C.Silva, 1996	5 -115(10)	15 -25(2)	10 - 280(7)	25 -180(3)
161	C		R		*Meuniera* spp.				
162	C		R		***Navicula directa*** (W.Smith) Ralfs, 1861 *	5 -15(11)	5(4)	5 - 15(8)	5 (1)
163	C		R		*Navicula distans* (W.Smith) Ralfs, 1861				
164	C		R		*Navicula septantronalis* (Grunow) Gran, 1908		10(1)		
165	C		R		*Navicula subinflata*				
166	C		R		*Navicula transitans* f. *delicatula*	5(1)			10 (1)
167	C		R		*Navicula transitans* var. *derasa* Cleve, 1883	5(1)		5(1)	
168	C		R		***Navicula* spp**. *	5 -295(109)	5 -150(31)	5 - 400(36)	5 -120(4)
169	C		R		*Nitzschia angularis* W.Smith, 1853				
170	C		R		*Nitzschia longisima* (Brébisson) Ralfs, 1861	5(1)	5 -20(2)	10 (2)	
171	C		R		*Nitzschia sigma* (Kützing) W.Smith, 1853				
172	C		R		***Nitzschia* spp**.*	5 -140(61)	15 -140(14)	5 - 630(23)	40 -290(4)
173	C		R		*Phaeodactylum tricornutum* Bohlin, 1897				

174	C		R		*Pinnularia* sps				

Appendix G continued

					Seasons	SWM	SWM	SWM	SWM
					Region (Tracks)	CPOS	AR	PKOS	RM
A	B	C	D	E	C	H1	H2	H3	H4
175	C		R		*Pleurosigma angulatum* W.Smith, 1852		5(1)		10 (1)
176	C		R		*Pleurosigma directum* Grunow, 1880			5 (1)	10 (1)
177	C		R		*Pleurosigma elongatum* W.Smith, 1852			20 (1)	20 (1)
178	C		R		*Pleurosigma normanii* Ralfs, 1861				
179	C		R		*Pleurosigma simonsenii* Hasle, 1990				
180	C		R		*Pleurosigma* spp.	5 -10(8)	5 (3)	10 - 20(4)	5 -50(2)
181	C		R		*Pseudonitzschia delicatissima* Heiden, 1928	5 -175(5)	5 -15(2)	115 - 115(1)	
182	C		R		*Pseudonitzschia lineola* (Cleve) Hasle, 1965				
183	C		R		*Pseudonitzschia fraudulenta* Hasle, 1993				
184	C		R		*Pseudonitzschia seriata* (Cleve) H.Peragallo, 1899	5 -65(3)	10 -45(3)	30 - 235(4)	
185	C		R		*Pseudonitzschia subfraudulenta* G.R.Hasle, 1993				
186	C		R		***Pseudonitzschia* spp.** *	5 -230(17)	5 -225(9)	10 - 8700(13)	80 -6340(5)
187	C		R		*Surirella* sp?		5 (1)		10 (1)
188	C		R		*Synedropsis* sp.	5 -10(8)		5 (1)	5 (1)
189	C		R		*Thalassionema bacillare* (Heiden) Kolbe, 1955	5 -10(2)	5 -45(3)	5 - 80(6)	95 -190(2)
190	C		R		***Thalassionema frauenfeldii*** Tempère & Peragallo, 1910 *	5 -45(11)	10 -130(6)	5 - 115(10)	30 -390(3)
191	C		R		*Thalassionema javanicum* (Grunow) G.R.Hasle				
192	C		R		*Thalassionema nitzschioides* Mereschkowsky, 1902 *	5 -15(4)	10 -410(5)	5 - 1300(13)	40 -960(6)
193	C		R		*Thalassionema pseudonitzschiodes* G.R.Hasle				

194	C		R		***Thalassionema* sp.** *	5 -20(16)	5 -485(13)	5 - 320(11)	10 -105(3)
195	C		R		*Thalassiothrix longissima* Cleve & Grunow, 1880	5 -40(3)		5 - 20(2)	
196	C		R		*Thalassiothrix* sp.	5 -10(4)	90 (1)		
197	C		R		*Triceratium* sp		5 (1)		

Appendix G continued

					Seasons Region (Tracks)	SWM CPOS	SWM AR	SWM PKOS	SWM RM
A	B	C	D	E	C	H1	H2	H3	H4
198	C				*Acanthogonyaulax spinifera* H.W.Graham, 1942				
199	C				*Akashiwo sanguinea* G.Hansen & Ø.Moestrup, 2000				
200	C				*Alexandrium catenella* (Whedon & Kofoid) Balech, 1985				
201	C				*Alexandrium concavum* (Gaarder) Balech, 1985				
202	C				*Alexandrium minutum* Halim, 1960	5(1)			
203	C				*Alexandrium tamerense* (Lebour, 1925) Balech, 1995				
204	C				***Alexandrium* spp.** *	5 -35(28)	5 -35(9)	5 - 20(4)	5 -10(2)
205	C				*Amphidinium cartere* Hulburt, 1957				
206	C				*Amphidinium sphaenoides* WüIff, 1916	10 (1)			
207	C				***Amphidinium* sp.** *	5 -25(37)	5 -30(13)	5 - 120(16)	20 -40(3)
208	C				*Amphidoma* sp.				
209	C		S		*Amphisolenia astragalus*				
210	C		S		*Amphesolenia bidentata* Schröder, 1900	5 -10(10)	5(1)	5 - 10(2)	
211	C		S		*Amphisolenia globifera* Stein, 1883	5(1)			
212	C		S		*Amphisolenia thrinax*				

213	C		S		*Amphisolenia* spp.	5 -10(9)	5(1)	10 (1)	
214	C				*Azadinium caudatum* (Halldal) Nézan & Chomérat, 2012				
215	C				***Blepharocysta* sp.? ***	5 -10(20)	5 -15(11)	5 (6)	
216	C				*Ceratocorys armata* (Schütt) Kofoid, 1910				
217	C				*Ceratocorys gourretii* Paulsen, 1931	5(1)			
218	C				*Ceratocorys horrida* Stein, 1883				
219	C				*Ceratocorys reticulata* H.W.Graham, 1942	5 (1)			
220	C				*Ceratocorys* sp.	5(1)			

Appendix G continued

					Seasons Region (Tracks)	SWM CPOS	SWM AR	SWM PKOS	SWM RM
A	B	C	D	E	C	H1	H2	H3	H4
221	C				*Cochlodinium* sp.		5(3)		
222	C				*Corythodinium diploconus* F.J.R.Taylor, 1976				
223	C				*Corythodinium globosum* F.J.R.Taylor, 1976				
224	C				*Corythodinium tesselatum* Loeblich III, 1966	5(4)	5(1)	5 (1)	
225	C				*Corythodinium* sp.				
226	C			VII	*Dinophysis acuminata* Claparède & Lachmann, 1859				
227	C			VII	*Dinophysis acuta* Ehrenberg, 1839				
228	C				*Dinophysis caudata* Saville-Kent, 1881	5 -30(8)	5 (2)	5 - 10(4)	5 -1400(5)
229	C				*Dinophysis exigua* Kofoid & Skogsberg, 1928				
230	C				*Dinophysis fortii* Pavillard, 1923				
231	C				*Dinophysis hastata* Stein, 1883				
232	C				*Dinophysis miles* Cleve, 1900			20 (1)	

233	C				*Dinophysis parvula* (Schütt) Balech, 1967				
234	C				*Dinophysis schuettii* Murray & Whitting, 1899				
235	C				*Dinophysis* spp.	5 -10(7)	5(2)	5 (2)	
236	C				*Ensiculifera*?	5(3)	5(1)	5 (1)	
237	C				*Gambierdiscus* sp?	5(1)			
238	C				*Goniodoma sphaericum* Murray & Whitting, 1899	5(1)			
239	C				*Goniodoma* sps	5(1)		5(1)	
240	C				*Gonyaulax birostris*? Stein, 1883				
241	C				*Gonyaulax digitale* (Pouchet) Kofoid, 1911				
242	C				*Gonyaulax fragilis* (Schütt) Kofoid, 1911				
243	C				*Gonyaulax fusiformis* H.W.Graham, 1942				

Appendix G continued

					Seasons	SWM	SWM	SWM	SWM
					Region (Tracks)	CPOS	AR	PKOS	RM
A	B	C	D	E	C	H1	H2	H3	H4
244	C				*Gonyaulax hyalina*? Ostenfeld & Schmidt, 1901				
245	C				*Gonyaulax kofoidii* Pavillard, 1909	5(1)			
246	C				*Gonyaulax minuta* Kofoid & Michener, 1911				
247	C				*Gonyaulax monospina* Rampi, 1951	5(1)		5 (1)	
248	C				*Gonyaulax pacifica* Kofoid, 1907				
249	C				***Gonyaulax polygramma*** Stein, 1883 *	5 -20(24)	5 -15(6)	5 - 15(5)	10 (2)
250	C				*Gonyaulax rotundata*? Rampi, 1951				
251	C				*Gonyaulax scrippsae* Kofoid, 1911	10 (2)	5(3)		
252	C				*Gonyaulax spinifera* Diesing, 1866	5(4)			10 (1)

253	C				*Gonyaulax subulata* Kofoid & Michener, 1911				
254	C				***Gonyaulax* sp** *	5 -50(43)	5(1)	5 - 10(9)	5 (1)
255	C				*Gymnodinium bicorne* Kofoid & Swezy, 1921	5(3)			
256	C			V	*Gymnodidinium catenatum*? H.W.Graham, 1943				
257	C			I	***Gymnodium* spp**. *	5 -100(21)	5 -10(5)	5 - 40(9)	5 -10(3)
258	C				*Heteraulacus* spp. Stein, 1883				
259	C				*Heterocapsa niei* Morrill & Loeblich III, 1981				
260	C			II	*Heterocapsa triquetra* Stein, 1883	10(1)	10 (2)	5 - 10(2)	
261	C				*Karenia brevis* Gert Hansen & Ø.Moestrup, 2000				
262	C			V	*Lingulodinium polyedrum* J.D.Dodge, 1989	5 -10(2)			
263	C				*Oxytoxum caudatum* Schiller, 1937		10(1)		
264	C				*Oxytoxum constrictum* (Stein) Bütschli, 1885				
265	C				*Oxytoxum globosum* Schiller				

					Seasons	SWM	SWM	SWM	SWM
					Region (Tracks)	CPOS	AR	PKOS	RM
A	B	C	D	E	C	H1	H2	H3	H4
266	C				*Oxytoxum laticeps* Schiller, 1937	5(2)	5(1)		
267	C				*Oxytoxum milneri* Murray & Whitting, 1899	5 -10(5)	5(1)		
268	C				*Oxytoxum parvum* Schiller, 1937	5(4)		5 - 10(3)	
269	C				*Oxytoxum reticulatum* (Stein) Schütt, 1899	5(1)			
270	C				*Oxytoxum sceptrum* (F.Stein) Schröder, 1906				
271	C				***Oxytoxum scolopax*** Stein, 1883 *	5 -10(10)	5(4)	5 - 15(7)	
272	C				*Oxytoxum semicollatum* F.J.R.Taylor, 1976				

273	C				*Oxytoxum subulatum* Kofoid, 1907	5(1)			
274	C				*Oxytoxum variabile* Schiller, 1937				
275	C				***Oxytoxum* sp** *	5 -10(21)	5(5)	5(2)	
276	C				*Podolampas bipes* Stein, 1883	5 (3)			
277	C				*Podolampas elegans* Schütt, 1895				
278	C				***Podolampas palmipes*** Stein, 1883 *****	5 -10(13)	10 (1)	5 (2)	5 (1)
279	C				*Podolampas spinifera* Okamura, 1912	5(6)			
280	C				*Podolampas* spp.	5 (1)		5 (1)	
281	C				*Prorocentrum concavum* Y.Fukuyo, 1981	5 (1)		5(1)	
282	C				*Prorocentrum balticum* J.D.Dodge, 1975				
283	C				*Prorocentrum belizianum* M.A.Faust, 1993				
284	C				*Prorocentrum dentatum* Stein, 1883			5 (1)	
285	C				*Prorocentrum emarginatum* Y.Fukuyo, 1981			10 (1)	
286	C				***Prorocentrum gracile*** Schütt, 1895 *	5 -30(5)	5 (2)	5 - 10(3)	10 (1)
287	C				*Prorocentrum lenticulatum* F.J.R.Taylor, 1976	5 (1)			
288	C				*Prorocentrum lima* (Ehrenberg) F.Stein, 1878				
289	C				*Prorocentrum mexicanum* Osorio-Tafall, 1942				

					Seasons	SWM	SWM	SWM	SWM
					Region (Tracks)	CPOS	AR	PKOS	RM
A	B	C	D	E	C	H1	H2	H3	H4
290	C			II	***Prorocentrum micans*** Ehrenberg, 1834 *	5(12)	5 -15(3)	5 - 15(3)	5 -160(5)
291	C				*Prorocentrum minimum* (Ostenfeld) J.D.Dodge, 1975	5(1)			
292	C				*Prorocentrum oblongum* (Schiller) Ab~	5(2)	5(1)		
293	C				*Prorocentrum obtusum* Ostenfeld, 1908				

294	C				*Prorocentrum scutellum* Schröder, 1900	5(5)			
295	C				***Prorocentrum* sp.** *	5 -45(37)	5 -15(7)	5 - 25(12)	10 (1)
296	C				*Pyrocystis elegans* Pavillard, 1931	5 -10(2)	5(1)		
297	C				*Pyrocystis fusiformis* C.W.Thomson, 1876	5(2)			
298	C				*Pyrocystis gerbaultii* Pavillard, 1935				
299	C				*Pyrocystis lunula* Swift ex Elbrächter & Drebes, 1978				
300	C			IX	*Pyrocystis pseudonoctiluca* Wyville-Thompson, 1876	5(7)		10 (1)	
301	C				*Pyrocystis rhomboides* (Matzenauer) Schiller, 1937				
302	C				*Pyrocystis robusta* Kofoid, 1907	5 -10(4)		10 (1)	
303	C				*Pyrocystis* spp.	5 (4)			
304	C				*Pyrophacus horologium* Stein, 1883	5(3)		5(2)	5 -10(2)
305	C				*Pyrophacus steinii* (Schiller) Wall & Dale, 1971			5 (1)	
306	C				*Pyrophacus* spp.			5(1)	
307	C				*Scrippsiella spinifera* G.Honsell & M.Cabrini, 1991				
308	C			II	***Scrippsiella trochoidea*** (Stein) Loeblich III, 1976 *	5 -280(64)	5 -55(18)	5 - 85(28)	5 -160(4)
309	C				*Triadinium polyedricum* (Pouchet) Dodge, 1981	5 -15(7)	5(2)	5 - 10(5)	
310	C	R		III, VIII	*Tripos arietinus* (Cleve) F.Gómez, 2013		5(1)		
311	C	R		III, VIII	*Tripos azoricus* (Cleve) F.Gómez, 2013	5(1)	5 -10(3)	10(1)	
312	C	R		III, VIII	*Tripos belone* (Cleve) F.Gómez, 2013	5 (1)			

Appendix G continued

					Seasons	SWM	SWM	SWM	SWM
					Region (Tracks)	CPOS	AR	PKOS	RM
A	B	C	D	E	C	H1	H2	H3	H4
313	C	R		III, VIII	*Tripos boehmii* (Graham & Bronikovsky) F.Gómez, 2013	5(1)			

				Seasons	SWM	SWM	SWM	SWM
314	C	R	III, VIII	*Tripos brevis* (Ostenfeld & Johannes) F.Gómez, 2013	5 -15(3)			
315	C	R	III, VIII	*Tripos candelabrus* (Ehrenberg) F.Gómez, 2013	5(2)			
316	C	R	III, VIII	*Tripos concilians* (Jørgenen) F.Gómez, 2013	5 -20(5)			
317	C	R	III, VIII	*Tripos contortus* (Gourret) F.Gómez, 2013	5(1)			
318	C	R	III, VIII	***Tripos declinatus*** (G.Karsten) F.Gómez, 2013 *	5 -20(24)	5 -10(3)	5(5)	
319	C	R	III, VIII	*Tripos deflexus* (Kofoid) F.Gómez, 2014	5 -10(4)			
320	C	R	III, VIII	*Tripos dens* (Ostenfeld & Johannes) F.Gómez, 2013	15 (1)	5 (1)	5 (1)	
321	C	R	III, VIII	*Tripos digitatus* (F.Schütt) F.Gómez, 2013	5 (1)			
322	C	R	III, VIII	*Tripos extensus* (Gourret) F.Gómez, 2013	5(1)			
323	C	R	III, VIII	*Tripos euarcatus (Jørg.1920) F. Gómez,2013*				
324	C	R	III, VIII	***Tripos furca*** (Ehrenberg) F.Gómez, 2013 *	5 -20(21)	5 -35(4)	5 - 35(14)	5 -240(6)
325	C	R	III, VIII	***Tripos fusus*** (Ehrenberg) F.Gómez, 2013 *	5 -20(32)	5 -10(4)	5 - 15(8)	5 -20(3)
326	C	R	III, VIII	***Tripos horridus*** (Cleve) F.Gómez, 2013 *	5 -10(9)	5 -10(2)	5 - 10(5)	10(1)
327	C	R	III, VIII	*Tripos incisus* (Karsten) F.Gómez, 2013	5(1)			
328	C	R	III, VIII	*Tripos inflatus* (Karsten) F.Gómez, 2013	5(5)		5 (3)	
329	C	R	III, VIII	*Tripos karstenii* (Pavillard) F.Gómez, 1907				
330	C	R	III, VIII	*Tripos kofoidii* (Jörgenen) F.Gómez, 2013	5(2)			
331	C	R	III, VIII	*Tripos limulus* (Pouchet) F.Gómez, 2013				
332	C	R	III, VIII	*Tripos lineatus* (Ehrenberg) F.Gómez, 2013	5 (7)			
333	C	R	III, VIII	*Tripos linflatus* (Karsten) F.Gómez, 2013				
334	C	R	III, VIII	*Tripos longirostrus* (Gourret) F.Gómez, 2013	5 (1)			
335	C	R	III, VIII	*Tripos lunula* (Karsten) F.Gómez, 2013	5(1)			
336	C	R	III, VIII	*Tripos macroceros* (Ehrenberg) F.Gómez, 2013	5(5)		5(1)	

Appendix G continued

A	B	C	D	E	Region (Tracks) C	CPOS H1	AR H2	PKOS H3	RM H4
337	C	R		III, VIII	*Tripos massiliensis* (Gourret) F.Gómez, 2013	5(2)			
338	C	R		III, VIII	*Tripos minutus* (Jörgensen) F.Gómez, 2013	5(1)			
339	C	R		III, VIII	*Tripos muelleri* Bory de Saint-Vincent, 1824	5 -20(3)	5 (2)	10 - 20(2)	10(1)
340	C	R		III, VIII	*Tripos muelleri* f. *atlanticus* (Ostenf. 1903) F. Gómez, 2013			5 (2)	
341	C	R		III, VIII	*Tripos pentagonus* (Gourret) F.Gómez, 2013	5(2)			
342	C	R		III, VIII	*Tripos pulchellus* (Schröder) F.Gómez, 2013	5 -20(13)	15(2)	5 - 30(3)	
343	C	R		III, VIII	*Tripos ranipes* (Cleve) F.Gómez, 2013				
344	C	R		III, VIII	*Tripos schmidtii* (Jørgesen) F.Gómez, 2013			5(1)	
345	C	R		III, VIII	*Tripos setaceus* (Jørgesen) F.Gómez, 2013				
346	C	R		III, VIII	*Tripos symmetricus* (Pavillard) F.Gómez, 2013				
347	C	R		III, VIII	***Tripos teres*** (Kofoidii) F. Gómez, 2013 *	5 -15(19)	5 -10(2)	5 (3)	
348	C	R		III, VIII	*Tripos trichoceros* (Ehrenberg) Gómez, 2013	5 -20(7)	5(1)	5 - 20(6)	40 (1)
349	C	R		III, VIII	*Tripos vultur* (Cleve) F.Gómez, 2013	5(2)		5 (1)	
350	C				***Tryblionella compressa*** (J.W.Bailey) M.Poulin, 1990 *	5 -10(8)	10 (1)	5 - 15(6)	
1	NC				*Archaeperidinium minutum* (Kofoid) Jørgensen, 1912	5 -10(3)	5(5)	5 - 10(3)	5(1)
2	NC				*Balechina coerulea* (Dogiel) F.J.R.Taylor, 1976				
3	NC				*Balechina* sps ?	5(1)			
4	NC				*Citharistes regius* Stein, 1883				
5	NC				*Dinophysis argus* (Stein) Abé				
6	NC				*Diplopsalis lenticula* Bergh, 1881				
7	NC				*Diplopsalis* sp.			5 (1)	
8	NC				*Gotoius* sps				
9	NC				*Gyrodinium* sp.	5 -100(11)	5(5)	5 - 30(4)	10 (1)

10	NC				*Heterodinium milneri* (Murray & Whitting) Kofoid, 1906				

Appendix G continued

					Seasons	SWM	SWM	SWM	SWM
					Region (Tracks)	CPOS	AR	PKOS	RM
A	B	C	D	E	C	H1	H2	H3	H4
11	NC				*Heterodinium* spp.				
12	NC		S		*Histioneis carinata* Kofoid, 1907				
13	NC		S		*Histioneis* spp.	5(4)		5(1)	
14	NC				*Noctiluca scintillans* (Macartney) Kofoid & Swezy, 1921	5 (1)		10 (1)	
15	NC				*Noctiluca* spp.	5(1)			
16	NC	K	S		*Ornithocercus formosus* Kofoid & Michener, 1911				
17	NC	K	S		*Ornithocercus hetroporus* Kofoid, 1907				
18	NC	K	S		*Ornithocercus magnificus* Stein, 1883	5 (7)	5(3)	5(2)	
19	NC	K	S		*Ornithocercus quadratus* Schütt, 1900	5(1)			
20	NC	K	S		*Ornithocercus steinii* Schütt, 1900	5(3)		5(3)	
21	NC	K	S		*Ornithocercus thumii* Kofoid & Skogsberg, 1928	5(4)	5 (2)	5 - 10(3)	
22	NC	K	S		*Ornithocercus* spp.				
23	NC				*Paleophalacroma*??	5 -10(4)			
24	NC				*Pentapharsodinium tyrrhenicum* Marino, 1993	5(4)			
25	NC				*Phalacroma circumcinctum* Kofoid & Michener, 1911				
26	NC				*Phalacroma cuneus* F.Schütt, 1895				
27	NC				*Phalacroma doryphorum* Stein, 1883	5(1)			
28	NC				*Phalacroma favus* Kofoid & Michener, 1911				
29	NC				*Phalacroma oxytoxoides* D.Moreira, 2011				
30	NC				*Phalacroma rapa* Jorgensen, 1923	5(2)		5 (3)	

31	NC	*Phalacroma rotundatum* Kofoid & Michener, 1911	5(1)		5 (2)	
32	NC	*Phalacroma* spp.	5 -15(3)		5 - 50(3)	30 -60(2)
33	NC	*Pronoctiluca acuta* (Lohmann) Schiller, 1933				
34	NC	*Pronoctiluca pelagica* Fabre-Domergue, 1889	5(1)			

Appendix G continued

					Seasons Region (Tracks)	SWM CPOS	SWM AR	SWM PKOS	SWM RM
A	B	C	D	E	C	H1	H2	H3	H4
35	NC				*Pronoctiluca rostrata* F.J.R.Taylor, 1976				
36	NC				*Pronoctiluca spinifera* (Lohmann) Schiller, 1932		5(1)		
37	NC				*Pronoctiluca* spp.			5 (1)	
38	NC				*Protoperidinium abei* (Paulsen, 1931) Balech, 1974				
39	NC				*Protoperidinium achromaticum* Balech 1974				
40	NC				*Protoperidinium biconicum* Balech, 1974				
41	NC				*Protoperidinium brevipes* Balech, 1974				
42	NC				*Protoperidinium claudicans* Balech, 1974	5 -10(3)	5(1)		60 (1)
43	NC				*Protoperidinium conicum* f. *quardafuiana* Balech, 1974	5(1)		5 (1)	10 (1)
44	NC				*Protoperidinium crassipes* Balech, 1974				
45	NC				*Protoperidinium curvipes* (Ostenfeld) Balech, 1974				
46	NC				*Protoperidinium divergens* Balech, 1974	5 -25(11)	5(2)	5(3)	5 -120(2)
47	NC				*Protoperidinium elegans* (Cleve, 1900) Balech, 1974		10 (1)		
48	NC				*Protoperidinium heteracanthum* (Dangeard) Balech				
49	NC				*Protoperidinium inflatum* (Okamura, 1912) Balech, 1974				

50	NC				*Protoperidinium latispinum* Balech, 1974				
51	NC				*Protoperidinium leonis* Balech, 1974			5 (1)	
52	NC				*Protoperidinium longicollum* Pavillard, 1916				
53	NC				*Protoperidinium oblongum* Parke & Dodge, 1976	5 (4)			
54	NC				*Protoperidinium oceanicum* Balech, 1974	5 (1)		5(2)	
55	NC				*Protoperidinium ovatum* Pouchet, 1883	5 (1)			
56	NC				*Protoperidinium pacificum* Balech ex Balech, 1988	5 (1)	5(3)	5 - 10(4)	

Appendix G continued

					Seasons	SWM	SWM	SWM	SWM
					Region (Tracks)	CPOS	AR	PKOS	RM
A	B	C	D	E	C	H1	H2	H3	H4
57	NC				*Protoperidinium pallidum* Balech, 1973			5 - 20(5)	5(1)
58	NC				*Protoperidinium pedunculatum* Balech, 1974	5 -10(4)	5(1)		
59	NC				*Protoperidinium pellucidum* Bergh, 1881	5 -15(6)	5(1)	5(1)	40 (1)
60	NC				*Protoperidinium pentagonum* Balech, 1974				
61	NC				*Protoperidinium ponticum* Vershinin & Morton, 2005				
62	NC				*Protoperidinium punctulatum* Balech, 1974			5(1)	
63	NC				*Protoperidinium pyriforme* Balech, 1974				
64	NC				*Protoperidinium sourniae* Balech, 1994				
65	NC				*Protoperidinium steinii* Balech, 1974	5 (5)		5(1)	
66	NC				*Protoperidinium subinerme* Loeblich III, 1969		5(1)	5 (1)	
67	NC				*Protoperidinium tristylum* Balech, 1974				
68	NC				*Protoperidinium tuba* Balech, 1974	5 (1)	5(1)		50 (1)

69	NC	*Protoperidinium* sp.	5 -115(66)	5 -55(12)	5 - 170(26)	10 -150(4)
70	NC	*Zygabikadonium lenticulatum* Loeblich III, 1970	5 -10(5)	5(1)	5(2)	
1	C	*Dictyocha**	5 -10(12)	5(1)	5 - 25(2)	

Appendix H1 and H2. (**H1**) Lambda (I) is the eigenvalue explained by the environment variable. (**H2**) Eigenvalues for CCA axes, results related to species-environment correlations, variation and cumulative % of species data and species-environment relation along the CPOS

Appendix H1

	Marginal Effects	Conditional Effects		
Variable	Lambda 1		Lambda A	P
SST	0.08	SST	0.08	0.008
DIN	0.04	DIN	0.04	0.157
DIP	0.04	DIP	0.03	0.177
Windspeed	0.04	Windspeed	0.04	0.131
Rainfall	0.04	Rainfall	0.04	0.233
SSS	0.03	SSS	0.03	0.351
PAR	0.03	PAR	0.03	0.388

Appendix H2

Axes	1	2	3	4	Total inertia
Eigenvalues :	0.097	0.048	0.04	0.037	10.748
Species-environment correlations :	0.42	0.354	0.305	0.279	

Cumulative percentage variance					
of species data	0.9	1.3	1.7	2.1	
of species-environment relation:	33.2	49.5	63.4	76.2	
Sum of all eigenvalues					10.748
Sum of all canonical eigenvalues					0.292

Appendix I1 and I2 (**I1**) Lambda (I) is the eigenvalue explained by the environment variable. (**I2**) Eigenvalues for CCA axes, results related to species-environment correlations, variation and cumulative % of species data and species-environment relation along the P-K Transect

Appendix I1

	Marginal Effects		Conditional Effects	
Variable	Lambda1	Variable	LambdaA	P
SSS	0.17	SSS	0.17	0.001
SST	0.06	SST	0.11	0.003
DIN	0.05	DIN	0.04	0.554

PAR	0.05	PAR	0.07	0.105
Rainfall	0.04	Rainfall	0.05	0.353
Windspeed	0.04	Windspeed	0.05	0.663
DIP	0.03	DIP	0.03	0.514

Appendix I2

Axes	1	2	3	4	Total inertia
Eigenvalues :	0.271	0.091	0.055	0.046	11.869
Species-environment correlations	0.553	0.401	0.295	0.276	
Cumulative percentage variance					
of species data	2.3	3.1	3.5	3.9	
of species-environment relation	52.5	70.1	80.6	89.6	
Sum of all eigenvalues					11.869
Sum of all canonical eigenvalues					0.517

Appendix J: List of Diatoms and Dinoflagellates cell sizes, cell volume and Carbon per cell from the Bay of Bengal and northeastern Arabian Sea. The columns from left to right (**A** to **K**) denote **A**– Species; **B** – length range of the cell [µm]; **C** – width range of the cell [µm]; **D** and **H**– number of cells; **E** and **I** – range of cell volume from minimum-maximum [$\mu m^{3]}$; **F** and **J** –median value [μm^3]; **G** and **K**; carbon per cell [pg C $cell^{-1}$] measured for Bay of Bengal and north eastern Arabian Sea respectively.

A	B	C	D	E	F	G	H	I	J	K
Diatoms										
Asterolampra marylandica Ehrenberg 1844	20 - 30	10-16	3	113097 - 452389	450269	11075	1	6715	6715	366
Asterolampra marylandica Ehrenberg 1844	30 - 56	10-30					8	9644 - 35008	20460	903
Asterolampra marylandica Ehrenberg 1844	56 - 50	10-30					11	19522 - 47582	32551	1315
Asterolampra marylandica Ehrenberg 1844										
Asterolampra marylandica	50 - 60	5-21					3	44423 - 66287	53778	1977
Asterolampra marylandica	60 - 50	20-65					11	60974 - 217979	90888	3025
Bacteriastrum furcatum Shadbolt 1854	35 - 50	10-16					9	2312 - 6122	2835	182
Bacteriastrum furcatum Shadbolt 1854	80 - 120	16-20					5	40925 - 50171	43054	1650
Chaetoceros affinis Lauder 1864	16 - 20	10 - 25					3	565 - 1005	719	60
Chaetoceros coarctatus Lauder 1864	25 - 30	10-16	1	7069	7069	381	1	23456	23456	1008
Chaetoceros coarctatus Lauder 1864	56 - 50	16-30					4	40998 - 67033	65101	2308
Chaetoceros concavicornis Mangin 1917	50 -50	10-16					3	16160 - 21672	19406	865
Chaetoceros convolutus Castracane,1886	16-20	10-20	5	8247 - 23229	21709	947				
Chaetoceros curvisetus Cleve 1889	5-10	10-16	1	8247	8247	432				
Chaetoceros curvisetus Cleve 1889	10-16	5-25					10	645 - 1171	858	69
Chaetoceros curvisetus Cleve 1889	16 - 20	16-20					10	778 - 2778	1079	83
Chaetoceros curvisetus Cleve 1889	20 - 25	10-25					3	2355 - 3058	2817	181
Chaetoceros curvisetus Cleve 1889	25 - 30	10-25								
Chaetoceros curvisetus Cleve 1889	30 - 35	10-25								
Chaetoceros decipiens Cleve 1873	16-20	60-65	4	95 - 104	102	12				
Chaetoceros decipiens Cleve 1873	20-25	60-65	1	7069	7069	381				
Chaetoceros diversus Cleve 1873	5-10	5-10	1	5890	5890	329	2	653 - 700	676	57
Chaetoceros lorenzianus Grunow, 1863	10-16	5-10					4	1533 - 2104	1801	126
Chaetoceros lorenzianus Grunow, 1863	20 - 25	25-30	4	3927 - 15463	5301	302	4	2645 - 3532	3229	202

Chaetoceros peruvianus Brightwell, 1856	30 - 35	20-35	4	4712 - 31102	11780	576

Appendix J continued

A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**
Climacodium frauenfeldianum Grunow, 1868	10-16	99-200					13	104104 - 19802	16043	741
Climacodium frauenfeldianum Grunow, 1868	16 - 20	80-203					34	111310 - 47675	14518	683
Climacodium frauenfeldianum Grunow, 1868	20 - 25	80-110					7	11807 - 17458	14643	688
Climacodium frauenfeldianum Grunow, 1868	25 - 30	300-350					1	264997	264997	7205
Climacodium frauenfeldianum Grunow, 1868	30 - 35	180-250					2	87242 - 350873	219058	6174
Climacodium frauenfeldianum Grunow, 1868	56 - 45	256-260					2	155796 - 160362	158079	4739
Coscinodiscus concinnus W.Smith, 1856	99 - 120	50-80					4	640822 - 768283	704554	15924
Coscinodiscus concinnus W.Smith, 1856	120 - 203	50-50					2	723938 - 1044273	884105	19143
Coscinodiscus concinnus W.Smith, 1856	180 - 200	99-110					1	2674996	2674996	46984
Coscinodiscus gigas Ehrenberg, 1841	203-300	60-99	1	427649	427649	10622				
Coscinodiscus granii Gough, 1905	99 - 99	56-50	1	1237002	1237002	25137				
Coscinodiscopsis jonesiana Sunesen, 2008	99-200	50-60	2	1077566 - 7775442	4426504	70688				
Coscinodiscus marginatus Ehrenberg, 1844	56 - 50	20-30					4	29194 - 36055	30902	1261
Coscinodiscus marginatus Ehrenberg, 1844	50 - 99	20-25	9	70686 - 99549	98960	3241	1	59660	59660	2150
Coscinodiscus marginatus Ehrenberg, 1844	99 - 120	20-30	7	132732 - 517682	153938	4638				
Coscinodiscus radiatus Ehrenberg, 1840	50 - 99	16-20	1	226195	226195	6336	1	129829	129829	4040
Coscinodiscus radiatus Ehrenberg,1840	200 - 180	16-30					3	899261- 2914648	1261249	25535
Coscinodiscus radiatus Ehrenberg,1840	180 - 250	16-30								
Coscinodiscus radiatus Ehrenberg,1840	250 - 280	16-30					3	2541966 - 2838294	2699529	47333
Dactyliosolen fragilissimus (Bergon)										
Dactyliosolen fragilissimus (Bergon)Hasle, 1996	50-80	5-20	1	6283	6283	347	1	19771	19771	877
Fragilariopsis cylindrus (Grunow) Hasle, 1996	80 - 99	5-20	1	116632	116632	3703	2	20394 - 22702	21548	941
Fragilariopsis cylindrus (Grunow)Krieger, 1954	10-20	5-12					3	29226 - 31463	29881	1227
Fragilariopsis cylindrus (Grunow)Krieger, 1954	30 - 56	5-12					5	924 - 1624	1267	95
Guinardia cylindrus(Cleve)Krieger, 1954	56 - 50	16-20					5	2349 - 4059	3064	194
Guinardia cylindrus(Cleve)Krieger, 1954	80-99	10-20	3	25133 - 73631	69115	2423				
Guinardia cylindrus(Cleve) Hasle, 1996	99-120	10-25	1	91891	91891	3052				
Guinardia cylindrus(Cleve) Hasle, 1996	120-203	10-30	1	155509	155509	4676				

Guinardia cylindrus(Cleve) Hasle, 1996	56 - 50	10-20	3	3142 - 50610	6786	369				
Guinardia striata (Stolterfoth)	30 - 56	10-20	1	69116	69116	2423				
Guinardia striata (Stolterfoth) Hasle, 1996	56 - 50	10-20	5	19439 - 205577	36128	1432				
Guinardia striata (Stolterfoth) Hasle, 1996	50 - 60	10-20	2	980160 - 392699	249363	6858	1	2354	2354	156

Appendix J continued

A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**
Guinardia striata (Stolterfoth) Hasle, 1996	60 - 50	10-20					5	2576 - 7275	4049	243
Guinardia striata (Stolterfoth) Hasle, 1996	50 - 80	10-20					1	3076	3076	194
Guinardia striata (Stolterfoth) Hasle, 1996	80 - 99	10-20	1	431989	431989	10709	3	4840 - 11929	4899	283
Guinardia striata (Stolterfoth) Hasle, 1996	99 - 120	10-20					1	27504	27504	1147
Guinardia striata (Stolterfoth) Hasle, 1996	120 - 164	10-20					1	4911	4911	284
Guinardia striata (Stolterfoth) Hasle, 1996	164 - 203	10-20					1	37192	37192	1466
Haslea wawrikae (Husedt) Simonsen, 1974	203 - 180	5-16					7	1803 - 3068	2260	151
Haslea wawrikae (Husedt) Simonsen, 1974	180 - 200	5-16					2	3727 - 4428	4077	244
Hemiaulus hauckii Grunow ex Van Heurck, 1882	10-20	5-10					5	3393 - 5439	5016	289
Hemiaulus hauckii Grunow ex Van Heurck, 1882	20 - 56	10-20	8	12566 - 56549	32987	1330	10	2173 - 11735	6576	360
Hemiaulus hauckii Grunow ex Van Heurck, 1882	56 - 60	20-56					3	6335 - 14131	6637	362
Hemiaulus hauckii Grunow ex Van Heurck, 1882	60 - 80	30-60					1	9060	9060	466
Hemiaulus indicus Karsten, 1907	50-80	50-99	2	106971	106971	3452				
Hemiaulus membranaceus Cleve	56 - 50	30-56	5	17671 - 28274	21991	957				
Hemiaulus membranaceus Cleve	56 - 50	56-45	11	32987 - 78540	47124	1776				
Hemiaulus membranaceus Cleve	56 - 50	56-50	1	148440	148440	4503				
Hemidiscus cuneiformis Wallich, 1860	110 - 120						6	1043011 - 18070576	7735561	111163
Lauderia annulata Cleve, 1873	20 - 56	16-35	2	12566 - 78540	45553	1728	5	9257 - 14291	13748	654
Leptocylindrus danicus Cleve, 1889	16 - 20	2-5	4	294 - 962	589	51				
Leptocylindrus danicus Cleve, 1889	20 - 25	2-5	3	3142	3142	198				
Leptocylindrus danicus Cleve, 1889	25 - 30	2-10	1	7856	7854	416				
Leptocylindrus danicus Cleve, 1889	35 - 56	2-10					1	1051	1051	81
Leptocylindrus danicus Cleve, 1889	56 - 45	2-10					1	1310	1310	97
Leptocylindrus danicus Cleve, 1889	45 - 50	2-10					3	808 - 2065	1894	131
Lioloma pacificum(Cupp) Hasle,1996	550-600	5-10	1	25600	25600	1083				

Mastogloia rostrata (Wallich) Hustedt, 1933	20-50	5-16	1	4712	4712	275				
Mastogloia rostrata (Wallich) Hustedt, 1933	30-50	5-16	1	9698	9698	493				
Mastogloia rostrata (Wallich) Hustedt, 1933	30-60	5-16	1	13254	13254	635				
Meuniera membranacea (Cleve) P.C.Silva, 1996	30 - 56	25-45	2	31416 - 82614	57014	2072	16	12205 - 23648	14663	689
Meuniera membranacea (Cleve) P.C.Silva, 1996	56 - 50	35-45					17	15681 - 25220	19960	885
Meuniera membranacea (Cleve) P.C.Silva, 1996	50 - 60	35-65					4	21382 - 67162	60189	2166
Meuniera membranacea (Cleve) P.C.Silva, 1996	60 - 50	35-56					1	43262	43262	1657

Appendix J continued

A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**
Navicula transitans var.*derasa* Cleve, 1883	5-10	5-50	6	188 - 438	375	35				
Navicula transitans var.*derasa* Cleve, 1883	10-20	5-50	7	656 - 875	750	62				
Navicula transitans var.*derasa* Cleve, 1883	20-30	5-50	13	1000 - 3150	1500	108				
Navicula transitans var.*derasa* Cleve, 1883	30-56	5-50	5	5250 - 7500	7500	400				
Navicula transitans var.derasa Cleve, 1883	56-50	5-50	1	16493	16493	758				
Neocalyptrella robusta Hernández-Becerril 1997	300-560	99-200	1	1256637	1256637	25460				
Neocalyptrella robusta Hernández-Becerril,1997	560-500	99-200	1	10602875	10602875	143553				
Odontella sinensis (Greville) Grunow, 1884	60 - 50	60-65	2	412334 - 9236282	4824308	75798				
Planktoniella sol (C.G.Wallich) Schütt, 1892	50 - 60	16-20					1	42798	42798	1642
Planktoniella sol (C.G.Wallich) Schütt, 1892	60 - 50	20-25					1	97643	97643	3206
Planktoniella sol (C.G.Wallich) Schütt, 1892	80 - 99	16-20					1	93018	93018	3082
Planktoniella sol (C.G.Wallich) Schütt, 1892	99 - 99	16-20					1	104834	104834	3396
Planktoniella sol (C.G.Wallich) Schütt, 1892	99 - 120	10-30					3	161432 - 282550	250205	6877
Planktoniella sol (C.G.Wallich) Schütt, 1892	120 - 130	25-30					1	312767	312767	8242
Planktoniella sol (C.G.Wallich) Schütt, 1892	130 - 164	16-25					3	257710 - 323949	322061	8440
Planktoniella sol (C.G.Wallich) Schütt, 1892	164 - 203	30-35					1	551806	551806	13061
Planktoniella sol (C.G.Wallich) Schütt, 1892	203 - 203	5-35					2	132653 - 540335	336494	8745
Planktoniella sol (C.G.Wallich) Schütt, 1892	203 - 180	20-25					1	605076	605076	14075
Planktoniella sol (C.G.Wallich) Schütt, 1892	180 - 199	20-25					1	621715	621715	14388
Pleurosigma normanii Ralfs,1861	99-203	10-25	2	9000	9000	464				
Proboscia alata (Brightwell) Sundström, 1986	99 - 203	5-20					1	1500	1500	108
Proboscia alata (Brightwell) Sundström, 1986	203 - 180	5-20					1	14148	14148	669

Proboscia alata (Brightwell) Sundström, 1986	180 - 220	5-20					1	11504	11504	566
Proboscia alata (Brightwell) Sundström, 1986	256 - 280	5-20					2	56614 - 61768	59191	2136
Proboscia alata (Brightwell) Sundström, 1986	280 - 300	5-20	1	6220	6220	344	2	44479 - 61266	52873	1950
Proboscia alata (Brightwell) Sundström, 1986	320 - 356	5-20	8	22089 - 114864	51689	1914	1	69172	69172	2424
Proboscia alata (Brightwell) Sundström, 1986	356 - 360	5-20	1	182212	182212	5318	1	86630	86630	2910
Proboscia indica Hernández-Becerril, 1995	280 - 300	20-30	1	97389	97389	3199	1	538835	538835	12812
Proboscia indica Hernández-Becerril, 1995	320 - 356	10-20	2	141372 - 204204	172788	5093				
Proboscia indica Hernández-Becerril, 1995	356 - 380	10-25	4	251327 - 380997	314159	8271	1	380685	380685	9666

Appendix J continued

A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**
Proboscia indica Hernández-Becerril, 1995	560 - 420	5-20					2	178260 - 187517	182889	5334
Proboscia indica Hernández-Becerril, 1995	420 - 450	5-20					1	434511	434511	10760
Proboscia indica Hernández-Becerril, 1995	450 - 480	5-20					2	94310 - 178369	136340	4203
Proboscia indica	860 - 880	16-20								
Pseudoguinardia recta von Stosch 1986	50 - 50	30-56					2	33050 - 33799	33424	1344
Pseudoguinardia recta von Stosch 1986	50 - 80	30-56	2	150796 - 210487	180642	5280	2	36847 - 46317	41582	1604
Pseudoguinardia recta von Stosch 1986	80 - 99	30-45					2	48566 - 57141	52854	1949
Pseudoguinardia recta von Stosch 1986	99 - 120	20-56					4	50401 - 95013	88260	2954
Pseudoguinardia recta von Stosch 1986	120 - 164	20-56					6	49874 - 156891	79052	2701
Pseudoguinardia recta von Stosch 1986	164 - 200	20-50					1	115022	115022	3662
Pseudo-nitzschia fraulendenta Hasle, 1993			7	2560 - 7031	4125	246				
Pseudo-nitzschia seriata H.Peragallo, 1899	80-120	4-5	2	2100 - 4125	3113	196				
Pseudosolenia calcar-avis B.G.Sundström, 1986	220 - 235	30-55	3	33576 - 61850	37699	1482				
Pseudosolenia calcar-avis B.G.Sundström, 1986	256 - 245	56-45	2	83449 - 114668	99058	3244				
Pseudosolenia calcar-avis B.G.Sundström, 1986	265 - 275	50-50	6	119381 - 388772	280289	7541				
Rhizosolenia bergonii H.Peragallo,1892	120 - 164	10-20					3	5499 - 12592	10362	520
Rhizosolenia bergonii H.Peragallo,1892	180 - 260	10-25					1	49852	49852	1859
Rhizosolenia bergonii H.Peragallo,1892	260 - 280	25-30	2	31134 - 51846	41485	1601	1	150689	150689	4558
Rhizosolenia bergonii H.Peragallo,1892	280 - 320	16-30					1	162075	162075	4836

Rhizosolenia bergonii H.Peragallo,1892	320 - 356	30-35	1	384846	384846	9751	1	310989	310989	8204
Rhizosolenia bergonii H.Peragallo,1892	356 - 380	30-35					1	89763	89763	2995
Rhizosolenia bergonii H.Peragallo,1892	380 - 456	10-46					4	256764 - 372673	358458	9205
Rhizosolenia bergonii H.Peragallo,1892	456 - 460	10-45								
Rhizosolenia borealis Sundström,1986	99-120	10-50	2	21205750 - 25849924	23527387	273993				
Rhizosolenia castracanei H.Peragallo, 1888	300-350	200-300	3	9924291 - 72158456	11133019	149347				
Rhizosolenia castracanei H.Peragallo, 1888	350-560	200-250	1	260123872	260123872	1923551				
Rhizosolenia hebetata f. semispina Gran, 1908	200 - 220	5-25	3	12566 - 38877	12566	608	1	43240	43240	1656
Rhizosolenia hebetata f. *semispina* Gran, 1908	220 - 256	5-25	4	135088 - 346361	268606	7285	1	47016	47016	1773

Appendix J continued

A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**
Rhizosolenia hebetata f. *semispina* Gran, 1908	220 - 256	5-25	3	459458 - 798554	556651	13154				
Rhizosolenia hebetata f. *semispina* Gran, 1908	300 - 350	5-25					1	163490	163490	4870
Rhizosolenia hebetata f. *semispina* Gran, 1908	350 - 560	5-25					3	166647 -226185	217100	6130
Rhizosolenia hebetata f. *semispina* Gran, 1908	560 - 450	5-25					2	128027 - 177124	152576	4605
Rhizosolenia hebetata f. *semispina* Gran, 1908	450 - 500	5-25					2	233200 - 245728	239464	6637
Rhizosolenia hyalina Ostenfeld, 1901	80 - 99	16-35								
Rhizosolenia hyalina Ostenfeld, 1901	99 - 120	16-56					1	6915	6915	375
Rhizosolenia hyalina Ostenfeld, 1901	120 - 164	16-35								
Rhizosolenia hyalina Ostenfeld, 1901	164 - 203	20-30					1	53112	53112	1957
Rhizosolenia hyalina Ostenfeld, 1901	203 - 180	16-35					7	52521 - 124458	64048	2278
Rhizosolenia hyalina Ostenfeld, 1901	180 - 200	25-35					4	6452 - 31977	24087	1030
Rhizosolenia hyalina Ostenfeld, 1901	200 - 220	16-56					8	55553 - 160993	101689	3314
Rhizosolenia hyalina Ostenfeld, 1901	220 - 256	16-56					1	49851	49851	1859
Rhizosolenia hyalina Ostenfeld, 1901	256 - 260	16-56					1	107656	107656	3470
Rhizosolenia hyalina Ostenfeld, 1901	260 - 280	16-56					1	151059	151059	4568
Rhizosolenia hyalina Ostenfeld, 1901	280 - 300	16-56								
Rhizosolenia hyalina Ostenfeld, 1901	300 - 320	20-30					1	139136	139136	4273

Rhizosolenia hyalina Ostenfeld, 1901	320 - 356	20-45								
Rhizosolenia hyalina Ostenfeld, 1901	356 - 360	30-35								
Rhizosolenia hyalina Ostenfeld, 1901	360 - 380	16-56								
Rhizosolenia hyalina Ostenfeld, 1901	380 - 560	30-56					1	178130	178130	5221
Rhizosolenia imbricata Brightwell,1858	220 - 256	10-20	1	3534	3534	217				
Rhizosolenia imbricata Brightwell,1858	241 - 360	10-20	1	30159	30159	1237				
Rhizosolenia imbricata Brightwell,1858	360 - 380	10-20	6	114864 - 276460	244259	6744				
Rhizosolenia imbricata Brightwell, 1858	180 - 200	5-10								
Rhizosolenia imbricata Brightwell, 1858	320 - 356	5-10								
Rhizosolenia setigera Brightwell, 1858	60 - 50	2-10	1	97389	97389	3199				
Rhizosolenia setigera Brightwell, 1858	50 - 99	2-10								
Rhizosolenia setigera Brightwell, 1858	99 -1 20	2-10								
Rhizosolenia setigera Brightwell, 1858	120 - 164	2-10								
Rhizosolenia setigera Brightwell, 1858	164 - 180	2-35					4	6452 - 31977	24087	1030

Appendix J continued

A	B	C	D	E	F	G	H	I	J	K
Rhizosolenia setigera Brightwell, 1858	180 - 200	2-35								
Rhizosolenia setigera Brightwell, 1858	200 - 220	3-35					1	40857	40857	1582
Rhizosolenia setigera Brightwell, 1858	220 - 256	16-20								
Rhizosolenia setigera Brightwell, 1858	256 - 250	5-25								
Rhizosolenia setigera Brightwell, 1858	280 - 300	10-50								
Rhizosolenia setigera Brightwell, 1858	300 - 380	10-46					1	49489	49489	1848
Rhizosolenia setigera Brightwell, 1858	380 - 560	35-56								
Rhizosolenia setigera Brightwell, 1858	560-420	30-50								
Skeletonema costatum-grevillei Greville, 1865	5-10	5-16								
Thalassionema frauenfeldii Tempère &Peragallo,1910	200 - 250	5-10	4	15400 - 23625	19125	855				
Thalassionema frauenfeldii Tempère &Peragallo,1910	350 - 560	5-15	1	82500	82500	2797	4	16316 - 23076	17970	813
Thalassionema frauenfeldii Tempère &Peragallo,1910	560 - 450	5-15					3	20202 - 26966	25186	1068
Thalassionema frauenfeldii Tempère &Peragallo,1910	450 - 500	5-15								
Thalassionema frauenfeldii Tempère & Peragallo,1910	560-350	5-20								

Thalassionema javanicum (Grunow) G.R.Hasle	80-120	5-20	1	3500	3500	216				
Thalassionema nitzschioides Mereschkowsky, 1902	16 - 20	2-5	4	1500 - 1706	1547	111				
Thalassionema nitzschioides Mereschkowsky, 1902	20 - 25	3-6	2	2750	2750	177				
Thalassionema nitzschioides Mereschkowsky, 1902	25 - 30	2-5	1	4000	4000	240				
Thalassionema nitzschioides Mereschkowsky, 1902	30 - 35	3-10	1	8000	8000	422				
Thalassionema pseudonitzschiodes G.R.Hasle	80-120	5-20	1	5600	5600	316				
Thalassiosira eccentrica (Ehrenberg) Cleve, 1904	20 - 25	5-16	3	31416 - 83154	58905	2128	6	2753 - 9255	5113	293
Thalassiosira eccentrica (Ehrenberg) Cleve, 1904	25 - 30	10-20	14	98960 - 251327	142746	4363	7	5013 - 9810	7354	394
Thalassiosira eccentrica (Ehrenberg) Cleve, 1904	30 - 35	10-20					5	9896 - 14175	11193	553
Thalassiosira eccentrica (Ehrenberg) Cleve, 1904	35 - 56	25-30					2	15304 - 30643	22974	992
Thalassiosira eccentrica (Ehrenberg) Cleve, 1904	56 - 45	10-25					1	29401	29401	1211
Thalassiosira eccentrica (Ehrenberg) Cleve, 1904	45 - 50	10-30					2	23330 - 36927	30128	1236
Thalassiosira gravida Cleve, 1896	99-120	30-50	1	19242	19242	859				
Thalassiosira punctigera (Castracane)Hasle, 1983	30 - 35	10-16					1	8792	8792	455
Thalassiosira punctigera (Castracane)										
Thalassiosira punctigera (Castracane)Hasle, 1983	35 - 56	25-30								

Appendix J continued

A	B	C	D	E	F	G	H	I	J	K
Thalassiosira punctigera (Castracane) Hasle, 1983	56 - 60	16-45					3	58651 - 68379	60589	2177
Thalassiosira punctigera (Castracane) Hasle, 1983	50 - 75	20-50								
Thalassiosira punctigera (Castracane) Hasle, 1983	80 - 99	56-60					1	260610	260610	7108
Thalassiothrix longissima Cleve & Grunow, 1880	1203-1300	5-20	2	41250 - 43500	42375	1629				
Dinoflagellates										
Akashiwo sanguinea G.Hansen & Ø.Moestrup, 2000	20-60		4	5890 - 11310	8600	1069				
Amphidinium carterae Hulburt, 1957	25-56	10-20	1	4712	4712	608				
Amphidinium carterae Hulburt, 1957	56-60	10-20	1	26114	26114	3033				
Amphidinium carterae Hulburt, 1957	60-75	10-20	1	77313	77313	8405				
Amphidinium sphenoides WüIff, 1916	75-99	20-25	1	25133	25133	2926				
Amphisolenia bidentata Schröder,1900	800-990	16-30					5	85226-154016	119360	12636
Amphisolenia bidentata Schröder,1900	990-990	16-30	2	141372	141372	14813	7	165951- 311132	241324	24475

Amphisolenia bidentata Schröder,1900	990-199	16-30	4	4117748-56199386	4503566	382070				
Amphisolenia bidentata Schröder,1900	199-1200	16-30	2	78251104-8511753	8168485	668274				
Amphisolenia bidentata Schröder,1900	1200-2030	16-30	1	997160011	997160011	60854675				
Amphisolenia globifera Stein, 1883	250-300	10-16					3	16041 - 17752	16701	1993
Archaeperidinium minutum Jørgensen, 1912	20 - 30	20-30	2	524-10425	41074	4641	2	6637- 8098	7368	924
Archaeperidinium minutum Jørgensen, 1912	30 - 56	30-56	3	19906-51846	42563	4798	8	3487 - 8256	4350	564
Azadinium caudatum (Halldal)	80-99	99-110	2	4712-77313	41003	4634				
Blepharocysta denticula Nézan & Chomérat, 2012	50-50	56-60	2	65450-113097	89274	9620				
Ceratocorys armata(Schütt) Kofoid,1910	99-200		2	113097-268083	190590	19610				
Ceratocorys horrida Stein, 1883	50-99		2	99766	99766	10678	6	27574-212215	142408	14915
Ceratocorys horrida Stein, 1883	99-200						3	351983-974908	516869	50040
Ceratocorys reticulata H.W.Graham, 1942	99-200		1	80517	80517	8731	3	601446 -764753	659271	62886
Citharistes regius Stein, 1883	30-45	35-45					6	13785-19613	16255	1943
Cochlodinium polykrikoides Margalef, 1961	20-56	20-30					5	8980-20305	13663	1651
Corythodinium cristatum F.J.R.Taylor, 1976	50-99	56-50					6	11277-20098	18531	2198
Corythodinium tesselatum Loeblich III, 1966	50-99	56-50	1	46077	46077	5169	6	9637-14059	11439	1397
Dinophysis acuta Ehrenberg, 1839	35-45	16-25								
Dinophysis argus(Stein) Abé	80-99	80-99					5	114572- 349390	140944	14771

Appendix J continued

A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**
Dinophysis caudata Saville-Kent,1881	60-50	56-50	2	98960	98960	10597				
Dinophysis caudata Saville-Kent,1881	50-80	56-55								
Dinophysis exiguia Kofoid & Skogsberg, 1928	30-56	20-56					3	9978-12098	10747	1318
Dinophysis fortii Pavillard, 1923	30-50	20-50					5	9461 - 37960	11909	1451
Dinophysis hastata Stein, 1883	80-99	50-99					2	172190-240751	206471	21140
Dinophysis miles Cleve 1900	110 - 120						1	98565	98565	10356
Dinophysis miles Cleve 1900	120 - 130									
Dinophysis miles Cleve, 1900	130 - 164						1	107198	107198	11423

Dinophysis miles Cleve, 1900	164 - 203						1	123193	123193	13017
Dinophysis miles Cleve, 1900	150 - 160						4	112346-165087	130294	13720
Dinophysis miles Cleve, 1900	160 - 170						2	135844-300084	217964	22243
Dinophysis schuettii Murray & Whitting, 1899	20-50	20-56	2	25133-703717	364425	36042				
Diplopsalis lenticula Bergh, 1881	20-56	30-50					1	64379	64379	7077
Diplopsalis lenticula Bergh, 1881	56-50	56-60					10	45112 - 294639	151768	15834
Diplopsalis lenticula Bergh, 1881	50-50	60-80					8	163759 - 434149	271724	27359
Diplopsalis lenticula Bergh, 1881	50-99	80-99					1	1212356	1212356	111425
Goniodoma sphaericum Murray & Whitting, 1899	56-50		5	113097-179594	113097	12013	1	175849	175849	18182
Goniodoma sphaericum Murray & Whitting, 1899	50-60						4	77125-91299	85384	9226
Goniodoma sphaericum Murray & Whitting, 1899	60-50						2	34104-55606	44855	5041
Gonyaulax fusiformis	56-80	56-50					4	104258 - 160141	131266	13816
Gonyaulax polygramma Stein, 1883	45-55	56-50	2	4909 - 5727	5318	681				
Gonyaulax polygramma Stein, 1883	55-65	56-50	2	8247 - 9425	8836	1096				
Gonyaulax polygramma Stein, 1883	65-50	56-50	8	20944 - 84823	37176	4226	6	38806-146336	71574	7817
Gonyaulax polygramma Stein, 1883	50-75	56-50	1	101390	101390	10841	3	80906-145051	143389	15011
Gonyaulax rotundata Rampi, 1951	50-80		2	20944 - 31809	26376	3062				
Gonyaulax spinifera Diesing,1866	56-50	35-56	2	1534 - 4909	3221	425				
Gonyaulax spinifera Diesing,1866	50-60	56-45					2	16321-57823	37072	4215
Gotoius abei K.Matsuoka,1988	30-56		3	4909 - 8247	8247	1028				
Gymnodium spp.	20-60		16	2356 - 70686	8954	1110				
*Heterocapsa niei*Morrill & Loeblich III, 1981	16-20						4	478-605	570	84

Appendix J continued

A	B	C	D	E	F	G	H	I	J	K
Heterocapsa triquetra (Ehrenberg) Stein, 1883	16-30		1	1696	1696	233				
Heterodinium milneri Kofoid,1906	56-99		1	29321	29321	3382				
Karenia brevis Gert Hansen & Ø.Moestrup, 2000	20-56		1	8059	8059	1006				
Karenia brevis Gert Hansen & Ø.Moestrup,	56-50		3	19242 - 58643	24881	2899				
Noctiluca scintillans Kofoid & Swezy, 1921	500 - 700						1	101107213	101107213	303322
Noctiluca scintillans Kofoid & Swezy, 1921	500 - 990						1	128655710	128655710	385967

Noctiluca scintillans Kofoid & Swezy, 1921	990-199						2	216504756 - 257429849	236967302	710902
Noctiluca scintillans Kofoid & Swezy, 1921	110-1200						9	315913910 - 515783998	355954939.9	1067865
Noctiluca scintillans Kofoid & Swezy, 1921	1200-1300						3	606131033 - 800490274	693664886	2080995
Ornithocercus magnificus Stein, 1883	30-60		1	452389	452389	44155	17	11992-39397	25483	2964
Ornithocercus steinii Schütt, 1900	99-120		1	883573	883573	82790	22	22831-682955	331262	32953
Ornithocercus thumii Kofoid & Skogsberg, 1928	99-120		8	348455 - 575173	385461	37992				
Oxytoxum laticeps Schiller,1937	10-30		2	131 - 368	250	39	4	1381-1930	1641	226
Oxytoxum parvum Schiller, 1937	20-80		1	23562	23562	2754	5	3699 - 5189	4670	602
Oxytoxum scolopax Stein, 1883	60-80						9	2920 - 6999	4140	538
Oxytoxum scolopax Stein, 1883	80-99		6	2356 - 5278	4131	537	6	5297 - 13620	8108	1011
Oxytoxum scolopax Stein, 1883	99-120		2	16493 - 23136	19815	2341	4	15780 - 22232	17497	2083
Phalacroma cuneus F.Schütt, 1895	99-110	99-110					4	404229 - 573470	473850	46119
Phalacroma rapa Jorgensen, 1923	50-99	50-80					5	134041 - 159330	140092	14687
Phalacroma rotundatum Kofoid & Michener,1911	20-50	20-56	2	3927	3927	512	20	4635-43573	13105	1588
Podolampas bipes Stein, 1883	50 - 80		2	112312	112312	11934	6	23943 - 76460	51123	5700
Podolampas bipes Stein, 1883	80 - 99						1	66556	66556	7302
Podolampas bipes Stein, 1883	99-120		2	294723	294723	29528				
Podolampas palmipes Stein, 1883	50-80		1	6283	6283	796	14	9021-71894	11401	1393
Podolampas palmipes Stein, 1883	80-99		1	18850	18850	2233	3	8687-14371	11163	1366
Podolampas spinifera Okamura,1912	50-80		1	2618	2618	350	3	2340 - 3120	2855	380
Podolampas spinifera Okamura,1912	80-99						8	1869 - 7143	4065	529
Prorocentrum belizeanum M.A.Faust, 1763	50-50	56-60	1	2513	2513	337				

Appendix J continued

A	B	C	D	E	F	G	H	I	J	K
Prorocentrum belizeanum M.A.Faust, 1763	56-80	50-55	2	12566	12566	1526				
Prorocentrum concavum Y.Fukuyo,1981	50-50		2	13744	13744	1660				
Prorocentrum cordatum J.D.Dodge,1755	20-30						4	2926 - 3248	3136	415
Prorocentrum gracile Schütt, 1895	56-50						2	6642- 9901	8272	1031
Prorocentrum gracile Schütt, 1895	50-60		4	10810 - 27489	16859	2011	1	11417	11417	1395

Prorocentrum gracile Schütt, 1895	60 - 50						8	10630 - 19244	12134	1477
Prorocentrum gracile Schütt, 1895	50 - 80						1	12753	12753	1547
Prorocentrum gracile Schütt, 1895	99 - 99						1	15258	15258	1831
Prorocentrum gracile Schütt, 1895	99-120		1	70686	70686	7726				
Prorocentrum lenticulatum F.J.R.Taylor, 1976	20-56		3	5498 - 9163	5498	702				
Prorocentrum lenticulatum F.J.R.Taylor, 1976	30-50		1	27612	27612	3196				
Prorocentrum micans Ehrenberg, 1834	20-35						2	2689 - 3625	3157	417
Prorocentrum micans Ehrenberg, 1834	35 - 56		6	13404 - 18326	15708	1882	3	11149 - 20618	11724	1430
Prorocentrum micans Ehrenberg, 1834	56 - 45						10	8865 - 13948	9788	1207
Prorocentrum micans Ehrenberg, 1834	45 - 50									
Prorocentrum micans Ehrenberg, 1834	50 - 60						2	12919 - 14255	13587	1642
Prorocentrum oblongum(Schiller) Ab~	56-50		2	12566 - 20527	16547	1976				
Prorocentrum oblongum (Schiller) Ab~	50-80		1	51836	51836	5774				
Prorocentrum ovum (Schiller) J.D.Dodge, 1975	56-55						8	16937 - 25610	23998	2802
Prorocentrum rhathymum Sherley & Schmidt, 1759	80-99						6	15997 - 20636	18019	2141
Preperidinium meunieri (Pavillard) Elbrächter, 1993	56-60	80-99	2	45816 - 47124	464610	45274				
Preperidinium meunieri(Pavillard) Elbrächter, 1993	50-60	80-99	2	99531 - 314240	184345	19006				
Protoperidinium abei (Paulsen, 1931) Balech, 1974	50-60	56-50					1	26580	26580	3083
Protoperidinium abei (Paulsen, 1931) Balech, 1974	60-50	50-60					1	47382	47382	5307
Protoperidinium abei (Paulsen, 1931) Balech, 1974	50-99	60-99					5	75840-142061	100277	10730
Protoperidinium abei (Paulsen, 1931) Balech, 1974	99-99	60-99					3	115876-179460	136581	14341
Protoperidinium biconicum Balech, 1974	56-50	56-50					3	22718-30017	27507	3185
Protoperidinium brevipes Balech, 1974	30-50	30-56					5	13429-17000	14060	1696
Protoperidinium conicum (Gran, 1990) Balech, 1974	30-56	30-55					9	9858-21223	2894	384
Protoperidinium conicum (Gran, 1990) Balech, 1974	56-50	60-50	2	11781-75398	43590	4907	8	17797-36164	4170	542

Appendix J continued

A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**
Protoperidinium conicum Balech, 1974	50-60	50-80								
Protoperidinium conicum Balech, 1974	60-75	60-99					1	34387	34387	3928
Protoperidinium crassipes Balech, 1974	55-65	45-60					7	34161-58243	43626	4911

Protoperidinium crassum Balech,1971	30-56	20-30					1	13559	13559	1639
Protoperidinium crassum Balech,1971	56-50	30-55					11	3907-35740	13632	1647
Protoperidinium curtipes Balech, 1974	60-50	99-203					2	57455 - 98330	77893	8464
Protoperidinium curtipes Balech, 1974	50-80	99-203					2	184485 - 197087	190786	19629
Protoperidinium curtipes Balech, 1974	80-99	99-203					1	231493	231493	23537
Protoperidinium curtipes Balech, 1974	99-99	99-203					1	314511 - 314511	314511	31386
Protoperidinium divergens Balech, 1974	50-50	50-75	2	821003-824668	822835	77434				
Protoperidinium divergens Balech, 1974	50-99	50-99	1	1005310	1005310	93457				
Protoperidinium elegans Balech, 1974	203-180	203-220	1	392699	392699	38661				
Protoperidinium heteracanthum Balech	50-85	60-50					4	83886 - 94125	88663	9558
Protoperidinium inflatum Balech, 1974	110-120	99-110					2	192046 - 338633	265340	26755
Protoperidinium inflatum Balech, 1974	120-130	75-85					2	209130 - 223225	216178	22072
Protoperidinium inflatum Balech, 1974	130-164	75-85					1	234179	234179	23794
Protoperidinium latispinum , Balech, 1974	80 - 99	50-80					3	115349 - 154058	134450	14131
Protoperidinium latispinum , Balech, 1974	99 - 120	80-99					3	230499 - 359846	302954	30302
Protoperidinium latispinum Balech, 1974										
Protoperidinium latispinum Balech, 1974	120-164	80-99					1	313237	313237	31266
Protoperidinium leonis Balech, 1974	30-50	56-50	1	75398	75398	8209	6	17781 - 30206	24334	2839
Protoperidinium oceanicum Balech, 1974	99 - 99	60-99					2	110902 - 245743	178323	18422
Protoperidinium oceanicum Balech, 1974	99 - 120	110-120					3	224222 - 310529	257181	25982
Protoperidinium oceanicum Balech, 1974	120 - 130	80-120					3	288281 - 392306	373880	36919
Protoperidinium oceanicum Balech, 1974	130 - 164	80-120					2	296104 - 467723	381916	37664
Protoperidinium oceanicum Balech, 1974	164 - 203	80-120					4	348880 - 525041	509646	49383
Protoperidinium oceanicum Balech, 1974	203 - 203	80-120					3	237893 - 549146	490522	47641
Protoperidinium oviforme Balech, 1974	30 - 50	20-45					3	9624 - 18770	10422	1280
Protoperidinium oviforme Balech, 1974	50 - 50	30-50					6	18997 - 43424	29647	3416
Protoperidinium ovum Balech, 1974	30-45	30-56					8	8052-15622	10030	1235
Protoperidinium pellucidum Bergh, 1881	20-30	20-35	1	8247	8247	1028	3	4314 - 15862	7967	995

Appendix JA continued

A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**

Protoperidinium pellucidum Bergh, 1881	30-56	35-45					3	28759 - 40072	39534	4477
Protoperidinium pellucidum Bergh, 1881	56-50	56-55								
Protoperidinium pentagonum Balech, 1974	50 - 60	60-50					1	69791	69791	7634
Protoperidinium pentagonum Balech, 1974	60 - 50	60-50					2	81600 - 84963	83281	9013
Protoperidinium pentagonum Balech, 1974	50 - 80	60-50					3	88604 - 121620	97067	10407
Protoperidinium pyriforme Balech, 1974	50 - 50	50-60					5	37614 - 50233	44296	4982
Protoperidinium steinii Balech, 1974	30 - 56	20-30	1	18644	18644	2210	3	7502 - 8416	7642	957
Protoperidinium steinii Balech, 1974	56 - 50	20-30					1	16236	16236	1941
Protoperidinium steinii Balech, 1974	50 - 60	56-50					6	19430 - 38723	23812	2781
Protoperidinium steinii Balech, 1974	60 - 50	56-50					2	35110 - 37913	36511	4155
Protoperidinium subinerme Loeblich III, 1969										
Protoperidinium subinerme Loeblich III, 1969	60-50	60-75	1	12828	12828	1556	1	71922	71922	7853
Protoperidinium subinerme Loeblich III, 1969										
Protoperidinium subinerme Loeblich III, 1969	50 - 80	65-75					3	87964 - 99733	93552	10052
Pyrocystis elegans Pavillard, 1931	120-200	80-1203	2	70686	70686	7726				
*Pyrocystis fusiformis C.W.*Thomson, 1876	99-200		1	32987	32987	3777				
Pyrocystis hamulus var. *hamulus* Cleve 1990	120-200									
Pyrocystis lunula (Schütt) Schütt, 1896	600 - 500	200-250					4	12327823 - 30823105	21553549	1661988
Pyrocystis lunula (Schütt) Schütt, 1896	500 - 800	180-200					5	12738776 - 19554738	14389327	1137244
Pyrocystis lunula (Schütt) Schütt, 1896	800 - 990	200-220					4	12505386 - 22024802	19687855	1526532
Pyrocystis lunula (Schütt) Schütt, 1896	990-990	200-250					2	29696289 - 29717210	29706750	2246284
Pyrocystis pseudonoctiluca Wyville-Thompson,1876	99 - 200		14	696910 - 47712938	28804478	2182161	10	1399184 - 31100605	2449982	215714
Pyrocystis pseudonoctiluca Wyville-Thompson,1876	200 - 300						6	5686801 - 12688321	8196667	670439
Pyrocystis pseudonoctiluca Wyville-Thompson,1876	300 - 560						17	203373160 - 33056043	24230063	1855080
Pyrocystis pseudonoctiluca Wyville-Thompson,1876	560 - 500						4	351100410 - 582711006	37782902	2815361
Pyrocystis pseudonoctiluca Wyville-Thompson,1876	500 - 600						1	81289989.17	81289989	5780675
Pyrocystis robusta Kofoid, 1907	80-120		1	33510	33510	3833				
Pyrophacus steinii (Schiller) Wall & Dale, 1971	35-45	60-80								
Scrippsiella trochoidea (Stein) Loeblich III, 1976	16-20	10-16	19	1021-10138	7854	982	4	2580-3957	3664	480
Scrippsiella trochoidea (Stein) Loeblich III, 1976										
Scrippsiella trochoidea (Stein) Loeblich III, 1976	20-25	20-25	4	14726 - 117810	26507	3076	35	4229 -12133	6094	773
Scrippsiella trochoidea (Stein)										

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A	B	C	D	E	F	G	H	I	J	K
Scrippsiella trochoidea Loeblich III, 1976	25-30	20-25					5	7574-9004	8341	1039
Triadinium polyedricum Dodge, 1981	46-50		4	25133 - 63617	44375	4990	8	67215 - 82851	80101	8689
Triadinium polyedricum Dodge, 1981	50-60		7	163363 - 280387	184726	19042				
Triadinium polyedricum (Pouchet)										
Triadinium polyedricum Dodge, 1981	60-50		3	391652 - 448921	391652	38564				
Tripos azoricus (Cleve) F.Gómez, 2013	50-75						7	23866 - 61823	54289	6030
Tripos buceros (Zacharias)F.Gómez, 2013	56 - 50						1	26851	26851	3113
Tripos buceros (Zacharias) F.Gómez, 2013	50 - 99						4	54834 - 132703	95616	10261
Tripos candelabrus (Ehrenberg) F.Gómez, 2013	56 - 50						3	42801 - 104022	45432	5102
Tripos candelabrus (Ehrenberg) F.Gómez, 2013	50 - 60						5	29013 - 42937	36121	4113
Tripos candelabrus (Ehrenberg)F.Gómez, 2013	60 -80						2	37033 - 41454	39244	4446
Tripos candelabrus (Ehrenberg) F.Gómez, 2013	80 - 99						2	31960 - 40419	36190	4121
Tripos carriensis (Gourret) F.Gómez, 2013	40-56						1	5338	5338	683
Tripos carriensis (Gourret) F.Gómez, 2013	60 - 80						3	90687 - 170685	93012	9998
Tripos carriensis (Gourret) F.Gómez, 2013	80 - 99						5	56415 - 225428	84159	9102
Tripos carriensis (Gourret) F.Gómez, 2013	50 - 50						2	15560 - 42723	29142	3362
Tripos carriensis (Gourret) F.Gómez, 2013	50 - 99						3	51409 - 57112	54721	6076
Tripos carriensis (Gourret) F.Gómez, 2013	50-80						1	60491	60491	6675
Tripos carriensis (Gourret) F.Gómez, 2013	80-99						3	94585 - 135665	124348	13132
Tripos carriensis (Gourret) F.Gómez, 2013	99-110						2	69719 - 79814	74766	8145
Tripos carriensis (Gourret) F.Gómez, 2013	120-130						5	48433 - 116933	72221	7884
Tripos carriensis (Gourret) F.Gómez, 2013	50-60						4	58038 - 75677	68664	7519
Tripos declinatus(G.Karsten)F.Gómez, 2013	50-60		1	49345	49345	5513				
Tripos deflexus (Kofoid) F.Gómez, 2014	60-99						11	4171000 - 68853	53806	5980
Tripos digitatus (F.Schütt)F.Gómez, 2013	120-164						3	946160 - 1137160	1023716	95063
Tripos extensus (Gourret)F.Gómez, 2013	990-1200		1	32987	32987	3777	1	148851	148851	15548
Tripos extensus (Gourret)F.Gómez, 2013	1200-2030						1	200968	200968	20611
Tripos extensus (Gourret) F.Gómez, 2013	2030-2000						6	234203 - 320747	274679	27638

Tripos extensus (Gourret) F.Gómez, 2013	2000-2200						2	285166 - 354409	319788	31880
Tripos furca (Ehrenberg) F.Gómez, 2013	50-60		2	18577	18577	2203	11	3256 - 132334	26442	3069
Tripos furca (Ehrenberg) F.Gómez, 2013	56 - 60		4	20239 - 36591	33532	3836	19	3452 - 163661	18399	2183

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A	B	C	D	E	F	G	H	I	J	K
Tripos furca (Ehrenberg) F.Gómez, 2013	60 -80		1	56908	56908	6303	48	10321 - 159510	34495	3939
Tripos furca (Ehrenberg)										
Tripos furca (Ehrenberg) F.Gómez, 2013	80- 99		1	83646	83646	9050	17	11700 - 80548	44711	5026
Tripos furca (Ehrenberg)										
Tripos furca (Ehrenberg) F.Gómez, 2013	99 - 120						3	22927 - 30934	27871	3224
Tripos *fusus* (Ehrenberg) F.Gómez, 2013	560-500		3	3056 - 9916	7879	985				
Tripos fusus (Ehrenberg F.Gómez, 2013	500 - 600		20	20944 - 50265	29452	3396	4	57354 - 90146	70935	7752
Tripos fusus (Ehrenberg)F.Gómez, 2013	560 - 500						6	11224 - 94875	48438	5418
Tripos fusus (Ehrenberg)F.Gómez, 2013	300 - 560						14	13546 - 91041	44973	5053
Tripos fusus (Ehrenberg) F.Gómez, 2013	200 - 300						4	7073 - 52373	27032	3133
Tripos gibberus (Gourret) F.Gómez, 1883	80 - 99						3	63507 - 67689	67576	7407
Tripos gibberus (Gourret) F.Gómez, 1883	99 - 110						1	79074	79074	8584
*Tripos gibberus (*Gourret)F.Gómez, 1883	110 - 203						1	94172	94172	10115
Tripos gravidus (Gourret) F.Gómez, 2013	56-60						3	6100855 - 7338763	6624969	548966
Tripos hexacanthus F.Gómez, 2013	99-120						3	66507 - 123028	90223	9716
Tripos horridus (Cleve)F.Gómez, 2013	30 - 56						1	2681	2681	358
Tripos horridus (Cleve)F.Gómez, 2013	56 - 50						7	6975 - 33192	13715	1657
Tripos horridus (Cleve) F.Gómez, 2013	50 - 60						4	19468 - 40516	27056	3136
Tripos inflatus (Karsten)F.Gómez, 2013	600 - 500						2	93207 - 100605	96906	10391
Tripos inflatus (Karsten) F.Gómez, 2013	500 - 800						4	88146 - 113012	99677	10670
Tripos inflatus (Karsten) F.Gómez, 2013	800 -990						3	133588 - 156294	140972	14774
Tripos inflatus (Karsten)	990 - 990						1	99504	99504	10652
Tripos kofoidii (Jörgenen)	30 - 56						6	3666 - 7590	4566	590
Tripos kofoidii (Jörgenen) F.Gómez, 2013	56 - 50						9	2367 - 11768	5266	674

Tripos limulus (Pouchet)F.Gómez, 2013	50-50						3	34454 - 38097	35097	4004
Tripos lunula F.Gómez, 2013	99 - 120						7	71656 - 269749	139660	14645
Tripos lunula F. Gómez, 2013	120 - 256						1	2458541	2458541	216421
Tripos macroceros F.Gómez, 2013	50-50						3	27538 - 1137231	49374	5516
Tripos massiliensis f. *armatus* F.Gómez,	25 - 35						3	2928 - 23722	3869	505
Tripos massiliensis f. *armatus* F.Gómez, 2013	35 - 75						6	43265 - 101584	54862	6090

Appendix JA continued

A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**
Tripos massiliensis f. *armatus* F.Gómez, 2013	75 - 99						1	296234	296234	29670
Tripos muelleri Bory de Saint-Vincent, 1824	50 - 80		1	93208	93208	10018	1	79142	79142	8591
Tripos muelleri Bory de Saint-Vincent, 1824	80 - 99						7	39784 - 70198	42400	4781
Tripos muelleri Bory de Saint-Vincent, 1824	99 - 99						5	48879 - 95632	68342	7486
Tripos muelleri Bory de Saint-Vincent, 1824	99 - 110						1	96034	96034	10303
Tripos pentagonus(Gourret) F.Gómez, 2013	50 - 50						1	11886	11886	1449
Tripos pentagonus(Gourret) F.Gómez, 2013	50 - 99						3	25449 - 69749	25449	2961
Tripos pentagonus (Gourret) F.Gómez, 2013	99 - 120						10	23905 - 66911	38055	4320
Tripos pentagonus (Gourret) F.Gómez, 2013	120 - 164						1	123985	123985	13096
Tripos praelongus Gómez, 2013	60-110						4	619284 - 2016088	1521411	137906
Tripos pulchellus (Schröder)F.Gómez, 2013	50 - 80						1	34353	34353	3924
Tripos pulchellus (Schröder) F.Gómez, 2013	80 - 99						6	31475 - 78552	51619	5751
Tripos pulchellus (Schröder) F.Gómez, 2013	99 - 99						8	51985 - 95411	86571	9346
Tripos ranipes (Cleve) F.Gómez, 2013	60-80						3	109498 - 147275	145174	15187
Tripos schrankii (Kofoid)	80-99						2	260376 - 342461	301418	30157
Tripos schrankii (Kofoid) F.Gómez, 2013	99-120						10	79598 - 194045	99339	10635
Tripos symmetricus (Pavillard) F.Gómez, 2013	60-75						3	30484 - 40477	35844	4084
Tripos teres (Kofoid) F.Gómez, 2013	50 - 50						4	3313 - 10452	7301	917
Tripos teres (Kofoid) F.Gómez, 2013	50 - 99						6	31711 - 47334	42964	4841
Tripos trichoceros (Ehrenberg) F.Gómez, 2013	30 - 56						1	34736	34736	3965
Tripos trichoceros (Ehrenberg) F.Gómez, 2013	56 - 50						18	14378 - 62112	27575	3192
Tripos trichoceros (Ehrenberg)F.Gómez, 2013	50 - 60						16	15237 - 58314	37840	4297

Tripos trichoceros (Ehrenberg) F.Gómez, 2013	60 - 50					2	29210 - 55756	42483	4790
Tripos vultur(Cleve) F.Gómez, 2013	56 - 50	1	15215	15215	1826	4	26137 - 36912	31192	3584
Tripos vultur(Cleve) F.Gómez, 2013	50 - 60					3	7917 - 76917	33715	3856
Tripos vultur(Cleve) F.Gómez, 2013	60 - 50					6	56229 - 99320	64021	7040
Tripos vultur(Cleve) F.Gómez, 2013	50 - 80					1	52278	52278	5820
Tripos vultur (Cleve) F.Gómez, 2013	80 - 99					1	106349	106349	11338
Tripos vultur (Cleve) F.Gómez, 2013	99 - 203					1	784656	784656	74056
Tryblionella compressa M.Poulin, 1990	20-30	5	4712 - 9163	7422	930	3	3248-4230	3654	479
Tryblionella compressa M.Poulin, 1990	56-50	10	10996 - 18850	15708	1882	4	11052-25427	20305	2395
Tryblionella compressa M.Poulin, 1990	50-60	3	27612 - 42706	42706	4814				

Appendix K: List of Diatoms and Dinoflagellates cell sizes, cell volume and Carbon per cell from the Dona Paula Bay. The columns from left to right (A to K) denote, **A** – species; **B** – length range of the cell [μm]; **C** – width range of the cell [μm]; **D** and **H** – number of cells measured; **E** and **I** – range of cell volume from minimum – maximum [μm^3]; **F** and **J** – median value [μm^3]; **G** and **K** – carbon per cell [pg C $cell^{-1}$] measured for live and fixed cells respectively.

Appendix K

A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**
Diatoms										
Asterionellopsis glacialis Round, 1990	90-100	5-10					35	2962 - 7834	5141	294
Bacteriastrum furcatum Shadbolt 1854	5-10	15-20	5	1629 - 2142	1682	119				
Bacteriastrum furcatum Shadbolt 1854	10-15	15-20	13	1896 - 2977	2311	154				
Bacteriastrum furcatum Shadbolt 1854	15-20	7-15					20	654 - 5416	3314	206
Bacteriastrum furcatum Shadbolt 1854	20-25	11-20					14	933 - 5149	3450	213
Bacteriastrum furcatum Shadbolt 1854	25-30	10-15					3	2665 - 5741	5560	314
Bacteriastrum furcatum Shadbolt 1854	30-35	10-15					2	2665 - 5741	4203	250
Bacteriastrum furcatum Shadbolt 1854	35-50	10-15	7	2312 - 6122	2640	172				
Bacteriastrum furcatum Shadbolt 1854	50-60	10-15	1	5918	5918	330				
Bacteriastrum furcatum Shadbolt 1854	60-80	10-15								
Bacteriastrum furcatum Shadbolt 1854	80-120	15-20								
Bacteriastrum hyalinum Lauder 1864	5-10	20-25	17	1234 - 2876	1934	133				
Bacteriastrum hyalinum Lauder 1864	10-20	10-25	21	2115 - 31821	3621	222	6	4706 - 5714	5374	305
Bacteriastrum hyalinum Lauder 1864	20-25	10-25	6	6931- 53348	40553	1572	5	11685 - 28748	27492	1147
Bacteriastrum hyalinum Lauder 1864	25-30	10-25	4	16535 - 55365	18588	835	23	1205 - 15860	2904	185
Bacteriastrum hyalinum Lauder 1864	30-35	10-25	1	25156	25156	1067	5	4018- 42651	19291	861
Bacteriastrum hyalinum Lauder 1864	35-50	25-30					4	47758 - 54928	51639	1913
Bacteriastrum hyalinum Lauder 1864	50-55	30-35					1	60652	60652	2179
Chaetoceros affinis Lauder 1864	5-10	10-25					1	4333	4333	256
Chaetoceros affinis Lauder 1864	15-20	10-25	16	1096 - 2391	1358	100	8	2495- 6457	5731	322
Chaetoceros affinis Lauder 1864	20-25	10-25	12	1286 - 2442	1675	119	5	2408- 7550	3198	200
Chaetoceros affinis Lauder 1864	25-30	10-20					3	3246-4025	3947	238
Chaetoceros affinis Lauder 1864	30-35	15-20					2	4539 - 4692	4615	270

Chaetoceros castracanei Karsten 1905	15-20	10-20					3	2752-3206	2994	190
Chaetoceros castracanei Karsten 1905	20-25	10-25					6	2501 - 9307	3743	228

Appendix K continued

A	B	C	D	E	F	G	H	I	J	K
Chaetoceros castracanei Karsten 1905	25-30	20-35					10	10685 - 13393	11270	557
Chaetoceros castracanei Karsten 1905	30-35	25-35	4	13290 - 16134	14586	686	4	13106 - 14901	14798	694
Chaetoceros coarctatus Lauder 1864	20-25	10-20								
Chaetoceros coarctatus Lauder 1864	25-30	10-30								
Chaetoceros coarctatus Lauder 1864	40-50	10-30								
Chaetoceros concavicornis Mangin 1917	15-20	10-15	5	1636 - 2918	2670	173	2	2179 - 3675	2927	187
Chaetoceros concavicornis Mangin 1917	20-25	7-25					6	1335 - 6189	3840	232
Chaetoceros concavicornis Mangin 1917	25-30	10-15					1	1724	1724	121
Chaetoceros concavicornis Mangin 1917	50-70	10-15								
Chaetoceros convolutus Castracane, 1886	15-20	10-20								
Chaetoceros curvisetus Cleve 1889	5-10	10-15	1	1732	1732	122	1	631	631	54
Chaetoceros curvisetus Cleve 1889	10-15	5-25	68	594 - 2615	1096	84	19	551 - 2786	1115	85
Chaetoceros curvisetus Cleve 1889	15-20	15-20	51	750 - 3487	1501	108	4	3057 - 3378	3155	198
Chaetoceros curvisetus Cleve 1889	20-25	10-25	8	1976 - 4219	2914	186				
Chaetoceros diversus Cleve 1873	5-10	5-10					2	212 - 220	216	22
Chaetoceros diversus Cleve 1873	10-15	5-10					1	254	254	26
Chaetoceros diversus Cleve 1873	15-20	10-15								
Chaetoceros furcellatus Yendo, 1911	10-15	15-25					4	3764 - 5087	4106	245
Chaetoceros furcellatus Yendo, 1911	15-20	15-25					20	3641 - 9340	4847	281
Chaetoceros furcellatus Yendo, 1911	20-25	15-25					3	4637 - 4900	4748	276
Chaetoceros lorenzianus Grunow, 1863	10-15	5-10	19	1045 - 7681	1652	117				
Chaetoceros lorenzianus Grunow, 1863	15-20	10-15	57	1245 - 20263	3629	222	1	6944	6944	376
Chaetoceros lorenzianus Grunow, 1863	20-25	25-30	34	2147 - 21946	4160	248	14	4339 - 9396	6420	353
Chaetoceros lorenzianus Grunow, 1863	25-30	25-30	34	2147 - 21946			9	4705 - 9777	5232	299

Chaetoceros lorenzianus Grunow, 1863	30-35	25-30	2	8702-9658	9180	471	8	8332 - 23779	11445	564
Chaetoceros lorenzianus Grunow, 1863	35-40	25-30					4	11445 - 27277	21950	956
Chaetoceros lorenzianus Grunow, 1863	45-50	25-30					4	15198 - 34776	26363	1109
Chaetoceros simplex Ostenfeld, 1902	15-20	20-25	2	1709 - 1713	1711	121				
Chaetoceros subtilis Cleve, 1896	5-10	15-25					3	1247 - 1352	1341	99

Appendix K continued

A	B	C	D	E	F	G	H	I	J	K
Chaetoceros subtilis Cleve, 1896	10-15	15-25					11	1308 - 2395	1518	110
Corethron pennatum Ostenfeld, 1909										
Corethron pennatum Ostenfeld, 1909	30-40	15-20	2	6161- 6449	6305	347				
Corethron pennatum Ostenfeld, 1909	40-50	15-30	4	6393-34643	17771	805				
Corethron pennatum Ostenfeld, 1909	50-65	30-40	14	7302 - 47256	10735	535	9	24408 - 80697	52317	1933
Corethron pennatum Ostenfeld, 1909	65-100	30-40	10	12623 - 83788	67469	2376				
Corethron pennatum Ostenfeld, 1909	100-200	30-40					2	160650 - 218498	189574	5491
Coscinodiscus granii Gough, 1905	90-100	40-50					1	169624	169624	5018
Coscinodiscus granii Gough, 1905	100-110	60-70					4	463774 - 618043	522651	12499
Coscinodiscus granii Gough, 1905	110-130	70-100					1	1129166	1129166	23344
Coscinodiscus marginatus Ehrenberg, 1844	50-90	20-25					1	54897	54897	2010
Coscinodiscus radiatus Ehrenberg, 1840	50-90	15-20					1	66129	66129	2337
Coscinodiscus radiatus Ehrenberg, 1840	110-120	10-20					1	150351	150351	4550
Coscinodiscus radiatus Ehrenberg, 1840	130-140	10-20					1	219776	219776	6191
Coscinodiscus radiatus Ehrenberg, 1840	140-160	15-20					3	236417 - 270844	247897	6826
Coscinodiscus radiatus Ehrenberg, 1840	160-170	10-35					4	297368 - 654016	342004	8861
Coscinodiscus radiatus Ehrenberg, 1840	170-180	15-20					1	461128	461128	11292
Coscinodiscus radiatus Ehrenberg, 1840	180-200	15-30					2	488840 - 1116668	802754	17701
Coscinodiscus radiatus Ehrenberg, 1840	200-230	15-30					4	592059 - 1235161	857039	18666
Coscinodiscus radiatus Ehrenberg, 1840	230-250	15-30					1	759921	759921	16932
Detonula pumila (Castracane) Gran,1900	50-100	50-60					14	9034-13182	11711	574
Ditylum brightwellii (T.West) Grunow, 1885	10-30	30-40	2	1882 - 18835	10359	520				

Ditylum brightwellii (T.West) Grunow, 1885	60-70	30-35	1	90219	90219	3007	4	30338 - 38142	35624	1415
Ditylum brightwellii (T.West) Grunow, 1885	70-80	30-60	8	93494 - 216538	160772	4804	10	35477 - 158781	47705	1794
Ditylum brightwellii (T.West) Grunow, 1885	80-90	20-140	13	76871- 275929	201412	5768	6	23659 - 612886	394936	9958
Ditylum brightwellii (T.West) Grunow, 1885	90-99	20-120	5	112601 - 343843	141915	4342	6	21226 - 527924	159396	4771
Ditylum brightwellii (T.West) Grunow, 1885	99-110	25-85	6	127807 - 186872	142704	4362	7	37441 - 329762	51192	1899
Ditylum brightwellii (T.West) Grunow, 1885	110-120	25-115	14	150566 - 403128	182855	5333	10	39015 - 671638	67917	2388
Ditylum brightwellii (T.West) Grunow, 1885	120-130	20-85	25	156300 - 357372	210989	5989	10	23609 - 376469	53339	1963

Appendix K continued

A	B	C	D	E	F	G	H	I	J	K
Ditylum brightwellii (T.West) Grunow, 1885	130-1 40	20-140	9	163744 - 378872	256128	7009	12	35599 - 979179	70081	2450
Ditylum brightwellii (T.West) Grunow, 1885	140-150	20-40	5	212972 - 304728	272221	7364	5	27173 - 77668	68505	2405
Ditylum brightwellii (T.West) Grunow, 1885	150-160	20-45	4	235151 - 482808	348493	8997	9	27363 - 461913	71700	2496
Ditylum brightwellii (T.West) Grunow, 1885	160-180	30-40					2	80374 - 118742	99558	3257
Ditylum brightwellii (T.West) Grunow, 1885	180-190	20-40					3	72773 - 95159	91978	3055
Ditylum brightwellii (T.West) Grunow, 1885	190-200	30-40	1	495977	495977	11979	1	118655	118655	3755
Ditylum brightwellii (T.West) Grunow, 1885	200-220	40-50					1	174960	174960	5145
Eucampia cornuta (Cleve) Grunow, 1883	50-70	20-50	6	8255 - 10201	9289	476				
Eucampia groenlandica Cleve, 1896	60-75	15-20	3	12072 - 14331.89	14092	667				
Eucampia groenlandica Cleve, 1896	75-85	20-25					4	26514 - 31265	29823	1225
Eucampia zodiacus Ehrenberg, 1839	10-20	20-25	5	7071 - 10655	8234	431				
Eucampia zodiacus Ehrenberg, 1839	20-25	20-40	5	9184 - 11320	11156	552	16	4290-7224	6406	352
Eucampia zodiacus Ehrenberg, 1839	25-30	20-45	1	11742	11742	575	20	5529 - 8606	7224	388
Eucampia zodiacus Ehrenberg, 1839	30-35	20-45					17	6844 - 10637	8919	460
Eucampia zodiacus Ehrenberg, 1839	35-40	20-50					12	7478-11919	9958	503
Eucampia zodiacus Ehrenberg, 1839	40-45	20-50					13	9225 - 12685	10870	540
Guinardia delicatula(Cleve) Hasle, 1997	10-20	5-10	4	536 - 1233	603	52				
Guinardia delicatula(Cleve) Hasle, 1997	20-30	10-20	15	530 - 3916	1380	101				
Guinardia delicatula(Cleve) Hasle, 1997	30-40	10-20	17	2161 - 10239	5656	318				

Guinardia delicatula(Cleve) Hasle, 1997	40-50	10-20	6	3731 - 8752	6743	367	2	19968 - 22065	21016	923
Guinardia delicatula(Cleve) Hasle, 1997	55-60	10-20	1	10132	10132	510				
Guinardia delicatula(Cleve) Hasle, 1997	60-70	10-20	1	5676	5676	319				
Guinardia delicatula(Cleve) Hasle, 1997	100-120	10-20					1	63761	63761	2269
Guinardia flaccida(Castracane) H.Peragallo, 1892	40-50	20-30	1	47631	47631	1791				
Guinardia flaccida(Castracane) H.Peragallo, 1892	50-60	20-45	2	61523 - 71779	66651	2352	2	18081 - 88084	53083	1956
Guinardia flaccida(Castracane) H.Peragallo, 1892	60-70	10-50	4	81835 - 94116	85541	2880				
Guinardia flaccida (Castracane) H.Peragallo, 1892	70-80	30-45	2	93022 - 118300	105661	3418	2	11810 - 113346	62578	2235
Guinardia flaccida (Castracane) H.Peragallo, 1892	80-90	30-45	7	82766 - 117728	94893	3133	3	84777 - 117154	89857	2997
Guinardia flaccida H.Peragallo, 1892	100-120	30-45	3	102653 - 174149	116809	3708	5	101768 - 174030	129423	4029

Appendix K continued

A	B	C	D	E	F	G	H	I	J	K
Guinardia flaccida H.Peragallo, 1892	120-140	40-45	3	175534 189032	183090	5338	1	167527	167527	4967
Guinardia striata (Stolterfoth) Hasle, 1996	20-30	5-10	3	1241 - 1374	1249	93				
Guinardia striata (Stolterfoth) Hasle, 1996	30-40	10-20	26	1162 - 4154.99	2342	156	8	2513 - 4810	3502	216
Guinardia striata (Stolterfoth) Hasle, 1996	40-50	10-20	45	1098 - 10038	2428	160	2	9480 - 11815	10648	531
Guinardia striata (Stolterfoth) Hasle, 1996	50-60	10-20	18	1443 - 13996	4313	255	3	6142 - 13281	10699	534
Guinardia striata (Stolterfoth) Hasle, 1996	60-70	10-20	13	2011 - 13778	9779	496				
Guinardia striata (Stolterfoth) Hasle, 1996	80-100	10-20	28	12180 - 50634	18122	818	6	9327 - 96296	12782	616
Guinardia striata (Stolterfoth) Hasle, 1996	100-120	10-20	27	12981 - 51328	19621	873	3	7138 - 127544	18828	844
Guinardia striata (Stolterfoth) Hasle, 1996	120-140	10-20	4	18316 - 20436	19376	864	3	18519 - 25147	22695	982
Haslea wawrikae (Husedt) Simonsen, 1974	180-200	5-15								
Helicotheca tamesis M.Ricard, 1997	60-90	45-85					3	17239 - 81810	29044	1199
Helicotheca tamesis M.Ricard, 1997	130-150	120-135					2	83401 - 153945	118673	3756
Hemiaulus hauckii Grunow ex Van Heurck, 1882	10-20	5-10								
Hemiaulus hauckii Grunow ex Van Heurck, 1882	20-40	10-20					9	3587 - 6888	4253	252
Hemiaulus hauckii Grunow ex Van Heurck, 1882	40-60	20-40								
Hemiaulus hauckii Grunow ex Van Heurck, 1882	60-80	30-60					2	9382 - 10036	9709	493

Hemiaulus indicus Karsten, 1907	30-50	30-40								
Hemiaulus membranaceus Cleve	40-50	30-40					4	30081 - 40772	31789	1290
Lauderia annulata Cleve, 1873	20-40	15-35	5	5732 - 88370	6101	338	6	7982 - 24706	10403	522
Lauderia annulata Cleve, 1873	40-60	30-40	1	7640	7640	406	5	47096 - 65482	64238	2283
Leptocylindrus danicus Cleve, 1889	5-15	2-5	20	83 - 452	224	25				
Leptocylindrus danicus Cleve, 1889	15-20	2-5	25	197 - 1455	391	36	2	244 - 371	308	30
Leptocylindrus danicus Cleve, 1889	20-25	2-5	51	118 - 2377	605	52	18	408 - 2424	1054	81
Leptocylindrus danicus Cleve, 1889	25-30	2-10	94	200 - 3136	2062	140	7	526 - 2990	2473	163
Leptocylindrus danicus Cleve, 1889	30-35	2-10	50	175 - 3714	1636	116	8	430 - 1945	698	58
Leptocylindrus danicus Cleve, 1889	35-40	2-10	48	309 - 4405	1997	137	20	409 - 4656	3234	202
Leptocylindrus danicus Cleve, 1889	40-45	2-10	15	1208 - 3867	2895	185	9	666 - 3762	3482	215
Leptocylindrus danicus Cleve, 1889	45-50	2-10	6	4077 - 9803	5020	289	1	3428	3428	212
Leptocylindrus minimus Gran, 1915	20-25	2-5	19	90 - 557	365	34				

Appendix K continued

A	B	C	D	E	F	G	H	I	J	K
Leptocylindrus minimus Gran, 1915	25-30	2-8	14	128 - 623	204	22	1	244	244	25
Leptocylindrus minimus Gran, 1915	30-35	2-10	3	242 - 436	273	27	3	119 - 368	358	34
Leptocylindrus minimus Gran, 1915	35-40	2-10					4	221-272	257	26
Odontella sinensis(Greville)Grunow, 1884	50-60	50-60					1	149244	149244	4523
Odontella sinensis(Greville)Grunow, 1884	60- 70	60-65					1	170272	170272	5033
Odontella sinensis(Greville)Grunow, 1884	70-80	60-100	1	155472	155472	4675				
Odontella sinensis(Greville)Grunow, 1884	80-90	60-110	1	188150	188150	5458	3	258389 - 311172	297833	7921
Odontella sinensis(Greville)Grunow, 1884	120-140	35-100	3	151014 - 232832	156568	4702	11	90046 - 732113	336430	8744
Odontella sinensis(Greville)Grunow, 1884	140-160	30-60	9	121047 - 319037	163515	4871	3	204463 - 487612	217499	6139
Odontella sinensis (Greville)Grunow, 1884	160-180	60-105					4	487175 - 966265	639531	14721
Pleurosigma angulatum W.Smith, 1852	100-110	10-15					1	6246	6246	345
Pleurosigma angulatum W.Smith, 1852	110-120	10-15					3	5552 - 10296	8249	432
Pleurosigma angulatum W.Smith, 1852	120-130	15-20	1	22817	22817	986	1	21562	21562	942
Pleurosigma angulatum W.Smith, 1852	130-140	15-20					4	19451 - 30263	25257	1071

Pleurosigma angulatum W.Smith, 1852	140-150	8-20	1	35424	35424	1409	1	32760	32760	1322
Pleurosigma angulatum W.Smith, 1852	150-160	25-30					1	39006	39006	1523
Pleurosigma angulatum W.Smith, 1852	160-170	10-26					2	43436 - 46183	44810	1705
Pleurosigma angulatum W.Smith, 1852										
Pleurosigma angulatum W.Smith, 1852	200-220	25-32					7	53752 - 94705	83009	2811
Pleurosigma angulatum W.Smith, 1852	220-230	25-28					5	79918 - 87390	86115	2896
Pleurosigma angulatum W.Smith, 1852										
Pleurosigma angulatum W.Smith, 1852	230-240	20-28	1	106938	106938	3452	2	88125 - 100211	94168	3113
Pleurosigma angulatum .Smith, 1852	240-250	30-35					1	132111	132111	4097
Pleurosigma angulatum W.Smith, 1852	250-260	30-35					3	103767 - 122687	118940	3763
Pleurosigma angulatum W.Smith, 1852	260-270	30-35					1	103847	103847	3370
Pleurosigma angulatum (Queckett)										
Pleurosigma angulatum W.Smith, 1852	300-310	30-35					1	121128	121128	3819
Pleurosigma angulatum W.Smith, 1852	310-350	35-38	1	195788	195788	5637				
Pleurosigma directum Grunow, 1880	110-120	10-12					1	5968	5968	332

Appendix K continued

A	B	C	D	E	F	G	H	I	J	K
Pleurosigma directum Grunow, 1880	120-130	8-12					7	4456 - 8699	6212	343
Pleurosigma directum Grunow, 1880	130-140	8-15					11	6265 - 11646	8853	458
Pleurosigma directum Grunow, 1880	140-150	8-25					6	6428 - 11293	2159	146
Pleurosigma directum Grunow, 1880	160-170	10-26					1	13840	13840	657
Pleurosigma directum Grunow, 1880	170-180	25-30					1	47333	47333	1782
Pleurosigma elongatum W.Smith,1852	100-120	10-12	1	6963	6963	377				
Proboscia alata Sundström, 1996	280-300	5-20					1	25571	25571	1082
Proboscia alata Sundström, 1996	360-380	5-20	1	30144	30144	1236				
Proboscia alata Sundström, 1996	380-400	5-20	3	28220 - 46972	42022	1618				
Proboscia alata Sundström, 1996	400-420	5-20					2	42022 - 46972	44497	1695
Proboscia alata Sundström, 1996	460-480	5-20	1	45403	45403	1723	2	28050 - 45403	45403	1723
Proboscia alata Sundström, 1996	480-860	5-20	1	28050	28050	1166	1	28050	28050	1166

Proboscia indica Hernández-Becerril, 1995	280-300	20-30					1	91732	91732	3048
Proboscia indica Hernández-Becerril, 1995	300-320	10-15					1	36074	36074	1430
Proboscia indica Hernández-Becerril, 1995	320-340	10-20					5	40726 - 94474	55771	2036
Proboscia indica Hernández-Becerril, 1995	340-380	10-25					9	60136-117190	98504	3229
Proboscia indica Hernández-Becerril, 1995	380-400	15-20						85741	85741	2885
Proboscia indica Hernández-Becerril, 1995	400-420	5-20					5	22857 - 126617	110153	3536
Proboscia indica Hernández-Becerril, 1995	860-880	15-20					1	252139	252139	6920
Pseudoguinardia recta von Stosch 1996	50-70	30-40								
Pseudoguinardia recta von Stosch 1996	70-80	30-40					1	91053	91053	3030
Pseudoguinardia recta von Stosch 1996	80-90	30-45					6	74331-117661	80551	2743
Pseudoguinardia recta von Stosch 1996	90-100	20-40								
Pseudoguinardia recta von Stosch 1996	100-120	20-40					3	48435 - 113356	79754	2721
Pseudoguinardia recta von Stosch 1996	120-140	20-40					11	51552 - 136070	65354	2315
Pseudosolenia calcar-avis B.G.Sundström, 1996	220-235	30-55					2	173882 - 481636	327759	8561
Pseudosolenia calcar-avis B.G.Sundström, 1996	240-245	40-45					2	305759 - 335296	320527	8407
Pseudosolenia calcar-avis B.G.Sundström, 1996	265-275	50-70					2	689369 - 936422	812896	17883
Pseudosolenia calcar-avis B.G.Sundström, 1996	290-300	50-60					2	664851 - 801215	733033	16444
Pseudosolenia calcar-avis B.G.Sundström, 1996	300-315	8-65					11	18152 - 979172	705755	15946
Pseudosolenia calcar-avis B.G.Sundström, 1996	330-340	45-60					7	588173 - 854708	696234	15771

Appendix K continued

A	B	C	D	E	F	G	H	I	J	K
Pseudosolenia calcar-avis B.G.Sundström, 1996	340-360	35-70					11	362885 - 1285793	705324	15938
Pseudosolenia calcar-avis B.G.Sundström, 1996	361-380	40-70					19	456664 - 1226689	781987	17329
Pseudosolenia calcar-avis B.G.Sundström, 1996	381-400	35-70					19	455149 - 1421842	826490	18125
Pseudosolenia calcar-avis B.G.Sundström, 1996	400-420	10-65					18	42616 - 1181348	722711	16256
Pseudosolenia calcar-avis B.G.Sundström, 1996	420-440	40-70					17	449844 -1458492	923327	19829
Pseudosolenia calcar-avis B.G.Sundström, 1996	440-460	30-65					14	382396-1407110	1082296	22555
Pseudosolenia calcar-avis B.G.Sundström, 1996	460-480	50-70					11	901562 - 1716897	1095885	22785

Pseudosolenia calcar-avis B.G.Sundström, 1996	685-695	40-70					3	1029062 - 2493671	2390603	42891
*Pseudosolenia calcar-a*vis B.G.Sundström, 1996	700-730	45-55					3	1139414 - 1527072	1428046	28242
Pseudosolenia calcar-avis B.G.Sundström, 1996	800-850	90-100					1	6374660	6374660	95018
Rhizosolenia hebetata f. semispina Gran, 1908	150-180	5-25	1	33156	33156	1335				
Rhizosolenia hebetata f. semispina Gran, 1908	180-200	5-25	2	31055 - 34195	32625	1318				
Rhizosolenia hebetata f. semispina Gran, 1908	200-220	5-25						69556	69556	2435
Rhizosolenia hebetata f. semispina Gran, 1908	220-240	5-25	1	46533	46533	1758		59776	59776	2154
Rhizosolenia hebetata f. semispina Gran, 1908	220-240	5-25								
Rhizosolenia hebetata f. semispina Gran, 1908	240-260	5-25						77517	77517	2659
Rhizosolenia hebetata f. *semispina Gran, 1908*	260-280	5-25	1	54424	54425	1996				
Rhizosolenia hyalina Ostenfeld, 1901	80-100	15-35	1	54294	54294	1992				
Rhizosolenia hyalina Ostenfeld, 1901	100-120	15-40								
Rhizosolenia hyalina Ostenfeld, 1901	120-140	15-35					3	74327-104390	79780	2722
Rhizosolenia hyalina Ostenfeld, 1901	140-160	20-30					6	62498 - 87311	70200	2453
Rhizosolenia hyalina Ostenfeld, 1901	160-180	15-35	2	8000 - 45590	26795	1123	34	32243 - 161506	94989	3135
Rhizosolenia hyalina Ostenfeld, 1901	180 - 200	25-35	1	60821	60821	2184	15	72070 - 124134	99698	3261
Rhizosolenia hyalina Ostenfeld, 1901	200 - 220	15-40	2	114663 - 131297	122980	3866	7	98709 - 143724	116867	3709
Rhizosolenia hyalina Ostenfeld, 1901	220 - 240	15-40					15	54910 - 190907	127932	3992
Rhizosolenia hyalina Ostenfeld, 1901	240 - 260	15-40	1	135292	135292	4177	15	77273 - 210158	136723	4213
Rhizosolenia hyalina Ostenfeld, 1901	260 - 280	15-40					3	133598 - 217661	194760	5613
Rhizosolenia hyalina Ostenfeld, 1901	280 - 300	15-40					2	176363 - 416458	296411	7890
Rhizosolenia hyalina Ostenfeld, 1901	300 - 320	20-30					5	140266 - 176955	169348	5011

Appendix K continued

A	B	C	D	E	F	G	H	I	J	K
Rhizosolenia hyalina Ostenfeld, 1901	340 - 360	30-35					1	280753	280753	7551
Rhizosolenia imbricata Brightwell, 1858	220 - 240	10-20	1	65236	65236	2312	1	65236	65236	2312
Rhizosolenia imbricata Brightwell, 1858	241 - 360	10-20	2	66037 - 76803	71420	2488	2	66037-76803	71420	2488
Rhizosolenia imbricate Brightwell, 1858	180 - 200	5-10	1	4021	4021	241				

Rhizosolenia imbricate Brightwell, 1858	320 - 340	5-10	1	14878	14878	697				
Rhizosolenia setigera Brightwell, 1858	60 - 70	10-40					1	415	415	38
Rhizosolenia setigera Brightwell, 1858	70 - 100	2-10	4	627 - 1612	991	79				
Rhizosolenia setigera Brightwell, 1858	100 -120	2-10	6	1027 - 4189	3177	199	5	2816 - 5180	3950	238
Rhizosolenia setigera Brightwell, 1858	120 - 140	2-10	7	1370 - 6499	5536	313	5	919 - 5497	4056	243
Rhizosolenia setigera Brightwell, 1858	140 - 180	2-35	4	2978 - 188795	163299	4865				
Rhizosolenia setigera Brightwell, 1858	180 - 200	2-35					2	1619 - 167511	84565	2853
Rhizosolenia setigera Brightwell, 1858	200 - 220	3-35					9	3293 - 196502	25001	1062
Rhizosolenia setigera Brightwell, 1858	220 - 240	15-20					2	4668 - 81720	43194	1655
Rhizosolenia setigera Brightwell, 1858	240 - 250	5-25					1	511907	511907	12290
Rhizosolenia setigera Brightwell, 1858	280 - 300	10-40					2	32746 - 338090	185418	5393
Rhizosolenia setigera Brightwell, 1858	380 - 400	35-40					1	431379	431379	10697
Skeletonema costatum-grevillei complex	5-10	5-15					20	213 - 869	499	44
Skeletonema costatum-grevillei complex	10-15.9	5-20	11	615 - 2372	881	70	147	288 - 2344	1158	88
Skeletonema costatum-grevillei complex	16 - 21	5-20	39	656 - 3010	1790	125	122	512 - 3813	2080	141
Skeletonema costatum-grevillei complex	21 - 25	5-20	29	782 - 4790	3389	210	4	1073- 2955	2232	150
Thalassionema nitzschioides Mereschkowsky, 1902	15 - 20	2-5					4	117 - 200	192	20
Thalassionema nitzschioides Mereschkowsky, 1902	20 - 25	3-6	5	295 - 518	478	43	11	169 - 512	326	31
Thalassionema nitzschioides Mereschkowsky, 1902	25 - 30	2-5	2	182 - 735	458	41	11	162 - 477	301	29
Thalassionema nitzschioides Mereschkowsky, 1902	30 - 35	3-10	3	340 - 491	413	38	8	200 - 817	549	48
Thalassionema nitzschioides Mereschkowsky, 1902	35 - 40	2-5	11	486 - 983	638	54	1	681	681	57
Thalassionema nitzschioides Mereschkowsky, 1902	40 - 45	3-10	13	322 - 1089	716	60	7	477 - 1316	596	51

Appendix K continued

A	B	C	D	E	F	G	H	I	J	K
Thalassionema nitzschioides Mereschkowsky, 1902	45 - 50	3-5	21	594 - 2103	831	67	7	613 - 1093	817	66
Thalassionema nitzschioides Mereschkowsky, 1902	50- 55	4-6	6	903 - 1587	1057	82	9	567 - 1882	1235	93

Thalassionema nitzschioides Mereschkowsky, 1902	55 - 60	4-6	3	985 - 1236	1098	84	3	1222 - 1359	1340	99
Thalassionema nitzschioides Mereschkowsky, 1902	60 - 65	4-6	1	921	921	73	1	1315	1315	97
Thalassionema nitzschioides Mereschkowsky, 1902	65 - 80	5-11	4	1136 - 2782	2041	139	1	8239	8239	432
Thalassionema nitzschioides Mereschkowsky, 1902	80 - 100	4-6	1	2437	2437	161	1	1080	1080	83
Thalassionema nitzschioides Mereschkowsky, 1902	100 - 110	3-10	5	2597 - 6637	5266	300	10	1700 - 3657	2975	189
Thalassionema nitzschioides Mereschkowsky, 1902	110 - 120	2-5					2	1065 - 1463	1264	94
Thalassionema nitzschioides Mereschkowsky, 1902	120 - 130	3-7	1	2164	2164	146	3	1662 - 4332	3053	193
Thalassionema nitzschioides Mereschkowsky, 1902	130 - 160	3-8	3	2774 - 8777	2995	190	1	4317	4317	256
Thalassionema nitzschioides Mereschkowsky, 1902	160 - 180	5-10					1	4069	4069	244
Thalassiosira eccentrica Cleve, 1904	20 - 25	5-15					12	3271 - 7176	4562	267
Thalassiosira eccentrica Cleve, 1904	25 - 30	10-20					5	6004 - 11501	9590	488
Thalassiosira eccentrica Cleve, 1904	30 - 35	10-20					7	8997 - 18897	10840	539
Thalassiosira eccentrica Cleve, 1904	35 - 40	25-30					8	9381 - 28583	16720	767
Thalassiosira eccentrica Cleve, 1904	40 - 45	10-25					3	15699 - 38246	32670	1319
Thalassiosira eccentrica Cleve, 1904	45 - 50	10-30					4	18247 - 47889	32959	1329
Thalassiosira eccentrica Cleve, 1904	50 - 60	10-15					1	32006	32006	1298
Thalassiosira gravida Cleve, 1896	100-120	30-50								
Thalassiosira punctigera Hasle, 1993	35 - 40	25-30					1	35467	35467	1410
Thalassiosira punctigera Hasle, 1993	40 - 60	15-45					7	40584 - 123880	82550	2798
Trieres mobiliensis Ashworth & Theriot, 2013	25-30	20-40					3	17921-36590	19248	859
Trieres mobiliensis Ashworth & Theriot, 2013	30-40	20-45	4	23103 - 55932	38760	1516	4	8304 - 30571	16217	748
Trieres mobiliensis Ashworth & Theriot, 2013	40-45	20-30	4	11011 - 57382	45183	1716	6	11944 - 25573	21001	922
Trieres mobiliensis Ashworth & Theriot, 2013	50-60	30-35	1	45364	45364	1722	5	33347-87439	57801	2096
Trieres mobiliensis Ashworth & Theriot, 2013	60-70	50-95					4	94911 - 223853	120137	3793

Appendix K continued

A	B	C	D	E	F	G	H	I	J	K
Dinoflagellates										
Alexandrium catenella Balech, 1995	35-50	40-50					1	16953		
Alexandrium catenella Balech, 1995	50-55	40-50					5	29730 - 44712		
Alexandrium catenella Balech, 1995	55-60	40-50					3	44712 - 93219	64317	7070
Dinophysis acuta Ehrenberg, 1839	35-45	15-25	19	3481 - 8709	6349	804	3	10307 - 11059	10941	1340
Dinophysis caudata Saville-Kent, 1881	60-70	40-50	3	29264 - 34729	31954	3666	3	30053 - 31862	31360	3602
Dinophysis caudata Saville-Kent, 1881	70-80	40-55					2	35203 - 39073	37138	4222
Diplopsalis lenticula Bergh, 1881	20-40	30-50					9	7412 - 54743	30071	3463
Gonyaulax minuta Kofoid & Michener,1911	20 - 25	15-25	2	2236 - 2872	2554	342	19	2690 - 9149	6616	836
Gonyaulax minuta Kofoid & Michener,1911	25 - 30	15-25	12	2147 - 4392	3128	413				
Gonyaulax minuta Kofoid & Michener,1911	30 - 35	20-25	2	3894 - 4370	4132	537				
Gonyaulax spinifera Diesing, 1866	40-50	35-40	1	13860	13860	1673				
Gonyaulax spinifera Diesing, 1866	50-60	40-45	3	23721 - 31474	26082	3030				
Prorocentrum micans Ehrenberg, 1834	35 - 40	20-25	8	3339 - 9064	8161	1017	6	4768 - 9995	7492	939
Prorocentrum micans Ehrenberg, 1834	40 - 45	20-25	2	5581 - 9564	7572	949	7	7337 - 12104	10112	1244
Prorocentrum micans Ehrenberg, 1834	45 - 50	20-25	1	7039	7039	886	1	13706	13706	1656
Prorocentrum micans Ehrenberg, 1834	50 - 60	20-25	2	7322 - 11025	9174	1136				
Protoperidinium conicum Balech, 1974	40-50	60-70					3	61281- 93058	80041	8683
Protoperidinium conicum Balech, 1974	50-60	70-80					1	114033	114033	12106
Protoperidinium divergens Balech, 1974	50-70	50-75					9	45053 - 97583	55570	6164
Protoperidinium latissimum Balech, 1974	50-60	70-80					7	76680 - 101403	95568	10256
Protoperidinium latissimum Balech, 1974	60-70	80-90					19	94796 - 179073	120478	12748
Protoperidinium latissimum Balech, 1974	70-80	80-100					4	141411 - 219568	172569	17863
Protoperidinium pellucidum Bergh, 1881	20-30	20-35	1	6810	6810	859	9	3367 - 5597	4151	539
Protoperidinium pellucidum Bergh, 1881	30-40	35-45	7	13219 - 18303	15090	1812	1	7311	7311	918
Protoperidinium pellucidum Bergh, 1881	40-50	40-55	10	19006 - 30461	21715	2551	7	14713 - 28618	21188	2493
Pyrophacus steinii Wall & Dale, 1971	35-45	60-80	4	79284 - 119977	93119	10009				
Tripos furca (Ehrenberg) F.Gómez, 2013	50-60		1	1818	1818	248				

Tripos furca (Ehrenberg) F.Gómez, 2013	40 - 60	18	5182 - 19572	6517	824	4	1889 - 8560	7834	979
Tripos furca (Ehrenberg) F.Gómez, 2013	60-80	19	5972 - 24314	8246	1028	3	7909 - 11006	10997	1347
Tripos fusus (Ehrenberg) F.Gómez, 2013	500-600					4	15029 - 26044	21133	2487
Tripos fusus (Ehrenberg) F.Gómez, 2013	400-500					1	29222	29222	3371
Tripos fusus (Ehrenberg) F.Gómez, 2013	300-400					1	45334	45334	5091
Tripos macroceros (Ehrenberg) F.Gómez, 2013	50-70	4	25245 - 49628	33969	3883	2	33044 - 40644	36844	4191
Tripos muelleri Bory de Saint-Vincent, 1824	70-80	6	21580 - 43874	33940	3880				

Appendix L. Comparison of cell volume measured using Image analysis software (Q-Capture Pro7) and Ocular micrometer. Columns left to right (**A to J**) denote, **A** – Serial number; **B –** Species; **C** and **E** are the average values of cell volume; **D** and **F** are the number of cells (N) measured using Image Analysis and Ocular micrometer; **G** – represents Coefficient of Variation (CV%) of cell volume. **H** and **I** represent Cell carbon [pg carbon $cell^{-1}$] obtained from the average values of cell volume measured by Image Analysis (Q-Capture Pro 7, Olympus Inc.) and Ocular micrometer respectively. The **J** column denotes coefficient of variation (CV %) of Cell carbon

Appendix L

A	B	C	D	E	F	G	H	I	J
	Diatoms								
1	*Astramphalus marylandrica* Ehrenberg,1844	63361	11	54595	7	10.5	2221	1952	9.1
2	*Bacteriastrum furcatuum* Shadbolt, 1854	44410	5	46289	3	2.9	1692	1747	2.3
3	*Chaetoceros concavicornis* Mangin, 1917	19080	3	17671	3	5.4	852	802	4.3
4	*Chaetoceros messanense* Castracane, 1875	1615	1	1532	1	3.7	115	110	3.0
5	*Chateoceros lauderi* Ralfs, 1864	3476	2	2749	2	16.5	214	177	13.4
6	*Climacodium frauenfeldianum* Grunow, 1868	26077	9	35149	6	21.0	1089	1348	15.0
7	*Dactyliosolen fragilissimus* (Bergon) Hasle, 1996	110030	9	104725	9	3.5	3296	3190	2.3
8	*Eucampia groenlandrica* Cleve, 1896	70121	2	77926	2	7.5	2451	2670	6.0
9	*Eucampia zodiacus* Ehrenberg, 1839	69699	11	71365	7	1.7	2433	2481	1.4
10	*Fragilariopsis cylindrus* (Grunow) Krieger, 1954	27475	3	27423	3	0.1	1144	1142	0.1
11	*Guinardia cylindrus* (Cleve) Hasle, 1996	14742	2	14444	2	1.4	692	681	1.2
12	*Guinardia striata* (Stolterfoth) Hasle, 1996	3946	3	4369	3	7.2	237	257	5.7
13	*Helicotheca tamenses* (Shrubsole) M.Ricard, 1987	616995	3	662508	3	5.0	14287	15138	4.1
14	*Hemialus membranaceus* Cleve, 1873	25820	9	22449	9	9.9	1086	963	8.5
15	*Meuinera membrenecia*(Cleve) P.C.Silva, 1996	57700	4	56521	4	1.5	2088	2055	1.1
16	*Pinnularia rectangulata* Ehrenberg, 1843	2477	2	2062	2	13.0	163	140	10.5
17	*Planktonella sol* (C.G.Wallich) Schütt, 1892	395799	10	320099	8	15.0	9646	8078	12.5

Appendix L Continued

A	B	C	D	E	F	G	H	I	J
18	*Pleurosigma elongatum* W.Smith, 1852	5507	1	5938	1	5.3	311	331	4.3
19	*Proboscia alata* (Brightwell) Sundström, 1986	21449	3	22345	3	2.9	936	967	2.3
20	*Proboscia indica*(H.Peragallo)Hernández-Becerril, 1995	260174	8	242882	8	4.9	6786	6396	4.2
21	*Pseudoguinardia recta* von Stosch, 1986	103262	3	99811	3	2.4	3353	3263	1.9
22	*Rhizosolenia bergonii* H.Peragallo, 1892	238909	7	203538	5	11.3	6530	5709	9.5
23	*Rhizosolenia imbricata* Brightwell, 1858	271195	7	265780	7	1.4	7337	7218	1.2
24	*Rhizosolenia setigera* Brightwell, 1858	175406	2	165584	2	4.1	4882	4649	3.5
25	*Thalassionema frauenfeldii* (Grunow)Tempère & Peragallo, 1910	8059	2	6394	2	16.3	424	351	13.2
26	*Thalassiosira eccentrica* (Ehrenberg) Cleve, 1904	63513	4	65529	4	2.2	2262	2319	1.7
27	*Thalassiosira punctigera* (Castracane) Hasle, 1983	52275	7	50036	7	3.1	1898	1828	2.6
	Dinoflagellates								
28	*Dinophysis hastata* Stein, 1883	22778	3	18326	3	15.3	2668	2175	14.4
29	*Gyrodionium* sp.Kofoid & Swezy, 1921	9378	3	9521	3	1.1	1159	1176	1.0
30	*Ornithocercus steinii* Schütt, 1900	402931	5	400200	5	0.5	39560	39295	0.5
31	*Ornithocercus magnificus* Stein, 1883	36136	5	35244	5	1.8	4100	4005	1.7
32	*Oxytoxum scolopax* Stein, 1883	8017	3	7499	3	4.7	1001	940	4.4
33	*Prorocentrum micans* Ehrenberg, 1834	3157	4	3007	4	3.4	417	398	3.2
34	*Phalacroma rotundatum* (Claparéde & Lachmann) Kofoid & Michener, 1911	11160	3	10832	3	2.1	1365	1327	2.0
35	*Tripos furca* (Ehrenberg) F.Gómez, 2013	25553	5	17009	5	28.4	2967	2021	26.8
36	*Tripos fusus* (Ehrenberg) F.Gómez, 2013	40042	3	39706	3	0.6	4530	4495	0.5
37	*Scrippsiella trochoidea* (Stein) Loeblich III, 1976	11330	3	11562	3	1.4	1378	1406	1.4
38	*Tryblionella compressa* (J.W.Bailey) M.Poulin, 1990	7462	5	7756	5	2.7	934	968	2.5

Appendix M: Comparison of average cell volume (μm^3× 10^4) of the present study (Northern Indian Ocean) with different geographical regions. The species denoted with (*) were common to all the 4 regions. The columns (**A**–**G**) denote, **A** – serial number; **B** – Species; **C -** Present study (northern Indian Ocean); **D** – Barton et al., 2013 (northern Atlantic); **E** – Olenina et al., 2006 (northern Atlantic), **F** – Sun et al., 2000 (Pacific); **G** – Kim and Travers, 1995 (Mediterranean).

Appendix M

A	**B**	C	D	E	F	G
1	*Asterionellopsis glacialis* (Castracane) Round, 1990	0.5248				
2	*Asterolampra marylandrica* Ehrenberg 1844	7.9288				
3	*Azpeitia nodulifera* (A.W.F.Schmidt) G.A.Fryxell & P.A.Sims, 1996	26.0188			1.2000	
4	*Bacteriastrum furcatum* Shadbolt 1854	0.6176			0.3000	
5	*Bacteriastrum hyalinum* Lauder 1864	1.5064				1.0454
6	*Chaetoceros affinis* Lauder 1864	0.2730		0.1085		0.6082
7	*Chaetoceros castracanei* Karsten 1905	0.9428				0.8954
8	*Chaetoceros coarctatus* Lauder 1864	4.4792				
9	*Chaetoceros concavicornis* Mangin 1917	0.8723				
10	*Chaetoceros convolutus* Castracane 1886	1.9337				
11	*Chaetoceros curvisetus* Cleve 1889	0.1547			0.1600	0.6800
12	*Chaetoceros decipiens* Cleve 1873	0.1494		1.2492	0.6300	2.5447
13	*Chaetoceros diversus* Cleve 1873	0.1644				
14	*Chaetoceros furcellatus* Yendo, 1911	0.6496				
15	*Chaetoceros laciniosus* F.Schütt 1895	0.0448		0.2206	0.6500	1.6336
16	*Chaetoceros lauderi* Ralfs, 1864	0.2238		0.5313	0.7500	0.6609
17	*Chaetoceros lorenzianus* Grunow 1863	0.7564		0.9656	0.9300	4.3825
18	*Chaetoceros messanense* Castracane 1875	0.1788			0.6000	

Appendix M

A	B	C	D	E	F	G
19	*Chaetoceros peruvianus* Brightwell 1856	1.0827			0.3000	
20	*Chaetoceros simplex* Ostenfeld 1902	0.1533				
21	*Chaetoceros subtilis* Cleve 1896	0.1532				
22	*Climacodium frauenfeldianum* Grunow 1868	3.4374	0.6918			
23	*Corethron pennatum* (Castracane) Ostenfeld, 1909	4.2206	5.1286			
24	*Coscinodiscus concinnus* W.Smith, 1856	103.7346	467.7351	339.1472		
25	*Coscinodiscus gigas* Ehrenberg, 1841	31.0523				6126.7538
26	*Coscinodiscus granii* Gough, 1905	70.8761		208.0087		
27	*Coscinodiscopsis jonesiana* (Greville) E.A.Sar & I.Sunesen, 2008	442.6504				
28	*Coscinodiscus marginatus* Ehrenberg, 1844	12.0432				
29	*Coscinodiscus radiatus* Ehrenberg, 1840	97.8533		21.9440	3.0400	343.8957
30	*Dactyliosolen fragilissimus* (Bergon) Hasle, 1996	6.1458	1.6982	2.5139		
31	*Detonula pumila* (Castracane) Gran,1900	1.1596				
32	*Ditylum brightwellii* (T.West) Grunow, 1885 *	17.3332	7.5858	4.6603	10.6000	12.3889
33	*Eucampia cornuta* (Cleve) Grunow, 1883	0.9229				
34	*Eucampia groenlandica* Cleve 1896	2.2560				
35	*Eucampia zodiacus* Ehrenberg 1839	0.8497	1.2023	0.2708		
36	*Fragilariopsis cylindrus* (Grunow) Krieger, 1954	0.2181				
37	*Guinardia cylindrus* (Cleve) Hasle, 1996	5.6829			1.2000	
38	*Guinardia delicatula* (Cleve) Hasle, 1997 *	0.8725	1.0000	0.5037	0.7000	1.9096

Appendix M continued

A	B	C	D	E	F	G
39	*Guinardia flaccida* (Castracane) H.Peragallo, 1892	11.2419	13.1826	11.4394		17.1806
40	*Guinardia striata* (Stolterfoth) Hasle, 1996	1.8932				17.6714
41	*Haslea trompii* (Cleve)Simonsen, 1974	3.8839				
42	*Haslea wawrikae* (Husedt) Simonsen, 1974	0.2342				
43	*Helicotheca tamesis* (Shrubsole) M.Ricard, 1997	8.9973				
44	*Hemiaulus hauckii* Grunow ex Van Heurck, 1882	1.0661			2.7000	
45	*Hemiaulus indicus* Cleve 1873	2.0536				
46	*Hemiaulus membranaceus* Cleve	4.5428				
47	*Hemidiscus* cuneiformis Wallich, 1860	722.8434				
48	*Lauderia annulata* Cleve 1873 *	3.0136		3.0854	2.5000	5.3223
49	*Leptocylindrus danicus* danicus Cleve 1889 *	0.2206	0.1995	0.1339	0.1800	0.6322
50	*Leptocylindrus minimus* Gran 1915	0.0293		0.0155		
51	*Lioloma pacificum* (Cupp)Hasle, 1996	2.5600				
52	*Mastogloia rostrata* (Wallich) Hustedt 1933	0.9287				
53	*Meuniera membranacea* (Cleve) P.C.Silva, 1996	2.4157	2.4547			3.3697
54	*Navicula transitans* var.*derasa* (Grunow) Cleve 1883	0.2535				
55	*Neocalyptrella robusta* (G.Norman ex Ralfs) Hernández-Becerril & Meave del Castillo, 1997	592.9765				1582.3024
56	*Odontella aurita* (Lyngbye) C.Agardh, 1832	3.9010	3.5481	2.1760	7.4000	

57	*Odontella sinensis*(Greville) Grunow, 1884	52.7078	112.2018	100.0875		341.1260
58	*Planktoniella sol* (C.G.Wallich) Schütt, 1892	29.3785	7.0795			

Appendix M continued

A	B	C	D	E	F	G
59	*Pleurosigma angulatum*(Queckett) W.Smith, 1852	6.6324				
60	*Pleurosigma directum* Grunow, 1880	0.9883				
61	*Pleurosigma elongatum* W.Smith,1852	0.2188				
62	*Pleurosigma normanii* Ralfs,1861	0.9000				
63	*Proboscia alata* (Brightwell) Sundström 1996	4.6261			1.1000	6.3612
64	*Proboscia indica* (H.Peragallo) Hernández-Becerril, 1995	15.5470	16.5959		3.1000	178.0560
65	*Pseudoguinardia recta* von Stosch 1996	8.2134				
66	*Pseudo-nitzschia delicatisma*(Cleve) Heiden, 1928	0.0288		0.0157		
67	*Pseudo-nitzschia fraulendenta* (Cleve) Hasle, 1993	0.0847				
68	*Pseudo-nitzschia multiseries* Hasle, G.R. 1995	0.4007				
69	*Pseudo-nitzschia seriata* (Cleve) H.Peragallo, 1899	0.3311		0.4708	0.2100	
70	*Pseudonitzschia* spp.	0.4145				
71	*Pseudosolenia calcar-avis* (Schultze) B.G.Sundström, 1986	99.9256	33.1131		100.0000	229.0221
72	*Rhizosolenia bergonii* H.Peragallo, 1892	18.9556	46.7735			
73	*Rhizosolenia borealis* Sundström 1986	2352.7387				
74	*Rhizosolenia castracanei* H.Peragallo, 1888	5347.4318				
75	*Rhizosolenia crassa* Schimper, 1905	35.8976				
76	*Rhizosolenia formosa* H.Peragallo 1888	211.7313				

77	*Rhizosolenia hebetata* f. semispina Gran, 1908 *	16.4794	7.0795	4.7874	2.1000	1.1309
78	*Rhizosolenia hyalina* Ostenfeld & Schmidt 1901	11.0943				

Appendix M continued

A	B	C	D	E	F	G
79	*Rhizosolenia imbricata* Brightwell, 1858	19.7928			4.2000	155.5088
80	*Rhizosolenia setigera* Brightwell, 1858 *	6.0076	19.9526	25.1541	0.6800	0.6654
81	*Skeletonema costatum-grevillei* complex (Greville, 1865)	0.1643		0.0372	0.0310	
82	*Thalassionema frauenfeldii* (Grunow) Tempère & Peragallo,1910	2.2836			0.2800	0.6305
83	*Thalassionema javanicum* (Grunow) G.R.Hasle	0.3500				
84	*Thalassionema nitzschioides* (Grunow) Mereschkowsky 1902 *	0.1346	0.0891	0.0962	0.0530	0.1734
85	*Thalassionema pseudonitzschiodes* (G.Schuette & H.Schrader) G.R.Hasle	0.5600				
86	*Thalassiosira eccentrica* (Ehrenberg) Cleve 1904	3.8571		18.7311		
87	*Thalassiosira gravida* Cleve, 1896	1.9242		1.6632		
88	*Thalassiosira punctigera* (Castracane) Hasle 1983	46.0278		6.9620		
89	*Thalassiothrix longissigma* Cleve & Grunow 1880	4.2375				
90	*Trieres mobiliensis* (J.W.Bailey) Ashworth & Theriot, 2013	4.7677	31.6228	11.8692	14.5000	
	Dinoflagellates					
91	*Akashiwo sanguinea* (K.Hirasaka) G.Hansen & Ø.Moestrup, 2000	0.8600				
92	*Alexandrium catenella* (Whedon & Kofoid) Balech, 1985	4.8255				

93	*Amphidinium carterae* Hulburt, 1957	3.6047	
94	*Amphidinium sphenoides* WüIff, 1916	2.5133	
95	*Amphisolenia bidentata* Schröder, 1900	356.9031	42.6580
96	*Amphisolenia globifera* Stein, 1883	1.6701	

Appendix M continued

A	B	C	D	E	F	G
97	*Archaeperidinium minutum* (Kofoid) Jørgensen, 1912	1.8743		3.3773		
98	*Azadinium caudatum* (Halldal) Nézan & Chomérat, 2012	4.1013				
99	*Blepharocysta denticula* Nie, 1939	8.9274				
100	*Ceratocorys armata* (Schütt) Kofoid, 1910	19.0590				
101	*Ceratocorys horrida* Stein 1883	25.8707				
102	*Ceratocorys reticulata* H.W.Graham, 1942	52.6497				
103	*Citharistes regius* Stein, 1883	1.6562				
104	*Cochlodinium polykrikoides* Margalef, 1961	1.4283				
105	*Corythodinium tesselatum* (Stein) Loeblich Jr. & Loeblich III, 1966	1.6507				
106	*Corythodinium cristatum*(Kofoid) F.J.R.Taylor 1756	1.6785				
107	*Dinophysis acuta* Ehrenberg, 1839	0.6787		6.3750		
108	*Dinophysis argus* (Stein) Abé	23.5283				
109	*Dinophysis caudata* Saville-Kent, 1881	4.6142			5.8000	
110	*Dinophysis exiguia* Kofoid & Skogsberg, 1928	1.0941				

111	*Dinophysis fortii* Schütt 1895	2.0746				
112	*Dinophysis hastata* Stein, 1883	20.6471				
113	*Dinophysis miles* Cleve, 1900	16.0099				
114	*Dinophysis schuetii* Murray & Whitting, 1899	36.4425				
115	*Diplopsalis lenticula* Bergh, 1881	22.5191				
116	*Goniodoma sphaericum* Murray & Whitting 1899	11.9911				
117	*Gonyaulax fusiformis* H.W.Graham, 1942	13.1732				
118	*Gonyaulax minuta* Kofoid & Michener, 1911	0.5063				

Appendix M continued

A	B	C	D	E	F	G
119	*Gonyaulax polygramma* Stein, 1883	5.8511		1.0590		
120	*Gonyaulax rotundata* Rampi, 1951	2.6376				
121	*Gonyaulax spinifera* (Claparède & Lachmann) Diesing, 1866	2.4373		1.7908		
122	*Gotius abei* K.Matsuoka, 1998	0.7134				
123	*Gymnodinium* spp.	1.9157				
124	*Heterocapsa niei* (Loeblich III) Morrill & Loeblich III, 1991	0.0539				
125	*Heterocapsa triquetra* (Ehrenberg) Stein, 1883	0.1696				
126	*Heterodinium milneri* (Murray & Whitting) Kofoid 1906	2.9322				
127	*Karenia brevis* (C.C.Davis) Gert Hansen & Ø.Moestrup, 2000	2.7706				
128	*Noctiluca scintillans* (Macartney) Kofoid & Swezy, 1921	44973.0442		23445.3333		
129	*Ornithocercus magnificus* Stein, 1883	4.9846				
130	*Ornithocercus steinii* Schütt 1900	41.4460				

131	*Ornithocercus thumii* Kofoid & Skogsberg, 1928	42.3637				
132	*Oxytoxum laticeps* Schiller, 1937	0.0249				
133	*Oxytoxum parvum* Schiller 1937	0.7713				
134	*Oxytoxum scolopax* Stein, 1883	0.8437			3.9000	
135	*Phalacroma cuneus* F.Schütt, 1895	48.1350				
136	*Phalacroma rapa* Jorgensen, 1923	14.4451				
137	*Phalacroma rotundatum* (Claparéde & Lachmann) Kofoid & Michener 1911	1.4012				
138	*Podolampas bipes* Stein, 1883	10.7662				
139	*Podolampas palmipes* Stein, 1883	2.0123				

Appendix M continued

A	B	C	D	E	F	G
140	*Podolampas spinifera* Okamura, 1912	0.3908				
141	*Prorocentrum belizeanum* M.A.Faust, 1763	0.9215				
142	*Prorocentrum concavum* Y.Fukuyo, 1991	1.3744				
143	*Prorocentrum cordatum* J.D.Dodge, 1755	0.3111				
144	*Prorocentrum gracile* Schütt, 1895	1.6081				
145	*Prorocentrum lenticulatum* (Matzenauer) F.J.R.Taylor, 1976	1.1943				
146	*Prorocentrum micans* Ehrenberg, 1834	1.0180		2.0293	0.4300	1.1550
147	*Prorocentrum oblongum* (Schiller) Ab~	2.8310				
148	*Prorocentrum ovum* (Schiller) J.D.Dodge, 1975	2.2878				

149	*Prorocentrum rhathymum* Sherley & Schmidt, 1759	1.8079				
150	*Preperidinium meunieri*(Pavillard) Elbrächter, 1993	12.6707				
151	*Protoperidinium abei* (Paulsen, 1931) Balech, 1974	10.5342				
152	*Protoperidinium biconicum* (P.-A.Dangeard,1927) Balech, 1974	2.6747				
153	*Protoperidinium brevipes* (Paulsen, 1908) Balech, 1974	1.3429		1.4502		
154	*Protoperidinium conicum* (Gran, 1900) Balech, 1974	3.3422		15.4717		8.6057
155	*Protoperidinium crassipes* (Kofoid, 1907) Balech, 1974	4.4502				
156	*Protoperidinium crassum* Balech, 1971	1.5359				
157	*Protoperidinium curtipes* (Jørgensen, 1912) Balech 1974	18.0560		13.4628		
158	*Preperidinium diabolum* (Cleve,1900) Balech, 1974	15.9184				
159	*Protoperidinium divergens* (Ehrenberg, 1840) Balech 1974	17.3620		10.2618		

Appendix M continued

A	B	C	D	E	F	G
160	*Protoperidinium elegans* (Cleve, 1900) Balech 1974	185.6128				
161	*Protoperidinium heteracanthum* (Dangeard) Balech	8.8834				
162	*Protoperidinium inflatum* (Okamura, 1912) Balech, 1974	23.9443				
163	*Protoperidinium latispinum* (Mangin, 1926) Balech, 1974	23.0056				
164	*Protoperidinium latissimum* (Kofoid, 1907) Balech, 1974	12.5711				
165	*Protoperidinium leonis* (Pavillard, 1916) Balech, 1974	3.1352		3.9564		
166	*Protoperidinium minutissimum* (L. Mangin 1926) Balech, 1974	0.2198				
167	*Protoperidinium oceanicum* (VanHöffen, 1897) Balech, 1974	36.1038			74.0000	

168	*Protoperidinium oviforme* (Dangeard, 1927) Balech, 1974	2.5316				
169	*Protoperidinium ovum* (Schiller, 1911) Balech, 1974	11.6627				
170	*Protoperidinium pellucidum* Bergh, 1881	1.6065		2.8398		
171	*Protoperidinium pentagonum* (Gran, 1902) Balech, 1974	9.0607		5.2752		4.0453
172	*Protoperidinium pyriforme* (Paulsen, 1905) Balech, 1974	4.3828		2.9307		
173	*Protoperidinium steinii* (Jørgensen, 1899) Balech, 1974	2.2010		16.6100		
174	*Protoperidinium subinerme* (Paulsen) Loeblich III, 1969	7.3203		2.8793		
175	*Pyrocystis elegans* Pavillard, 1931	7.0686				
176	*Pyrocystis fusiformis* C.W.Thomson, 1876	6.6977				
177	*Pyrocystis hamulus* var. hamulus Cleve 1900	401.6105				
178	*Pyrocystis lunula* (Schütt) Schütt, 1896	1243.6742				

Appendix M continued

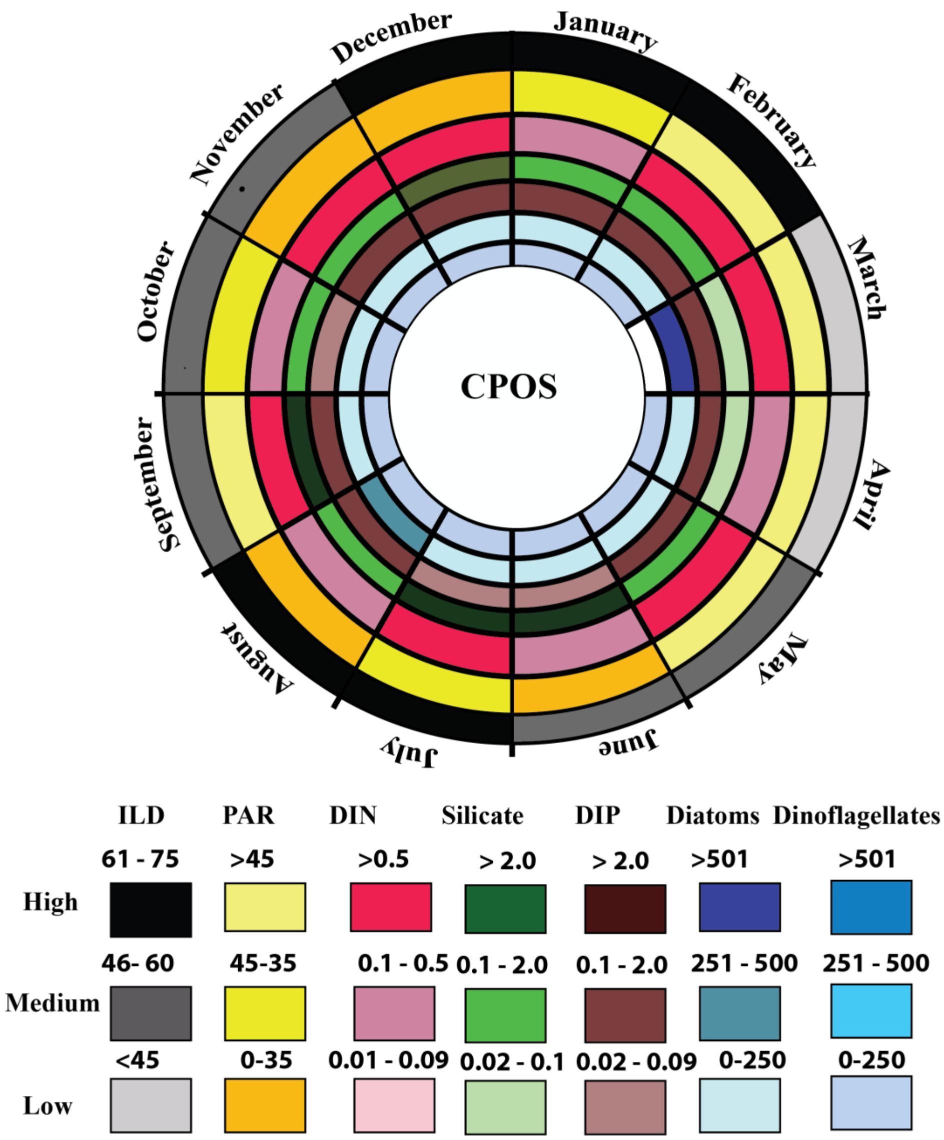
A	B	C	D	E	F	G
179	*Pyrocystis pseudonoctiluca* Wyville-Thompson, 1876	2142.5134				
180	*Pyrocystis robusta* Kofoid, 1907	3.3510				
181	*Pyrophacus steinii* (Schiller) Wall & Dale, 1971	9.9089				5.6549
182	*Scrippsiella trochoidea* Loeblich III, 1976	0.8525		0.5505		
183	*Triadinium polyedricum* (Pouchet) Dodge, 1991	16.1128				
184	*Tripos azoricus* (Cleve) F.Gómez, 2013	4.4887	6.3096			
185	*Tripos buceros* (Zacharias) F.Gómez, 2013	8.1124	2.1878			

186	*Tripos candelabrus* (Ehrenberg) F.Gómez, 2013	4.3768				
187	*Tripos carriensis* (Gourret) F.Gómez, 2013	10.5976	19.4984			
188	*Tripos coarctus* (Pavillard) F.Gómez, 2013	4.4305				
189	*Tripos contortus*(Zacharias) F.Gómez, 2013	8.5518				
190	*Tripos contrarius* (Gourret) F.Gómez, 2013	6.7761				
191	*Tripos declinatus* (G.Karsten) F.Gómez, 2013	4.9345	4.3652			
192	*Tripos deflexus* (Kofoid) F.Gómez, 2013	5.4903				
193	*Tripos digitatus* (F.Schütt) F.Gómez, 2013	103.9038				
194	*Tripos extensus* (Gourret) F.Gómez, 2013	24.4344	25.1189		4.6000	
195	*Tripos furca* (Ehrenberg) F.Gómez, 2013	2.8585	5.3703	5.1667		1.9457
196	*Tripos fusus* (Ehrenberg) F.Gómez, 2013 *	3.7485	5.0119	1.9500	1.4000	1.2840
197	*Tripos gibberus* (Gourret) F.Gómez, 2013	7.4404	31.6228			

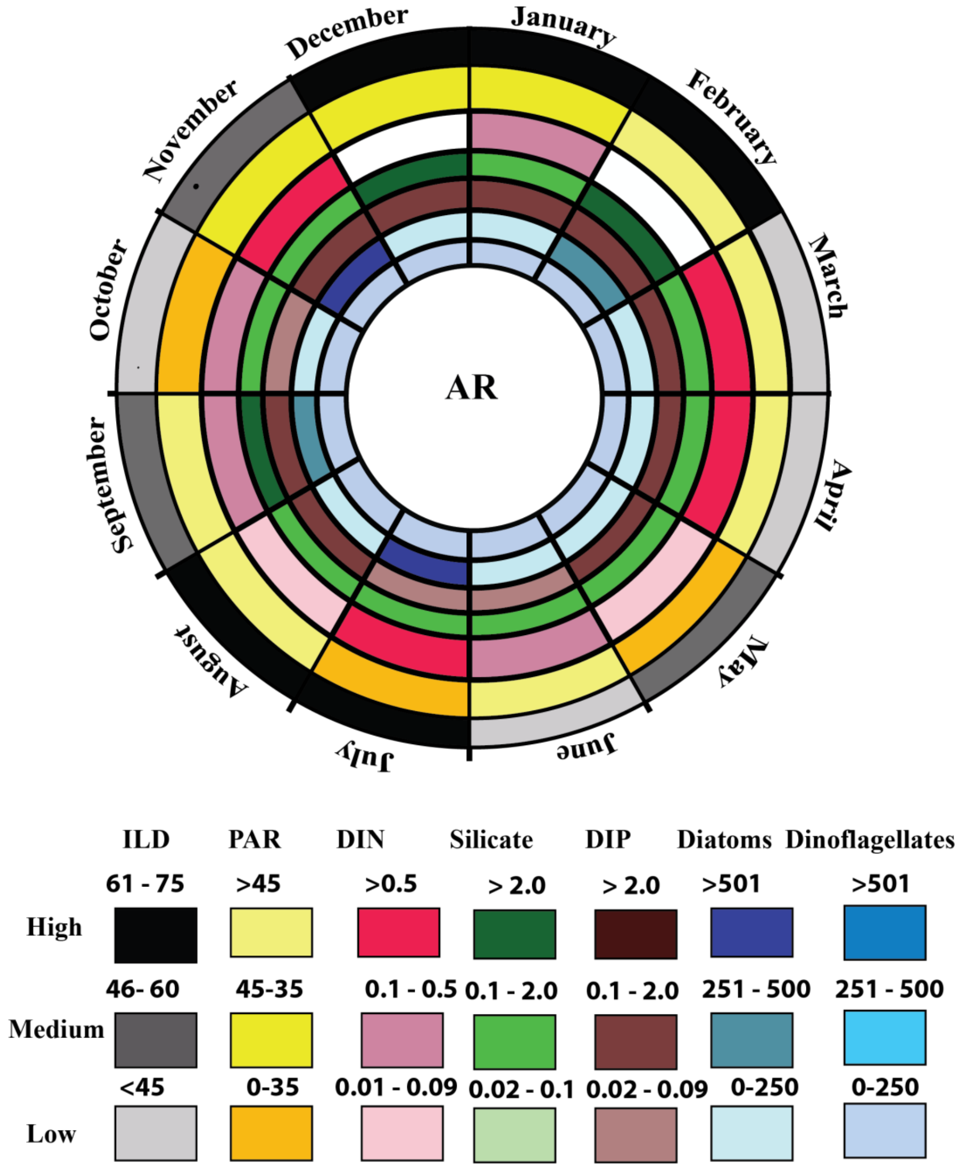
Appendix M continued

A	B	C	D	E	F	G
198	*Tripos gravidus* (Gourret) F.Gómez, 2013	668.8196				
199	*Tripos hexacanthus* (Gourret) F.Gómez, 2013	9.3253	46.7735			

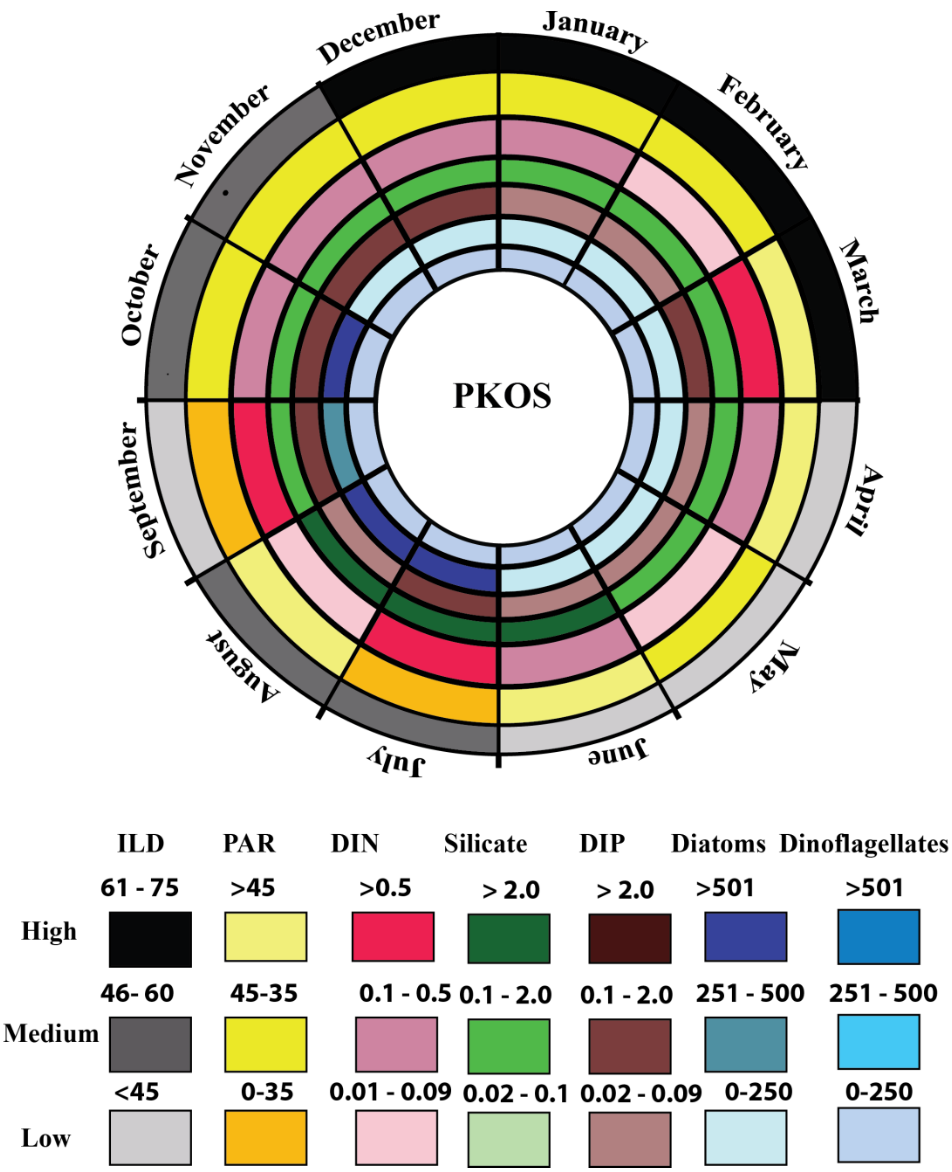
200	*Tripos horridus* (Cleve) F.Gómez, 2013	1.8117	14.4544	8.1211		
201	*Tripos inflatus* (Karsten) F.Gómez, 2013	11.2468	2.3988			
202	*Tripos kofoidii* (Jörgenen) F.Gómez, 2013	0.5568	3.0903		2.0000	
203	*Tripos limulus* (Pouchet) F.Gómez, 2013	3.5883				
204	*Tripos lunula* (Schimper ex Karsten) F.Gómez, 2013	43.2716				
205	*Tripos macroceros* (Ehrenberg) F.Gómez, 2013	3.9073	4.6774	5.0629		
206	*Tripos massiliensis* (Gourret) F.Gómez, 2013	15.5693	15.1356		11.0000	
207	*Tripos massiliensis f.armatus* (Karsten) F.Gómez, 2013	7.0373				
208	*Tripos muelleri* Bory de Saint-Vincent, 1824 *	5.4338	11.2202	10.2700	20.2000	1.2115
209	*Tripos pentagonus* (Gourret) F.Gómez, 2013	4.5960	11.4815			
210	*Tripos platycornis* (Daday) F.Gómez, 2013	54.4047				
211	*Tripos praelongus* (Lemmermann) F.Gómez, 2013	141.9549				
212	*Tripos pulchellus* (Schröder) F.Gómez, 2013	6.5312	8.9125			
213	*Tripos ranipes* (Cleve) F.Gómez, 2013	13.3982			7.2000	
214	*Tripos schrankii* (Kofoid) F.Gómez, 2013	14.2614				
215	*Tripos symmetricus* (Pavillard) F.Gómez, 2013	3.5602			11.7000	
216	*Tripos teres* (Kofoid) F.Gómez, 2013	2.7318	4.5709			
217	*Tripos trichoceros* (Ehrenberg) F.Gómez, 2013	3.4261	2.6915			
218	*Tripos vultur* (Cleve) F.Gómez, 2013	9.4990	11.7490			
219	*Tryblionella compressa* (J.W.Bailey) M.Poulin, 1990	1.5348				



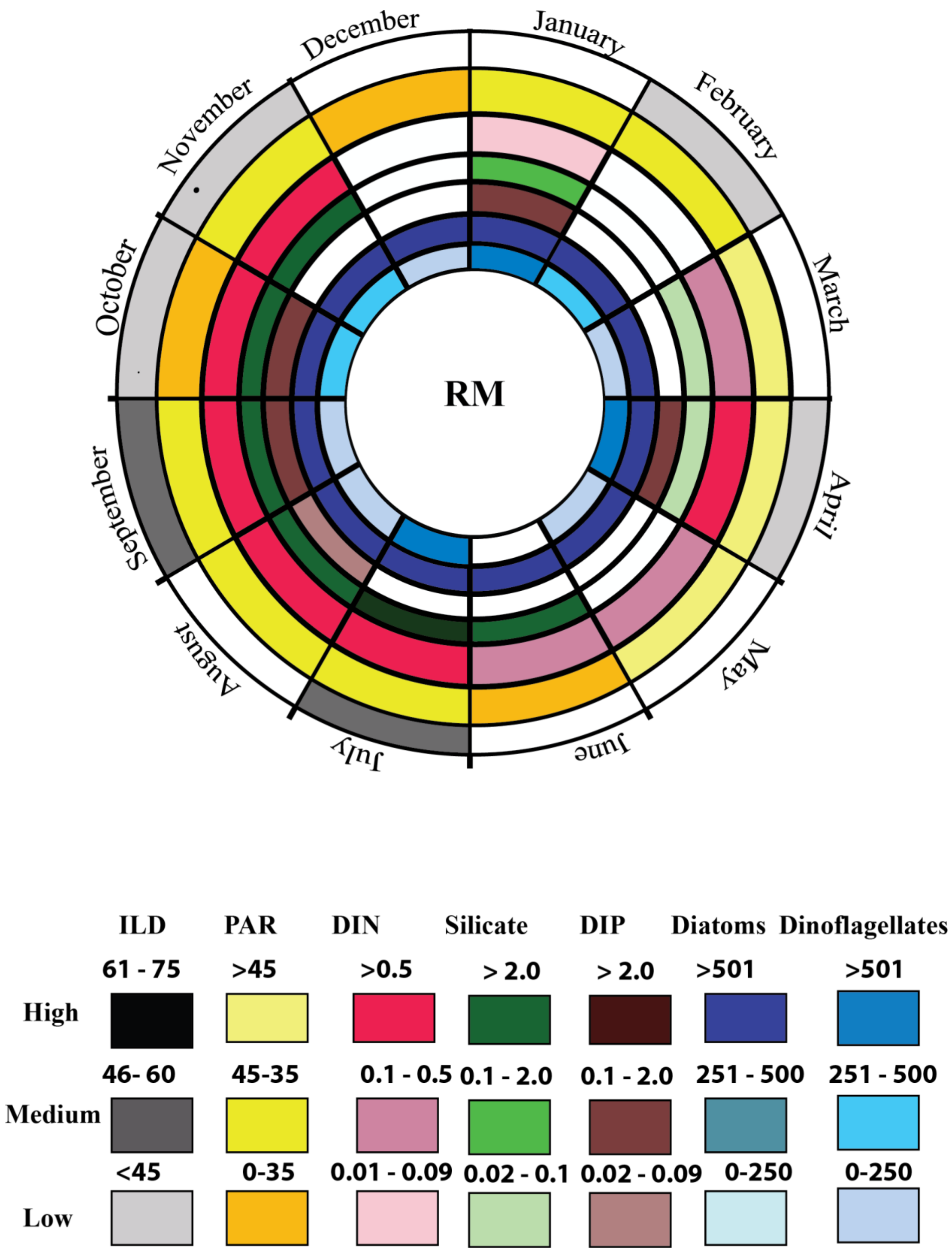
Appendix N. The concentric rings from the outer to the inner portion shows temporal variations in the environmental variables (ILD, PAR, Dissolved Inorganic Nitrogen, Silicate, and Phosphate), and microphytoplankton abundance (diatoms, dinoflagellates) in the CPOS region. The three different colour codes include (box at the base) high medium and low range of variations for each variable. The variations in the physico-chemical parameters and microphytoplankton abundance (diatoms and dinoflagellates) are described based on monthly average values that is provided in **Appendix R**.



Appendix O. The concentric rings from the outer to the inner portion shows temporal variations in the environmental variables (ILD, PAR, Dissolved Inorganic Nitrogen, Silicate, and Phosphate), and microphytoplankton abundance (diatoms, dinoflagellates) in the Andaman Region (AR). The three different colour codes include (box at the base) high medium and low range of variations for each variable. The variations in the physico-chemical parameters and microphytoplankton abundance (diatoms and dinoflagellates) are described based on monthly average values that is provided in **Appendix R**.



Appendix P. The concentric rings from the outer to the inner portion shows temporal variations in the environmental variables (ILD, PAR, Dissolved Inorganic Nitrogen, Silicate, and Phosphate), and microphytoplankton abundance (diatoms, dinoflagellates) in the PKOS. The three different colour codes include (box at the base) high medium and low range of variations for each variable. The variations in the physico-chemical parameters and microphytoplankton abundance (diatoms and dinoflagellates) are described based on monthly average values that is provided in **Appendix R**.



Appendix Q. The concentric rings from the outer to the inner portion shows temporal variations in the environmental variables (ILD, PAR, Dissolved Inorganic Nitrogen, Silicate, and Phosphate), and microphytoplankton community (diatoms, dinoflagellates) abundance respectively for the River Mouth region. The three different shaded colour for each variables within the concentric ring denotes high, moderate , and low values and is shown in the square box. The monthly average values of physico-chemical parameters and microphytoplankton community (diatoms and dinoflagellates) based on which the schematic diagram described is provided **Appendix R**.

AAppendix R : Average values of physico-chemical parameters (ILD (meters), PAR (mol quanta m^{-2} /day), DIN (µmol L^{-1}), Silicate(µmol L^{-1}) and DIP(µmol L^{-1})), abundance of Diatoms and Dinoflagellates (cells L^{-1}). The values for respective months (2006 to 2011) was pooled for an average value for four different tracks of Bay of Bengal.

Regions	CPOS							AR						
Parameters	ILD	PAR	DIN	Silicate	DIP	Diatoms	Dinoflagellates	ILD	PAR	DIN	Silicate	DIP	Diatoms	Dinoflagellates
January	73	41	0.31	0.97	0.69	191	54	71	45	0.29	1.96	0.06	156	49
February	80	50	0.63	1.85	0.66	173	64	65	49		2.34		279	73
March	40	49	0.97	0.04	0.17	1783	77	35	52	0.57	0.61	0.03	95	61
April	35	51	0.48	0.08	0.17	42	89	26	47	0.54	0.43	0.12	49	64
May	58	48	0.63	0.60	0.47	130	71	47	10	0.02	0.62	0.09	107	74
June	52	36	0.13	2.08	0.10	132	64	36	51	0.43	1.51	0.07	241	34
July	61	41	0.86	2.20	0.08	212	39	68	17	0.69	1.99	0.12	551	32
August	62	34	0.11	0.54	0.37	499	48	61	55	0.07	1.29	0.09	181	162
September	56	49	0.69	2.11	0.61	147	84	55	48	0.32	2.21	3.32	286	36
October	49	45	0.36	1.35	0.06	214	63	34	33	0.32	1.31	0.53	158	123
November	53	34	0.70	1.14	0.28	201	102	52	44	0.55	0.96	0.08	616	65
December	67	32	1.50	1.78	0.50	85	36	64	41		2.76	0.09	57	20

Appendix R Continued

Regions	PKOS							RM						
Parameters	ILD	PAR	DIN	Silicate	DIP	Diatoms	Dinoflagellates	ILD	PAR	DIN	Silicate	DIP	Diatoms	Dinoflagellates
January	77	41	0.26	1.30	0.07	101	74		36	0.026	1.53	0.12	41931	555
February	67.	37	0.06	1.99	0.02	100	85	43	43				2925	372
March	65	48	0.70	0.39	0.20	146	68		46	0.47	0.06		19145	204
April	39	52	0.29	1.29	0.07	226	97	32	51	1.16	0.05	0.24	3943	527
May	24	38	0.07	0.45	0.08	135	65		54	0.29			290	243
June	38	50	0.18	2.46	0.09	94	64		28	0.22	2.43			
July	51	35	0.59	2.55	0.11	892	49	47	41	1.37	3.19		8098	797
August	45	49	0.10	2.08	0.06	1640	115		37	0.52	2.67	0.09	5355	225
September	39	34	0.79	1.59	0.8	462	52	50.5	36	0.79	2.63	0.43	1514	169
October	45	36	0.36	0.58	0.25	5670	78	33	30	1.34	2.06	0.1	92635	312
November	53	38	0.40	0.88	0.11	204	90	37	38	0.71	5.11		23778	463
December	80	38	0.16	1.84	0.24	38	13		34				880	20

Appendix S: Spatial variations of diatom and dinoflagellate taxa encountered during early winter. Colum 1, 2 denotes trophic strategies (T)of diatoms, dinoflagellates and species list. Column A1 to C2 denotes microphytoplankton taxa (Diatoms, Dinoflagellates and Dictyoca) encountered at different depths during Early winter (Warmer Portion (WP) - A1 to A3, Filament (CF1) - B1 to B3 and Fronts - (C1 to C2), (A1 - 0-25 m, A2 – 26-50 m, A3 – 51-100 m, B1 – 0-25 m, B2 – 26 – 50 m, B3 – 51-100 m, , C1 – 0-25 m, C2 – 51 – 100 m respectively.

T	Diatoms	A1 0-25	A2 26-50	A3 51-100	B1 0-25	B2 26-50	B3 51-100	C1 0-25	C2 51-100
P	*Actinoptychus senarius* Ehrenberg, 1843								
P	*Asterolampra marylandica* Ehrenberg, 1844								
P	*Asterolampra* spp.		1 (10)						
P	*Asteromphalus* spp.					1 (10)			1 (10)
P	*Bacteriastrum furcatum* Shadbolt, 1854								
P	*Bacteriastrum hyalinum* Lauder, 1864								
P	*Bacteriastrum* spp.	4(10-20)	2 (10-20)	3 (10)	3 (20 - 30)	2 (20-40)	2 (10)	1 (10)	4 (10)
P	*Cerataulina pelagica* (Cleve) Hendey, 1937								
P	*Chaetoceros affinis* Lauder, 1864								
P	*Chaetoceros costatus* Pavillard, 1911								
P	*Chaetoceros coarctatus* Lauder, 1864								
P	*Chaetoceros compressus* Lauder, 1864	3(20 - 120)	1 (70)	1 (100)					
P	*Chaetoceros concavicornis* Mangin, 1917								
P	*Chaetoceros convolutus* Castracane, 1886								
P	*Chaetoceros curvisetus* Cleve, 1889								
P	*Chaetoceros danicus* Cleve, 1889								
P	*Chaetoceros decipiens* Cleve, 1873								
P	*Chaetoceros didymus* Ehrenberg, 1845								
P	*Chaetoceros diadema* (Ehrenberg) Gran, 1897								
P	*Chaetoceros dichaeta* Ehrenberg, 1844								
P	*Chaetoceros diversus* Cleve, 1873								
P	*Chaetoceros eibenii* Grunow, 1882	1(10)							
P	*Chaetoceros laciniosus* F.Schütt, 1895								
P	*Chaetoceros lauderi* Ralfs, 1864								

		A1	A2	A3	B1	B2	B3	C1	C2
P	*Chaetoceros lorenzianus* Grunow, 1863								
P	*Chaetoceros messanensis* Castracane, 1875	3(10 - 120)		1 (20)					

Appendix S continued

		A1 0-25	A2 26-50	A3 51-100	B1 0-25	B2 26-50	B3 51-100	C1 0-25	C2 51-100
P	*Chaetoceros peruvianus* Brightwell, 1856	1(10)							
P	*Chaetoceros pseudocurvisetus* Mangin, 1910								
P	*Chaetoceros socialis* H.S.Lauder, 1864								
P	*Chaetoceros teres* Cleve, 1896								
P	*Chaetoceros* spp.	11(10 - 110)	8 (10-320)	11 (10 -210)	6 (180 - 1780)	2 (20-1270)	1 (20)	1 (20)	3 (10 - 20)
P	*Climacodium frauenfeldianum* Grunow, 1868	11(20 - 120)	2 (20-140)	2 (70 - 90)	6 (20 - 80)	1 (40)	1 (20)	1 (60)	
P	*Corethron hystrix* Hensen, 1887								
P	*Corethron* sp.				1 (10)				
P	*Coscinodiscus oculus-iridis* Ehrenberg, 1840								
P	*Coscinodiscus gigas* Ehrenberg, 1841	1(10)							
P	*Coscinodiscus granii* Gough, 1905								
P	*Coscinodiscus johneius*								
P	*Coscinodiscus marginatus* Ehrenberg, 1844								
P	*Coscinodiscus radiatus* Ehrenberg, 1840								
P	*Coscinodiscus* spp.		1 (10)						
P	*Coscinodiscus* spp.2	17 (10 - 100)	8 (10-80)	14 (10 - 100)	10 (10-90)	3 (10-60)	5 (10-40)	2 (90 - 180)	4 (30 - 110)
P	*Cyclotella* sp.	1(10)							
P	*Dactyliosolen fragilissimus* (Bergon) Hasle, 1996								
P	*Dactyliosolen* sp?			1 (20)			1 (10)		
P	*Eucampia groenlandica* Cleve, 1896								
P	*Eucampia cornuta* (Cleve) Grunow, 1883								
P	*Eucampia zodiacus* Ehrenberg, 1839								
P	*Guinardia cylindrus* (Cleve) Hasle, 1996	4(10-50)	1 (20)	1 (20)	2 (20-60)				
P	*Guinardia delicatula* (Cleve) Hasle, 1997								

P	*Guinardia flacida* (H.Peragallo, 1892								
P	*Guinardia striata* (Stolterfoth) Hasle, 1996	5(10-40)	1 (20)						
P	*Guinardia* sp.	1(820)	1 (10)	1 (220)					
P	*Helicotheca tamesis* (Shrubsole) M.Ricard, 1987								
P	*Hemiaulus hauckii* Grunow ex Van Heurck, 1882	4(10)	1 (10)	2 (10 - 20)	2 (10-20)				

Appendix S continued

		A1 0-25	A2 26-50	A3 51-100	B1 0-25	B2 26-50	B3 51-100	C1 0-25	C2 51-100
P	*Hemiaulus indicus* Karsten, 1907								
P	*Hemiaulus membranaceus* Cleve	7(10)	2 (20 - 40)	1 (10)					1 (10)
P	*Hemidiscus cuneiformis* Wallich, 1860								
P	*Hemidiscus* sp.							1 (10)	
P	*Leptocylindrus danicus* Cleve, 1889								
P	*Leptocylindrus* sp.	2(20)		3 (10-20)					
P	*Odontella aurita* (Lyngbye) C.Agardh, 1832								
P	*Trieres mobiliensis* Ashworth & Theriot, 2013								
P	*Odontella sinensis* (Greville) Grunow, 1884								
P	*Planktoniella sol* (C.G.Wallich) Schütt, 1892								
P	*Proboscia alata* (Brightwell) Sundström, 1986								
P	*Pseudoguinardia recta* von Stosch, 1986								
P	*Pseudosolenia calcar-avis* B.G.Sundström, 1986								
P	*Rhizosolenia alata* f. *indica*								
P	*Rhizosolenia alata* f. *semispina*								
P	*Rhizosolenia bergonii* H.Peragallo, 1892								
P	*Rhizosolenia castracanei* H.Peragallo, 1888								
P	*Rhizosolenia clevei*	1(10)							
P	*Rhizosolenia crassa* Schimper, 1905								
P	*Rhizosolenia hyalina* Ostenfeld, 1901								
P	*Rhizosolenia decipiens* B.G.Sundström, 1986								
P	*Rhizosolenia formosa* H.Peragallo, 1888	1(10)							

P	*Rhizosolenia hebetata* forma *semispina*
P	*Rhizosolenia imbricata* Brightwell, 1858
P	*Neocalyptrella robusta*
P	*Rhizosolenia setigera* Brightwell, 1858
P	*Rhizosolenia stolterfortii*
P	*Rhizosolenia striata* Greville, 1864
P	*Rhizosolenia styliformis* T.Brightwell, 1858

Appendix S continued

		A1 0-25	A2 26-50	A3 51-100	B1 0-25	B2 26-50	B3 51-100	C1 0-25	C2 51-100
P	*Rhizosolenia* spp.	5(10 - 260)	8 (20 - 220)	9 (10 - 50)	8 (10-420)	2 (10-110)	1 (10)		3 (10 - 20)
P	*Skeletonema costatum* (Greville) Cleve, 1873			1 (10)					
P	*Skeletonema* sp			1 (40)					
P	*Stephanopyxis* sp.								
P	*Thalassiosira angulata* (W.Gregory) Hasle, 1978								
P	*Thalassiosira eccentrica* (Ehrenberg) Cleve, 1904								
P	*Thalassiosira gravida* Cleve, 1896								
P	*Thalassiosira punctigera* (Castracane) Hasle, 1983								
P	*Thalassiosira* spp.	6(10)	4 (10 - 20)	4 (10 - 40)	4 (10-40)	1 (20)		3 (10 - 20)	3 (10 - 50)
P	*Achnanthes* sp.								
P	*Amphiprora* spp.								2 (10 - 10)
P	*Asterionellopsis* sp?	1(20)						1 (20)	
P	*Cylindrotheca closterium* J.C.Lewin, 1964								
P	*Diploneis crabro* (Ehrenberg) Ehrenberg, 1854								
P	*Diploneis lenticula*								
P	*Diploneis* sp.								

P	*Fragilariopsis cylindrus* (Grunow) Krieger, 1954								
P	*Fragilariopsis oceanica* (Cleve) Hasle, 1965				2 (50 - 180)				
P	*Fragilariopsis doliolus* Medlin & P.A.Sims, 1993	4(40 - 130)	3 (20 - 50)	1 (30)	3 (40 - 1600)	2 (50-200)		1 (100)	
P	*Fragilariopsis* spp.	1(40)							
P	*Grammatophora undulata* Ehrenberg								
P	*Haslea trompii* (Cleve) Simonsen, 1974								
P	*Haslea wawrikae* (Hustedt) Simonsen, 1974								
P	*Haslea* spp.								
P	*Lioloma elongatum*								

Appendix S continued

		A1 0-25	A2 26-50	A3 51-100	B1 0-25	B2 26-50	B3 51-100	C1 0-25	C2 51-100
P	*Lioloma pacificum*								
P	*Lioloma* sp.	1(10)							
P	*Meuniera membranacea*	1(40)	1 (40)		1 (10)				
P	*Navicula septantronalis*								
P	*Navicula* spp.	23 (20 - 2280)	11 (10 - 540)	13 (10 - 200)	9 (20 - 480)	3 (30-490)	5 (20-90)	3 (10 - 320)	6 (10 - 280)
P	*Nitzschia longisima*								
P	*Nitzschia* spp.								
P	*Pleurosigma naviculaceae*								
P	*Pleurosigma angulatum* W.Smith, 1852								
P	*Pleurosigma directum* Grunow, 1880								
P	*Pleurosigma elongatum* W.Smith, 1852								
P	*Pleurosigma normanii* Ralfs, 1861								
P	*Pleurosigma* spp.	1(10)	1 (10)	1 (10)	2 (10)		1 (10)	1 (10)	
P	*Pseudonitzschia delicatissima* Heiden, 1928								
P	*Pseudonitzschia fraudulenta* (Cleve) Hasle, 1993								

P	*Pseudonitzschia pungens*								
P	*Pseudonitzschia lineola*								
P	*Pseudonitzschia seriata* H.Peragallo, 1899								
P	*Pseudonitzschia* spp.	21 (10 - 780)	12 (10 - 360)	9 (10 - 160)	10 (30-3760)	3 (10-410)	2 (10-20)	3 (110 - 380)	5 (40 - 120)
P	*Surirella ovata*								
P	*Thalassionema bacillare* (Heiden) Kolbe, 1955	1(30)		1 (40)				2 (20 - 150)	1 (10 - 10)
P	*Thalassionema frauenfeldii* Peragallo, 1910								
P	*Thalassionema nitzschioides* Mereschkowsky, 1902								
P	*Thalassionema* sp.	11 (10 - 200)	3 (20 -180)	8 (10 - 70)	9 (10-100)	1 (40)	2 (10)		3 (10 - 20)
P	*Thalassiothrix longissima* Cleve & Grunow, 1880								
P	*Thalassiothrix franfundii*								

Appendix S continued

		A1 0-25	A2 26-50	A3 51-100	B1 0-25	B2 26-50	B3 51-100	C1 0-25	C2 51-100
P	*Thalassiothrix* sp.								
P	*Triceratium fauvas* Ehrenberg, 1839								
	Unidentified centric diatom								
	Unidentified pennate Diatom								
	Unidentified spp.			1 (20)	1 (60)				
M	*Alexandrium affine* Balech, 1995								
M	*Alexandrium catenella* Balech, 1985								
M	*Alexandrium minutum* Halim, 1960								
M	*Alexandrium tamerense* (Balech, 1995								
M	*Alexandrium* spp. Halim, 1960		3 (10)						
M	*Amphidinium* sp. Claparède & Lachmann, 1859	8(10-20)	6 (10 - 60)	4 (10 - 20)	4 (10-20)			1 (10)	
M	*Amphidoma* sp.								
M	*Amphesolenia bidentata* Schröder, 1900	2 (10)	1 (20)		3 (10-20)				

M	*Amphisolenia globifera* Stein, 1883								
M	*Amphisolenia* spp.	2(20)		1 (1010		1 (10)			
M	*Balechina coerulea* (Dogiel) F.J.R.Taylor, 1976								
M	*Blepharocysta denticulata* Nie, 1939		2 (10)						
M	*Ceratocorys horrida* Stein, 1883	2(10)	1 (10)						
M	*Ceratocorys reticulata* H.W.Graham, 1942								
M	*Corythodinium constrictum* F.J.R.Taylor, 1976								
M	*Corythodinium tesselatum* Loeblich III, 1966	1(10)	2 (10)			1 (10)			
M	*Corythodinium* sp.		1 (20)						
M	*Pyrocystis lunula* (Schütt) Schütt, 1896								
M	*Ensiculifera* sp. Balech, 1967				2 (10)				
M	*Triadinium polyedricum* (Pouchet) Dodge, 1981								
M	*Goniodoma sphaericum* Murray & Whitting, 1899								
M	*Gonyaulax minuta* Kofoid & Michener, 1911								
M	*Gonyaulax polygramma* Stein, 1883								
M	*Gonyaulax scrippsae* Kofoid, 1911		1 (10)		1 (10)				
M	*Gonyaulax ceratocoroides* Kofoid, 1910	1(10)							

Appendix S continued

		A1 0-25	A2 26-50	A3 51-100	B1 0-25	B2 26-50	B3 51-100	C1 0-25	C2 51-100
M	*Gonyaulax* sp	1(10)		1 (10)	2 (10-20)	1 (10)			
M	*Gotoius abei* K.Matsuoka, 1988								
M	*Gymnodinium catenatum* H.W.Graham, 1943								
M	*Karenia mikimotoi* Ø.Moestrup, 2000								
M	*Gymnodinium* sp.								
M	*Gymnodium* spp.								
M	*Heterocapsa niei* Morrill & Loeblich III, 1981								
M	*Heterocapsa* sp.	2(10)							
M	*Heterodinium* sphaeroideum Kofoid, 1906								
M	*Heterodinium milneri* Kofoid, 1906								

M	*Heterodinium* sps								
M	*Protoperidinium diabolum* Balech, 1974								
M	*Hetaraulacus* spp.								
M	*Lingulodinium polyedrum* (F.Stein) J.D.Dodge, 1989								1 (10 - 10)
M	*Oxytoxum parvum* Schiller, 1937								
M	*Oxytoxum laticeps* Schiller, 1937								
M	*Oxytoxum scolopax* Stein, 1883	3(10)			2 (10)				1 (20 - 20)
M	*Oxytoxum* sp	1(10)			1 (10)		1 (10)		
M	*Phalacroma rotundatum* Kofoid & Michener, 1911								
M	*Podolampas bipes* var. *reticulata* (Kofoid) Taylor		1 (10)						
M	*Podolampas palmipes* Stein, 1883		1 (20)	3 (10)	2 (10-20)				
M	*Podolampas spinifera* Okamura, 1912	1(10)							1 (10)
M	*Podolampas* spp.								
M	*Pyrophacus steinii* (Schiller) Wall & Dale, 1971	1(10)		1 (10)					
M	*Phytodiscus noctulica*								
M	*Tripos arietinus* (Cleve) F.Gómez, 2013								
M	*Tripos azoricus* (Cleve) F.Gómez, 2013								
M	*Tripos balechii* F.Gómez, 2013								
		A1 0-25	A2 26-50	A3 51-100	B1 0-25	B2 26-50	B3 51-100	C1 0-25	C2 51-100
M	*Tripos coarctus* (Pavillard) F.Gómez, 2013								
M	*Tripos boehmii* F.Gómez, 2013								
M	*Tripos bumile*								
M	*Tripos candelabrus*								
M	*Tripos carriensis* (Gourret) F.Gómez, 2013								
M	*Tripos belone* (Cleve) F.Gómez, 2013								
M	*Tripos bigelowii* (Kofoid) F.Gómez, 2013								
M	*Tripos contrarius* (Gourret) F.Gómez, 2013								
M	*Tripos contortus* (Gourret) F.Gómez, 2013								

M	*Tripos concilians* (Jørgenen) F.Gómez, 2013								
M	*Tripos declinatus* (G.Karsten) F.Gómez, 2013	2(10)							
M	*Tripos deflexus* (Kofoid) F.Gómez, 2014								
M	*Tripos extensus* (Gourret) F.Gómez, 2013								
M	*Tripos furca* (Ehrenberg) F.Gómez, 2013	3(10)			1 (10)			1 (20)	
M	*Ceratium furca* var *eugammus*								
M	*Tripos fusus* (Ehrenberg) F.Gómez, 2013	5(10)	4 (10-20)		1 (20)			1 (10)	
M	*Tripos falcatus* (Kofoid) F.Gómez, 2013								
M	*Tripos horridus* (Cleve) F.Gómez, 2013	2(10)	1 (10)	1 (10)					
M	*Tripos horridus molle*								
M	*Tripos horridum* var. beuceus								
M	*Tripos gibberus* (Gourret) F.Gómez, 1883								
M	*Tripos gravidus* (Gourret) F.Gómez, 2013								
M	*Tripos geniculatus* (Lemmermann) F.Gómez, 2013		1 (10)						
M	*Tripos hexacanthus* (Gourret) F.Gómez, 2013								
M	*Tripos inflatus* (Karsten) F.Gómez, 2013								
M	*Tripos karstenii* (Pavillard) F.Gómez, 1907								
M	*Ceratium karstenii* var *saltans*								
M	Tripos kofoidii (Jörgenen) F.Gómez, 2013	1(20)		1 (10)					
M	*Tripos linflatus*								
M	*Tripos lineatus* (Ehrenberg) F.Gómez, 2013	3(10)	2 (20)		2 (10)	1 (10)		1 (20)	
M	*Tripos longirostrus* (Gourret) F.Gómez, 2013								

Appendix S continued

		A1 0-25	A2 26-50	A3 51-100	B1 0-25	B2 26-50	B3 51-100	C1 0-25	C2 51-100
M	*Tripos lunula* (Schimper ex Karsten) F.Gómez, 2013								
M	*Tripos macroceros* (Ehrenberg) F.Gómez, 2013				1 (10)				
M	*Tripos minutus* (Jörgensen) F.Gómez, 2013								
M	*Tripos pentagonus* (Gourret) F.Gómez, 2013	2(10)							
M	*Tripos platycornis* (Daday) F.Gómez, 2013			1 (10)					

M	*Tripos praelongus* (Lemmermann) Gómez, 2013								
M	*Tripos pulchellus* (Schröder) F.Gómez, 2013								
M	*Tripos schrankii* (Kofoid) F.Gómez, 2013								
M	*Tripos symmetricus* (Pavillard) F.Gómez, 2013								
M	*Tripos schoeteri* (Schröder) F.Gómez, 2013								
M	*Tripos teres*								
M	*Tripos trichoceros* (Ehrenberg) Gómez, 2013								
M	*Tripos muelleri* Bory de Saint-Vincent, 1824								
M	*Tripos muelleri* var bumile								
M	*Tripos muelleri* var atlanticum								
M	*Tripos vultur* (Cleve) F.Gómez, 2013								
M	*Tripos massiliensis* (Gourret) F.Gómez, 2013								
M	*Tripos ranipes* (Cleve) F.Gómez, 2013								
M	*Tripos* spp.	1(20)		1 (10)	1 (20)	1 (40)		2 (10 - 20)	
M	*Dinophysis apicata* (Kofoid & Skogsberg) Abé								
M	*Dinophysis acuta* Ehrenberg, 1839	1(10)							
M	*Dinophysis argus* (Stein) Abé								
M	*Dinophysis caudata* Saville-Kent, 1881	4(10)							
M	*Dinophysis exigua* Kofoid & Skogsberg, 1928								
M	*Dinophysis hastata* Stein, 1883								
M	*Dinophysis infundibulum* J. Schiller, 1928								
M	*Dinophysis miles* Cleve, 1900								
M	*Dinophysis parvula* (Schütt) Balech, 1967								
M	*Dinophysis fortii* Pavillard, 1923								
M	*Dinophysis schuettii* Murray & Whitting, 1899								

Appendix S continued

	A1	A2	A3	B1	B2	B3	C1	C2
	0-25	26-50	51-100	0-25	26-50	51-100	0-25	51-100

Appendix S continued

		A1	A2	A3	B1	B2	B3	C1	C2
M	*Dinophysis* spp.	4(10)	2 (10-20)	1 (10)		3 (10)			2 (10)
M	*Prorocentrum belizeanum* M.A.Faust, 1993								
M	*Prorocentrum dentatum* Stein, 1883								
M	*Tryblionella compressa* M.Poulin, 1990								
M	*Prorocentrum cordatum* J.D.Dodge, 1975								
M	*Prorocentrum gracile* Schütt, 1895		1 (10)		1 (10)				
M	*Prorocentrum micans* Ehrenberg, 1834	1(10)							
M	*Prorocentrum obtusum* Ostenfeld, 1908								
M	*Prorocentrum rhytatum*								
M	*Prorocentrum* sp	1(40)		1 (10)			2 (10)		
M	*Pyrocystis barnulus*								
M	*Pyrocystis fusiformis* C.W.Thomson, 1876								
M	*Pyrocystis hamulus*								
M	*Pyrocystis lunula* (Schütt) Schütt, 1896	1(10)	1 (10)						
M	*Pyrocystis pseudo-noctiluca* Wyville-Thompson, 1876								
M	*Pyrocystis robusta* Kofoid, 1907								
M	*Pyrocystis* spp.								
M	*Pyrodinium bahamense* Plate, 1906								
M	*Cochlodinium* sp. Schütt, 1896								
M	*Scrippsiella spinifera* G.Honsell & M.Cabrini, 1991								
M	*Scrippsiella trochoidea* Loeblich III, 1976 *	8(10-30)	4 (10-40)	5 (10)	5 (10-40)	2 (10-20)			1 (10)
H	*Citharistes regius* Stein, 1883								
H	*Preperidinium meunieri* Elbrächter, 1993								
H	*Gyrodinium* spp. Kofoid & Swezy, 1921	8(10-30)	5 (10 - 30)		3 (10-60)		1 (10)		2 (10)
H	*Histioneis carinata* Kofoid, 1907								
H	*Histioneis hyalina* Kofoid & Michener, 1911		1 (10)						
H	*Histioneis biremis* Stein, 1883								
H	*Histiones* spp.	1(10)		1 (10)	1 (10)				

		0-25	26-50	51-100	0-25	26-50	51-100	0-25	51-100
H	*Phytodiscus Noctulica*								
H	*Metaphalacroma skogsbergii* L.-S.Tai, 1934								
H	*Noctiluca scintillans* Kofoid & Swezy, 1921 *								
H	*Ornithocercus formosus* Kofoid & Michener, 1911								
H	*Ornithocercus magnificus* Stein, 1883								
H	*Ornithocercus quadratus* Schütt, 1900								
H	*Ornithocercus steinii* Schütt, 1900								
H	*Ornithocercus thumii* Kofoid & Skogsberg, 1928								
H	*Ornithocercus* spp.	1(10)							
H	*Dinophysis argus* (Stein) Abé								
H	*Phalacroma cuneus* F.Schütt, 1895								
H	*Phalacroma doryphorum* Stein, 1883								
H	*Phalacroma favus* Kofoid & Michener, 1911								
H	*Phalacroma* mitra F.Schütt, 1895								
H	*Phalacroma* rapa Jorgensen, 1923								
H	*Phalacroma rotundatum* Kofoid & Michener, 1911								
H	*Phalacroma* spp.	10-20		1 (10)	1 (10)				
H	*Pronoctiluca pelagica* Fabre-Domergue, 1889								
H	*Protoperidinium asymmetricum* Balech, 1974								
H	*Protoperidinium abei* (Paulsen, 1931) Balech, 1974								
H	*Protoperidinium acutipes* Balech, 1974								
H	*Protoperidinium biconicum* Balech, 1974								
H	*Protoperidinium brevipes* Balech, 1974								
H	*Protoperidinium conicoides* Balech, 1974								
H	*Protoperidinium crassipes* Balech, 1974								
H	*Protoperidinium crassum* Balech, 1971								
H	*Protoperidinium curvipes* Balech, 1974								
H	*Protoperidinium depressum* Balech, 1974								
H	*Protoperidinium diabolum* Balech, 1974								

H	*Protoperidinium divergens* Balech, 1974	1(10)							

Appendix S continued

		A1 0-25	A2 26-50	A3 51-100	B1 0-25	B2 26-50	B3 51-100	C1 0-25	C2 51-100
H	*Protoperidinium elegans* Balech, 1974		1 (10)						
H	*Protoperidinium heteracanthum* Balech, 1974								
H	*Protoperidinium inflatum* Balech, 1974								
H	*Protoperidinium latispinum* Balech, 1974								
H	*Protoperidinium leonis* Balech, 1974								
H	*Protoperidinium longicollum* Pavillard, 1916								
H	*Archaeperidinium minutum* Jørgensen, 1912								
H	*Protoperidinium minutissimum* Balech, 1974								
H	*Protoperidinium oblongum* Parke & Dodge, 1976								
H	*Protoperidinium oceanicum* Balech, 1974								
H	*Protoperidinium oviforme* Balech, 1974								
H	*Protoperidinium ovatum* Pouchet, 1883								
H	*Protoperidinium pacificum* ex Balech, 1988								
H	*Protoperidinium pallidum* Balech, 1973								
H	*Protoperidinium pedunculatum* Balech, 1974								
H	*Protoperidinium pellucidum*								
H	*Protoperidinium pentagonum* Balech, 1974							1 (20)	
H	*Protoperidinium pyriforme* Balech, 1974								
H	*Protoperidinium quinquecorne* Balech, 1974								
H	*Protoperidinium sphaericum* Balech, 1974								
H	*Protoperidinium steinii* Balech, 1974								
H	*Protoperidinium subinerme* Loeblich III, 1969								
H	*Protoperidinium tristylum* Balech, 1974								
H	*Protoperidinium tuba* (Schiller) Balech, 1974								
H	*Protoperidinium* sp.	10 - 100	9 (10 - 160)	13 (10 - 90)	10 (10-240)	5 (10-80)	4 (10-30)	3 (50 - 140)	6 (20 - 40)

H *Preperidinium meunieri* Elbrächter, 1993
Dictyoca sp.
Dictyocha fibula

APPENDIX T: Spatial variations of diatom and dinoflagellate taxa encountered during peak winter. Colum 1 denotes species list. Column D1 to F2 denotes microphytoplankton taxa (Diatoms, Dinoflagellates and Dictyoca) encountered at different depths during peak winter (Oceanic fronts - D1 to D3, Oceanic Non fronts - E1 to E3, Shelf fronts - (F1 to F2), (D1; 0-25 m, D2 ; 26-50 m, D3 ; 51-100 m, E1 ; 0-25 m, E2 ; 26 – 50 m, E3 ; 51-100 m, F1 ; 0-25 m, F2 ; 26 – 50 m respectively.

	D1 0-25	D2 26-50	D3 51-100	E1 0-25	E2 26-50	E3 51-100	F1 0-25	F2 26-50
Diatoms								
Actinoptychus senarius Ehrenberg, 1843						1(3)		
Asterolampra marylandica Ehrenberg, 1844	3 (20-36)	2 (7 - 100)		5 (7-95)	2 (7)	2(5 -7	7 (3 - 25)	2 (7-20)
Asterolampra spp.								
Asteromphalus spp.				1 (35)		1(3)		
Bacteriastrum furcatum Shadbolt, 1854	15 (10-675)	1 (10)	2 (7-87)	16 (11-960)	3 (6 - 30)	4(9 - 40)		
Bacteriastrum hyalinum Lauder, 1864			1 (7)	4 (13-160)				
Bacteriastrum spp.								
Cerataulina pelagica (Cleve) Hendey, 1937	2 (23-47)			2 (6-23)				
Chaetoceros affinis Lauder, 1864	5 (7-33)	2 (40 - 92)		5 (5 - 90)	1 (9)	2(3 -13)		
Chaetoceros costatus Pavillard, 1911								
Chaetoceros coarctatus Lauder, 1864	13 (7-140)	1 (7)		4 (3 - 24)	2 (10 - 20)	2(10 -20)		
Chaetoceros compressus Lauder, 1864	2 (47 - 150)			4 (20-167)				
Chaetoceros concavicornis Mangin, 1917	1 (225)		1 (23)	2 (200- 210)		1(53)		
Chaetoceros convolutus Castracane, 1886	3 (10-60)	2 (7 - 10)	1 (10)	1 (120)				
Chaetoceros curvisetus Cleve, 1889	5 (133-300)	3 (27 - 80)		8 (13 - 162)	1 (53)	3(2 - 140)		
Chaetoceros danicus Cleve, 1889				3 (30 - 160)				
Chaetoceros decipiens Cleve, 1873	14 (10-600)	1 (8)	1 (17)	11 (29 - 500)	2 (20 - 25)	4(10 - 77)		1 (27))
Chaetoceros didymus Ehrenberg, 1845	10 (10-60)			5 (16 - 120)		2(5 - 20)		
Chaetoceros diadema (Ehrenberg) Gran, 1897				1 (27)				
Chaetoceros dichaeta Ehrenberg, 1844	4 (10-70)			2 (300 - 400)				
Chaetoceros diversus Cleve, 1873	3 (10-20)			6 (3 - 33)				
Chaetoceros eibenii Grunow, 1882								
Chaetoceros laciniosus F.Schütt, 1895	10 (10-825)	3 (30 - 50)		17 (10 - 275)	2 (15 - 17)	2(7 - 23)		
Chaetoceros lauderi Ralfs, 1864				1 (37)				

Chaetoceros lorenzianus Grunow, 1863	13 (10-253)			10 (13 - 135)		1(44)		
Chaetoceros messanensis Castracane, 1875	14 (7 - 350)	5 (8 - 110)	4 (5-40)	12 (3 - 820)	3 (6 - 43)	5(7 - 66)	2 (3 - 13)	2 (33-43)

	D1 0-25	D2 26-50	D3 51-100	E1 0-25	E2 26-50	E3 51-100	F1 0-25	F2 26-50
Chaetoceros peruvianus Brightwell, 1856	10 (3 - 287)	3 (17 - 90)		6 (10 - 400)		2(10 - 20)		
Chaetoceros pseudocurvisetus Mangin, 1910	2 (10-12)			2 (48-153)				
Chaetoceros socialis H.S.Lauder, 1864			1 (10)					
Chaetoceros teres Cleve, 1896								
Chaetoceros spp.	17 (30-3400)	3 (50 - 950)	1 (30)	20 (27-4200)	2 (12 - 25)	1(75)	1 (123)	1 (133)
Climacodium frauenfeldianum Grunow, 1868	20 (84 - 4300)	5 (30 - 1070)	6 (15-284)	24 (47-2160)	3 (12 - 510)	8(17 - 825)	4 (50 - 917)	2 (20-673)
Corethron hystrix Hensen, 1887								
Corethron sp.				1 (20)				
Coscinodiscus oculus-iridis Ehrenberg, 1840								
Coscinodiscus gigas Ehrenberg, 1841								
Coscinodiscus granii Gough, 1905	2 (9-30)			1 (4)			2 (7 - 15)	1 (25)
Coscinodiscus johneius								
Coscinodiscus marginatus Ehrenberg, 1844	1 (3)	2 (10 - 20)	1 (10)	6 (4-90)	2 (17 - 45)	4(3 - 14)	2 (3)	
Coscinodiscus radiatus Ehrenberg, 1840	3 (9 - 60)	1 (30)	1 (7)		2 (3)	2(3 - 10)	2 (3)	1 (205)
Coscinodiscus spp.	3 (7 - 40)	2 (4 -10)	2 (7-10)	2 (15-17)	1 (13)	1(10)	2 (7 - 10)	1 (19)
Coscinodiscus spp.2								
Cyclotella sp.								
Dactyliosolen fragilissimus (Bergon) Hasle, 1996	11 (13 - 280)	3 (40 - 77)	1 (23)	12 (10-500)	1 (43)	2(27 - 190)	4 (7 - 120)	1 (65)
Dactyliosolen sp?								
Eucampia groenlandica Cleve, 1896				1 (3)				
Eucampia cornuta (Cleve) Grunow, 1883				1 (20)				
Eucampia zodiacus Ehrenberg, 1839				2 (20-23)				
Guinardia cylindrus (Cleve) Hasle, 1996	8 (15 - 300)	1 (50)		3 (13-240)			1 (10)	1 (7)
Guinardia delicatula (Cleve) Hasle, 1997	10 (30 - 500)	2 (10 - 23)	1 (10)	6 (12-120)		1(175)	3 (7 - 50)	1 (30)
Guinardia flacida (Castracane) H.Peragallo, 1892	7 (20 - 400)	2 (8 -10)		6 (14-180)	1 (20)	1(40)	1 (7)	

	D1 0-25	D2 26-50	D3 51-100	E1 0-25	E2 26-50	E3 51-100	F1 0-25	F2 26-50
Guinardia striata (Stolterfoth) Hasle, 1996	19 (20 - 2145)	5 (40 - 490)	2 (20-225)	20 (10-975)	2 (35 - 67)	1(50)	3 (70 - 133)	1 (83)
Guinardia sp.				1 (50)				
Helicotheca tamesis (Shrubsole) M.Ricard, 1987	1 (30)						1 (10)	2 (7-13)
Hemiaulus hauckii Grunow ex Van Heurck, 1882	6 (13 - 60)			4 (10-200)	1 (10)			1 (20)
Hemiaulus indicus Karsten, 1907						1(25)		
Hemiaulus membranaceus Cleve				3 (3-113)				
Hemidiscus cuneiformis Wallich, 1860				1 (3)			1 (5)	
Hemidiscus sp.		1 (4)			2 (7 - 15)			
Leptocylindrus danicus Cleve, 1889	4 (53 - 215)	1 (27)		5 (14-225)				
Leptocylindrus sp.								
Odontella aurita (Lyngbye) C.Agardh, 1832							1 (10)	
Trieres mobiliensis Ashworth & Theriot, 2013				2 (3-5)				2 (10-215)
Odontella sinensis (Greville) Grunow, 1884						1(10)	1 (10)	1 (5)
Planktoniella sol (C.G.Wallich) Schütt, 1892	8 (3 - 20)	5 (10 - 24)	3 (3-7)	9 (5-53)	4 (7 - 18)	3(7 - 15)	1 (3)	
Proboscia alata (Brightwell) Sundström, 1986	16 (30 - 490)	3 (30 - 192)		16 (10-700)	2 (57 - 80)	1(23)	1 (40)	1 (13)
Pseudoguinardia recta von Stosch, 1986	4 (3 - 290)			1 (153)				
Pseudosolenia calcar-avis B.G.Sundström, 1986	8 (3 - 345)	2 (30 - 36)		6 (5-40)		1(10)		
Rhizosolenia alata f. *indica*	15 (17 - 390)	3 (3 - 30)	1 (20)	9 (10-160)	1 (17)	1(5)		
Rhizosolenia alata f. *semispina*	3 (33 - 40)	1 (13)						
Rhizosolenia bergonii H.Peragallo, 1892	18 (7 - 80)	4 (20 - 50)	2 (7)	11 (3-60)		3(3 - 24)		1 (7)
Rhizosolenia castracanei H.Peragallo, 1888	4 (7 - 13)					1(7)		
Rhizosolenia clevei								
Rhizosolenia crassa Schimper, 1905	6 (7 - 180)			10 (18- 660)	1 (40)	1(102)	1 (27)	
Rhizosolenia hyalina Ostenfeld, 1901	12 (10 - 130)	2 (10 - 20)	1 (7)	5 (13-43)	3 (6 - 20)	3(5 - 60)	1 (7)	
Rhizosolenia decipiens B.G.Sundström, 1986								
Rhizosolenia formosa H.Peragallo, 1888								
Rhizosolenia hebetata forma *semispina*	13 (10 - 250)	2 (48 - 350)		14 (9-700)	1 (25)	2(13 - 145	1 (27)	
Rhizosolenia imbricata Brightwell, 1858	18 (27 - 300)	3 (30 - 36)	1 (10)	15 (6-480)	2 (23 - 150)	3(3 - 100		1 (73)

Neocalyptrella robusta						1(3)		
Rhizosolenia setigera Brightwell, 1858	7 (7 - 60)		1 (7)	4 (5-60)				
Rhizosolenia stolterfortii				1 (73)				
Rhizosolenia striata Greville, 1864			1 (10)	1 (37)		1(150)		1 (10)
Rhizosolenia styliformis T.Brightwell, 1858	3 (7 - 60)			1 (40)		3(10 - 100		
Rhizosolenia spp.	2 (90 - 100)			2 (17-100)			1 (15)	1 (27)
Skeletonema costatum (Greville) Cleve, 1873				1 (80)				
Skeletonema sp								
Stephanopyxis sp.	1 (30)			1 (10)				

	D1 0-25	D2 26-50	D3 51-100	E1 0-25	E2 26-50	E3 51-100	F1 0-25	F2 26-50
Thalassiosira angulata (W.Gregory) Hasle, 1978								
Thalassiosira eccentrica (Ehrenberg) Cleve, 1904	2 (3 - 12)	2 (43)		7 (3-68)	2 (10 - 33)	2(5 - 25	1 (20)	
Thalassiosira gravida Cleve, 1896							2 (17 - 87)	1 (9)
Thalassiosira punctigera (Castracane) Hasle, 1983	3 (10 - 30)	1 (30)	2 (3-7)	4 (7-33)		2(10 - 25	1 (30)	2 (10-80)
Thalassiosira spp.	11 (5 - 360)	2 (7 - 8)	2 (7-13)	10 (3-240)	1 (25))	4(3 - 21	4 (3 - 35)	2 (20-80)
Achnanthes sp.	1 (7)					1(15)		
Amphiprora spp.							1 (15)	
Asterionellopsis sp?								
Cylindrotheca closterium Reimann & J.C.Lewin, 1964	6 (10 - 2380)			2 (9-133)				
Diploneis crabro (Ehrenberg) Ehrenberg, 1854							1 (15)	
Diploneis lenticula				1 (12)				
Diploneis sp.								
Fragilariopsis cylindrus (Grunow) Krieger, 1954	4 (3)	1 (47)	2 (15-43)	3 (16-380)	3 (9 - 60)		1 (40)	
Fragilariopsis oceanica (Cleve) Hasle, 1965				1 (54)				
Fragilariopsis doliolus Medlin & P.A.Sims, 1993	1 (17)		2 (20-53)					
Fragilariopsis spp.								
Grammatophora undulata Ehrenberg								
Haslea trompii (Cleve) Simonsen, 1974	5 (3 - 70)	1 (7)	1 (7)	3 (4-13)	2 (5 - 7)	2(3 - 23		

Haslea wawrikae (Hustedt) Simonsen, 1974	4 (7 -30	1 (7)		7 (3-13)		3(3 -21		
Haslea spp.	1 (13)	2 (7 - 23)	3 (3-14)	2 (4-7)	3 (7 - 10)	2(3 -27		2 (7-10)
Lioloma elongatum								
Lioloma pacificum	14 (7 - 300)	3 (30 - 140)	1 (7)	8 (7-59)	1 (20))	3(7 - 35		
Lioloma sp.								
Meuniera membranacea	12 (11 - 230)	3 (17 - 260)		10 (10-267)	1 (20)			
Navicula septantronalis								
Navicula spp.	8 (9 - 627)	1 (10)		5 (9-165)	1 (10)	1(10)	2 (10 -)	1 (7)
Nitzschia longisima				1 (20)				
Nitzschia spp.								
Pleurosigma naviculaceae								
Pleurosigma angulatum (Queckett) W.Smith, 1852	1 (18)	1 (3)					2 (10 -)	1 (53)

	D1	D2	D3	E1	E2	E3	F1	F2
	0-25	26-50	51-100	0-25	26-50	51-100	0-25	26-50
Pleurosigma directum Grunow, 1880								
Pleurosigma elongatum W.Smith, 1852				1 (11)			1 (30)	1 (47)
Pleurosigma normanii Ralfs, 1861	2 (3 - 10)	1 (20)					1 (11)	
Pleurosigma spp.	4 (3 - 20)			3 (10-27)	1 (3)	3(3 - 17	5 (7 -)	4 (7-37)
Pseudonitzschia delicatissima (Cleve) Heiden, 1928	10 (13 - 1200)	1 (300)		5 (9-225)		2(7 - 90		
Pseudonitzschia fraudulenta (Cleve) Hasle, 1993				1 (600)				
Pseudonitzschia pungens	1 (75)							
Pseudonitzschia lineola	2 (20 - 36)	1 (50)	1 (7)	2 (48-73)	1 (7)	2(12 - 24	1 (30)	
Pseudonitzschia seriata (Cleve) H.Peragallo, 1899	18 (47 - 1300)	3 (133 - 300)	2 (10-28)	15 (7-1140)	2 (10 - 50)	3(17 - 400)	4 (7 - 240)	2 (20-65)
Pseudonitzschia spp.	13 (17 - 900)	3 (90 - 550)	2 (7-)	8 (13-1300)	1 (10)	3(57 - 210)		1 (9)
Surirella ovata								
Thalassionema bacillare (Heiden) Kolbe, 1955	3 (27 - 30)	1 (30)		3 (33-45)	1 (3)	1(7)	1 (16)	1 (13)
Thalassionema frauenfeldii Tempère & Peragallo, 1910	5 (7 - 45)	1 (17)		2 (9-32)	1 (6)		1 (15)	
Thalassionema nitzschioides Mereschkowsky, 1902	13 (10 - 800)	2 (13 - 50)		8 (21-375)	2 (13 - 43)	4(6 -40)	9 (10 - 250)	4 (20-200)
Thalassionema sp.	4 (13 - 350)	1 (27)	1 (15)	9 (3-75)		1(78)	1 (10)	2 (27)

	D1	D2	D3	E1	E2	E3	F1	F2
	0-25	26-50	51-100	0-25	26-50	51-100	0-25	26-50
Thalassiothrix longissima Cleve & Grunow, 1880	10 (7 - 740)	4 (8 - 40)	1 (3)	7 (6-160)	1 (6)	3(3 - 95)		
Thalassiothrix franfundii				1 (20)	1 (3)			
Thalassiothrix sp.				1 (4)		1(125)	2 (15 - 16)	
Triceratium fauvas Ehrenberg, 1839			1 (20)	1 (7)				
Unidentified centric diatom	2 (3 - 7)			1 (7)	1 (6)			
Unidentified pennate Diatom								
Unidentified spp.								
Alexandrium affine Balech, 1995								
Alexandrium catenella Balech, 1985				1 (12)				
Alexandrium minutum Halim, 1960	2 (3 - 7)			1 (6)				
Alexandrium tamerense (Balech, 1995	2 (10 - 20)							
Alexandrium spp. Halim, 1960	1 (7)	1 (20)	1 (7)	1 (7)			1 (5)	
Amphidinium sp. Claparède & Lachmann, 1859	4 (3 - 30)		1 (5)	2 (9-97)	2 (6 - 15)	1(2)	1 (4)	
Amphidoma sp.				1 (3)			1 (5)	
Amphesolenia bidentata Schröder, 1900	5 (3 - 10)			2 (3-6)	1 (10)			
Amphisolenia globifera Stein, 1883	1 (18)							
Amphisolenia spp.								
Balechina coerulea (Dogiel) F.J.R.Taylor, 1976	1 (7)						1 (3)	
Blepharocysta denticulata Nie, 1939				1 (7)			1 (3)	
Ceratocorys horrida Stein, 1883				2 (6-8)				
Ceratocorys reticulata H.W.Graham, 1942	1 (3)							
Corythodinium constrictum F.J.R.Taylor, 1976				1 (7)				
Corythodinium tesselatum Loeblich III, 1966	6 (3 - 60)	1 (3)		6 (3-15)	1 (3)	1(3)	4 (3 - 10)	
Corythodinium sp.								
Pyrocystis lunula (Schütt) Schütt, 1896	1 (10)							
Ensiculifera sp. Balech, 1967								

Triadinium polyedricum (Pouchet) Dodge, 1981	1 (7)	1 (20)		1 (3)				
Goniodoma sphaericum Murray & Whitting, 1899	5 (3 - 20)	1 (20)		3 (5-12)	1 (10)	1(5)	3 (3 - 15)	
Gonyaulax minuta Kofoid & Michener, 1911								
Gonyaulax polygramma Stein, 1883	2 (3 - 10)			1 (5)	1 (3)			1 (35)
Gonyaulax scrippsae Kofoid, 1911								
Gonyaulax ceratocoroides Kofoid, 1910				1 (5)				
Gonyaulax sp	2 (10				1 (3)			
Gotoius abei K.Matsuoka, 1988				2 (4-15)	1 (3)		2 (5 - 13)	2 (7 - 14)
Gymnodinium catenatum H.W.Graham, 1943	1 (10)			2 (7-32)				
*Karenia mikimotoi*Gert Hansen & Ø.Moestrup, 2000	1 (30)							
Gymnodinium sp.	1 (23)			1 (9)				
Gymnodium spp.				1 (4)				
Heterocapsa niei Morrill & Loeblich III, 1981	1 (10)							
Heterocapsa sp.								
Heterodinium sphaeroideum Kofoid, 1906								
Heterodinium milneri Kofoid, 1906						1(5)		
Heterodinium sps	3 (7 - 20)			2 (3-8)	1 (3)			
Protoperidinium diabolum Balech, 1974	1 (7)							

	D1	D2	D3	E1	E2	E3	F1	F2
	0-25	26-50	51-100	0-25	26-50	51-100	0-25	26-50
Hetaraulacus spp.								
Lingulodinium polyedrum (F.Stein) J.D.Dodge, 1989								
Oxytoxum parvum Schiller, 1937			1 (3)	1 (4)				
Oxytoxum laticeps Schiller, 1937								
Oxytoxum scolopax Stein, 1883	6 (3 - 75)	2 (4 - 10)	2 (10-23)	5 (3-7)	2 (3 - 5)	3(7 - 10)		
Oxytoxum sp								
Phalacroma rotundatum Kofoid & Michener, 1911								
Podolampas bipes var. *reticulata* (Kofoid) Taylor	1 (6)	2 (3 - 4)		2 (8-20)				

Podolampas palmipes Stein, 1883		1 (3)	1 (3)	3 (7-7)	2 (5 - 6)	4(2 - 9)	2 (3 -)	1 (14)
Podolampas spinifera Okamura, 1912						3(3 - 6)		
Podolampas spp.								
Pyrophacus steinii (Schiller) Wall & Dale, 1971	1 (3)							
Phytodiscus noctulica								
Tripos arietinus (Cleve) F.Gómez, 2013								
Tripos azoricus (Cleve) F.Gómez, 2013	3 (3)				1 (5)			
Tripos balechii F.Gómez, 2013				1 (4)				
Tripos coarctus (Pavillard) F.Gómez, 2013								
Tripos boehmii F.Gómez, 2013				1 (3)			1 (3)	
Tripos bumile								
Tripos candelabrus		1 (8)						
Tripos carriensis (Gourret) F.Gómez, 2013				2 (5-12)	1 (10)			
Tripos belone (Cleve) F.Gómez, 2013							1 (3)	
Tripos bigelowii (Kofoid) F.Gómez, 2013	1 (10)							
Tripos contrarius (Gourret) F.Gómez, 2013	1 (3)							
Tripos contortus (Gourret) F.Gómez, 2013	1 (3)							
Tripos concilians (Jørgenen) F.Gómez, 2013	1 (3)							
Tripos declinatus (G.Karsten) F.Gómez, 2013				2 (3-6)				
Tripos deflexus (Kofoid) F.Gómez, 2014								
Tripos extensus (Gourret) F.Gómez, 2013	3 (7 - 10)			4 (3-40)				
Tripos furca (Ehrenberg) F.Gómez, 2013	10 (3 - 40)	1 (8)		15 (3-56)	2 (7 - 10)	1(15)	14 (3 - 180)	1 (10)

	D1 0-25	D2 26-50	D3 51-100	E1 0-25	E2 26-50	E3 51-100	F1 0-25	F2 26-50
Tripos longirostrus (Gourret) F.Gómez, 2013	1 (9)							
Ceratium furca var *eugammus*							1 (110)	
Tripos fusus (Ehrenberg) F.Gómez, 2013	8 (6 - 40)	1 (10)		8 (3-15)	1 (7)	2(5 - 10)	4 (5 - 30)	
Tripos falcatus (Kofoid) F.Gómez, 2013	1 (6)							

Tripos horridus (Cleve) F.Gómez, 2013	4 (3 - 10)		1 (7)	1 (3)	1 (5)		1 (5)	
Tripos horridus molle	1 (6)			1 (20)			1 (5)	
Tripos horridum var. beuceus	1 (7)	1 (20)		1 (5)				
Tripos gibberus (Gourret) F.Gómez, 1883				1 (4)				
Tripos gravidus (Gourret) F.Gómez, 2013	2 (3)			1 (3)				
Tripos geniculatus (Lemmermann) F.Gómez, 2013								
Tripos hexacanthus (Gourret) F.Gómez, 2013								
Tripos inflatus (Karsten) F.Gómez, 2013								
Tripos karstenii (Pavillard) F.Gómez, 1907	1 (7)							
Ceratium karstenii var *saltans*	1 (3)							
Tripos kofoidii (Jörgenen) F.Gómez, 2013	4 (7 - 30)			4 (4-13)				
Tripos linflatus				1 (5)				
Tripos lineatus (Ehrenberg) F.Gómez, 2013								
Tripos lunula (Schimper ex Karsten) F.Gómez, 2013	1 (3)					1(3)		
Tripos macroceros (Ehrenberg) F.Gómez, 2013							1 (3)	
Tripos minutus (Jörgensen) F.Gómez, 2013								
Tripos pentagonus (Gourret) F.Gómez, 2013	2 (3)	1 (12)		2 (7-12)			1 (3)	
Tripos platycornis (Daday) F.Gómez, 2013								
Tripos praelongus (Lemmermann) Gómez, 2013	1 (3)		1 (3)	1 (4)				
Tripos pulchellus (Schröder) F.Gómez, 2013		1 (10)		1 (5)				
Tripos schrankii (Kofoid) F.Gómez, 2013				1 (6)				
Tripos symmetricus (Pavillard) F.Gómez, 2013								1 (5)
Tripos schoeteri (Schröder) F.Gómez, 2013	1 (10)							
Tripos teres	3 (3 - 13)							
Tripos trichoceros (Ehrenberg) Gómez, 2013	12 (3 - 40)	1 (4)		6 (3-7)			1 (3)	
Tripos muelleri Bory de Saint-Vincent, 1824	1 (15)			3 (7-13)			3 (5 - 7)	
Tripos muelleri var bumile				2 (5-12)	1 (7)			
Tripos muelleri var atlanticum								
Tripos vultur (Cleve) F.Gómez, 2013								
Tripos massiliensis (Gourret) F.Gómez, 2013								
Tripos ranipes (Cleve) F.Gómez, 2013	1 (3)							

Tripos spp.								
Dinophysis apicata (Kofoid & Skogsberg) Abé							1 (3)	
Dinophysis acuta Ehrenberg, 1839								
Dinophysis argus (Stein) Abé				1 (5)				
Dinophysis caudata Saville-Kent, 1881								
Dinophysis exigua Kofoid & Skogsberg, 1928			1 (5)					
Dinophysis hastata Stein, 1883								
Dinophysis infundibulum J. Schiller, 1928				1 (5)				
Dinophysis miles Cleve, 1900								
Dinophysis parvula (Schütt) Balech, 1967								
Dinophysis fortii Pavillard, 1923	2 (3 - 10)			1 (9)		2(3 - 22)	1 (3)	
Dinophysis schuettii Murray & Whitting, 1899				1 (4)				
Dinophysis spp.								
Prorocentrum belizeanum M.A.Faust, 1993								
Prorocentrum dentatum Stein, 1883					1 (9)			
Tryblionella compressa M.Poulin, 1990	5 (3 - 20)			2 (4-8)	1 (6)	1(3)		
Prorocentrum cordatum J.D.Dodge, 1975			1 (3)	1 (6)		1(7)	1 (120)	
Prorocentrum gracile Schütt, 1895					1 (5)		5 (3 - 20)	1 (10)
Prorocentrum micans Ehrenberg, 1834	1 (3)			2 (3-5)	1 (3)		3 (7 - 28)	
Prorocentrum obtusum Ostenfeld, 1908	1 (9)				1 (12)		2 (7 - 16)	
Prorocentrum rhytatum	1 (10)			1 (12)			1 (3)	
Prorocentrum sp	1 (7)			1 (13)				
Pyrocystis barnulus								
Pyrocystis fusiformis C.W.Thomson, 1876				1 (7)				
Pyrocystis hamulus				2 (5-7)			1 (3)	
Pyrocystis lunula (Schütt) Schütt, 1896	2 (3 - 60)			1 (3)				
Pyrocystis pseudo-noctiluca Wyville-Thompson, 1876	5 (7 - 20)	2 (8 - 20)	2 (5-7)	6 (3-17)	2 (3 - 15)	2(5 - 10)	3 (3 -)	
Pyrocystis robusta Kofoid, 1907								
Pyrocystis spp.								
Pyrodinium bahamense Plate, 1906	1 (10)							
Cochlodinium sp. Schütt, 1896								

Scrippsiella spinifera G.Honsell & M.Cabrini, 1991		1 (3)						
Scrippsiella trochoidea Loeblich III, 1976 *	3 (3 - 10)	2 (30 - 40)		4 (13-30)		1(3)	8 (3 - 11592)	
Citharistes regius Stein, 1883				1 (5)			1 (3)	
Preperidinium meunieri Elbrächter, 1993	2 (13 - 27)	1 (40)		3 (3-10)		1(3)	2 (7 - 50)	
Gyrodinium spp. Kofoid & Swezy, 1921	10 (3 - 90)	1 (20)	1 (3)	6 (3-40)	1 (25)	2(3)	4 (3 - 10)	2 (10 - 14)
Histioneis carinata Kofoid, 1907								
Histioneis hyalina Kofoid & Michener, 1911								
Histioneis biremis Stein, 1883			1 (3)					
Histiones spp.								
Phytodiscus Noctulica				3 (3-9)				
Metaphalacroma skogsbergii L.-S.Tai, 1934								
Noctiluca scintillans Kofoid & Swezy, 1921 *	8 (7 - 60)		2 (7-14)	7 (7-30)	1 (3)	2(2 - 7)		

	D1 0-25	D2 26-50	D3 51-100	E1 0-25	E2 26-50	E3 51-100	F1 0-25	F2 26-50
Ornithocercus formosus Kofoid & Michener, 1911								
Ornithocercus magnificus Stein, 1883	6 (3 - 36)			3 (5-20)	1 (7)	1(3)	5 (3 -)	
Ornithocercus quadratus Schütt, 1900	1 (10)							
Ornithocercus steinii Schütt, 1900	3 (3 - 9			1 (16)				
Ornithocercus thumii Kofoid & Skogsberg, 1928							1 (3)	
Ornithocercus spp.								
Dinophysis argus (Stein) Abé								
Phalacroma cuneus F.Schütt, 1895								
Phalacroma doryphorum Stein, 1883	1 (10)							
Phalacroma favus Kofoid & Michener, 1911	1 (4)							
Phalacroma mitra F.Schütt, 1895								
Phalacroma rapa Jorgensen, 1923								
Phalacroma rotundatum Kofoid & Michener, 1911	2 (7 - 10)	1(20)		2 (5-13)	1 (13)		5 (3 - 10)	
Phalacroma spp.								
Pronoctiluca pelagica Fabre-Domergue, 1889	1 (9)	1 (4)		2 (10-12)		1(5)		
Protoperidinium asymmetricum Balech, 1974				1 (15)				
Protoperidinium abei (Paulsen, 1931) Balech, 1974	2 (6 - 20)			1 (60)	1 (5)	1(3)		
Protoperidinium acutipes Balech, 1974								
Protoperidinium biconicum Balech, 1974								
Protoperidinium brevipes Balech, 1974	1 (30)			1 (10)	1 (3)		2 (3 - 12)	2 (5 - 13)
Protoperidinium conicoides Balech, 1974	4 (3 - 20)	1 (4)		5 (3-24)		1(3)	2 (15 - 16)	
Protoperidinium crassipes Balech, 1974	5 (3 - 10)	2(4 - 7)						1 (5)
Protoperidinium crassum Balech, 1971	4 (3 - 30)	1 (10)		2 (20)		1(3)	3 (3 - 11)	1 (7)
Protoperidinium curvipes Balech, 1974	2 (7 - 300)			1 (8)				
Protoperidinium depressum Balech, 1974				2 (4-9)				

Protoperidinium diabolum Balech, 1974	1 (6)			1 (5)			2 (3 -)	
Protoperidinium divergens Balech, 1974	6 (7 - 20)	2 (4)	1 (3)	4 (3-7)		1(3)	2 (3 - 5)	
Protoperidinium elegans Balech, 1974				2 (4-7)				
Protoperidinium heteracanthum Balech, 1974				2 (4-10)				
Protoperidinium inflatum Balech, 1974								

	D1 0-25	D2 26-50	D3 51-100	E1 0-25	E2 26-50	E3 51-100	F1 0-25	F2 26-50
Protoperidinium latispinum Balech, 1974	2 (7 - 9)	1 (20)	1 (7)	7 (3-10)			1 (132)	1 (15)
Protoperidinium leonis Balech, 1974	1 (10)	1 (4)	1 (33)	2 (3-9)				
Protoperidinium longicollum Pavillard, 1916	1 (7)							
Archaeperidinium minutum Jørgensen, 1912	3 (10 - 17)			5 (4-10)	1 (5)		6 (3 - 68)	1 (9)
Protoperidinium minutissimum Balech, 1974			1 (3)	1 (15)			1 (40)	
Protoperidinium oblongum Parke & Dodge, 1976	1 (3)							
Protoperidinium oceanicum Balech, 1974	6 (3 - 54)	3 (3 - 16)		3 (5-27)	1 (5)	1(5)	1 (15)	1 (3)
Protoperidinium oviforme Balech, 1974				1 (8)	1 (3)	1(3)		
Protoperidinium ovatum Pouchet, 1883	1 (10)							
Protoperidinium pacificum ex Balech, 1988		1 (10)						
Protoperidinium pallidum Balech, 1973	2 (15 - 30)	1 (4)						
Protoperidinium pedunculatum Balech, 1974								
Protoperidinium pellucidum	7 (7 - 13)			7 (4-16)	1 (5)	1(10)	2 (3 - 8)	1 (5)
Protoperidinium pentagonum Balech, 1974	3 (7 - 15)	1 (8)					1 (3)	
Protoperidinium pyriforme Balech, 1974	1 (40)					1(4)		
Protoperidinium quinquecorne Balech, 1974								
Protoperidinium sphaericum Balech, 1974	1 (15)	1 (20)		1 (3)		2(3 - 9)		
Protoperidinium steinii Balech, 1974	2 (3 - 7)	1 (3)		4 (3-7)				
Protoperidinium subinerme Loeblich III, 1969				2 (5-10)				1 (3)
Protoperidinium tristylum Balech, 1974								
Protoperidinium tuba (Schiller) Balech, 1974								
Protoperidinium sp.	4 (7 - 20)	1 (23)	1 (7)	3 (7-36)	2 (3 - 7)	1(10)	1 (7)	3 (5-15)

Preperidinium meunieri Elbrächter, 1993	1 (3)						1 (8)	
Dictyoca sp.	7 (3 - 20)	4 (3 - 70)	1 (10)	12 (5-48)	3 (10 - 20)	3(10 - 15)	9 (3 - 30)	1 (20)
Dictyocha fibula								

Appendix U : Spatial variations of diatom and dinoflagellate taxa encountered during peak winter. Colum 1 denotes species list. Column G1 to I3 denotes microphytoplankton taxa (Diatoms, Dinoflagellates and Dictyoca) encountered at different depths during peak winter (Shelf non fronts - G1 to G3, Transistion fronts - H1 to H3, Transistion non fronts - (I1 to I3), (G1; 0-25 m, G2 ; 26-50 m, G3 ; 51-100 m, H1 ; 0-25 m, H2 ; 26 – 50 m, H3 ; 51-100 m, I1 ; 0-25 m, I2 ; 26 – 50 m, I3; 51-100 m respectively.

	G1 0-25	G2 26-50	G3 51-100	H1 0-25	H2 26-50	H3 51-100	I1 0-25	I2 26-50	I3 50-100
Diatoms									
Actinoptychus senarius Ehrenberg, 1843	1 (7)								
Asterolampra marylandica Ehrenberg, 1844	9 (7-35)	2 (7-20)	4 (3 - 10)	4 (10 - 53)		1(5)	2(13-45)	2 (5-30)	
Asterolampra spp.									
Asteromphalus spp.	1 (13)								
Bacteriastrum furcatum Shadbolt, 1854	16 (6 - 150)		3 (7 - 85)	4 (27 - 85)	1(7)	1(20)	5 (7-20)	3 (6- 255)	2 (27 - 90)
Bacteriastrum hyalinum Lauder, 1864	2 (20)								
Bacteriastrum spp.									
Cerataulina pelagica (Cleve) Hendey, 1937	1 (10)		1 (3 -)						
Chaetoceros affinis Lauder, 1864	4 (13-27)						3 (13-130)	1 (3)	1 (20)
Chaetoceros costatus Pavillard, 1911									
Chaetoceros coarctatus Lauder, 1864	1 (47)		1 (10)	1 (13)			1 (53)		
Chaetoceros compressus Lauder, 1864	4 (10-70)								
Chaetoceros concavicornis Mangin, 1917									
Chaetoceros convolutus Castracane, 1886	2 (16-20)								
Chaetoceros curvisetus Cleve, 1889	8 (7 - 180)			2 (25 - 60)				2 (100 - 250)	
Chaetoceros danicus Cleve, 1889	1 (13)								
Chaetoceros decipiens Cleve, 1873	11 (5 - 114)	1 (27)	2 (10 - 100)	3 (15 - 56)	1(20)	1(15)	5 (7-150)		3 (30 - 550)
Chaetoceros didymus Ehrenberg, 1845	7 (13- 325)						1(10)		

Chaetoceros diadema (Ehrenberg) Gran, 1897									
Chaetoceros dichaeta Ehrenberg, 1844			1 (10 -)				1(10)		

Appendix U continued

	G1 0-25	G2 26-50	G3 51-100	H1 0-25	H2 26-50	H3 51-100	I1 0-25	I2 26-50	I3 50-100
Chaetoceros diversus Cleve, 1873	5 (7 - 47)			3 (10 - 40)			3(13-65)	1 (120)	
Chaetoceros eibenii Grunow, 1882									
Chaetoceros laciniosus F.Schütt, 1895	11 (10 - 133)		2 (13 - 77)	5 (5 - 60)			4(47-60)	1 (300)	1 (220)
Chaetoceros lauderi Ralfs, 1864									
Chaetoceros lorenzianus Grunow, 1863	7 (15 - 87)		2 (7 - 13)	2 (12 - 75)			2(47-60)	2 (13 - 100)	1 (250)
Chaetoceros messanensis Castracane, 1875	14 (3 - 250)	2 (33 - 43)	4 (7 - 145)	3 (9 - 132)	1(16)	2(7-15)	10(7-127)	1 (7)	2 (40 - 47)
Chaetoceros peruvianus Brightwell, 1856	3 (27 - 90)			1 (48)			1(3)	2 (7 - 15)	2 (10-100)
Chaetoceros pseudocurvisetus Mangin, 1910	1 (105)								
Chaetoceros socialis H.S.Lauder, 1864									
Chaetoceros teres Cleve, 1896	2 (23- 87)								
Chaetoceros spp.	18 (3 - 2350)	1 (133)	3 (20 - 870)	1 (120)	1(10)	1(50)		2 (100 - 1580)	2 (127 - 1100)
Climacodium frauenfeldianum Grunow, 1868	28 (3 - 1795)	2 (20 - 673)	7 (10 - 600)	10 (60 - 628)	2(64-133)	4(27-230)	10(13-300)	3 (45 - 350)	3 (120 - 1950)
Corethron hystrix Hensen, 1887									
Corethron sp.									
Coscinodiscus oculus-iridis Ehrenberg, 1840				1 (5 -)		1(10)			
Coscinodiscus gigas Ehrenberg, 1841									
Coscinodiscus granii Gough, 1905	1 (10)	1 (25)	2 (3 - 20)	1 (3 -)			1(7)	1 (20)	
Coscinodiscus johneius									

Coscinodiscus marginatus Ehrenberg, 1844	6 (5 - 27)		3 (7 - 10)		1(11)	1(7)	1(7)	3 (310)	
Coscinodiscus radiatus Ehrenberg, 1840	4 (3 - 33)	1 (205)	5 (3 - 13)	2 (15 - 20)		2(10-27)	1(3)	3 (7)	2 (7 - 10)
Coscinodiscus spp.	10 (3 - 27)	1 (19)	2 (10 - 17)		1(7)	2(5-7)	4(3-113)	3 (7 - 25)	1 (200)
Coscinodiscus spp.2			1 (5)						
Cyclotella sp.							1(10)		

Appendix U continued

	G1 0-25	G2 26-50	G3 51-100	H1 0-25	H2 26-50	H3 51-100	I1 0-25	I2 26-50	I3 50-100
Dactyliosolen fragilissimus (Bergon) Hasle, 1996	12 (7 - 300)	1 (65)	3 (10-37)	2 (35 - 130)			2(20-53)	1 (25)	2 (200-400)
Dactyliosolen sp?									
Eucampia groenlandica Cleve, 1896									
Eucampia cornuta (Cleve) Grunow, 1883	1 (6)						1(13)		
Eucampia zodiacus Ehrenberg, 1839	4 (23- 45)		1 (7)						
Guinardia cylindrus (Cleve) Hasle, 1996	6 (3 - 105)	1 (7)	1 (20)	4 (8 - 55)		1(10)			1 (10)
Guinardia delicatula (Cleve) Hasle, 1997	3 (10 -67)	1 (30)	1 (10)	4 (7 - 65)		1(15)	2(20-40)		2 (20 - 250)
Guinardia flacida (Castracane) H.Peragallo, 1892	4 (6 - 50)			1 (20)			1(13)		
Guinardia striata (Stolterfoth) Hasle, 1996	14 (7 - 550)	1 (80)	2 (17-90)	8 (13 - 300)	1(33)		6(10-107)	1 (110)	2 (153 - 580)
Guinardia sp.									
Helicotheca tamesis (Shrubsole) M.Ricard, 1987		2 (7 - 13)	1 (40)						
Hemiaulus hauckii Grunow ex Van Heurck, 1882	2 (7 - 67)	1 (20)	2 (10-40)			1(7)	1(110)	2 (50 - 70)	
Hemiaulus indicus Karsten, 1907	1 (10)								
Hemiaulus membranaceus Cleve	3 (7 - 75)							1 (3)	
Hemidiscus cuneiformis Wallich, 1860									
Hemidiscus sp.	2 (7 - 8)		1 (60)	2 (10 - 55)			2(3-7)	1 (75)	
Leptocylindrus danicus Cleve, 1889	2 (17 - 27)		1 (10)						1 (267)
Leptocylindrus sp.									
Odontella aurita (Lyngbye) C.Agardh, 1832	1 (9)								

	G1	G2	G3	H1	H2	H3	I1	I2	I3
Trieres mobiliensis Ashworth & Theriot, 2013	1 (21)	2 (10 - 215)	1 (3)						
Odontella sinensis (Greville) Grunow, 1884		1 (5)							
Planktoniella sol (C.G.Wallich) Schütt, 1892	10 (3-13)		4 (3-7)	5 (5 - 60)	2(5-13)	3(7-10)	5(3-33)	2 (3)	
Proboscia alata (Brightwell) Sundström, 1986	20 (7 - 297)	1 (13)	3 (17-37)	6 (15 - 100)	1(30)	2(5-77)	3(20-33)	3 (7-80)	1 (480)

Appendix U continued

	G1	G2	G3	H1	H2	H3	I1	I2	I3
	0-25	26-50	51-100	0-25	26-50	51-100	0-25	26-50	50-100
Pseudoguinardia recta von Stosch, 1986	1 (30)						1(13)		
Pseudosolenia calcar-avis B.G.Sundström, 1986	3 (7 - 9)		1 (3)				1(7)		
Rhizosolenia alata f. *indica*	7 (3- 220)		31959)	1 (28)		1(45)			3 (13 - 70)
Rhizosolenia alata f. *semispina*	4 (14 - 110)								
Rhizosolenia bergonii H.Peragallo, 1892	18 (3 - 150)	1 (7)	4 (3-30)	5 (3 - 40)	1(8)		6(3)	3 (3 - 40)	2 (30 - 60)
Rhizosolenia castracanei H.Peragallo, 1888							1(20)		1 (20)
Rhizosolenia clevei									
Rhizosolenia crassa Schimper, 1905	8 (3 - 187)			2 (5 - 25)		1(20)	1(20)		2 (63 - 150)
Rhizosolenia hyalina Ostenfeld, 1901	12 (3 - 60)		3 (3-17)	6 (3 - 40)			4(3-27)	1 (10)	3 (17 - 40)
Rhizosolenia decipiens B.G.Sundström, 1986			1 (33)						
Rhizosolenia formosa H.Peragallo, 1888									
Rhizosolenia hebetata forma *semispina*	10 (9- 192)		2 (50-53)	3 (27 - 80)		1(23)	2(47-80)	2 (15 - 40)	
Rhizosolenia imbricata Brightwell, 1858	16 (5 - 290)	1 (73)	1 (37)	3 (10 - 288)		1(30)	3(17-30)	1 (50)	1 (45)
Neocalyptrella robusta				2 (15 - 25)		1(5)	1(20)	1 (55)	1 (15)
Rhizosolenia setigera Brightwell, 1858	2 (10 -23)						2(3-13)		1 (20)
Rhizosolenia stolterfortii									

Rhizosolenia striata Greville, 1864		1 (10)							
Rhizosolenia styliformis T.Brightwell, 1858	2 (10-20)		1 (20)				1(20)		
Rhizosolenia spp.	4 (10-167)	1 (27)	2 (17-20)	3 (25 - 60)			1(3)		1 (500)
Skeletonema costatum (Greville) Cleve, 1873									
Skeletonema sp									
Stephanopyxis sp.	1 (7)								
Thalassiosira angulata (W.Gregory) Hasle, 1978				1 (13)					

Appendix U continued

	G1 0-25	G2 26-50	G3 51-100	H1 0-25	H2 26-50	H3 51-100	I1 0-25	I2 26-50	I3 50-100
Thalassiosira eccentrica (Ehrenberg) Cleve, 1904	15 (3-103)		10)	4 (7 - 13)	2(11-27)	2(5-67)	4(3-23)	1 (25)	
Thalassiosira gravida Cleve, 1896		1 (9)		1 (15)			1(27)	1 (30)	
Thalassiosira punctigera (Castracane) Hasle, 1983	4 (4-20)	2 (10 - 80)	1 (15)			1(10)	1(27)	1 (10)	
Thalassiosira spp.	14 (3 - 60)	2 (20 - 80)	1 (17)				5(10-13)	1 (15)	
Achnanthes sp.									
Amphiprora spp.									
Asterionellopsis sp?									
Cylindrotheca closterium Reimann & J.C.Lewin, 1964	2 (7 - 153)		1 (60)	1 (30)	1(7)		1(20)		1 (50)
Diploneis crabro (Ehrenberg) Ehrenberg, 1854									
Diploneis lenticula	1 (13)		1 (15)						
Diploneis sp.			1 (3)			1(7)		1 (3)	
Fragilariopsis cylindrus (Grunow) Krieger, 1954	9 (13-153)		1 (23)			1(30)	2(33-40)	2 (80)	
Fragilariopsis oceanica (Cleve) Hasle, 1965	1 (16)								
Fragilariopsis doliolus Medlin & P.A.Sims, 1993							1(17)		

Fragilariopsis spp.									
Grammatophora undulata Ehrenberg									
Haslea trompii (Cleve) Simonsen, 1974	2 (3-13)		1 (5)	3 (4 - 7)		2(10)	1(27)	1 (20)	1 (50)
Haslea wawrikae (Hustedt) Simonsen, 1974	7 (3 - 153)			1 (12)			2(13-33)		1 (60)
Haslea spp.	2 (7 - 70)	2 (7 - 10)	3 (13)		1(3)	2(5)	2(17-20)		1 (10)
Lioloma elongatum									
Lioloma pacificum	4 (7-200)		2 (3-10)	1 (8)	1(13)	2(5-40)	1(35)		

Appendix U continued

	G1 0-25	G2 26-50	G3 51-100	H1 0-25	H2 26-50	H3 51-100	I1 0-25	I2 26-50	I3 50-100
Lioloma sp.	1 (27)								
Meuniera membranacea	14 (3-235)		1 (20)	3 (53 - 67)	1(20)		2(13-47)		1 (95)
Navicula septantronalis									
Navicula spp.	5 (10-350)	1 (7)	2 (3-23)	1 (16)		2(5)	1(153)		
Nitzschia longisima									
Nitzschia spp.									
Pleurosigma naviculaceae						1(7)			
Pleurosigma angulatum (Queckett) W.Smith, 1852		1 (53)							
Pleurosigma directum Grunow, 1880			1 (3)						
Pleurosigma elongatum W.Smith, 1852		1 (47)							
Pleurosigma normanii Ralfs, 1861			1 (3)		1(3)		1(13)	1 (10)	
Pleurosigma spp.	1 (13)	4 (7 - 37)	2 (10)				1(13)		

Pseudonitzschia delicatissima (Cleve) Heiden, 1928	2 (23)								
Pseudonitzschia fraudulenta (Cleve) Hasle, 1993									
Pseudonitzschia pungens									
Pseudonitzschia lineola	2 (20-450)					1(10)	1(50)		1 (20)
Pseudonitzschia seriata (Cleve) H.Peragallo, 1899	18 (10-1400)	2 (20 - 65)	3 (23-200)	2 (24 - 75)			5(10-286)	1 (500)	2 (225 - 600)
Pseudonitzschia spp.	11 (7-1450)	1 (9)	5 (3-125)	2 (27 - 155)		1(40)	4(10-387)	1 (150)	2 (150 - 1150)
Surirella ovata									
Thalassionema bacillare (Heiden) Kolbe, 1955	5 (6 - 50)	1 (13)	2 (3-15)	2 (15 - 20)		1(113)	1(7)	1 (30)	
Thalassionema frauenfeldii Tempère & Peragallo, 1910	6 (3-50)		1 (3)	1 (10)	1(3)		4(3-33)	2 (20 - 25)	1 (30)
Thalassionema nitzschioides Mereschkowsky, 1902	15 (7-530)	4 (20 - 200)	3 (13-75)	1 (32)	1(17)	1(10)	6(7-153)	1 (110)	2 (30 - 175)
Thalassionema sp.	3 (6-120)	2 (37 - 120)	3 (10-475)	1 (20)	1(8)		4(3-27)		
Thalassiothrix longissima Cleve & Grunow, 1880	8 (7-140)		4 (10)	3 (13 - 28)	2(11)	1(55)	4(7-60)	2 (6.66685	
Thalassiothrix franfundii									
Thalassiothrix sp.				1 (16)			1(13)	1 (3)	
Triceratium fauvas Ehrenberg, 1839	1 (7)								

Appendix U continued

	G1 0-25	G2 26-50	G3 51-100	H1 0-25	H2 26-50	H3 51-100	I1 0-25	I2 26-50	I3 50-100
Unidentified centric diatom	3 (20-45)		1 (10)						
Unidentified pennate Diatom	1 (13)								
Unidentified spp.									
Alexandrium affine Balech, 1995									
Alexandrium catenella Balech, 1985							1(7)		
Alexandrium minutum Halim, 1960									
Alexandrium tamerense (Balech, 1995									
Alexandrium spp. Halim, 1960	3 (3-16)						1(7)		1 (3)
Amphidinium sp. Claparède & Lachmann, 1859	9 (3-13)			1 (4)			2(3-40)		1 (3)

Amphidoma sp.									
Amphesolenia bidentata Schröder, 1900	5 (3-7)			1 (3)			1(3)		
Amphisolenia globifera Stein, 1883	2 (3)								
Amphisolenia spp.	1 (7)								
Balechina coerulea (Dogiel) F.J.R.Taylor, 1976	2 (3-7)			1 (5)					
Blepharocysta denticulata Nie, 1939	1 (15)		1 (10)	1 (3)	1(3)				
Ceratocorys horrida Stein, 1883	1 (3)								
Ceratocorys reticulata H.W.Graham, 1942									
Corythodinium constrictum F.J.R.Taylor, 1976	2 (7)								
Corythodinium tesselatum Loeblich III, 1966	4 (3)		3 (3)	1 (8)	1(3)	1(5)	2(3-7)	1 (10)	
Corythodinium sp.									
Pyrocystis lunula (Schütt) Schütt, 1896	1 (3)								
Ensiculifera sp. Balech, 1967									
Triadinium polyedricum (Pouchet) Dodge, 1981	4 (3-5)			4 (6 - 15)			1(7)		

Appendix U continued

	G1 0-25	G2 26-50	G3 51-100	H1 0-25	H2 26-50	H3 51-100	I1 0-25	I2 26-50	I3 50-100
Goniodoma sphaericum Murray & Whitting, 1899	2 9-10)		1 (3)	1 (3)		1(3)	2(3-13)		
Gonyaulax minuta Kofoid & Michener, 1911							1(3)		
Gonyaulax polygramma Stein, 1883	3 (3)	1 (35)		1 (5)	1(3)		2(3-7)		
Gonyaulax scrippsae Kofoid, 1911	1 (4)								
Gonyaulax ceratocoroides Kofoid, 1910									
Gonyaulax sp	1 (15)								
Gotoius abei K.Matsuoka, 1988	3 (7-13)	2 (7 - 14)		1 (10)			5(3-13)		

Gymnodinium catenatum H.W.Graham, 1943									
*Karenia mikimotoi*Gert Hansen & Ø.Moestrup, 2000	1 (7)								
Gymnodinium sp.	3 (3-33)								
Gymnodium spp.						1(5)			
Heterocapsa niei Morrill & Loeblich III, 1981									
Heterocapsa sp.	1 (13)								
Heterodinium sphaeroideum Kofoid, 1906							1(10)		
Heterodinium milneri Kofoid, 1906				1 (3)					
Heterodinium sps	4 (3-20)						3(3)		
Protoperidinium diabolum Balech, 1974									
Hetaraulacus spp.									
Lingulodinium polyedrum (F.Stein) J.D.Dodge, 1989				1 (5)					
Oxytoxum parvum Schiller, 1937	2 (3-5)				1(3)	2(3-5)	1(3)		
Oxytoxum laticeps Schiller, 1937	3 (5-10)								1 (3)
Oxytoxum scolopax Stein, 1883	3 (3-7)		1 (7)			1(7)			1 (10)
Oxytoxum sp									
Phalacroma rotundatum Kofoid & Michener, 1911									

Appendix U continued

	G1 0-25	G2 26-50	G3 51-100	H1 0-25	H2 26-50	H3 51-100	I1 0-25	I2 26-50	I3 50-100
Podolampas bipes var. *reticulata* (Kofoid) Taylor	4 (3-7)			2 (5 - 7)			2(5-7)		
Podolampas palmipes Stein, 1883	1 (5)	1 (14)	3 (3-10)	1 (10 -)	1(3)	1(5)	2(7)		1 (3)
Podolampas spinifera Okamura, 1912			1 (3)	1 (3)		1(10)			
Podolampas spp.	1 (7)								

Pyrophacus steinii (Schiller) Wall & Dale, 1971	3 (3-4)								
Phytodiscus noctulica				1 (3)					
Tripos arietinus (Cleve) F.Gómez, 2013	2 (3)								
Tripos azoricus (Cleve) F.Gómez, 2013									
Tripos balechii F.Gómez, 2013									
Tripos coarctus (Pavillard) F.Gómez, 2013				1 (5)					
Tripos boehmii F.Gómez, 2013							1(3)		
Tripos bumile							1(3)		
Tripos candelabrus	1 (3)			1 (6)					
Tripos carriensis (Gourret) F.Gómez, 2013	3 (3-10)						1(7)		1 (3)
Tripos belone (Cleve) F.Gómez, 2013				1 (10)					
Tripos bigelowii (Kofoid) F.Gómez, 2013									
Tripos contrarius (Gourret) F.Gómez, 2013	1 (3)								
Tripos contortus (Gourret) F.Gómez, 2013	1 (3)								1 (10)
Tripos concilians (Jørgenen) F.Gómez, 2013									
Tripos declinatus (G.Karsten) F.Gómez, 2013									
Tripos deflexus (Kofoid) F.Gómez, 2014				1 (7)		1(5)	1(3)		
Tripos extensus (Gourret) F.Gómez, 2013	3 (3-10)		2 (3-13)	1 (3)			1(3)	1 (3)	

Appendix U continued

	G1	G2	G3	H1	H2	H3	I1	I2	I3
	0-25	26-50	51-100	0-25	26-50	51-100	0-25	26-50	50-100
Tripos furca (Ehrenberg) F.Gómez, 2013	29 (3-70)	1 (10)	1 (3)	7 (3 - 60)		1(5)	9(3-50)	2 (9 - 10)	1 (17)

Ceratium furca var *eugammus*								
Tripos fusus (Ehrenberg) F.Gómez, 2013	12 (3-11)	1 (10)	6 (3 - 12)			7(3-13)	1 (10)	
Tripos falcatus (Kofoid) F.Gómez, 2013			1 (4)					
Tripos horridus (Cleve) F.Gómez, 2013	3 (3-5)	2 (3-5)	3 (3 - 13)	1(3)		1(3)		
Tripos horridus molle	1 (3)					2(3)		
Tripos horridum var. beuceus								
Tripos gibberus (Gourret) F.Gómez, 1883	4 (3-20)					1(3)		
Tripos gravidus (Gourret) F.Gómez, 2013			1 (3)					
Tripos geniculatus (Lemmermann) F.Gómez, 2013								
Tripos hexacanthus (Gourret) F.Gómez, 2013	1 (3)							
Tripos inflatus (Karsten) F.Gómez, 2013	1 (3)		1 (5)					
Tripos karstenii (Pavillard) F.Gómez, 1907	2 (3-7)							
Ceratium karstenii var *saltans*			1 (3)					
Tripos kofoidii (Jörgenen) F.Gómez, 2013	4 (3)		1 (5)		1(3)	1(7)		
Tripos linflatus								
Tripos lineatus (Ehrenberg) F.Gómez, 2013								
Tripos longirostrus (Gourret) F.Gómez, 2013		1 (7)						
Tripos lunula (Schimper ex Karsten) F.Gómez, 2013	1 (7)							
Tripos macroceros (Ehrenberg) F.Gómez, 2013	1 (3)							
Tripos minutus (Jörgensen) F.Gómez, 2013			1 (13)					
Tripos pentagonus (Gourret) F.Gómez, 2013	3 (5-10)	1 (3)	5 (3 - 20)			2(3-13)		1 (13)

Appendix U continued

	G1 0-25	G2 26-50	G3 51-100	H1 0-25	H2 26-50	H3 51-100	I1 0-25	I2 26-50	I3 50-100
Tripos platycornis (Daday) F.Gómez, 2013									
Tripos praelongus (Lemmermann) Gómez, 2013									
Tripos pulchellus (Schröder) F.Gómez, 2013	1 (7)			1 (4)					
Tripos schrankii (Kofoid) F.Gómez, 2013									
Tripos symmetricus (Pavillard) F.Gómez, 2013		1 (5)					1(7)		
Tripos schoeteri (Schröder) F.Gómez, 2013									
Tripos teres			3)	1 (3)			2(3-7)		
Tripos trichoceros (Ehrenberg) Gómez, 2013	6 (3-16)			3 (3 - 7)			3(3-10)	2 (6 - 10)	1 (10)
Tripos muelleri Bory de Saint-Vincent, 1824	5 (3-15)		3)	1 (3)					1 (7)
Tripos muelleri var bumile									
Tripos muelleri var atlanticum									1 (3)
Tripos vultur (Cleve) F.Gómez, 2013							1(10)		1 (10)
Tripos massiliensis (Gourret) F.Gómez, 2013				1 (5)			1(3)		
Tripos ranipes (Cleve) F.Gómez, 2013									
Tripos spp.									
Dinophysis apicata (Kofoid & Skogsberg) Abé									
Dinophysis acuta Ehrenberg, 1839									
Dinophysis argus (Stein) Abé				1 (4)					
Dinophysis caudata Saville-Kent, 1881									
Dinophysis exigua Kofoid & Skogsberg, 1928									
Dinophysis hastata Stein, 1883							1(13)		
Dinophysis infundibulum J. Schiller, 1928							1(3)		
Dinophysis miles Cleve, 1900									
Dinophysis parvula (Schütt) Balech, 1967						1(3)			
Dinophysis fortii Pavillard, 1923	3 (3)		3)	1 (7)	1(3)				
Dinophysis schuettii Murray & Whitting, 1899					1(3)		1(3)	1 (3)	
Dinophysis spp.	1 (3)								
Prorocentrum belizeanum M.A.Faust, 1993					1(3)				

Appendix U continued

	G1 0-25	G2 26-50	G3 51-100	H1 0-25	H2 26-50	H3 51-100	I1 0-25	I2 26-50	I3 50-100
Prorocentrum dentatum Stein, 1883				1 (7)			1(3)		
Tryblionella compressa M.Poulin, 1990	2 (3-10)		7)	2 (3 - 5)			3(7-13)		
Prorocentrum cordatum J.D.Dodge, 1975									
Prorocentrum gracile Schütt, 1895	7 (3-13)	1 (10)					4(3-7)	1 (20)	1 (3)
Prorocentrum micans Ehrenberg, 1834	4 (3-7)						1(10)		
Prorocentrum obtusum Ostenfeld, 1908	1 (20)			1 (10)					
Prorocentrum rhytatum	1 (7)			1 (3)			2(10-13)		
Prorocentrum sp				1 (3)					
Pyrocystis barnulus									
Pyrocystis fusiformis C.W.Thomson, 1876	3 (3-13)								
Pyrocystis hamulus	1 (3)					1(3)		1 (3)	1 (7)
Pyrocystis lunula (Schütt) Schütt, 1896	2 (7-10)			3 (5 - 15)			2(3-5)		
Pyrocystis pseudo-noctiluca Wyville-Thompson, 1876	9 (3-13)			4 (5 - 20)			1(3)	2 (3-5)	
Pyrocystis robusta Kofoid, 1907	1 (3)						1(7)		
Pyrocystis spp.									
Pyrodinium bahamense Plate, 1906									
Cochlodinium sp. Schütt, 1896	1 (3)								
Scrippsiella spinifera G.Honsell & M.Cabrini, 1991									
Scrippsiella trochoidea Loeblich III, 1976 *	9 (5-2520)						2(7-37)		
Citharistes regius Stein, 1883									
Preperidinium meunieri Elbrächter, 1993	2 (10)								
Gyrodinium spp. Kofoid & Swezy, 1921	8 (3-140)	2 (10 - 14)	10)	4 (3 - 20)			5(5-7)	1 (10)	1 (15)

Appendix U continued

	G1 0-25	G2 26-50	G3 51-100	H1 0-25	H2 26-50	H3 51-100	I1 0-25	I2 26-50	I3 50-100
Histioneis carinata Kofoid, 1907						1(3)		1 (3)	
Histioneis hyalina Kofoid & Michener, 1911									
Histioneis biremis Stein, 1883									
Histiones spp.				2 (3 - 13)					
Phytodiscus Noctulica									
Metaphalacroma skogsbergii L.-S.Tai, 1934									
Noctiluca scintillans Kofoid & Swezy, 1921 *	8 (3-43)		10)	4 (8 - 25)	1(5)	1(15)	1(3)	2 (3-10)	1 (10)
Ornithocercus formosus Kofoid & Michener, 1911	1 (3)								
Ornithocercus magnificus Stein, 1883	7 (3)			5 (3 -20)			2(3)		1 (10)
Ornithocercus quadratus Schütt, 1900	2 (3-7)								
Ornithocercus steinii Schütt, 1900	7 (3-7)			2 (3 - 4)				1 (3)	
Ornithocercus thumii Kofoid & Skogsberg, 1928								1 (3)	
Ornithocercus spp.									
Dinophysis argus (Stein) Abé	3 (3-7)			1 (3)					
Phalacroma cuneus F.Schütt, 1895	1 (3)								
Phalacroma doryphorum Stein, 1883	1 (3)								
Phalacroma favus Kofoid & Michener, 1911									
Phalacroma mitra F.Schütt, 1895							1(7)		
Phalacroma rapa Jorgensen, 1923	2 (3)								
Phalacroma rotundatum Kofoid & Michener, 1911	2 (7-13)			2 (5 - 6)				1 (30)	
Phalacroma spp.									
Pronoctiluca pelagica Fabre-Domergue, 1889							1(3)		

Protoperidinium asymmetricum Balech, 1974	2 (3-16)			1 (3)					
Protoperidinium abei (Paulsen, 1931) Balech, 1974	2 (3-7)						1(3)		
Protoperidinium acutipes Balech, 1974				1 (5)					

Appendix U continued

	G1 0-25	G2 26-50	G3 51-100	H1 0-25	H2 26-50	H3 51-100	I1 0-25	I2 26-50	I3 50-100
Protoperidinium biconicum Balech, 1974	2 (3)			1 (4)					
Protoperidinium brevipes Balech, 1974	6 (3-10)	2 (5 - 13)					2(3-13)		
Protoperidinium conicoides Balech, 1974	7 (3-20)			2 (3 - 5)			2(3)		1 (3)
Protoperidinium crassipes Balech, 1974	1 (3)	1 (1)		2 (5 - 7)	1(3)		1(3)		
Protoperidinium crassum Balech, 1971	3 (7-13)	1 (7)		1 (5)			1(10)	1 (55)	
Protoperidinium curvipes Balech, 1974	2 (10-11)			1 (5)			2(3-10)		
Protoperidinium depressum Balech, 1974							1(3)		
Protoperidinium diabolum Balech, 1974	3 (3)						1(3)		
Protoperidinium divergens Balech, 1974	5 (3-7)		2(3-7)	7 (5 - 40)					1 (3)
Protoperidinium elegans Balech, 1974	1 (3)						1(7)		
Protoperidinium heteracanthum Balech, 1974						1(10)			
Protoperidinium inflatum Balech, 1974			1 (5)						
Protoperidinium latispinum Balech, 1974	7 (3-11)	1 (15)	2 (3-17)				3(3-13)	1 (6)	
Protoperidinium leonis Balech, 1974	1 (3)								
Protoperidinium longicollum Pavillard, 1916									
Archaeperidinium minutum Jørgensen, 1912	5 (7-30)	1 (9)		2 (6 - 20)		1(13)	3(3-7)	2 (10 - 21)	1 (15)
Protoperidinium minutissimum Balech, 1974	2 (3-10)		1 (3)				2(13-27)		1 (7)
Protoperidinium oblongum Parke & Dodge, 1976							1(7)		
Protoperidinium oceanicum Balech, 1974	5 (3-7)	1 (3)	1 (3)	3 (5 - 7)			3(3-7)		1 (3)

Protoperidinium oviforme Balech, 1974	3 (3-8)			1 (40)	1(3)		1(3)		
Protoperidinium ovatum Pouchet, 1883	1 (10)			1 (7)					
Protoperidinium pacificum ex Balech, 1988									

Appendix U continued

	G1 0-25	G2 26-50	G3 51-100	H1 0-25	H2 26-50	H3 51-100	I1 0-25	I2 26-50	I3 50-100
Protoperidinium pallidum Balech, 1973	5 (3-11						1(3)		
Protoperidinium pedunculatum Balech, 1974									
Protoperidinium pellucidum	7 (3-21)	1 (5)	1 (7)	1 (3)			6(3)		1 (17)
Protoperidinium pentagonum Balech, 1974	2 (3-10)								
Protoperidinium pyriforme Balech, 1974	2 (3-5)								
Protoperidinium quinquecorne Balech, 1974							1(3)		
Protoperidinium sphaericum Balech, 1974	1 (5)		1 (3)	1 (5)			1(10)	1 (5)	1 (10)
Protoperidinium steinii Balech, 1974	2 (3-7)		1 (3)	1 (12)	1(3)				2 (3 - 10)
Protoperidinium subinerme Loeblich III, 1969		1 (3)							
Protoperidinium tristylum Balech, 1974									
Protoperidinium tuba (Schiller) Balech, 1974				1 (3)					
Protoperidinium sp.	5 (3-11)	3 (5 - 15)	2 (3-10)	3 (5 - 20)	1(7)		3(3-7)	1 (6)	
Preperidinium meunieri Elbrächter, 1993	1 (3)			2 (13 - 20)			4(3-7)	1 (3)	
Dictyoca sp.	24 (3-77)	1 (20)	3 (10-40)	8 (5 - 53)	2(8-17)	1(30)	8(3-47)	2 (15 - 20)	1 (20)
Dictyocha fibula									

Inter- and intra-annual variations in the population of *Tripos* from the Bay of Bengal

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***Tripos*, a species-rich ubiquitous thecate dinoflagellate, serves as an excellent biological indicator of the water mass in the oceans. The inter- and intra-annual variations in the surface-water distribution of *Tripos* along the shipping routes of Chennai (C)–Port Blair (P)–Kolkata (K) in the Bay of Bengal was evaluated from October 2006 to September 2011. The highest numbers were recorded during fall intermonsoon (October 2007) in the C–P transect, and southwest monsoon (July 2010) in the P–K transect. In the C–P transect high numbers of *T. furca* can be attributed to mesoscale eddies, whereas in the P–K transect, it can be attributed to riverine discharge. The results point that, *Tripos* persists throughout the year in the Bay of Bengal and tend to increase with the elevation of nutrients.**

Keywords: Bay of Bengal, currents, dinoflagellates, eddies, monsoon, micro-phytoplankton, *Tripos*.

DINOFLAGELLATES constitute one of the important groups of marine protists in all aquatic ecosystems and form the second most dominant group of the total of phytoplankton community[1,2]. It comprises a wide range of genera with 117 genus and 1555 species[3]. Amongst them, *Tripos* is one of the important ubiquitous marine thecate genera, whose distribution ranges from polar to tropical environments[4]. The *Tripos* species are slow-growing, found round the year[4–8], and are known to be a model species within the dinoflagellates for biogeographic and global change studies[9]. In relation to temperature some of its forms are referred as excellent water mass indicators, North Atlantic[4,10], Mediterranean Sea[11,12], Pacific[13,14], Arctic[15] and Indian Ocean[16]. Phytogeographical studies also showed close relationship of individual species with temperature, while some are fairly tolerant towards wide temperature range[8]. Recently, the taxonomy of this genus has been revised based on the numbers and arrangement of cingular plates. The freshwater species are referred to as *Ceratium* and the marine species renamed as *Neoceratium*[17]. Recently, Gómez[18] has elaborated on nomenclature priority of this species and reinstated genus *Neoceratium* to *Tripos*. The genus is strong-armoured, large-sized cells (100–300 μm) that is readily identified and distinctly characterized when preserved in any of the common fixatives[17].

In the waters around the subcontinent of India, *Tripos* species have been documented from the east and west coasts of India[19–24]. Taxonomic studies on dinoflagellates from the Indian Ocean date back to 1968 (ref. 16), although there is information available on dinoflagellates from several international expeditions as well as those that have passed through waters along the Indian subcontinent. Most of the authors studied *Tripos* qualitatively by reporting the presence of species in the form of description and illustration[25]. Taylor[25] pointed out that in the description of dinoflagellates, Matzenauer[26] had also omitted genus *Tripos*. However, from the above literature, we can say that information on the abundance and diversity at the spatio-temporal scale is lacking. The only tropical ocean being bounded by a continent to the north, the Indian Ocean comprising of the Arabian Sea and Bay of Bengal, hereafter referred to as BoB[27], is home for the semi-annually reversing monsoon wind system[28]. Changes in the environmental conditions (salinity, temperature, nutrients) driven by major riverine discharges and monsoon reversals (precipitation and wind) make the bay a unique system in the northern Indian Ocean. Given the understanding that the *Tripos* has been used as an indicator of water mass as stated above, a study was undertaken to map the distribution of *Tripos* in BoB for five years (October 2006–September 2011).

Materials and methods

Study area and sampling strategy

Surface water samples were collected from BoB, along the shipping route, viz. from Chennai to Port Blair (C–P, 81°00′E/13°00′N to 92°00′E/11°23′N) and Port Blair to Kolkata (P–K, 12°00′N/93°14′E–21°00′N/88°23′E) (Figure 1). Sampling was done at monthly intervals from 22 stations (separated by 1° intervals), 12 and 10 stations along C–P and P–K transect respectively, from October 2006 to September 2011 (Table 1). To depict the influence of monsoon and wind stress, monthly datasets are categorized into seasons as fall intermonsoon (FIM;

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October), northeast monsoon (NEM; November to February), spring intermonsoon (SIM; March to May) and southwest monsoon (SWM; June to September). March–May and October both experience moderate winds; hence these months are termed as intermonsoon (IM), spring intermonsoon and fall intermonsoon respectively. In order to see regional variability in the *Tripos* population along with its associated environmental variables, the C–P transect is also referred to as CPOS (stations 1 to 12) and the P–K transect that includes Andaman Region (AR; stations 13 to 15), P–K oceanic stations (PKOS; stations 16 to 21) and Riverine Mouth (RM; stations 22). When all the three regions are considered, it is referred to as P–K transect.

Environmental parameters

The vertical temperature profile of the water column was recorded by launching XBT-MK21-T7 Probes (Sippican Inc.) at 1° intervals. The conductivity of surface sea water was measured using Autosal and later converted into salinity; salinity accuracy of the instrument <0.002 and detection range 2–42.

For nutrient, 10 ml of sea-water samples was collected into 10 ml cryo-vials, immediately frozen in liquid nitrogen and then analysed for dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphate (DIP). The samples collected from October 2006 to October 2009 were analysed using Technicon Auto Analyzer. The precision of nitrate, nitrite and phosphate was ±0.02, 0.02 and 0.01 $\mu mol\ l^{-1}$ respectively. The samples collected from November 2009 to September 2011 were analysed by auto analyser (Skylar, San ++) continuous flow analyser.

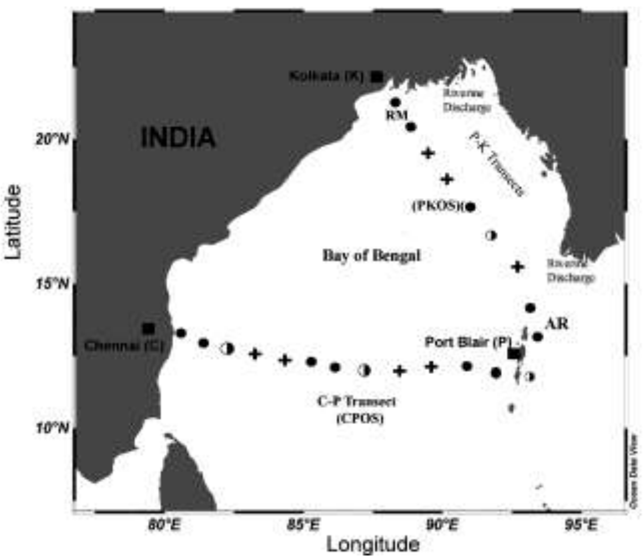

Figure 1. Map of sampling area showing 12 stations along Chennai–Port Blair (C–P) and 10 stations along Port Blair–Kolkata (P–K) transects. Symbol denotes sampling time. ●, Night hours (absence of sunlight); ◑, Late evening and early morning (faint sunlight); +, Day hours (presence of sunlight).

For both the analyses, standard spectrophotometric procedures were followed using Grasshoff *et al.*[29].

The wind speed data were obtained from APDRC (Asia Pacific Data Research Centre) data access (http://apdrc.soest.hawaii.edu) for the grid area of 7°38′N–21°38′N and 74°38′E–95°38′E. Rainfall data were obtained from NOAA (NOAA Earth System Research Laboratory), data access (http://www.esrl.noaa.gov/psd/data/gridded/data.unified.daily.conus.html) for the gridded area of 7°28′N–25°88′N and 7°88′E–97°28′E. The values of PAR were extracted from level-3 MODIS, 9 km resolution at each 1° interval from 10°95′E to 21°95′N and 80°04′E to 95°04′E data access (http://oceandata.sci.gsfc.nasa.gov).

For detection of eddies, SSHA images obtained from the 7-day snapshots of merged sea-level anomalies from live access server having a spatial resolution of 1/3 of a degree (http://las.aviso.oceanobs.com) during the period 2006–2008 coinciding with high microphytoplankton abundance.

Analysis of micro-phytoplankton

Plankton analysis was carried out with surface water samples collected from the moving ship at any given time. Two litres of water was collected from each station, and each one litre was fixed using acetic Lugol's (2%) iodine and buffered formaldehyde (0.6%). Samples were brought back to the laboratory, kept undisturbed for 48 h, concentrated to a final volume of 10 ml and stored in vials. The samples were analysed using an inverted microscope by placing 4 ml of preserved subsample each separately (2 ml of acetic Lugol's iodine and 2 ml of buffered formaldehyde) from the oceanic stations (stations 1–21), and 0.2–0.5 ml from RM in a petri dish of 3.8 cm diameter, with phase contrast attachment at 100× and 200× magnification. Micro-phytoplankton cells were identified based on identification keys provided by Subrahmanyan[16], Taylor[25], Tomas[30] and Horner[31]. Their abundance is expressed in terms of cells per litre. To study the *Tripos* species composition and distribution, samples preserved with acetic Lugol's iodine were used. We draw information of *Tripos* from the micro-phytoplankton population, since the sampling was carried out using the ships of opportunity. The *Tripos* abundance was further compared with other geographical regions.

The abundance of ciliates (*Rhabdonellopsis*, *Albatrossiella*, *Eutintinnus*, *Ormosella*, *Salpingella*, *Steenstrupiella*, *Xystonella*, *Dictyocysta* and *Salpingacantha*) to genus level was also enumerated from 1 litre of water sample preserved separately with buffered formaldehyde (0.6%).

Data analyses

The *Tripos* species that contributed to more than 0.5% of the total *Tripos* population were subjected to ordination

Table 1. Details of sampling dates (DD/MM/YYYY) with their respective codes sampled for 48 months along the Chennai to Port Blair route and for 38 months along the Port Blair to Kolkata route from October 2006 to September 2011

Chennai to Port Blair	Code	Chennai to Port Blair	Code
25/10/2006 to 28/10/2006	O6	26/11/2010 to 29/11/2010	N10
11/11/2006 to 16/11/2006	N6	16/02/2011 to 19/02/2011	F11
07/12/2006 to 09/12/2006	D6	09/05/2011 to 12/05 2011	MY11
02/01/2007 to 04/01/2007	JN7A	20/09/2011 to 23/09/2011	S11
27/01/2017 to 30/01/2017	JN7B		
26/02/2007 to 01/03/2007	F7	Port Blair to Kolkata	Code
04/04/2007 to 06/04/2007	A7A	03/11/2006 to 05/11/2006	N6A
25/04/2007 to 27/04/2007	A7B	23/11/2006 to 25/11/2006	N6B
28/05/2007 to 30/05/2007	MY7	16/01/2007 to 19/01/2007	JN7
26/06/2007 to 29/06/2007	J7	13/02/2007 to 15/02/2007	F7
21/07/2007 to 23/07/2007	JU7	02/03/2007 to 04/03/2007	M7
31/08/2007 to 03/09/2007	S7	12/04/2007 to 14/04/2007	A7
05/10/2007 to 08/10/2007	O7	02/05/2007 to 04/05/2007	MY7
09/11/2007 to 12/11/2007	N7	05/06/2007 to 08/06/2007	J7
14/12/2007 to 17/12/2007	D7	06/07/2007 to 10/07/2007	JU7A
12/01/2008 to 14/01/2008	J8	24/07/2007 to 26/07/2007	JU7B
24/02/2008 to 26/02/2008	F8	07/09/2007 to 09/09/2007	S7
24/03/2008 to 26/03/2008	M8	20/10/2007 to 23/10/2007	O7
14/04/2008 to 16/04/2008	A8	18/11/2007 to 21/11/2007	N7
08/05/2008 to 09/05/2008	MY8	19/12/2007 to 21/12/2007	D7
18/07/2008 to 21/07/2008	JU8	18/01/2008 to 21/01/2008	JN8
21/08/2008 to 23/08/2008	AU8	08/03/2008 to 11/03/2008	F8
18/09/2008 to 20/09/2008	S8	18/04/2008 to 24/04/2008	A8
27/10/2008 to 30/10/2008	O8	13/05/2008 to 16/05/2008	MY8
10/11/2008 to 13/11/2008	N8	28/08/2008 to 30/08/2008	AU8
25/12/2008 to 27/12/2008	D8	25/09/2008 to 28/09/2008	S8
13/01/2009 to 16/01/2009	JN9	05/11/2008 to 07/11/2008	N8
18/02/2009 to 21/02/2009	F9	06/01/2009 to 08/01/2009	JN9A
18/03/2009 to 21/03/2009	M9	26/01/2009 to 28/01/2009	JN9B
16/04/2009 to 19/04/2009	A9	24/03/2009 to 27/03/2009	M9
06/06/2009 to 09/06/2009	J9	20/04/2009 to 23/04/2009	A9
10/07/2009 to 12/07/2009	JU9	12/06/2009 to 14/06/2009	J9
13/08/2009 to 16/08/2009	AU9	17/07/2009 to 20/07/2009	JU9
12/09/2009 to 13/09/2009	S9	20/08/2009 to 22/08/2009	AU9
14/10/2009 to 17/10/2009	O9	21/09/2009 to 24/09/2009	S9
09/11/2009 to 12/11/2009	N9	21/10/2009 to 24/10/2009	O9
26/12/2009 to 28/12/2009	D9	19/11/2009 to 21/11/2009	N9
22/01/2010 to 25/01/2010	JN10	28/01/2010 to 31/01/2010	JN10
17/02/2010 to 20/02/2010	F10	25/03/2010 to 27/03/2010	M10
20/03/2010 to 23/03/2010	M10	31/05/2010 to 03/06/2010	J10
21/04/2010 to 23/04/2010	A10	25/07/2010 to 27/07/2010	JU10
24/05/2010 to 27/05/2010	MY10	04/10/2010 to 07/10/2010	O10
21/07/2010 to 24/07/2010	JU10	28/02/2011 to 02/03/2011	M11
22/09/2010 to 26/09/2010	S10	29/09/2011 to 01/10/2011	S11

analysis. The relationship among *Tripos*, ciliates and environmental parameters (sea-surface temperature (SST), sea-surface salinity (SSS), DIN, DIP, wind speed, rainfall and PAR) was evaluated separately for CPOS, and P–K transect by performing canonical correspondence analysis (CCA), CANOCO version 4.5 (ref. 32). An automatic selection, on seven environmental variables was performed, and using a Monte Carlo permutation test and statistical significance of each variable was tested under the reduced model with 999 permutations. Only those stations were considered for which physicochemical data was available.

Results

Hydrography

Along CPOS, low SST (26.1–29.9°C) was observed during monsoon (NEM and SWM) and relatively higher during SIM and FIM (28.2–31.0°C). Along the P–K transect (PKOS, AR and RM), low SST was observed during NEM (24.3–30.0°C) and relatively higher values during FIM, SIM and SWM (27.9–30.9°C). The SST was lowest during NEM (irrespective of the region), and this trend was observed in all the five years. The CPOS comprises of stations that are away from riverine influence, whereas AR and RM are closer to the Irrawaddy and Ganges–Brahmaputra river basins. The SSS was relatively high in CPOS (29.2–34.4) when compared to P–K transect (25.7–34.4). Low SSS was observed during SWM, especially in RM and was relatively high during SIM and FIM (Tables S1–S3, see Supplementary Material online).

Nutrient concentrations in the surface waters of the BoB were below detectable range for most part of the year, especially during SIM. In CPOS, maximum concentration of DIN and DIP was observed on some occasion during the monsoons, and was up to 3.02 and 2.88 μmol l^{-1}. In PKOS, it was in par with CPOS. However, in AR and RM it was noticed that the concentration was up to 4.23 μmol l^{-1} for DIN and 3.08 μmol l^{-1} for DIP (Table S1–S3, see Supplementary Material online).

The variations in wind speed and PAR in all the four regions are presented in Tables S1–S3 (see Supplementary Material online). In all the regions, high wind speed was recorded during the SWM, followed by NEM, whereas low wind speed was recorded during IM. PAR was also high during IM, and low during SWM and NEM.

Rainfall showed a different pattern. High precipitation was noticed during SWM and NEM in the entire CPOS, whereas during SWM it was observed in the P–K transect (Tables S1–S3, see Supplementary Material online). However, we could also see the intra-annual variation, where rainfall was also recorded during SIM in the stations of AR.

Based on the SSHA mesoscale eddy was identifiable on 4 occasions. The first eddy had a centre at 13°00′N lat. and 83°00′E long. The second eddy had a centre at 18°50′N and 87°00′E. The third and fourth had a centre at 16°00′N and 85°00′E and13°00′N and 83°00′E (Table S4, Figure S1 *a–d*, see Supplementary Material online).

Micro-phytoplankton community and abundance

Total micro-phytoplankton abundance varied from 25 to 6.3 $\times 10^4$ cells l^{-1} along the CPOS transect and 30 to 2.7 $\times 10^5$ cells l^{-1} along the P–K transect. The highest abundance was observed during SWM followed by NEM. However, at AR and RM the abundance was also high during SIM and FIM (Figure 2 *a* and *d*). The trend was opposite in the case of dinoflagellates, except at RM and AR (Figure 2 *b* and *e*). Diatoms were the dominant group with respect to their numbers, whereas dinoflagellates was the highest with respect to its taxonomic composition (data not shown). Apart from diatoms and dinoflagellates, high numbers of ciliates were also encountered in the AR and RP. Their abundance varied from 5 to 200 cells l^{-1} along CPOS and up to 1000 cells l^{-1} along RM (Figure 2 *c* and *f*).

Tripos species composition and community structure

Tripos abundance varied from 5 to 125 cells l^{-1} along the CPOS and up to 280 cells l^{-1} along the P–K transect (Figure 3 *a* and *b*). Altogether 40 species of *Tripos* were recorded, of which 29 were common to the two transect (Table 2). It was also noticed that 10 species were exclusively found along the C–P and 1 species along the P–K transect (Figures S2 and S3, Tables S5–S8, see Supplementary Material online). Along the CPOS, maximum abundance of *Tripos* was noticed at station 5 during FIM and SIM, and at station 7 during NEM, whereas along the P–K transect the highest abundance was observed in the RM during SWM–IV then followed by SIM. In addition, *T. furca*, *T. fusus*, *T. muelleri* and *T. lineatus* having the potential to form blooms were also encountered.

Tripos distribution in the C–P and P–K transects

Tripos abundance along the CPOS showed inter- and intra-annual variations as illustrated in Figure 3 *a* and *b*. The highest abundance (125 cells l^{-1}) was observed during FIM (October 2007 and October 2008), and the abundance was low during October 2006 and October 2009 (40 cells l^{-1}). During November, which is a northeast monsoon month, *Tripos* was widely distributed.

During the later stage of SIM, abundance was high and reached up to 60 cells l^{-1}, and these high numbers continued in the initial stages of SWM and decreased at the end of SWM. On an inter-annual scale, September 2010 was an exception yielding high numbers.

Along the P–K transect, irrespective of the seasons, maximum abundance was recorded at RM, followed by AR, and ranged from 100 to 280 cells l^{-1}. In PKOS, the cell abundance was on par with CPOS (Figure 3 *b*).

Comparison of Tripos with different biogeographical regions

A comparison of the *Tripos* abundance in different regions of the oceans is provided in Table 3. In the open ocean the abundance is generally low. Higher abundance of *Tripos* population have been reported from the Sagami Bay, Buyukcekmece Bay and Chesapeake Bay and have been related to nutrient regeneration (decay of *Noctiluca scintillans*), higher DIN concentration (up to 10.79 μmol l^{-1}) and availability of feed *Strobilidium* spp. in the Chesapeake Bay.

Influence of environmental characteristics on the distribution of Tripos

The CCA was used to link the distribution of *Tripos* species to environmental variables. The orientation and arrow lengths shown in Figure 4 *a* and *b* (environmental

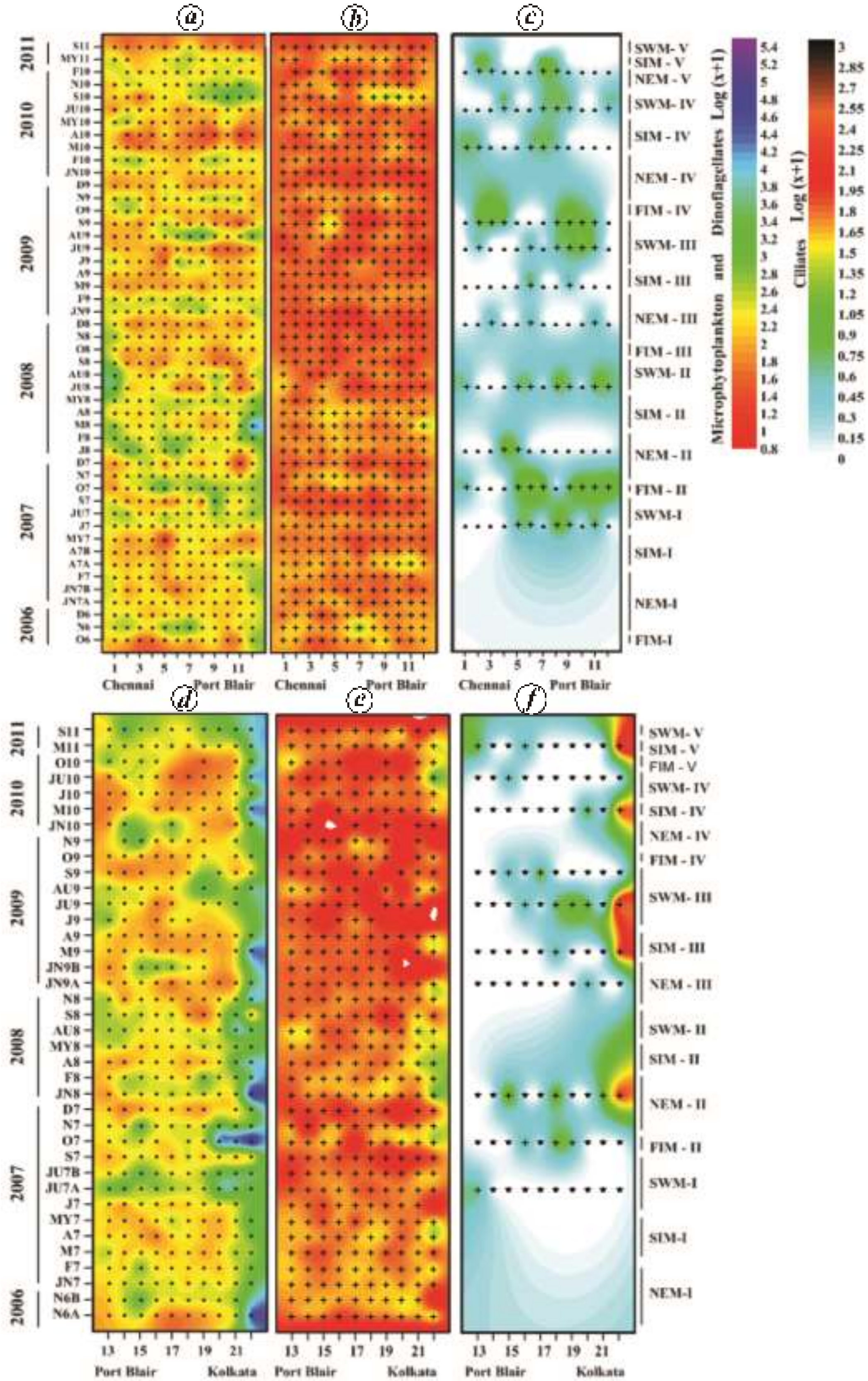

Figure 2 ***a–f*****.** Spatio-temporal variation of micro-phytoplankton (***a***, ***d***), dinoflagellate (***b***, ***e***) and ciliates (***c***, ***f***), abundance along the CPOS and P–K transect. The $\log(x + 1)$ transformed abundance values are used in the plot. + denotes presence of the taxa at sampled stations. * denotes the stations sampled where ciliates were not recorded. The sampling dates with their respective codes along the CPOS and P–K transect are provided in Table 1.

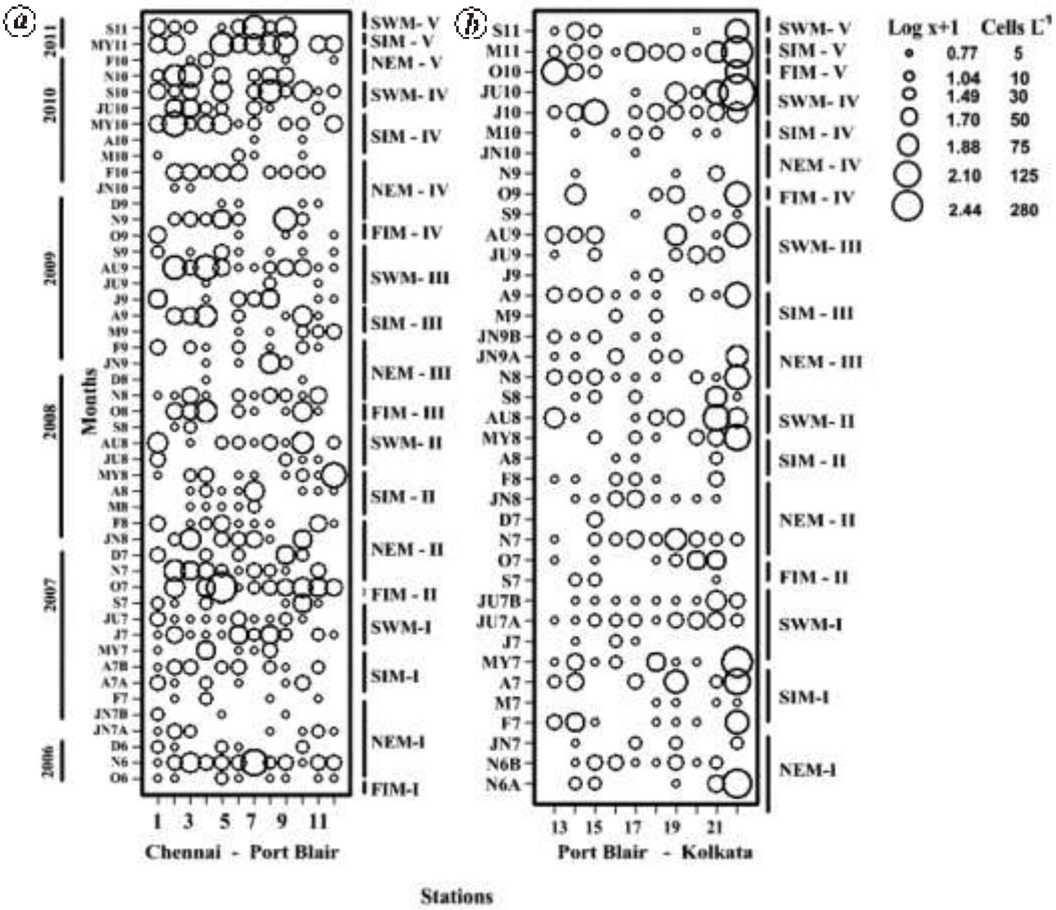

Figure 3 *a*, *b*. Spatio-temporal variation of *Tripos* along the CPOS (***a***) and P–K transect (***b***). The log(x + 1) transformed abundance values were used in the plot. The sampling dates with its respective codes along the CPOS and P–K transect are provided in Table 1.

variables) indicate their relative importance and approximate correlation to the axes. Arrows point in the direction of increase of the environmental gradient. Based on automatic selection and Monte Carlo permutation test of the total 7 environmental variables, SST and SSS was statistically significant in CPOS and P–K transect (Tables S9a and S10a, see Supplementary Material online).

In the CPOS, CCA results showed that 10.74% of the total inertia (2.1%) in the species data could be explained by environmental variables (Figure 4 *a*). The CCA axes 1 and 2 (eigenvalues of 0.09 and 0.05 respectively) explained cumulative variance (49.5%) of the relation of species–environmental variables (Table S9, see Supplementary Material online). Based on the intersect correlation of environmental variables with the CCA axis, we could notice, *T. fusus*, *T. candelabrus* and *T. deflexus* preferred moderate to higher DIN concentration, whereas *T. trichoceros* preferred higher DIP. *T. karstenii* and *T. kofoidii* preferred higher rainfall, whereas *T. longirostrus*, *T. extensus* and *T. inflatus* preferred low SST. *T. furca* was not seen to be influenced by any of the environmental variables.

In the P–K transect, CCA results showed 3.9% of the total inertia (11.8%) in the *Tripos* was explained by environmental variables (Figure 4 *b*). The CCA axes 1 and 2 (eigenvalues of 0.27 and 0.09 respectively) explained 70.6% of the environmental variables (Table S10, see Supplementary Material online). Based on the intersect correlation of environmental variables with the CCA axis, we could notice that the cosmopolitan forms which are most dominant (*T. furca*, *T. fusus* and *T. horridus* preferred higher DIN, DIP, rainfall, photosynthetic active radiation and wind speed). The open ocean forms (*T. extensus*, *T. macroceros*, *T. schmidtii*, *T. inflatus* and *T. declinatus*) preferred higher SSS and SST.

Discussion

The BoB is characterized by unique features such as seasonally reversing monsoon winds that blow during May–September from the southwest and during November–February from the northeast, March–April and October (IM) being the months of transition phase with weak winds[28]. The bay is also known for its enormous fresh

Table 2. List of *Tripos* species recorded along the C–P and P–K transects from October 2006 to September 2011

Taxa	CCA codes	C–P	P–K
Tripos arietinus (Cleve 1900)	ar	5–10 (4)	5 (3)
Tripos azoricus (Cleve 1900)	az	5 (3)	5–10 (4)
Tripos belone (Cleve 1900)*	be	5 (1)	
Tripos boehmii (H. W. Grahm & Bronik 1944)	bh	5 (1)	10 (1)
Tripos brevis (Ostenf. & Johannes Schmidt 1901)	br	5–15 (24)	5–10 (5)
Tripos candelabrus (Ehrenb. 1859)	ca	5–20 (4)	10 (1)
Tripos concilians (Jorg. 1920)*	cc	5 (2)	
Tripos contortus (Gourret 1883)	co	5 (2)	5 (1)
Tripos declinatus (G. Karst. 1911)	de	5–20 (75)	5–10 (35)
Tripos deflexus (Kof. 1907)	df	5–10 (10)	5–20 (3)
Tripos dens (Ostenf. & Johannes Schmidt 1901)	dn	5–20 (3)	5–15 (7)
Tripos digitatus (F. Schutt 1895)*	di	5–10 (3)	
Tripos extensus (Gourret 1883)	ex	5–20 (14)	5–20 (5)
Tripos euarcuatus (Jorg 1920)*	eu	5 (1)	
Tripos furca (Ehrenb. 1834)	fr	5–40 (76)	5–240 (65)
Tripos fusus (Ehrenb. 1834)	fu	5–25 (69)	5–40 (47)
Tripos hexacanthus (Gourret 1883)*	hex	5 (3)	
Tripos horridus (Cleve 1897)	hr	5–30 (35)	5–60 (23)
Tripos incisus (G. Karst. 1906)*	inc	5 (1)	
Tripos inflatus (Kof. 1907)	inf	5–10 (17)	5–15 (14)
Tripos karstenii (Pavill. 1907)*	kar	5 (5)	
Tripos kofoidii (Jorg. 1911)	kof	5 (5)	20 (1)
Tripos lineatus (Ehrenb. 1854)	lin	5–20 (17)	5–10 (5)
Tripos limulus (C.H.G. Pouchet 1883)*	lim	5 (1)	
Tripos longirostrus (Gourret 1883)	lon	5–10 (9)	5 (3)
Tripos lunula (Schimper 1900 ex G. Karst. 1906)	lu	5 (1)	5 (1)
Tripos macroceros (Ehrenb. 1840)	mac	5–10 (13)	5–15 (5)
Tripos massiliensis (Gourret 1883)	mes	5–15 (5)	5 (2)
Tripos minutus (Jorg. 1920)*	min	5 (2)	
Tripos muelleri (Bory 1825)	tri	5–20 (21)	5–15 (5)
Tripos muelleri var. *atlanticus* (Ostenf. 1903)	tra	5 (5)	5–20 (4)
Tripos pentagonus (Gourret 1883)	pen	5–15 (26)	5–10 (11)
Tripos pulchellus (Schrod. 1911)	pul	5 (1)	5 (2)
Tripos ranipes (Cleve 1900)*	ran	5–25 (3)	
Tripos schmidtii (Jorg. 1911)	sc	5–20 (18)	5–15 (6)
Tripos setaceus (Jorg. 1911)**	se		5 (2)
Tripos symmetricus (Pavill 1905)	sy	5 (1)	5 (1)
Tripos teres (Kof. 1907)	te	5–15 (61)	5–20 (22)
Tripos trichoceros (Ehrenb. 1859)	trh	5–20 (25)	5–100 (18)
Tripos vulture (Cleve 1900)	vu	5–10 (6)	5–80 (10)

Values outside the brackets indicate variation in cell numbers (cells l^{-1}) and those inside the brackets indicate the number of occurrences. * and ** indicate species which were exclusively recorded in the C–P and P–K transects respectively. CCA codes for the species are also indicated,

water influx (riverine discharge and precipitation), vertical stratification, low light (due to cloud cover and silt), and low nutrients[33,34]. Under such environmental settings, only those organisms that have developed an alternate mechanism for switching mode of nutrition have the efficiency to cope up in an oligotrophic environment. Studies indicate that dinoflagellates thrive well in low nutrient condition through a wide range of nutritional modes[35,36]. The present study revealed that in the BoB, genus *Tripos* is known to be widespread in its distribution.

In earlier studies (Pacific and NW Mediterranean)[8,12] large volume of water (~70 l) was utilized to enumerate *Tripos* and their abundance quantified was in the range of 0–24 cells l^{-1}. In this study we utilized only one litre of surface water sample. Inspite of this limited volume the numbers are comparatively higher (5–280 cells l^{-1}) than that observed in the Pacific and Mediterranean. In this study, we covered spatial (CPOS, PKOS, AR and RM) and seasonal (FIM, NEM, SIM and SWM) variations in the distribution of *Tripos* species. The stations of CPOS and PKOS are in the open ocean, and the AR and RM are more restricted to riverine discharge. Though all the four regions are influenced by seasonally reversing monsoons, the hydrographic settings (changes brought by variations in SSS) in these transects are different. In AR and RM, the main factors are precipitation and riverine discharge; Irrawady basin and Hooghly–Ganga estuarine complex are the major sources of freshwater influx[37]. In the CPOS

Table 3. Comparison of *Tripos* abundance and the two most dominant forms (*T. furca* and *T. fusus*) from different geographical regions

Ocean/sea	Locality	Cell abundance *Tripos* spp. cells m^{-3}	Cell abundance *T. furca* cells m^{-3}	Cell abundance *T. fusus* cells m^{-3}	Reference
Indian	Bay of Bengal		$0–2 \times 10^4$	$0–2 \times 10^4$	23
Indian	Cochin backwaters	$1.8–2 \times 10^3$			48
Indian	Jakartha Bay	5.1×10^5			49
Indian	Northwestern Red Sea		70–100,000		50
Pacific	Sagami Bay		7.5×10^7	1.1×10^7	40
Pacific	Sagami Bay		1.4×10^7	4.9×10^7	41
Pacific	North Pacific Central gyre	166–2399	0–38	0–5.5	7
Pacific	Eastern North Pacific	2000–22,000			8
Pacific	Tropical Central Pacific	48,000–108,000	12,000–24,000	40×10^3	51
Mediterranean	Büyükçekmece Bay, Sea of Marmara		5000×10^3		52
Mediterranean	East–west transects of the Mediterranean		$1.4–1.6 \times 10^5$	17,000–230,000	53
Mediterranean	Mediterranean Gulf of Kalloni		2.84×10^6	2.1×10^6	54
Mediterranean	Ligurian sea	24,000			12
Mediterranean	Northwest Mediterranean	834–3734			55
Atlantic	Chesapeake Bay		$7–480 \times 10^6$		56
Atlantic	East coast of USA		10,000	70,000	57
Atlantic	English Channel and North Sea	90×10^6			58
Arctic	Barent and Karas Sea	$10–500 \times 10^3$			59
Atlantic	Brazil–Malvinas confluence region		0–20,000	0–20,000	60

and PKOS, precipitation is the main source of salinity variation. The prevailing mesoscale eddies in the CPOS are also known for high biological production[38]. Observations in this study indicate that the influence of eddies is restricted to upper 30 m of water column. Under such conditions, we observed distinct seasonality in the timing of occurrence of *Tripos*.

The number of species encountered was relatively higher along the CPOS than along the P–K transect. Most of the species recorded in the two transects (16 species; present during all four seasons) were widespread in the Bay, of which 15 species along C–P and four along P–K were noticed in all the four seasons. Among them, two species (*T. furca* and *T. fusus*) were dominant in both the transects (Tables S5–S8, Figures S2 and S3, see Supplementary Material online). Their dominance in these two contrasting environmental settings indicates that they can also tolerate a wide range of salinity (25–34). Investigations from the Sagami Bay, Japan, also showed similar results[39–41]. For example, *T. furca* was observed in salinities varying from 17 to 34 and *T. fusus* from 24 to 30. It was also observed that apart from low salinity, rainfall results in nutrient loading especially DIN into the coastal waters. In both field and laboratory studies densities and specific growth rates tend to increase with higher N : P ratios[41]. In our studies as indicated in CCA biplot, high number of *T. furca* was related to high DIN concentration (Figure 4 *b*).

The species that formed the second dominant group are *T. vultur*, *T. trichoceros*, *T. muelleri*, *T. teres*, *T. pentagonus*, *T. macroceros*, *T. longirostrus*, *T. lineatus*, *T. inflatus*, *T. horridus*, *T. extensus*, *T. deflexus* and *T. brevis*. Although these species were not found in relatively high numbers (except *T. tricoceros*) they were present during SWM, NEM, SIM and were absent during FIM (Figures S2 and S3, see Supplementary Material online). In both the transects especially open ocean (CPOS and PKOS), the following species *T. lunula*, *T. contortus* and *T. candelabrus* were exclusively observed during the monsoon (SWM and NEM). The ten exclusive species observed along the C–P transect were found in very low numbers and occurrence (Table 2). These results indicate that they are purely oceanic forms with unique water mass characteristics and prevail mostly in less stratified water with a salinity range 31–34. Dodge and Marshall[4] have observed tolerance of some of these species (*T. gracilis* var. *symmetricus*, *T. karstenii* and *T. ranipes*) to a maximum of 28°C. However, their occurrence in BoB indicates their tolerance to higher temperature (29–31°C).

Several physical factors such as wind, current, tidal flow and density gradient have been suggested to concentrate phytoplankton in specific areas and play an important role in its regulation[42]. Studies in the NE Atlantic Ocean have also shown distinct dinoflagellate community in two different current patterns[10]. The current along the east coast of India (EICC; East India coastal current) reverses seasonally during the monsoon. Its poleward phase is developed during March–April, and the equator phase begins as the SWM withdraws. The equatorward flow appears first in the north in September and by November it is present along the entire coast[43]. We could observe high wind speeds (11–15, 7–10 m/s) during June and November in CPOS and during July in PKOS, AR and RM. Since high density of *T. furca* is usually found in the coastal waters, its widespread occurrence in November in CPOS can be related to the influence of the above monsoon events.

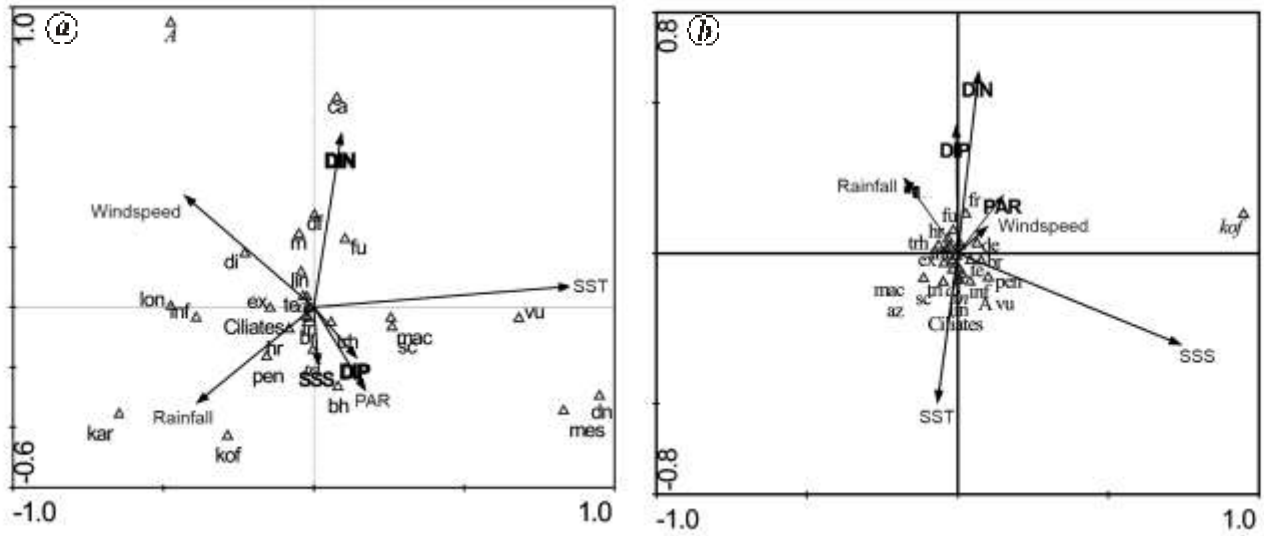

Figure 4. Ordination diagrams for CPOS (***a***), P–K transect (***b***), based on canonical correspondence analysis of *Tripos* and ciliates. The physico-chemical variables (temperature, salinity, dissolved inorganic nitrogen, dissolved inorganic phosphorus, rainfall and PAR) are indicated by arrows. Species abbreviations are listed in Table 2.

During IM the nutrient concentrations were below detectable levels, whereas during SWM and NEM, they were in the detectable range which can be attributed to rainfall. The distribution of field population of *T. furca* and *T. fusus* was positively related with DIN, DIP and increased wind speed[44]. We could also observe a similar trend with *T. furca* in BoB. However, the level of enrichment was considerably lower than that reported in the Sagami Bay. It is also evident from the CCA biplots (Figure 4 *a* and *b*), that one dominant form, i.e. *T. furca* persist under low DIN concentration, in the CPOS and the numbers tend to increase with elevated DIN in the stations of P–K transect.

The low numbers sustained in the oceanic stations can be attributed to species-specific nutrient adaptation using half-saturation constant (K_s) and have been evaluated by several authors[45–47]. K_s describes the ability of a species to take up low concentration of nutrients and thus determine the minimum nutrient concentration in which the species can grow. Dinoflagellates have low K_s compared with diatoms and raphidophytes. It has been reported that the half saturation constant for *T. furca* and *T. fusus* is low (0.15 μmol l^{-1}) for phosphate and high for nitrate (0.44 μmol l^{-1})[44]. Field and laboratory results also suggested that *T. furca* and *T. fusus* have a competitive advantage against other algal species under low nutrient conditions because of their low K_s values.

Conclusion

Observation of spatio-temporal variation in the dinoflagellate community of BoB revealed that *Tripos* is present round the year and is widespread in occurrence. Amongst the *Tripos* population, *T. furca* was the dominant form. The high numbers of *T. furca* recorded in AR, RM and in the C–P transect relate to the influence of monsoon, freshwater discharge and mesoscale eddies respectively. Dominance of *T. furca* was also observed with an increase in the ciliates population in AR and RM. Further studies on this association elucidating the depth-integrated information of *Tripos* community along with its environmental settings will be a step forward.

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SHORT COMMUNICATION

Estimation of diatom and dinoflagellate cell volumes from surface waters of the Northern Indian Ocean

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KEYWORDS
Diatoms;
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Cell volume;
Dona Paula Bay;
Bay of Bengal

Summary Phytoplankton samples collected from the Northern Indian Ocean (Bay of Bengal, northern Arabian Sea, and Dona Paula Bay Goa, west coast of India), were utilized to quantify changes in cell size, cell volume and carbon per cell of diatoms and dinoflagellates. The dataset from the Bay of Bengal also provides inter- and intra-annual variations (April 2008 to March 2010). The variations in cell size and volume were large in regions influenced by the riverine influx or terrigenous inputs. An interregional comparison of commonly available forms (8 species) points out that cell volumes are highest in the North Atlantic and lowest in the Mediterranean. The information provided will be useful in estimation of carbon biomass and biogeochemical studies.

1. Introduction

Trait-based characteristics are increasingly used to predict the phytoplankton community distribution along the environmental gradient (Margalef, 1978; Reynolds, 1988). They are not necessarily taxonomy related but determined based on size and the physiological processes such as growth (light and nutrient assimilation) and loss (sinking and grazing) (Morabito et al., 2007). The cell size is referred as a master trait which places important constraints on many key organismal characteristics and biotic interactions (Barton et al.,

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2013 and references therein). Smaller organisms have several advantages over large ones for e.g. a lower sinking rate, which is proportional to cell radius squared (Stokes law) (Smayda, 1970). Higher surface to volume ratio that helps efficient acquisition of limiting nutrients (Ploug et al., 1999; Sherwood et al., 1975) and higher maximum growth rates (Banse, 1976). In contrast, the large size organisms carry the advantage of motility, access nutrient resources unavailable to other organisms; avoid grazing and higher possibility of survival (Reynolds, 2006). The trade-off between these traits represents an ecological strategy to exploit better the available resources (Litchman et al., 2010). Since micro-phytoplankton exhibit a wide range in their size (20—200 μm) and shape, quantification of cell numbers only will not provide accurate information on carbon biomass. Hence, there is a need to convert cell count to cell volume since a large number of small cells are equivalent to few larger cells in terms of carbon biomass (Harrison et al., 2015). Cell size and its carbon content evaluations from cell volume can provide useful inputs to ecosystem applications, modeling and biogeochemistry studies. Phytoplankton cell volume and its associated parameters have been reported from Chinese Sea, Baltic Sea, Mediterranean Sea, Beagle Channel and North of Atlantic (Almandoz et al., 2011; Barton et al., 2013; Olenina et al., 2006; Sarno et al., 1993; Stanca et al., 2013; Sun et al., 2000). However, a similar kind of work from the waters surrounding the Indian subcontinent is lacking. Although Harrison (Harrison et al., 2015) has cited some of the references in this context, published literature is meager. In the Indian waters, the phytoplankton cell volume is measured in a few cases from the mangrove habitat and near coastal sites (Biswas et al., 2010; Mitra et al., 2012; Munir et al., 2015). This study provides information on cell volume and carbon per cell of diatoms and dinoflagellates from coastal and open ocean stations. The dataset is further compared for inter bioregional variations.

2. Material and methods

2.1. Study area

Surface water samples from the Bay of Bengal hereafter referred as "BoB" (XBT program using ships of opportunity) were collected from April 2008 to March 2010 on seven occasions along the Chennai — Port Blair; 81°00′E, 13°00′N to 92°00′E, 11°23′N, and on six occasions (April 2008 to March 2010) along Port Blair to Kolkata; 12°00′N, 93°14′E to 21°00′N, 88°23′E at 22 different stations. The stations are categorized into C-P open ocean (CPOS), Andaman Region (AR), P-K Open Ocean (PKOS) and River Mouth (RM) regions as shown in Fig. 1. From the northern Arabian Sea the surface water samples were collected while on a cruise SSK60 from 25th January 2014 to 1st February 2014 (40 stations covering 6 transects; 20°13′E, 68°90′N to 18°50′E, 69°99′N) and one coastal station located off Goa, Dona Paula Bay (15°27′N, 73°48′E), weekly twice from 1st September to 24th December 2015 with a total 34 samples.

2.2. Hydrological parameters

From the BoB, vertical temperature profile of the water column was recorded by launching XBT-MK21-T7 probes (Sippican Inc.) at one-degree intervals. From the northern Arabian Sea, the temperature was recorded using CTD (Sea - Bird Electronics, Inc.). In the Dona Paula Bay, surface water temperature was measured in situ. The conductivity of surface seawater from the Bay of Bengal and Dona Paula Bay was measured using Autosal and later converted into salinity (Guildline Autosal 8400B). From the northern Arabian Sea, the conductivity was measured using dual conductivity (SBE4) sensor fitted to CTD.

In all regions, for nutrients, 10 ml of seawater samples were collected into 10 ml cryovials, immediately frozen in

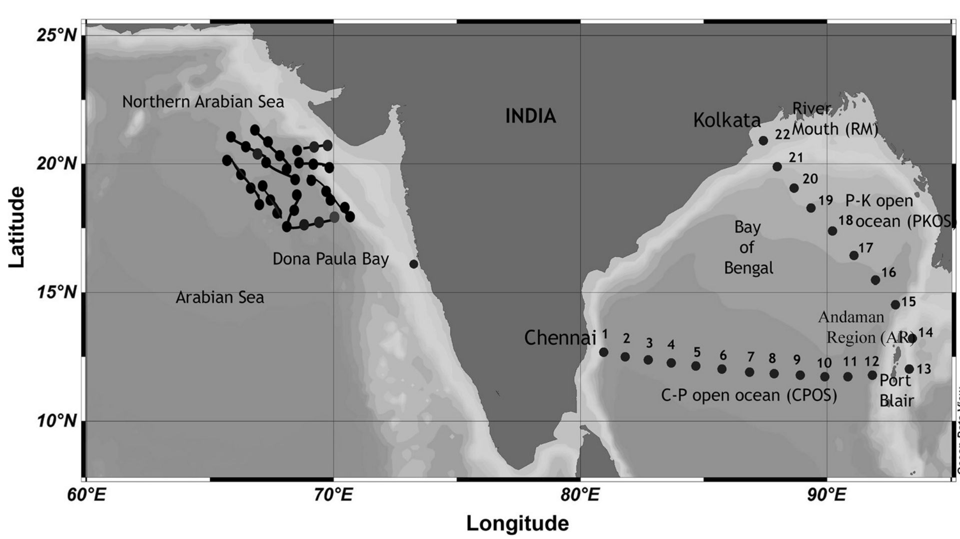

Figure 1 Locations of sample collection from the northern Indian Ocean (Bay of Bengal, northern Arabian Sea, and Dona Paula Bay). In the Bay of Bengal, samples were collected from four different tracks (Chennai to Port Blair open ocean — CPOS; Andaman Region — AR; Port Blair to Kolkata open ocean — PKOS; and River Mouth — RM). From the northern Arabian Sea samples were collected from 40 stations and in the Dona Paula Bay from one station.

liquid nitrogen and then analyzed using Skylar, (San++ segmented flow analyzer) following the method of Grasshoff et al. (1983).

2.3. Estimation of micro-phytoplankton cell volume

From the BoB, three liters of surface water samples were collected separately and preserved with different preservatives. (0.40% of Lugol's iodine, 0.60% buffered formaldehyde and 0.20% glutaraldehyde). The samples were allowed to settle in the laboratory for quantification of diatoms and dinoflagellates through a microscope. From the northern Arabian Sea, only one liter of surface water samples was collected and fixed with 0.40% Lugol's iodine for the estimation of diatom cell volume and a similar procedure was followed as that of BoB. For the estimation of dinoflagellates, thirty-five liters of surface water samples were collected and concentrated to 50.0 ml, using 20 μm nylon mesh. The samples were immediately fixed with 0.40% Lugol's iodine. At the end of the cruise, the samples were brought to the laboratory and concentrated to 35.0 ml and 5.00 ml of this concentrated sample was analyzed for dinoflagellates. For the coastal station of Dona Paula Bay, one liter of surface water was concentrated to 20.0 ml, of which 2.00 ml of sample was dispensed on a 3.80 cm petridish and measured for both diatoms and dinoflagellates.

The cell dimensions of diatoms and dinoflagellates from the BoB were measured using an ocular micrometer, calibrated with a stage micrometer. From the northern Arabian Sea and Dona Paula Bay, the cells were measured using image analysis software (Q-Capture Pro 7, Olympus Inc). In all the three sites cells were observed using an inverted microscope (Olympus IX71) at 100 and 200 times magnification. The measured dimension for each taxon was calculated for its cell volume using assigned geometric shape (Hillebrand et al., 1999; Sun and Liu, 2003). The range of cell size and cell volume, its classification according to size classes, the median value of cell volume and the number of cells measured (N) from three different regions are provided in Appendix (1A and 1B). A comparative analysis of the cell volume, 10 species of diatoms and dinoflagellates (which has a minimum number of 8 measurements) is presented in Fig. 2a—g. The rest of the species with cell volume are provided in Appendix 1A.

The carbon per cell was calculated using the equation provided by Menden-Deuer and Lessard (2000). The median volume was converted to carbon per cell using the equation $C = aV^b$ where a and b are 0.288 and 0.811 for diatoms, 0.216 and 0.939 for other protists, and 0.003 and 1 for *Noctiluca scintillans* (Macartney) Kofoid and Swezy, 1921. We also measured cell volume of live and fixed cells. The data is provided in (Appendix 1A and 1B). Studies on phytoplankton cell volume have emphasized that at least a minimum of 10—50 randomly selected cells for each species should be measured. Although we have measured most of the cells up to 25 or more, it was not possible to measure all the taxa since some of them were rare forms and they are measured as they occurred in the samples. The dataset from three different sites of northern Indian Ocean is compared with the published literature from different bioregions to evaluate the variations in the cell size (Appendix 2).

3. Results and discussion

3.1. Hydrological parameters

The BoB, (CPOS and PKOS) comprised of stations that are away from the riverine influence, whereas the AR and RM are closer to the Irrawaddy and Hooghly — Ganga river basins. The variations in Sea Surface Temperature (SST), Sea Surface Salinity (SSS) and nutrients during the observation period are provided in detail in another publication (Chitari et al., 2017). In brief, the SST was low during monsoon (NEM and SWM; 26.1—29.9°C) and relatively higher during the intermonsoon (SIM and FIM; 28.2—31.0°C). The SSS was relatively high in CPOS (29.2—34.4) when compared to P-K (25.7—34.4). Low SSS, was observed during the SWM, especially in the RM and was relatively high during the SIM and FIM.

Nutrient concentrations in the surface waters of the BoB were below detectable range for the most part of the year, especially during the SIM. In the CPOS, maximum concentrations of DIN and DIP were observed on some occasions during the monsoon and was upto 3.02 and 2.88 μmol L^{-1}. In the PKOS it was on par with CPOS. However, in the AR and RM, it was noticed that the concentration was upto 4.23 μmol L^{-1} for DIN and 3.08 μmol L^{-1} for DIP. The relatively higher nutrient concentration can be attributed to freshwater discharge.

The temperature in the northern Arabian Sea was observed to be low compared to BoB and Dona Paula Bay. The nutrients were higher (Nitrate >2.00 μmol) compared to BoB and both are attributed to winter convective mixing. In the Dona Paula Bay high nitrate (0.40—8.00 μmol L^{-1}) and phosphate (0.01—0.68 μmol L^{-1}) concentration was also observed. The details of hydrological parameters of the northern Arabian Sea (Roy et al., 2015; Sarma et al., 2015) and Dona Paula Bay (Patil and Anil, 2011, 2015) are available in the published literature.

3.2. Micro-phytoplankton cell volume

A total of 219 micro-phytoplankton species, 90 diatoms, and 129 dinoflagellates were measured during the study period from three different sites of Indian Ocean (BoB, northern Arabian Sea, and Dona Paula Bay) (Appendix 1A and 1B). Regarding species composition, amongst the diatoms, *Chaetoceros* spp. followed by *Rhizosolenia* spp. were the dominant forms, whereas amongst the dinoflagellate, genus *Tripos* spp. was dominant and this was followed by *Protoperidinium* spp. The higher number of size classes was observed in diatoms especially in the Dona Paula Bay and River Mouth (Hooghly Estuary) when compared to dinoflagellates except for *Pyrocystis pseudonoctiluca* Wyville-Thompson, 1876 in the open ocean. The higher number of size classes observed in diatoms belonged to *Bacteriastrum furcatum* Shadbolt, 1854, *Ditylum brightwellii* (T. West) Grunow, 1885, *Guinardia striata* (Stolterfoth) Hasle, 1996, *Guinardia delicatula* (Cleve) Hasle, 1997, *Leptocylindrus danicus* Cleve, 1889, *Proboscia indica* (H.Peragallo) Hernández-Becerril, 1995, *Rhizosolenia hylina* Ostenfeld, 1901, *Rhizosolenia hebetata* f. *semispina* (Hensen) Gran, 1908, *Rhizosolenia setigera* Brightwell, 1858, *Proboscia alata* (Brightwell) Sundström, 1986 and *Pseudo-solenia calcar-avis*

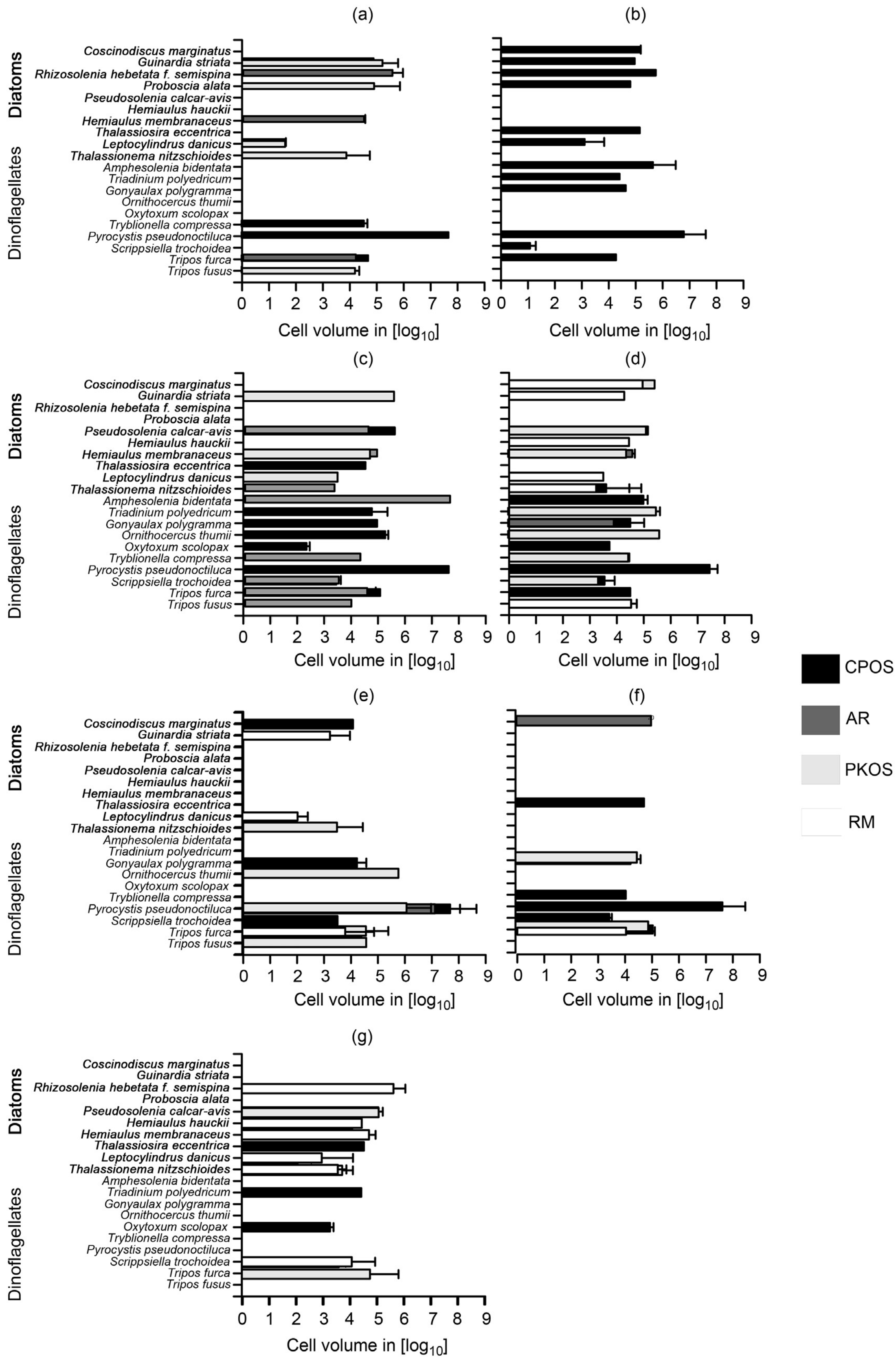

Figure 2 (a—g) Intra- and inter-annual variations in the cell volume (log transformed values) of 10 diatoms and dinoflagellates species from the Bay of Bengal, which had minimum numbers of 8 measurements. The cells measured were from April 2008 to March 2010 (a: April 2008; b: July 2008; c: Sept 2008; d: March 2009; e: July 2009; f: Sept 2009; g: March 2010) along the 4 different tracks (Chennai to Port Blair open ocean — CPOS; Andaman Region — AR; Port Blair to Kolkata open ocean — PKOS; and River Mouth — RM). The regions are denoted in different shades. Species of Diatoms are indicated in bold and Dinoflagellates are indicated in regular font.

(Schultze) B. G. Sundström, 1986. Such a size variation in the Dona Paula Bay and the River Mouth can be attributed to the nutrients and variation in salinity. Finenko et al. (2003) observed diatoms possess a greater degree of plasticity and are dependent on the growth conditions (mainly nutrients and irradiance). Patil and Anil (2015) also observed blooms of these forms in the Dona Paula Bay and are driven mainly by variation in salinity (14—30) and nutrients by freshwater discharge. Similarly, their variations in the Andaman Region can also be attributed to terrigenous inputs and rainfall.

The cumulative variance in the cell volume between similar taxa measured by ocular micrometer and image analysis software showed maximum variations in most complex shapes. In the simplest forms having minimum line parameters, the CV was within a range of 2—3%. However, a maximum variation of 21% was observed in more complex shapes having multiple line parameters such as *Climacodium frauenfeldianum* Grunow, 1868 and then followed by *Chaetoceros* spp. Ehrenberg, 1844 and *Thalassionema frauenfeldii* Tempère and Peragallo, 1910 (Appendix 3).

3.3. Seasonal and spatial variations in microphytoplankton cell volume in the Bay of Bengal

Seasonal variations in cell volume among the diatoms along the BoB was maximum during the SWM (July 2008, September 2008 and July 2009), and minimum during Intermonsoon (April 2008, March 2009 and March 2010). Among the diatoms, variations were observed in *L. danicus*, *G. striata Thalassionema nitzschoides* (Grunow) Mereschkowsky, 1902, *Proboscia alata, R. hebetata* f. *semispina*, *Rhizosolenia castracanii* H. Peragallo, 1888 and *Rhizosolenia bergonii* H. Peragallo, 1892 (Fig. 2a—g).

In some of the dinoflagellates, maximum variation was observed during the monsoon and minimum during Intermonsoon (*P. pseudonoctulica, Tripos furca* (Ehrenberg) F. Gómez, 2013 and *Tripos fusus* (Ehrenberg) F. Gómez, 2013) and can be attributed due to wind-driven mixing (Fig. 2a—g). Irrespective to the seasons, the Andaman Region and River Mouth showed maximum variations in cell volume when compared to the open ocean sectors of C-P and P-K (Fig. 2a—g). Dinoflagellates are known to be a poor competitor for nitrates and half of them are heterotrophic. Vertical migration in the water column allows them to persist with non-competitive parameters for nitrogen uptake and growth (Eppley and Thomas, 1969; Smayda, 1997). The utilization of energy for mobility could be one of the reasons for minimum variation in cell volume.

3.4. Comparision of cell volumes from the Indian ocean with different regions of the world

The cell volume data from this study is compared with the information available, from Atlantic (Barton et al., 2013; Olenina et al., 2006), Pacific (Sun et al., 2000), and the Mediterranean Sea (Kim and Travers, 1995) and is summarized in Fig. 3. Out of 219 species measured for cell volume from this study, we could compare only 8 species for which the reference data in all the regions were available (Fig. 3, Appendix 2). The maximum cell volume was observed from the waters of North Atlantic and the minimum was observed from the Mediterranean Sea. Larger cell size observed in the northern Atlantic, compared to the Mediterranean could be due to variation in temperature. Smith and Reynolds (2003) observed annual mean SST within a range of 0—25.0°C. In the Mediterranean waters, several authors (Sarno et al., 1993 and Stanca et al., 2013) observed temperature variation from 3.00 to 30.0°C. The temperature variations in the two different regions could be the factor for the variations in the cell volume.

Till date, only 8.00% of the studies have estimated cell volume in the waters surrounding Indian subcontinent (Leblanc et al., 2012). In the Atlantic, Pacific and Arctic

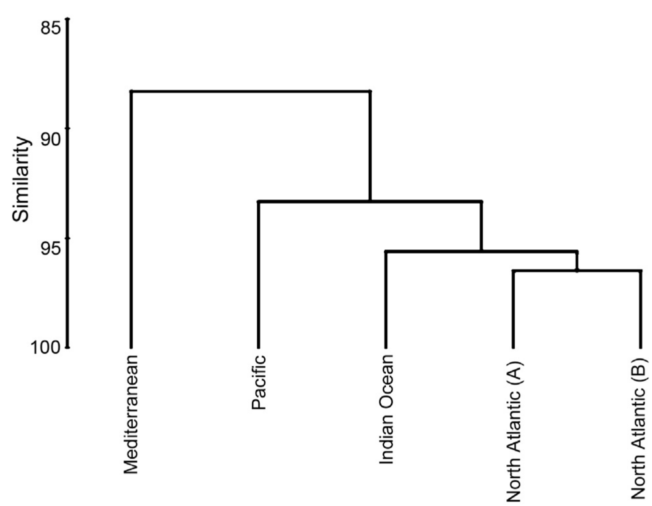

Figure 3 Comparison of cell volume from 4 different geographical regions. These include present dataset, North Atlantic (Barton et al., 2013; Olenina et al., 2006), Pacific Ocean (Sun et al., 2000), and Mediterranean Sea (Kim and Travers, 1995). The eight species which are found to be common in all the 4 regions were clustered using the Bray—Curtis similarity coefficient and group average method (log transformed). The species used for clustering are marked by (*) and is provided in Appendix 2.

region several organized groups such as HELCOM (Helsinki Commission), PEG (Phytoplankton Expert Group), ECS (European Committee for Standardization) have set up standard protocols, to estimate biovolumes using recommended shapes of Hillebrand et al. (1999), and Sun and Liu (2003) for various phytoplankton species (Harrison et al., 2015; Olenina et al., 2006). In the Indian waters, although few datasets are available there is a need to follow the most simple and common protocol to facilitate inter bioregional comparison.

According to Harrison et al. (2015), the diatom cell volumes and carbon estimates are a single largest source of uncertainty. Since larger diatoms are 20,000 times more in its cell volume than the small diatoms. Volumes of big dinoflagellates are 1500 times larger than small dinoflagellates. The ranges in diatom cell volumes are 10 times greater than across dinoflagellates (i.e. >20,000 vs. 1500 times). The Information from the Indian Ocean region provided in this paper adds a number of species from the open ocean and provide their size ranges.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.oceano.2017.03.001.

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