ResearchGate

See discussions, stats, and author profiles for this publication at: http://www.researchgate.net/publication/236142132

Symbiosis between the stramenopile protist Solenicola setigera and the diatom Leptocylindrus mediterraneus in the North Eastern Arabian Sea

ARTICLE *in* SYMBIOSIS · MAY 2012

Impact Factor: 1.44 · DOI: 10.1007/s13199-012-0160-8

CITATION
1

READS
53

5 AUTHORS, INCLUDING:

K.B. Padmakumar
Centre For Marine Living Resources and Ecology
36 PUBLICATIONS **71** CITATIONS

SEE PROFILE

Lathika Cicily
Centre For Marine Living Resources and Ecology
20 PUBLICATIONS **35** CITATIONS

SEE PROFILE

V. N. Sanjeevan
Centre For Marine Living Resources and Ecology
51 PUBLICATIONS **137** CITATIONS

SEE PROFILE

All in-text references underlined in blue are linked to publications on ResearchGate, letting you access and read them immediately.

Available from: K.B. Padmakumar
Retrieved on: 11 December 2015

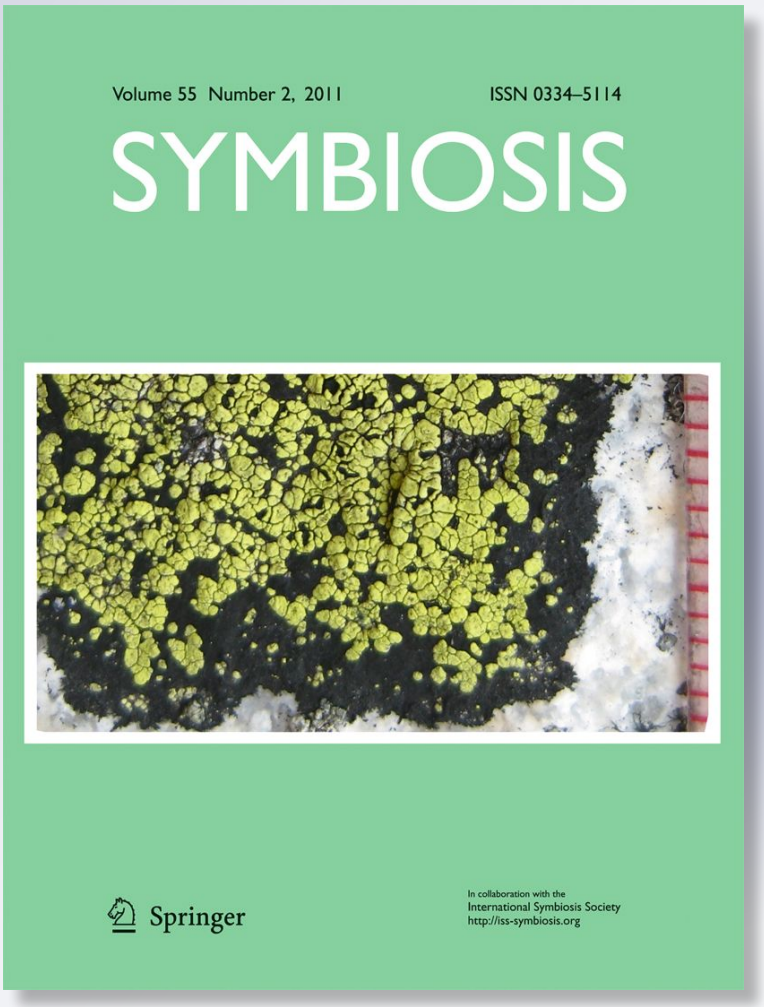
Symbiosis between the stramenopile protist Solenicola setigera and the diatom Leptocylindrus mediterraneus in the North Eastern Arabian Sea

K. B. Padmakumar, Lathika Cicily, Anu Shaji, T. P. Maneesh & V. N. Sanjeevan

Symbiosis

ISSN 0334-5114

Symbiosis
DOI 10.1007/s13199-012-0160-8



Springer

Your article is protected by copyright and all rights are held exclusively by Springer Science+Business Media B.V.. This e-offprint is for personal use only and shall not be self-archived in electronic repositories. If you wish to self-archive your work, please use the accepted author's version for posting to your own website or your institution's repository. You may further deposit the accepted author's version on a funder's repository at a funder's request, provided it is not made publicly available until 12 months after publication.

Author's personal copy

Symbiosis
DOI 10.1007/s13199-012-0160-8

Symbiosis between the stramenopile protist Solenicola setigera and the diatom Leptocylindrus mediterraneus in the North Eastern Arabian Sea

K. B. Padmakumar · Lathika Cicily · Anu Shaji · T. P. Maneesh · V. N. Sanjeevan

Received: 10 January 2012 / Accepted: 8 March 2012
© Springer Science+Business Media B.V. 2012

Abstract Symbiotic associations between the diatoms and other organisms like cyanobacteria, flagellates etc. is less studied in Indian waters. Here, we report the occurrences of Solenicola setigera, a colonial protist found only in association with centric chain forming diatom Leptocylindrus mediterraneus. We observed these consortia in the surface waters (~80–100 colonies L-1) of North Eastern Arabian Sea (NEAS) during the spring inter monsoon season of 2011 and were also observed in the water column (<20 colonies L-1) up to 120 m depth. The consortium observed in the surface waters comprised single or few frustule with the protozoan colonies spread along the entire frustule, but those in the water column with the protozoan colony restricted to the central section of the frustule. Our observations suggest that Solenicola setigera is a heterotroph that grazes on pico and nanoplanktonic organisms thereby play an important ecological role in the North Eastern Arabian Sea ecosystem.

Keywords *Solenicola setigera* · *Leptocylindrus mediterraneus* · Protist · Diatom · Symbiosis · North Eastern Arabian Sea

1 Introduction

Solenicola setigera is a colonial protozoan growing epiphytically on the outer wall of the diatom frustules. Earlier studies on marine plankton have reported the colonies of these protozoan on the empty frustules of diatom *Leptocylindrus* (= *Dactyliosolen*) *mediterraneus* (H. Peragallo) Hasle (Gran 1908; Mangin 1912; Pavillard 1916; Hasle 1975; Taylor 1982). *Solenicola- Leptocylindrus* association is ubiquitous in the world's oceans. The centric diatom *Leptocylindrus mediterraneus* has a cylindrical shape with numerous girdle bands and can appear solitary or united by the valve face forming chains (Scott and Thomas 2005). This species has a marine cosmopolitan distribution; in general it has been found without chloroplasts and with epiphytic flagellates attached to the girdle bands. On the other hand, its taxonomic position is questionable (Hasle and Syvertsen 1997). According to Fryxell (1989) *L. mediterraneus* is frequently found in Antarctica, even under the ice and particularly it was well represented in deep waters in the Weddell Sea. While Scott and Thomas (2005) recognize the epiphytic flagellate as *Rhizomonas setigera*, Gomez (2007) prefers to retain *Solenicola setigera* name and call the association between both species as *Solenicola-Leptocylindrus* consortium. Buck and Bentham (1998) reported the cyanobacteria *Synechococcus* sp. and picoeukaryote cells to be embedded in the matrix of some of the larger chains of *Solenicola setigera*, presenting this consortium as a three-partner association and he hypothesized that *Solenicola* could be favoured by the association with a nitrogen-fixing cyanobacteria. *Solenicola* is the first documented member of a highly and widespread group of stramenopiles or heterokonts, the MAST-3 and this group are more active than other planktonic protists (Massana et al. 2004; Not et al. 2009). These observations indicate that MAST-3/ Solenicolida species play an important ecological role in the marine ecosystems, most likely as nanoflagellate grazers. According to Gomez (2007) *Solenicola* becomes the first identified member of the widely distributed, abundant and active marine stramenopile group MAST-3.

During an oceanographic cruise in North Eastern Arabian Sea in spring inter monsoon season of 2011, a high

K. B. Padmakumar (✉) · L. Cicily · A. Shaji · T. P. Maneesh · V. N. Sanjeevan
CMLRE,
Kochi, Kerala, India
e-mail: kbpadmakumar@gmail.com

Published online: 30 March 2012

Author's personal copy

concentration of *Solenicola- Leptocylindrus* consortium was observed. There was only a single report on these associations from the Indian waters by Gopinathan (1975), he has described a new record of diatom *Dactyliosolen mediterraneus* with its epiphytic flagellate *Solenicola setigera*. We report here on the occurrence of the association between *S. setigera* that we observed on the cell walls of *L. mediterraneus* in Northern Arabian Sea.

2 Materials and methods

This observation was based on phytoplankton samples collected during the FORV Sagar Sampada cruise from North Eastern Arabian Sea (Lat. 21–22° N and Long. 66–70° E, Fig. 1) from ten stations covering an area of 4.9×10^4 sq. km during the spring inter monsoon (March, 2011). The phytoplankton samples were collected from these ten stations, and in station no. 10 (Lat. 21°07.91′N, Long. 66°54.13′E) the consortium *Solenicola- Leptocylindrus* was observed. The physico-chemical characteristics of the water where this association was observed were analysed following the standard procedure and protocol. The surface phytoplankton samples were obtained by filtering surface sea water through a 20 μ bolting silk and the filtrates preserved in 3% buffered formalin and Lugol's iodine. Subsurface samples (up to 120 m) collected using Niskin bottles attached to CTD profiler and allowed to settle in glass sedimentation cylinders and concentrated to 50 ml after adding formalin-lugol's iodine solution. Vertical profiling of parameters like temperature, salinity, density etc. was also done using the CTD (*Seabird 911 plus CTD*) attached sensors to understand the oceanic processes. Sea surface temperature (SST) of the area was measured by ordinary thermometer. Nitrite, nitrate, phosphate and silicate were analysed using a segmented flow auto analyzer (*SKALAR*) onboard the vessel adopting standard procedures (Grasshoff et al. 1983). Dissolved oxygen

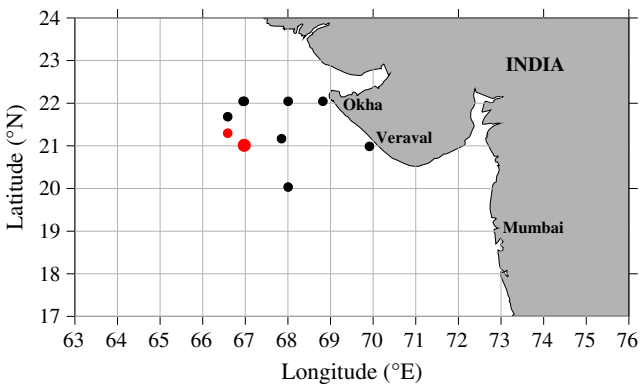


Fig. 1 Map showing the study area. (*Black circle*) represents sampling stations and (*Red circle*) the area where the *Solenicola- Leptocylindrus* consortium was observed

was estimated following Winkler method. Chlorophyll *a* was measured spectrophotometrically using a double beam *Perkin Elmer* UV-Visible spectrophotometer following 90% acetone extraction method (Parsons et al. 1984). Live specimens of *Solenicola- Leptocylindrus* consortium was analysed and microphotographed onboard using Nikon Eclipse light microscope attached with Nikon DN 100 series digital camera. Standard identification books and keys were used for the species level identification of diatoms (Cupp 1943; Hasle 1975; Hasle and Syvertsen 1997) and protists (Pavillard 1916; Patterson and Zolffel 1991). Abundance of picoplankton was determined by epifluorescence microscopy on black-stained 0.2 μm nuclepore filters under blue-light excitation on a Leica DM4000B epifluorescence microscope.

3 Results and discussion

High concentration of *Solenicola- Leptocylindrus* consortium was observed in North Eastern Arabian Sea during spring inter monsoon period. Individuals of *Solenicola setigera* found in clusters on the surface of frustules of a chain forming diatom, *Leptocylindrus mediterraneus*, as previously reported by Taylor (1982). *L. mediterraneus* was a species easily identified by the presence of epiphytic flagellates fixed to the girdle bands. *Solenicola* cells formed small groups or colonies around the intercalary region of the *Leptocylindrus* and in few cases *Solenicola* cells entirely cover the diatom frustules (Fig. 2a, b and c). Unpreserved phytoplankton samples observed onboard under epifluorescence microscope showed live cells of *Leptocylindrus* in the consortium with auto fluorescence; hence we considered that the consortium was between live cells of *Leptocylindrus* and *Solenicola*. Total phytoplankton cell density of the area where the *Solenicola- Leptocylindrus* association observed was 1.1×10^4 cells L^{-1}. Diatoms formed 89% of the total phytoplankton population and among them *Leptocylindrus mediterraneus* are dominant with cell density 9.5×10^3 cells L^{-1}. Other diatoms were represented by the genus *Chaetoceros* spp., *Pseudonitzschia* sp., *Rhizosolenia* spp., *Planktoniella sol* and *Haslea* spp. Dinoflagellate were few in number and represented by the genus *Ceratium, Gonyaulax, Protoperidinium* and *Ornithocercus*. All previous studies reported that, no free living specimens of *L. mediterraneus* were recorded and the frustules were devoid of cell protoplasm (Hasle 1975; Taylor 1982; Gomez 2007). But here in our observation free living cells and the frustules with protoplasm were identified. Table 1 shows the surface hydrographic parameters of the area where the *Solenicola- Leptocylindrus* consortium was recorded and Fig. 3 represents the vertical profiles of physico-chemical parameters of the area. Sea surface temperature (SST) and salinity of the area was 25.63°C and 35.96 psu respectively. Eventhough there was not much variation in the temperature and salinity pattern, an

Author's personal copy

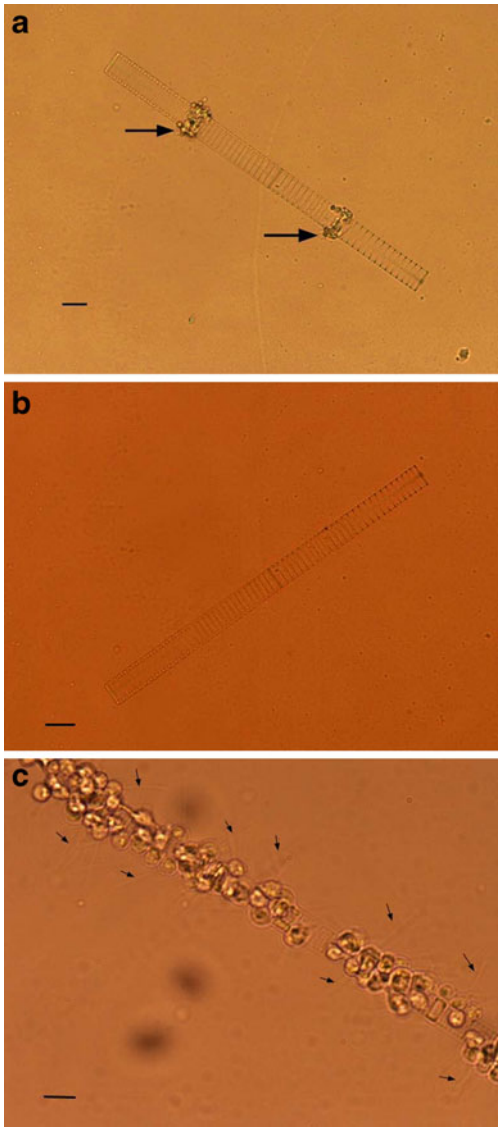


Fig. 2 (**a**) Photomicrographs of *Leptocylindrus mediterraneus* with *Solenicola setigera* colonies attached around the growth bands (Scale bar 10 μm). (**b**) Photomicrographs of *Leptocylindrus mediterraneus* without *Solenicola setigera* (Scale bar 10 μm). (**c**) Photomicrographs of *L. mediterraneus* frustule entirely covered by *Solenicola setigera* with flagella like structures (Scale bar 10 μm)

increased concentration of nitrate was observed in the station where the consortium was identified in comparison with other stations. The presence of diazotrophic picoplanktons such as *Synechococcus* and *Prochlorococcus* in the region might be the reason for an increased nitrate concentration. Hence the presence of *Solenicola-Leptocylindrus* consortium can be considered as an indicator for the presence of diazotrophs in the region which forms their major food items. Maximum number of *Solenicola- Leptocylindrus* consortium was observed in the surface waters. These consortiums were present in the water column, but the density was meagre. From the vertical distribution of chlorophyll *a* subsurface maxima was observed at 30 m and is contributed by *Rhizosolenia* spp.

Table 1 Surface hydrographic parameters of the area where the *Solenicola- Leptocylindrus* consortium was observed

Parameters	
SST (°C)	25.63
Salinity (psu)	35.96
pH	8.48
DO (ml L^{-1})	5.91
NO_2-N (μmol L^{-1})	0.08
NO_3- N (μ mol L^{-1})	0.48
PO_4-P (μ mol L^{-1})	0.31
SiO_4 (μ mol L^{-1})	0.73
Chlorophyll *a* (μg L^{-1})	0.22

The colony of *Solenicola* was comprised of 5–8 cells and individual *Solenicola* cells were 4–8 μm long and are globular or tear shaped. Long flagellum like protuberances emanates from each cell and was more apparent in highly dense colonies. Chains of *L. mediterraneus* were also observed without the colonies of *S. setigera*. According to Gomez (2007) the morphology of *Solenicola* colonies may vary in respect to the occurrence of its picoplankton prey: in open ocean oligotrophic waters with less abundance of picoplankton, the consortia were formed of one or two *Leptocylindrus* frustules with the protozoan restricted to the central section of the frustule. Whereas in eutrophic waters with higher abundance of picoplanktonic prey, protozoans spread along the entire frustule. In the present study high picoplankton density (3×10^4 cells L^{-1}) was recorded in the area where the consortium was observed.

We observed a trend in the distribution of *Solenicola-Leptocylindrus* consortia in the NEAS, when comparing the productive and less productive seasons. Higher abundance was observed during the productive spring intermonsoon period (March 2011) with relatively large abundance of pico and large phytoplankton, whereas during the less productive season (Inter monsoon fall- Sept/ Oct 2000- from FORV Sagar Sampada Data Centre) the consortia *Solenicola-Leptocylindrus* was not observed in the NEAS, but the living cells of *L. mediterraneus* was observed in good proportion. Our study supports the view of diet based distribution trend of *Solenicola- Leptocylindrus* consortia as previously described by Gomez (2007) in Pacific Ocean and Cefarelli et al. (2011) in Antarctic waters.

Buck and Bentham (1998) considered this consortium as a three partner association with *L. mediterraneus*, *Solenicola* and nitrogen fixing cyanobacteria *Synechococcus* sp., the association with the latter being mutually beneficial. But in our observation, these three partner association was not revealed in the examinations of *Solenicola* colonies by epifluorescence microscopy. In this association major benefit goes to *Solenicola* where it obtains the substratum for attachment as well as shelter from predators. Since the *Solenicola* is

Author's personal copy

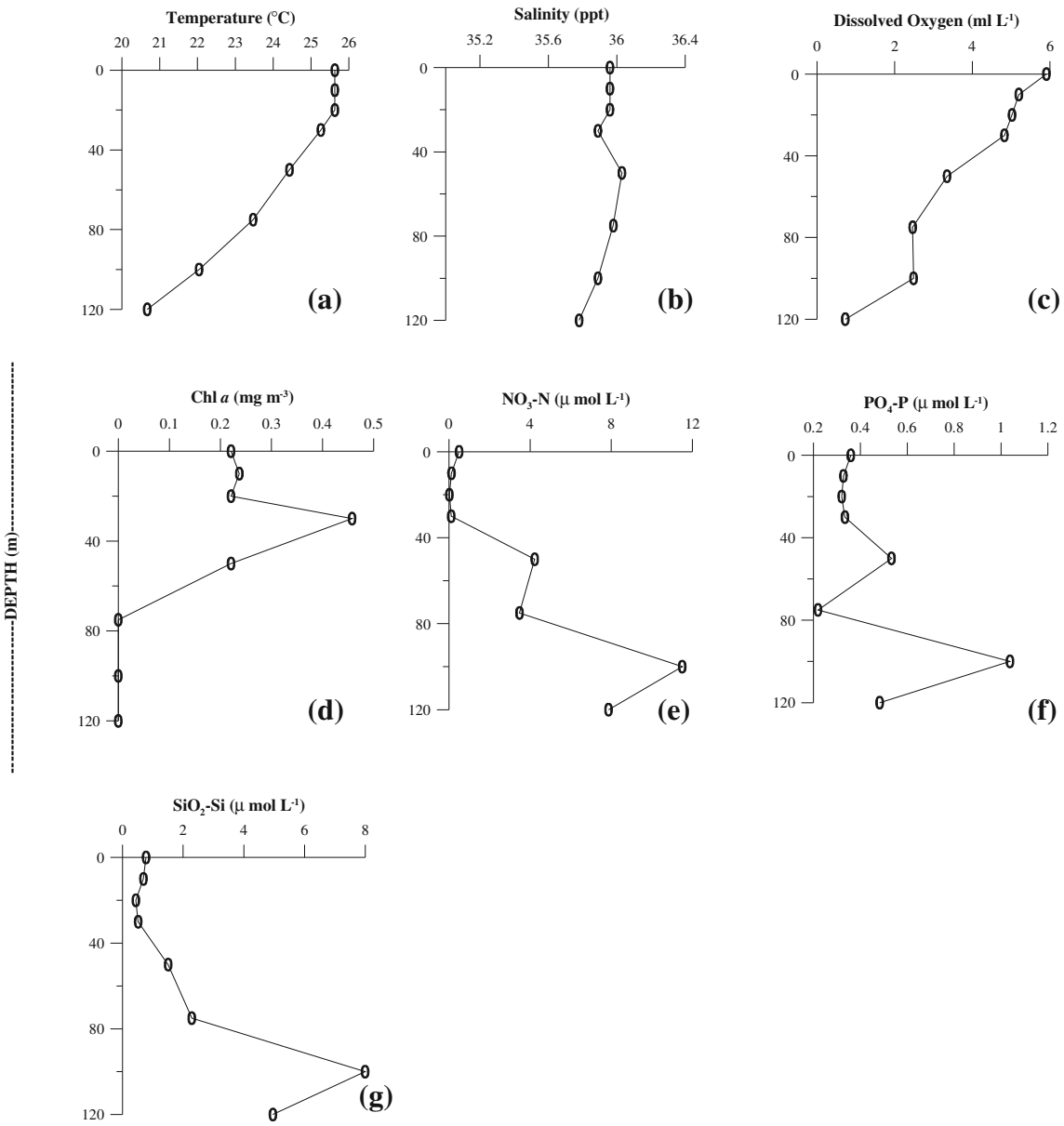


Fig. 3 Vertical distribution of hydrographical parameters of the area where the *Solenicola- Leptocylindrus* consortium was observed (**a**) Temperature (**b**) Salinity (**c**) Dissolved oxygen (**d**) Chlorophyll *a* (**e**) Nitrate (**f**) Phosphate (**g**) Silicate

known to produce exudates our assumption is that *Leptocylindrus* benefits from the exudates of *Solenicola* as nutrient source. Buck and Bentham (1998) reported that the *Solenicola* had vacuoles containing *Synechococcus* and picoeukaryotic cells. In the present study, few inclusions that were observed in the *Solenicola* colonies might have been the captured pico and nanoplanktonic microalgae. Individual *Solenicola* cells possessed a single flagellum and the undulating movement of these flagella creates water currents and helps in the traffic of small particles towards the colony. These observations suggest that *Solenicola setigera* is a heterotroph that grazes on pico and nanoplanktonic organisms thereby play an important ecological role in the North Eastern Arabian Sea ecosystem.

Phagotrophic protists (heterotrophic flagellates/ ciliates) are important components of food webs in the deep ocean and their high rate of metabolism facilitates carbon and energy flux through ecosystems. *Solenicola-Leptocylindrus* consortium plays an important role in the "microbial loop" of the North Eastern Arabian Sea and contributes to the flow of energy to higher trophic levels. Further research is required to document more fully the importance of these consortia in the NEAS, as well as the degree to which they contribute to the pelagic food webs.

Author's personal copy

Acknowledgments The authors are grateful to all the participants of FORV Sagar Sampada cruise 286 for the help rendered in sampling. This observation was made under the Marine Living Resources Programme funded by the Ministry of Earth Sciences, Government of India, New Delhi.

References

Buck KR, Bentham WN (1998) A novel symbiosis between a cyanobacterium, *Synechococcus* sp., an aplastidic protist, *Solenicola setigera*, and a diatom, *Leptocylindrus mediterraneus*, in the open ocean. Mar Biol 132:349–355

Cefarelli AO, Vernet M, Ferrario ME (2011) Phytoplankton composition and abundance in relation to free-floating Antarctic icebergs. Deep Sea Res II. doi:10.1016/j.dsr2.2010.11.023

Cupp EE (1943) Marine plankton diatoms of the west coast of North America. In: Sverdrup HU, Fleming RH, Miller LH, Zobell CE (eds) Bulletin of the scripps institution of oceanography of the University of California La Jolla, California, vol 1. Cambridge University Press, London, pp 1–238, Volume 5

Fryxell GA (1989) Marine phytoplankton at the Weddell Sea ice edge: seasonal changes at the specific level. Polar Biol 10:1–18

Gomez F (2007) The consortium of the protozoan *Solenicola setigera* and the diatom *Leptocylindrus mediterraneus* in the Pacific Ocean. Acta Protozoologica 46:15–24

Gopinathan CP (1975) On new distributional records of plankton diatoms from the Indian seas. J Mar Biol Ass India 17(1):223–240

Gran HH (1908) Diatomeen. In: Brandt K, Apstein C (eds) Nordisches plankton, vol 19. Lipsius and Tischer, Kiel, pp 1–146

Grasshoff K, Ehrhardt M, Kremling K, Almgren T (1983) Method of seawater analysis. Verlag Chemie, Weinheim, Germany, p 419

Hasle GR (1975) Some living marine species of the diatom family Rhizosoleniaceae. Beih Nova Hedwigia 53:99–140

Hasle GR, Syvertsen EE (1997) Marine diatoms. In: Tomas CR (ed) Identifying marine phytoplankton. Academic, San Diego

Mangin L (1912) Phytoplancton de la croisiere du Rene dans l'Atlantique (Septembre 1908). Annls Inst Océanogr 4:1–66

Massana R, Castresana J, Balague V, Guillou L, Romari K, Groisillier A et al (2004) Phylogenetic and ecological analysis of novel marine stramenopiles. Appl Environ Microbiol 70:3528–3534

Not F, del Campo J, Balague V, de Vargas C, Massana R (2009) New insights into the diversity of marine picoeukaryotes. PLoS One 4: e7143. doi:10.1371/journal.pone.0007143

Parsons TR, Maita Y, Lalli CM (1984) A manual of chemical and biological methods for seawater analysis. Pergamon Press, New York

Patterson DJ, Zolffel M (1991) Heterotrophic flagellates of uncertain taxonomic position. In: Patterson DJ, Larsen J (eds) The biology of free-living heterotrophic flagellates. Clarendon, Oxford, pp 427–476

Pavillard J (1916) Flagellees nouveaux epiphytes des diatomees pelagiques. Acad Sci Paris 163:65–68

Scott FJ, Thomas DP (2005) Diatoms. In: Scott FJ, Marchant HJ (eds) Antarctic marine protists. Australian Biological Resources Study, Canberra, pp 13–201

Taylor FJR (1982) Symbioses in marine microplankton. Ann Inst Oceanogr Paris 58:61–90