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An annotated checklist of Marine Phytoplankton taxa at the SOMLIT-Astan time series off Roscoff (Western English Channel, France): data collected from 2000 to 2010

Loïc GUILLOUX[1,2,3], Fabienne RIGAUT-JALABERT[1,2], Fabien JOUENNE[1,4], Stéphanie RISTORI[1,4],
Manon VIPREY[1,4], Fabrice NOT[1,4], Daniel VAULOT[1,4] and Nathalie SIMON[1,4]*
(1) *UPMC Univ. Paris 6, Station Biologique de Roscoff, Place Georges Teissier, F-29680 Roscoff, France*
(2) *CNRS, FR 2424, Service Mer et Observation, Station Biologique de Roscoff, Place Georges Teissier, F-29680 Roscoff, France*
(3) *Present address: Aix Marseille Université, Université du Sud Toulon-Var, CNRS/INSU, IRD, Mediterranean Institute of Oceanography (MIO), UM 110, 13288, Marseille, Cedex 09, France*
(4) *CNRS, UMR 7144, Station Biologique de Roscoff, Place Georges Teissier, 29680 Roscoff, France.*
** Corresponding author: simon@sb-roscoff.fr*

Abstract: A checklist of micro-phytoplankton taxa based on net tow and Niskin bottle samples taken twice a month during the periods 2000-2003 and 2006-2010 at station SOMLIT-Astan (north of Roscoff, Western English Channel, France) is presented. SOMLIT-Astan is a coastal long-term monitoring station. It was established off Roscoff, where the water column seldom becomes stratified, and where continental influence is limited. Taxonomic identification was done based on light microscopy observations. The checklist includes 178 taxa (genus or species) among which 70 genera and 131 species of diatoms are recorded. Diatoms with benthic affinities make up 51% of the list of diatoms genera identified. *Guinardia* (especially *G. delicatula*) and *Paralia sulcata* appear as key taxa, becoming dominant in spring/summer and winter, respectively. Dinoflagellates are less diversified and never dominate. This work although not exhaustive, provides a reference list for micro-phytoplankton off Roscoff, and more generally for the permanently mixed waters of the Western English Channel, as well as information on the most common and/or abundant taxa in this habitat.

Résumé : *Liste commentée des taxons phytoplanctoniques marins de la série temporelle de la station SOMLIT-Astan au large de Roscoff (Manche orientale, France) : données récoltées de 2000 à 2010.* La présente étude propose une liste de taxons de microphytoplancton observés à la station SOMLIT-Astan (nord de Roscoff, Manche, France). Elle est issue de l'identification, en microscopie optique, d'échantillons de phytoplancton prélevés bi-mensuellement, entre 2000 et 2003 et entre 2006 et 2010, au filet à plancton et à la bouteille Niskin. Le point SOMLIT-Astan, station côtière de suivi à long terme à faible influence continentale, est établi au large de Roscoff où la colonne d'eau est peu ou pas stratifiée. La liste présentée comprend 178 taxons (genres ou espèces) dont 70 genres et 131 espèces de diatomées. Les diatomées benthiques représentent 51% des genres de diatomées identifiés. *Guinardia* (et en particulier *G. delicatula*) et *Paralia sulcata* apparaissent comme des taxons clefs, dominant respectivement au printemps/été et en hiver. Les dinoflagellés sont moins diversifiés et ne dominent jamais les assemblages. Cette liste, bien que non exhaustive, constitue une liste de référence pour la station SOMLIT-Astan de Roscoff, et de façon plus générale, pour les eaux brassées de la Manche occidentale. Des informations sur les taxons les plus communs et/ou les plus abondants sont également présentées.

Keywords: Diatoms ● *Guinardia* ● Dinoflagellates ● Phytoplankton ● English Channel ● Roscoff SOMLIT-Astan

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Introduction

Phytoplanktonic species are sensitive indicators of environmental changes, and long-term time-series are effective tools to evaluate and understand these changes (Hays et al., 2005). Along the coasts of the Western English Channel and North Sea, phytoplankton monitoring programmes have been established for quite a long time. Examples include the Plymouth L4 time-series (running since 1992, Widdicombe et al., 2010a), the Helgoland Roads time-series (running since 1962, Wiltshire et al., 2010), the Boulogne-sur-mer time-series (Gomez & Souissi, 2007) or the Continuous Plankton Recorder (CPR) survey (Reid et al., 2003). Recently, analyses of datasets originating from these surveys showed that responses to climate changes can result in range expansion or contraction of key species, or shifts in timing and abundance of dominant taxa (Edwards & Richardson, 2004; Schlüter et al., 2012). Such phenomena may lead to major changes in ecosystem functioning (Beaugrand et al., 2003). Documenting and understanding such changes require high resolution and long term monitoring of biodiversity based on accurate checklists.

Micro-phytoplankton species composition of the coastal environment off Roscoff in the permanently mixed waters of the Western English Channel (Fig. 1) has been analysed in the framework of research programmes and time-series since the 1960s. The first lists of taxa were established for the period between February 1962 and November 1963, for both diatoms (32 genera, 88 species) and dinoflagellates (12 genera, 31 species) at the offshore "Point A" site (92 m depth, 48°57'N-3°59'W) and at the inshore "Point B" site (20 m depth, 48°43'45"N-3°57'36"W) (Jacques, 1963; Grall & Jacques, 1964). A list of diatoms (73 genera, 200 species) and dinoflagellates (20 species, 72 species) present in the 1960s in the estuaries of two rivers that drain into the Morlaix bay (Penzé and Morlaix rivers), was also provided by Paulmier (1969).

The phytoplankton composition in the vicinity of "Point B" ("St" site in Fig. 1, Martin-Jézéquel, 1981 & 1983) was re-investigated from 1979 to 1980 and a partial list of 23 genera and 47 species of diatoms was produced (Martin-Jézéquel, 1981). In 1985, an oceanographic time-series was established at the extremity of a 500 m pier off Roscoff harbor (Station "Estacade", 3 to 11 m depth depending on the tide; 48°43'56N-3°58'58W). Phytoplankton was monitored at this site, which is prone to continental influence, from 1985 to 1992, and patterns of variations in diatom abundances were studied (Klein & Sournia, 1987; Sournia et al., 1987; Sournia & Birrien, 1995). Comprehensive lists of taxa for this period are not available in the literature.

Phytoplankton monitoring was interrupted from 1992 to 2000. New phytoplankton monitoring programmes were set up in January 2000 at station "SOMLIT-Astan" and in June 2007 at station "Estacade". Pico- and nano-phytoplankton size fractions are monitored at both stations while composition and abundance of micro-phytoplankton are only monitored at SOMLIT-Astan. Using these data, we established an updated list of micro-phytoplankton taxa for the periods 2000-2003 and 2006-2010 at the SOMLIT-Astan station. Information regarding the most abundant or most common taxa is provided. The presence in this list of potentially introduced taxa, as well as of taxa with warm- or cold-water affinities is discussed.

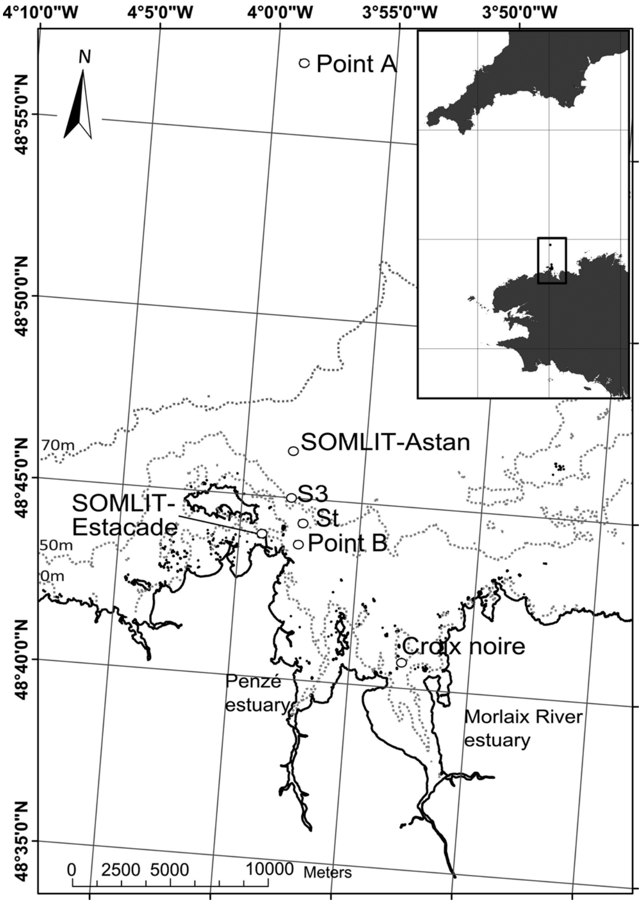

Figure 1. Location of the time-series stations SOMLIT-Astan and Estacade monitored in the frame of the French SOMLIT program since 2000. Other stations where detailed studies of phytoplankton diversity and ecology were conducted are also shown: "Point A" and "Point B" (Grall & Jacques, 1964; Jacques, 1963), station "S3" (Grall, 1972a), station "St" (Martin-Jézéquel, 1981), station "Estacade" (Sournia & Birrien, 1995) and station "Croix Noire" (Leroy, 2011). The 9 stations studied by Paulmier (1969) in the Penzé and Morlaix river estuaries are not shown. Maps were established using Ocean Data View (Schlitzer, R., 2012, Ocean Data View, http://odv.awi.de, map of the Channel) and ArcGIS 9.2 (http://www.esri.com/software/arcgis/, closer view of the Morlaix bay and Roscoff region).

Material and Methods

Sampling methods

Samples from surface water at SOMLIT-Astan station (60 m depth, 48°46’18’’N-3°58’6’’W, Fig. 1) have been collected twice a month during the highest neap tide, along with samples collected in the frame of the SOMLIT monitoring program (Service d’Observation du Milieu Littoral, http://somlit.epoc.u-bordeaux1.fr/fr/, Goberville et al., 2010). SOMLIT performs measurements of hydrological parameters (as well as, more recently, estimates of picophytoplankton abundances) according to standard protocols at 13 stations along the French marine coasts (Goberville et al., 2010). The monitoring of phytoplankton biodiversity is not included in these SOMLIT parameters.

Two types of phytoplankton samples were collected at each sampling date. For qualitative analyses, net samples were collected using a simple 20 µm nylon mesh cone (24 cm opening diameter, 80 cm long) towed during 3 minutes in subsurface. A fraction of the net sample was preserved with formalin acidified with acetic acid (formalin (40% HCHO): glacial acetic acid; 1:1, v/v). For quantitative analyses, seawater samples were collected at 1 m depth using a 5 L Niskin bottle. One hundred to 250 mL sub-samples were fixed with acid Lugol’s iodine according to Sournia (1978). All samples were stored in dark conditions at room temperature. Analyses were performed for net and/or Niskin samples collected from June 2000 to December 2010 (all year round for 2001, 2002, 2007, 2008, 2009 and 2010; June to December for 2000; January to September in 2003; April to December for 2006).

Phytoplankton identification and quantification

For net samples, taxa lists were established after examination of a few drops of live or fixed samples under light microscopes. Two different microscopes were used: an Olympus BH2 (samples from 2000 to July 2001) and an Olympus BX51 (samples from August 2001 onwards) equipped with a SPOT RT-slider digital camera (Diagnostics Instruments, Sterling Heights, MI).

For Niskin samples, a sub-sample of lugol preserved water was gently poured into a 50 mL composite settling chamber (HYDRO-BIOS, Kiel), according to the standard Utermöhl settlement method described in Sournia (1978). Quantitative analyses based on the examination of lugol preserved samples were performed between 15 days and up to 1 year after sampling. Cell counts for either the whole chamber, or half a chamber, were obtained after sedimentation, under an inverted light microscope at 400x magnification. Samples from 2000 to May 2003, June 2003 to August 2008, and September 2008 onwards were examined with an Olympus CK2, an Olympus IX71, and a Leica DMI 3000, respectively. This latter microscope was equipped with a SPOT Insight digital camera 2 Mpx (Diagnostics Instruments, Sterling Heights, MI).

The checklist provided in this paper combines observations performed on plankton net and Niskin samples (respectively 160 and 157 samples, Table 1) by S. Ristori (2000-2001), M. Viprey (2002 to 2003), F. Jalabert and F. Jouenne (2008), L. Guilloux and F. Jalabert (2009), and L. Guilloux (2010). References used for species identification included Tomas (1997), Throndsen et al. (2007), Hartley et al. (1996), Kraberg et al. (2010), Hoppenrath et al. (2009), Horner (2002) and the Plankton*Net Data Provider (http://www.planktonnet.eu/). All data are stored both in a local MS-Access database and in a national database (database from the “Réseau national des stations et laboratories marins”, RESOMAR-PELAGOS, http://abims.sb-roscoff.fr/pelagos/). For the establishment of the checklist provided in Table 2, taxa names were carefully examined and in case of doubts concerning the identification to the species level, only the genus name was retained.

Results and Discussion

A total of 178 taxa were identified at least to the genus level, among which 131 diatoms, 34 dinoflagellates, 4 prymnesiophytes, 4 prasinophytes (including 2 Pyramimonadales, 1 Mamiellophyceae and 1 Nephroselmidophyceae), 3 dictyochophytes and 2 raphidophytes (Table 2). Cryptophytes and euglenophytes were also identified but identification to the genus level was not achieved for these groups. Among dinoflagellates, some taxa have mixotrophic or heterotrophic behaviors.

Table 1. Summary of qualitative (net samples) and quantitative (Niskin samples, Utermöhl sedimentation method) analyses performed.

Years	**2000**	**2001**	**2002**	**2003**	**2006**	**2007**	**2008**	**2009**	**2010**	**2000-2010**
Quantitative analysis	14	25	24	11	0	8	25	25	25	**157**
Qualitative analysis	9	24	23	1	11	19	24	25	24	**160**
Total	14	25	24	22	22	24	25	25	25	**205**

Table 2. Checklist of marine phytoplankton taxa from the SOMLIT-Astan station off Roscoff, in the Western English Channel, France. Taxa listed were identified using light microscopy in samples Niskin and/or net collected between June 2000 and December 2010 (see Table 1). Information concerning the ecology of taxa were retrieved from Hoppenrath et al. (2009), Tomas (1997) and the Plankton*Net Data Provider (http://www.planktonnet.eu/).

[a] For the genus *Pseudo-nitzschia,* two groups were distinguished, (”*delicatissima complex”* and ”*seriata complex”,* Hasle & Syvertsen, 1997). Optical microscopic identification to species level was achieved according to Throndsen et al. (2007) and Kräberg et al. (2010). A confirmation using electron microscopic examination is required.

BACILLARIOPHYCEAE

Pelagic taxa

Achnanthes longipes Agardh
Actinocyclus octonarius Ehrenberg
Actinoptychus senarius (Ehrenberg) Ehrenberg
Asterionella formosa Hassall
Asterionellopsis glacialis (Castracane) Round
Bacteriastrum
Biddulphia alternans (Bailey) Van Heurck
Biddulphia biddulphiana (Smith) Boyer
Cerataulina pelagica (Cleve) Hendey
Chaetoceros affinis Lauder
Chaetoceros brevis Schütt
Chaetoceros cerastoporus var. *brachysetus* Rines et Hargraves
Chaetoceros concavicornis Mangin
Chaetoceros compressus Lauder
Chaetoceros costatus Pavillard
Chaetoceros curvisetus Cleve
Chaetoceros danicus Cleve
Chaetoceros debilis Cleve
Chaetoceros decipiens Cleve
Chaetoceros densus (Cleve) Cleve
Chaetoceros diadema (Ehrenberg) Gran
Chaetoceros didymus Ehrenberg
Chaetoceros ebeinii (Grunow) Meunier
Chaetoceros gracilis Schütt
Chaetoceros holsaticus Schütt
Chaetoceros karianus Grunow
Chaetoceros laciniosus Schütt
Chaetoceros lauderi Ralfs
Chaetoceros lorenzianus Grunow
Chaetoceros peruvianus Brightwell
Chaetoceros protuberans Lauder
Chaetoceros radicans Schütt
Chaetoceros similis Cleve
Chaetoceros simplex Ostenfeld
Chaetoceros socialis Lauder
Chaetoceros tenuissimus Meunier
Chaetoceros teres Cleve
Chaetoceros tortissimus Gran
Chaetoceros wighamii Brightwell
Corethron criophilum Castracane
Coscinodiscus centralis Ehrenberg
Coscinodiscus concinnus Smith
Coscinodiscus granii Gough
Coscinodiscus marginatus Ehrenberg
Coscinodiscus radiatus Ehrenberg
Dactyliosolen blavyanus Hasle
Dactyliosolen fragilissimus (Bergon) Hasle
Dactyliosolen phuketensis (Sundström) Hasle
Detonula pumila (Castracane) Gran
Ditylum brightwellii (West) Grunow
Eucampia zodiacus Ehrenberg
Guinardia delicatula (Cleve) Hasle
Guinardia flaccida (Castracane) Peragallo
Guinardia striata (Stolterfoth) Hasle
Haslea
Helicotheca tamesis Ricard
Lauderia annulata Cleve
Leptocylindrus danicus Cleve
Leptocylindrus minimus Gran
Lioloma
Meuniera membranacea (Cleve) Silva
Neocalyptrella robusta (Norman) Hernández-Becerril & Meave del Castillo
Neostreptotheca subindica Stosch
Odontella aurita (Lyngbye) Agardh
Odontella longicruris (Greville) Hoban
Odontella mobiliensis (Bailey) Grunow
Odontella regia (Schultze) Simonsen
Odontella sinensis (Greville) Grunow
Podosira stelligera (Bailey) Mann
Proboscia alata (Brightwell) Sundström
“Pseudo-nitzschia delicatissima complex” (P. delicatissima (Cleve) Heiden*, P. pseudodelicatissima* (Hasle) Hasle) [a]
“Pseudo-nitzschia seriata complex” (P. fraudulenta (Cleve) Hasle*, P. Seriata* (Cleve) Peragallo, *P. pungens* (Grunow) Hasle) [a]
Rhizosolenia hebetata Bailey
Rhizosolenia imbricata Brightwell
Rhizosolenia setigera Brightwell
Rhizosolenia setigera f. *pungens* (Cleve-Euler) Brunel
Rhizosolenia styliformis Brightwell
Skeletonema
Stephanopyxis turris (Greville) Ralfs
Thalassionema frauenfeldii (Grunow) Hallegraeff
Thalassionema nitzschioides (Grunow) Mereschkowsky
Thalassiosira anguste-lineata (Schmidt) Fryxell & Hasle
Thalassiosira levanderi Van Goor + *Thalassiosira minima* Gaarder (non distinguished)
Thalassiosira nordenskioeldii Cleve
Thalassiosira punctigera (Castracane) Hasle
Thalassiosira rotula Meunier
Thalassiothrix

Benthic, tychopelagic and epiphytic taxa

Amphora
Asteromphalus
Bacillaria paxillifera (Müller) Marsson
Campylodiscus
Campyloneis
Cocconeis pseudomarginata Gregory

Cylindrotheca closterium (Ehrenberg) Reiman & Lewin
Delphineis surirella (Ehrenberg) Andrews
Didymosphenia
Dimeregramma
Diploneis
Entomoneis
Fragilaria
Fragilariopsis
Grammatophora angulosa Ehrenberg
Grammatophora oceanica Ehrenberg
Grammatophora marina (Lyngbye) Kützing
Grammatophora serpentina Ehrenberg
Gyrosigma
Isthmia nervosa Kützing
Isthmia obliquata (Smith) Agardh
Licmophora
Lyrella hennedyi (Smith) Stickle & Mann
Melosira
Navicula transitans Cleve
Nitzschia longissima (Brébisson) Ralfs
Paralia sulcata (Ehrenberg) Cleve
Pinnularia
Plagiogrammopsis vanheurckii (Grunow) Hasle, von Stosch & Syvertsen
Plagiotropis
Pleurosigma directum Grunow
Pleurosigma normanii Ralfs
Psammodictyon panduriforme (Gregory) Mann
Rhabdonema
Rhaphoneis
Striatella unipunctata (Lyngbye) Agardh
Surirella
Synedra
Trachyneis
Triceratium
Tryblionella compressa (Bailey) Poulin

DINOFLAGELLATA (*heterotrophic, ** parasitic)
Alexandrium tamarense (Lebour) Balech
Dinophysis acuminata Claparède & Lachmann
Dinophysis acuta Ehrenberg
Dinophysis tripos Gourret
Diplopsalis *
Dissodinium pseudolunula Swift **
Gonyaulax
Gymnodinium
Gyrodinium *
Heterocapsa
Neoceratium concilians (Jörgensen) Gómez, Moreira & Lopez-Garcia
Neoceratium furca (Ehrenberg) Gómez, Moreira & Lopez-Garcia
Neoceratium fusus (Ehrenberg) Gómez, Moreira & Lopez-Garcia
Neoceratium horridum (Cleve) Gómez, Moreira & Lopez-Garcia
Neoceratium lineatum (Ehrenberg) Gómez, Moreira & Lopez-Garcia
Neoceratium longipes (Bailey) Gómez, Moreira & Lopez-Garcia
Neoceratium massiliense (Gourret) Gómez, Moreira & Lopez-Garcia
Neoceratium pentagonum (Gourret) Gómez, Moreira & Lopez-Garcia
Neoceratium tripos (Müller) Gómez, Moreira & Lopez-Garcia
Peridinium quiquecorne Abé
Phalacroma rotundatum (Claparede & Lachman) Kofoid & Michener*
Prorocentrum dentatum Stein
Prorocentrum gracile Schütt
Prorocentrum micans Ehrenberg
*Protoperidinium bipes (Paulsen) Balech**
Protoperidinium conicum (Gran) Balech*
Protoperidinium depressum (Bailey) Balech*
Protoperidinium leonis (Pavillard) Balech*
Protoperidinium minutum (Kofoid) Loeblich*
Protoperidinium oceanicum (VanHöffen) Balech*
Protoperidinium pellucidum Bergh*
Protoperidinium steinii (Jørgensen) Balech*
Pyrophacus
Scrippsiella trochoidea (Stein) Balech

OTHER GROUPS
Cryptophyceae
Dictyochophyceae
Dictyocha crux Ehrenberg
Dictyocha fibula Ehrenber
Dictyocha speculum Ehrenberg
Euglenophyceae
Mamiellophyceae
Micromonas pusilla (Butcher) Manton & Parke
Nephroselmidophyceae
Nephroselmis rotunda (Carter) Fott
Prasinophyte, Pyramimonadales
Halosphaera K.J.F. Schmitz, 1878
Pterosperma polygonum Ostenfeld
Prymnesiophyceae
Chrysochromulina Lackey, 1939
Emiliania huxleyi (Lohmann) Hay & Mohler
Phaeocystis globosa Scherffel
Pleurochrysis carterae (Braarud & Fagerland) Christensen
Raphidophyceae
Chattonella marina var. antiqua (Hada) Demura & Kawachi
Fibrocapsa japonica Toriumi & Takano

Diatoms

Taxonomic richness was the highest for diatoms (70 genera, 131 taxa identified to the species level, Table 2). Diatoms of benthic affinity (mostly pennate diatoms) made up 51% of the diatom genera identified (Fig. 2), but only 19 % of the diatom species identified. This is explained, at least in part, by the difficulties associated with species identification of pennate diatoms under light microscopy. Identification to species level for these diatoms often requires examination under electron microscopy. This problem was also encountered, for some common genera

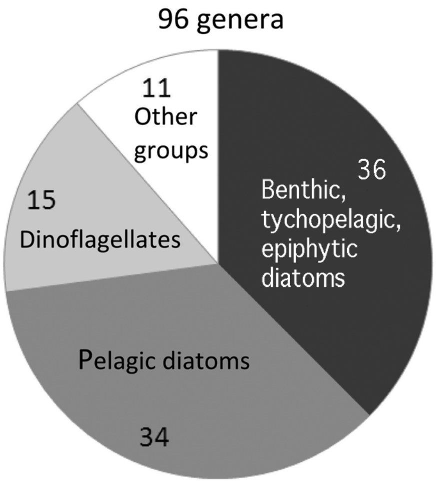

Figure 2. Pie chart showing the number of genera observed at the SOMLIT-Atan station (2000-2003 and 2006-2010), for each of the following groups: dinoflagellates, pelagic diatoms, other diatoms and other phytoplankton groups. The genera are those listed in Table 1.

with planktonic affinity such as *Thalassiosira* or *Chaetoceros*, for which identification to species level was not possible for all specimens.

A list of genera identified as major contributors to the micro-phytoplankton assemblage at SOMLIT-Astan was established (Fig. 3). This list includes both truly pelagic and tychopelagic species. *Guinardia* and *Paralia* were key diatom genera at our sampling station (Fig. 3A & B). Within the genus *Guinardia, G. delicatula* and to a lesser extend *G. striata* appeared as most prominent with mean abundances above respectively 8800 and 1600 cells.L^{-1} over the study period. Contribution of both species to total counts reached more than 20% in respectively 39 and 10% of the lugol samples examined. *Guinardia delicatula* was detected in 65% of those samples. This species was already identified as the dominating species off Roscoff during spring in all previous surveys (Jacques, 1963; Grall & Jacques, 1964; Grall, 1972a; Martin-Jézéquel, 1983; Klein & Sournia, 1987; Sournia et al., 1987; Sournia & Birrien, 1995). Grall (1972a) notes that it is present at very low abundances, or absent, outside the period of the bloom. *Guinardia delicatula* is also identified as a major contributor to the phytoplankton spring bloom in Atlantic coastal and estuarine systems such as the Seine estuary (Jouenne et al., 2007), the northeastern English Channel off Boulogne-sur-mer (Gómez & Souissi, 2007), the German Bight (Schlüter et al., 2012), and the coastal western Irish Sea (Gowen et al., 1999).

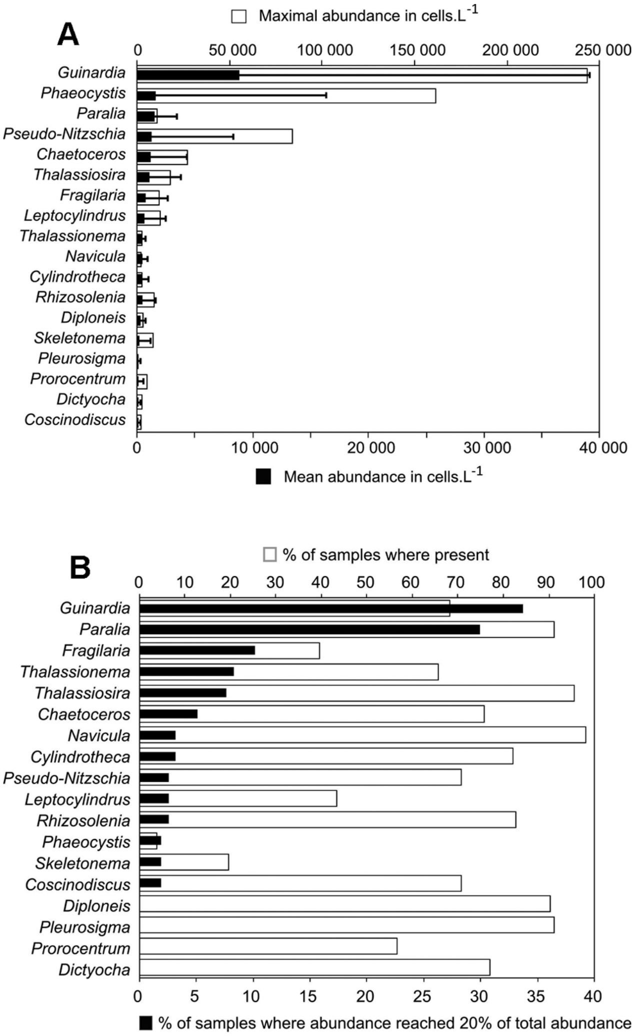

Figure 3. Genera identified as dominant over the studied period (2000-2003 and 2006-2010) at station SOMLIT-Astan. The genera chosen are those that either reached mean abundances > 500 cells.mL^{-1}, and/or reached at least 20% of total cell counts in at least one of the samples analysed, and/or where present in at least 50% of the samples examined. **A.** Mean and maximum abundance. **B.** Percentage of samples where the genera considered where present and percentage of samples where the genera were dominating (abundance > 20% of total abundance). Samples considered were those collected using Niskin bottles and analysed according to the standard Utermöhl settlement method.

Paralia sulcata (the only species within the genus *Paralia* identified in our samples), a robust chain-forming tychopelagic diatom, was abundant especially in winter (data not shown). This species made up more than 20% of the total counts in 30% of the samples and was detected in 91% of the lugol samples (Fig. 3B). It is commonly found in both plankton and benthos assemblages of coastal environments, and forms large populations in vertically mixed water columns (McQuoid & Nordberg, 2003). According to Wiltshire et al. (2010), both *G. delicatula* and *P. sulcata* have widened their occurrence period during the last 15 years (Helgoland Roads time-series). At Helgoland, *G. delicatula* also showed a significant trend towards earlier blooms during the last decade (Schlüter et al., 2012).

The typically pelagic genera *Pseudo-nitzschia, Chaetoceros, Thalassiosira*, and *Leptocylindrus* as well as the benthic/tychopelagic *Fragilaria* were also identified as abundant (above 500 cells.L^{-1} on average for all samples examined) and able to become dominating at times (Fig. 3A & B). *Pseudo-nitzschia, Thalassiosira* and *Chaetoceros* are cosmopolitan genera that are identified as typical recurrent bloomers in marine systems (Assmy & Smetacek, 2009). The species *Pseudo-nitzschia delicatissima* and *Leptocylindrus danicus* reached more than 20% of the total abundances in 4 out of the 157 lugol samples examined. These species were also considered as dominant taxa off Roscoff by Grall & Jacques (1964), Grall (1972a), and Martin-Jézéquel (1981).

The pelagic genera *Thalassionema, Rhizosolenia, Coscinodiscus* and *Skeletonema* and the benthic/tychopelagic genera *Cylindrotheca* and *Navicula,* could also contribute highly to the phytoplankton assemblage (Fig. 3B). *Thalassionema nitzschioides* and *Cylindrotheca closterium* were both extremely common in our samples and able to make up more than 20% of the cell counts in respectively 7 and 3% of the lugol samples examined.

Some diatoms with benthic affinities such as the benthic genera *Pleurosigma* and *Diploneis*, although not abundant in the assemblages, were extremely common (present in 91 and 90% respectively, of the lugol samples examined, Fig. 3B). The genus *Grammatophora* was present in 51% of the qualitative samples examined. The presence of taxa with benthic affinities is due to strong tidal mixing of the water column at SOMLIT-Astan. Taxa with benthic affinities (such as the genera *Diploneis*, *Fragilaria*, *Licmophora*, *Pinnularia*) are also present in checklists established in other marine systems subject to strong physical mixing, at least during part of the year (e.g. Jouenne et al., 2007).

Dinoflagellates

Fifteen genera and 28 species of pelagic dinoflagellates were identified at the SOMLIT-Astan time series (Table 2). Our species list is not exhaustive since identification to the species level (or even to the genus level) of some dinoflagellates is notoriously difficult for fixed cells using optical microscopy. Fixed cells were often too small and lacked distinctive features, especially when darkened by the lugol iodine solution. Naked dinoflagellates, in particular, are difficult to identify, even to the genus level after fixation. We may thus have missed some important taxa such as *Karenia*, a common bloom-forming dinoflagellate of the Western English Channel (Widdicombe et al., 2010a). Heterotrophic taxa (including the crustacean parasite *Dissodinium pseudolunula,* Gómez et al., 2009) were also appended to the checklist. Dinoflagellates are present all year round at the SOMLIT-Astan time-series (data not shown) but they never reach high abundances and never dominated the phytoplankton assemblages (counts always < 20% of total counts) (Fig. 3A & B). This is probably due to the strong mixing of the water column (Berdalet et al., 2007). At the Plymouth L4 time-series in the Western English Channel, 31 dinoflagellates genera were identified over the years 1992 to 2009 (Widdicombe et al., 2010b). At this station, where seasonal stratification occurs in summer, dinoflagellates dominate the microphytoplankton assemblages in August and September. At SOMLIT-Astan, the genus *Prorocentrum* was the most common dinoflagellate in lugol samples (Fig. 3A). The genera *Protoperidinium* and *Neoceratium* were also common (present in respectively 32.5 and 24% of the Niskin samples). This later genus was however observed in 67.5% of the net samples. The discrepancy between percentages calculated from net and Niskin samples highlights how sampling strategy and methodology (e.g. volume sampled) can impact a quantitative analysis of presence/absence data. Other dinoflagellate taxa were observed more sporadically.

Other groups

Representatives of prasinophytes (4 species), haptophytes (4 genera, 3 species), dictyochophytes (3 species), raphidophytes (2 species), euglenophytes, and cryptophytes were identified at SOMLIT-Astan in either lugol-preserved Niskin bottle samples or net samples (Table 2). The skeleton-bearing dictyochophytes belonging to the genus *Dictyocha* (*D. speculum* and D. *fibula*) were observed on a regular basis (*Dictyocha* was present in 77% of the lugol samples examined, Fig. 3B). The colony-forming prymnesiophyte *Phaeocystis*, observed every year since 2007, dominated the assemblages in 3 samples (in June 2007, and May 2008, Fig. 3B and data not shown). It reached a maximal abundance of 161 320 cells.L^{-1}. Cryptophytes were also observed on a regular basis but identification to the genus level was not achieved. This group had already been previously identified as persistent in the nanoplankton assemblage in the vicinity of Roscoff (Grall, 1972b; Klein & Sournia, 1987).

Techniques that were used for sampling, fixation (either acidic lugol or acidic formaldehyde) and identification are not appropriate for the detection and identification of most naked flagellates, and calcifying organisms. For those taxa, as well as for pico- and nano-planktonic cells, electron microscopy and genetic analyses are often required. Using phylogenetic probes and 18S rDNA sequencing technologies, Not et al. (2004), Foulon et al. (2008), Marie et al. (2010) and Romari & Vaulot (2004), have provided insights into the diversity of pico- and nano-phytoplanktonic compartment at the time-series station SOMLIT-Astan.

These studies pointed out the dominance of the Mamiellophyceae (especially *Micromonas,* but also *Ostreococcus* and *Bathycoccus)*, as well as the importance of haptophytes (mostly *Chrysochromulina* and *Phaeocystis*), cryptophytes (mostly *Geminigera* and *Teleaulax*) and other prasinophytes (such as *Pyramimonas*) in the small size fractions. In these size fractions, sequences of organisms belonging to the Picobiliphytes and to the classes Bolidophyceae, Chrysophyceae, and Pelagophyceae were also detected (Romari & Vaulot, 2004; Not et al., 2007; Marie et al., 2010). Sequences from the diatom (*Minutocellus)* and the dinoflagellate (*Phaeopolykrikos* and *Karlodinium)* genera that were not identified using microscopy were also recovered from 18S rRNA gene clone libraries (Marie et al., 2010).

Comments on introduced taxa

Our species list includes potentially introduced diatom species such as *Odontella sinensis* or *Thalassiosira punctigera*. *Odontella sinensis* was described from the China Sea (Greville, 1866), and recorded in the North Sea in 1903 by Ostenfeld (1908). It was already identified by Jacques (1963) in the vicinity of the station SOMLIT-Astan. *Thalassiosira punctigera,* initially described from Tokyo Bay, was first recorded in European waters in 1978 and considered as a non-indigenous species (Kat, 1982; Gómez, 2008). *Coscinodiscus wailesii* Gran & Angst*,* a large centric diatom, previously known in the Pacific and West Atlantic, and recorded in the Western English Channel for the first time in 1977 (Boalch, 1987), is absent from our list. It is commonly observed in the North Sea (Nehring, 1998) and Eastern English Channel (Gómez & Souissi, 2007). According to Gómez & Souissi (2010) this species is distributed world-wide, and has affinities with cold winter and spring waters. The raphidophyte *Chattonella marina var. antiqua* was identified in 5% of the lugol samples examined (once in 2002, twice in 2007, and 6 times in 2009). This species is known for the toxic blooms it has produced in Japan (Billard, 1992). The first European record of this species was in 1991 off the coast of Normandy (France) by Billard (1992) and along the Dutch coasts by Vrieling et al. (1995). However the status of introduced species for the taxa listed in this paragraph may be questioned. Distinguishing introduced from indigenous species is extremely difficult, in a context of decreasing numbers of taxonomists, and in consequence, of the potential errors propagated in the literature (Gómez, 2008).

Comments on taxa indicating cold or warm conditions

Both *Chaetoceros peruvianus* and *Corethron criophilum*, considered as potentially linked to the northwards expansion of warm Atlantic water species in the Channel (Nehring, 1998; Gómez & Souissi, 2007), were identified with low abundances in our samples (in 16 and 5 samples respectively). Both species were recorded for the first time in 2003 over the period 1995-2005 at two stations established off Boulogne-sur-mer (Eastern English Channel, France) in the frame of the SOMLIT monitoring program (Gómez & Souissi, 2007). In our samples, both *C. peruvianus* and *C. criophilum*, when present, were not abundant. *Chaetoceros peruvianus* was mainly present from July 2009 to March 2010. Mean water temperature in 2009 was the lowest recorded during the studied period (http://somlit.epoc.u-bordeaux1.fr/fr/), but in Autumn 2009, sea surface temperatures reached the highest values (16.95°C, 28 September 2009) recorded throughout the 2000-2010 period. Both *C. criophilum* and *C. peruvianus* were already identified at two stations off Roscoff in 1962-1963 (Jacques, 1963) as well as in the Penzé and Morlaix river estuaries between 1963 and 1966 (Paulmier, 1969). *Thalassiosira nordenskioeldii,* an octagonal chain forming diatom, was recorded four times from 2005 to 2010, between February and May, when the sea surface temperature is the coldest (9-12°C). This taxon is a typical cold-water species, described in the Arctic waters (Gómez, 2008), and is a potential biological indicator for cold conditions in our region. It was also recorded in 1962 and 1966 in the vicinity of Roscoff (Jacques, 1963; Paulmier 1969).

Comments on taxa with freshwater affinities

Five diatom taxa with potential freshwater affinities are reported in our checklist *Asterionella formosa, Biddulphia* sp., *Amphora* sp., *Melosira* sp. and *Didymosphenia* sp.

Asterionella formosa, and *Melosira* spp., both truly freshwater taxa, were probably transported from the two rivers flowing into the Morlaix Bay to the Roscoff SOMLIT-Astan station (over 10 km). The former species was observed several times between January and April 2001, a period characterized by heavy rainfall in West Brittany. The genus *Melosira* was observed only once, in September 2010 at the SOMLIT-Astan station, but was observed several times upstream in the Morlaix Bay at station “Croix Noire” (Fig. 1) by Leroy (2011) and in the adjacent estuaries by Paulmier (1969). This genus contains a small number of freshwater species such as *M. varians* C. Agardh, which is one of the most common species of the genus and grows in benthic habitats of eutrophic streams and lakes (Stoermer & Julius, 2002).

The genera *Biddulphia* and *Amphora*, include both marine and freshwater species. In our study, we did not perform identification to the species level for these genera. However, some of the specimens identified are probably of freshwater origin. Paulmier (1969) identified *Biddulphia* in the Penzé and Morlaix river estuaries, while Leroy (2011) recorded *Biddulphia* and *Amphora* in Morlaix Bay.

At the Roscoff SOMLIT-Astan station, *Didymosphenia* was observed only once in August 2008. *Didymosphenia geminata* (Lyngbye) M. Schmidt is a solitary diatom found in lakes, streams, and rivers in temperate regions (Kumar et al., 2009). Reports of massive growth of this species, with possible impacts on stream ecosystems have been reported during the last decade in streams in New Zealand, North America, Europe, and Asia (Whitton et al., 2009). In France, Jouenne et al. (2007) recorded the genus *Didymosphenia* in their benthic list of Bacillariophyceae in the Baie des Veys, a small intertidal estuarine-bay ecosystem.

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