

Marine micro-phytoplankton of Singapore, with a review of harmful microalgae in the region

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Abstract. A survey of marine phytoplankton in the Singapore Strait was carried out between May and June 2013, as part of an effort to determine the diversity of phytoplankton in Singapore's coastal waters. A total of 34 microalgal samples were collected using a 20 µm-mesh plankton net and from coastal sediments. Living samples and preserved samples in Lugol's solution were identified to species as far as possible under the microscope. A checklist of marine micro-phytoplankton was updated to encompass 270 taxa, including 49 new records from Singapore waters. Some 37 species from 15 families were dinoflagellates, and 233 species from 50 families were diatoms. Harmful microalgae, categorized as biotoxin-producers and fish killers, were also found in this survey. These were in the genera *Alexandrium*, *Amphidinium*, *Ceratium*, *Cochlodinium*, *Coolia*, *Dinophysis*, *Gambierdiscus*, *Karenia*, *Karlodinium*, *Ostreopsis*, *Prorocentrum*, *Nitzschia*, and *Pseudo-nitzschia*.

Key words. Diatoms; dinoflagellates; harmful; phytoplankton; microalgae; Singapore

INTRODUCTION

Phytoplankton, or plant plankton, refers to a group of microscopic unicellular cells containing photosynthetic pigments that convert light energy into chemical energy for the organisms' activity, although some species are mixotrophic (feeding on organic or inorganic compounds as a source of energy) or phagotrophic (feeding on other organisms). These microscopic cells form the basis of all marine food webs by acting as a food source for organisms from higher trophic levels. They release oxygen into the water as a byproduct of photosynthetic activity but consume oxygen due to respiration. Micro-phytoplankton is most abundant in coastal regions, as these organisms are dependent upon nutrient run-off from the terrestrial environment. Diatoms and dinoflagellates dominate the phytoplankton in the marine environment (Hasle & Syvertsen, 1997).

The term 'diatom' originated from the genus name *Diatoma* De Candolle (1805). They reproduce vegetatively by binary fission, and most are heterovalvate, i.e., comprising

two valves. Their siliceous cell wall sets them apart from dinoflagellates, which only have a membranous cell wall. Dinoflagellates possess two flagella that are used in locomotion and feeding. The shapes and patterns of their thecal membranous cell walls are used in identification (Steidinger & Tangen, 1997).

Singapore is a small country situated about 100 km north of the equator, with a typical equatorial climate, having temperatures ranging from 23 to 34°C annually. Rainfall is mostly uniform throughout the year and not affected by the Northeast or Southwest Monsoons (National Environment Agency, Singapore) although some months may be drier than others. As an island state located in the South China Sea between the Indian Ocean and Pacific Oceans, it is one of the busiest ports in the world. Despite its status as a developed country, phytoplankton diversity along the 200 km coastline of water body of this country has yet to be documented. Wee (1994) compiled a marine and freshwater phytoplankton checklist of 292 species of diatoms and two species of dinoflagellates. Subsequently, Pham et al. (2011) updated the list to 292 diatoms and 15 dinoflagellate species.

During the Singapore Strait Biodiversity Workshop hosted by the National Parks Board and National University of Singapore, phytoplankton sampling was conducted around the Singapore waters, focusing on the Singapore Strait. Phytoplankton samples were collected from various locations and sediment samples were collected from the mudflats, with the aim to survey and update the marine micro-phytoplankton checklist of Singapore waters. Potential harmful species were also identified and discussed in this study.

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MATERIAL AND METHODS

Marine plankton samples were collected throughout the Singapore Strait by a 20 µm-mesh plankton net haul during the Singapore Strait Biodiversity Workshop between 20th May and 7th June 2013. Sediment samples were collected from the mud flats of intertidal areas in the Southern Islands of Singapore.

Live samples were observed with an Olympus IX51 inverted microscope. Living cells, particularly naked dinoflagellates, were observed under the microscope and were identified based on their shape, size and movement pattern. Aliquots of samples were fixed with Lugol's solution and observed under an Olympus BX51 compound microscope and cells were documented using an Olympus DP72 digital camera.

RESULTS

Checklist of marine micro-phytoplankton in Singapore.

A total of 37 dinoflagellate species from 15 families (Table 1) and 233 diatoms species from 50 families (Table 2) were documented in this study, of which 49 are new records in Singapore. Micrographs were taken from the aliquot of preserved samples taken back to the laboratory and compiled separately for dinoflagellates (Fig. 1), pennate diatoms (Fig. 2) and centric diatoms (Fig. 3). A checklist was compiled as shown in Tables 1 and 2, based on this survey and previous work (Holmes et al., 2002; Holmes & Teo, 2002; Tang et al., 2007; Lee et al., 2009; Pham et al., 2011b).

DISCUSSION

Algae including phytoplankton, blue-green algae and macroalgae from Singapore were first compiled by Wee (1994), with a total of 585 species reported. The checklist was further augmented by Pham (2011) to 1056 species based on scientific literature and specimens in the herbaria in the Raffles Museum of Biodiversity Research, Department of Biological Sciences, National University of Singapore (now Lee Kong Chian Natural History Museum), Singapore Botanic Gardens and Public Utilities Board of Singapore (Pham et al., 2011). The present study focus solely on the marine micro-phytoplankton collected from the Singapore Strait. In this survey, observations were based extensively on living as well as preserved specimens.

Microscope-based species identification is based on the outer morphological characteristics. However, some fragile plankton, particularly the naked dinoflagellates, is hard to preserve in good condition. Common fixatives, e.g., Lugol's solution and saline ethanol, did not preserve the specimens well. Aldehyde fixatives, i.e., paraformaldehyde and glutaraldehyde, are often used to preserve these specimens and observed immediately to prevent sample degradation. Pigment content is one of the visible characteristics used in identifying species of *Amphidinium* and *Cochlo-dinium* (Iwataki et al., 2007), which are all naked dinoflagellates, but only fresh samples should be used to observe such features.

The outer morphology of several naked dinoflagellates is similar and lack diagnostic characters; this made species identification difficult and confusing. Often, observation of cells in cross-section under the transmission electron microscope (TEM) is essential in species discrimination of naked dinoflagellates (Wilcox et al., 1982, Iwataki et al., 2010).

Several diatom species in the genera *Pseudo-nitzschia* and *Nitzschia* could not be distinguished under light microscopy. Detailed examination of the diatom frustule structure by scanning and transmission electron microscopes (SEM and TEM) is crucial in precise identification to species level (Yang et al., 2013, Smida et al., 2014, Teng et al., 2014, Lim et al., 2013).

Harmful microalgae. In this survey, harmful microalgae known to produce biotoxins and cause fish kills were identified and documented. They belong to the following genera:

***Alexandrium* (Halim, 1960).** The dinoflagellate genus *Alexandrium* consists of more than 40 species and a third of them are toxic. In Southeast Asia, *A. tamiyavanichii* (previously known as *A. cohorticula*, Kodama et al., 1988) is a noteworthy species. The species was responsible for Paralytic Shellfish Poisoning (PSP) in Thailand (Tamiyavanich et al., 1985), Malaysia (Usup et al., 2002a, Lim et al., 2006, Hii et al., 2012, Lim et al., 2012b) and the Philippines (Bajarias et al., 2003), although its presence in other Southeast Asian countries has not been confirmed. This species produces a wide range of neurotoxins from the saxitoxin (STX) family that are sodium channel blockers in the mammalian nervous system. Proliferation of this toxin producer accumulates in filter feeding organisms such as clams or oysters, which can be vectors of human intoxication. The victims of poisoning could be fatal if no urgent medical support is given to prevent respiratory failure. No antidote is available for the treatment of PSP and the most useful treatment is to provide respiratory support and to naturally remove the toxin via induced vomiting or through urination (Acres & Gray, 1978).

Four *Alexandrium* species occur in Singapore waters, i.e., *Alexandrium leei* (Pham et al., 2011a), *A. affine*, *A. tamiyavanichii* and *A. tamutum* (this study, Table 1). *Alexandrium leei* produces a heat-stable ichthyotoxin that kills seabass and seahorse fingerlings (Tang et al., 2007) while *A. tamiyavanichii* is an STX producer responsible for PSP events (Usup et al., 2002b, Lim et al., 2006, 2012b).

***Amphidinium* (Claperède & Lachmann, 1859).** This dinoflagellate genus comprises 95 species, which include symbionts with cnidarians, turbellarians and molluscs. Some members of this genus cause blooms and produce hemolytic toxins that can lead to fish kills (Yasumoto, 1990). These ichthyotoxins (Yasumoto et al., 1987) induces temporary paralysis in mice which may lead to death (Yasumoto et al., 1980). Of the three known harmful *Amphidinium* species, i.e., *A. carterae*, *A. klebsii* and *A. operculatum*, *A. carterae*

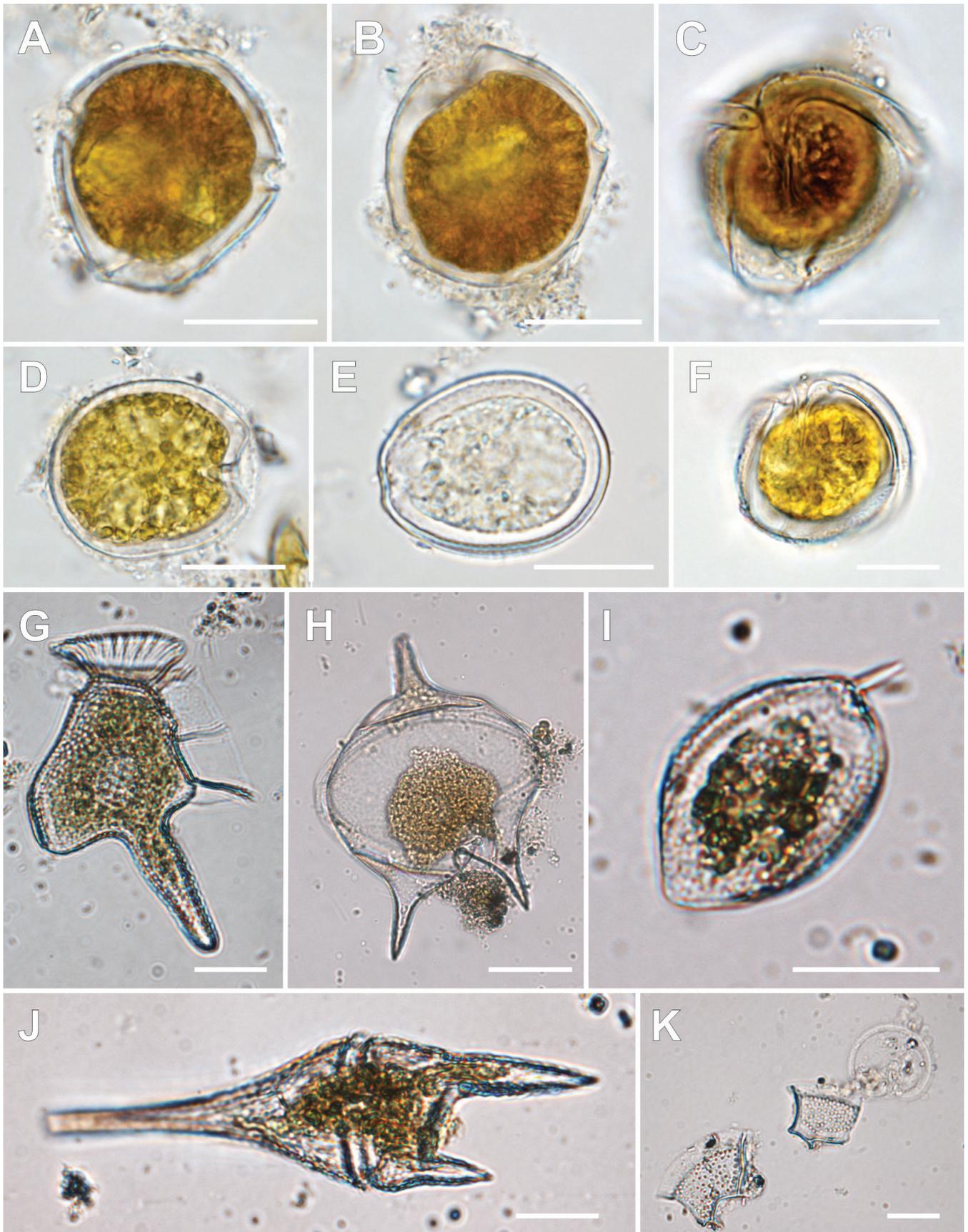


Fig. 1. Dinoflagellates from the Singapore Strait. (A, B) *Alexandrium affine* (C) *Gonyaulax* sp. (D) *Prorocentrum emarginatum* (E) *Prorocentrum lima* (F) *Gonyaulax* sp. (G) *Dinophysis caudata* (H) *Protoperidinium pallidum* (I) *Prorocentrum micans* (J) *Ceratium furca* (K) *Pyrodinium bahamense* var. *compressum* (squashed theca plates). Scale bar = 20 μ m.



Fig. 2. Pennate diatoms from the Singapore Strait. (A) *Cymbella* sp. (B–E) *Nitzschia* sp. (F) *Achnanthes* sp. (G) *Nitzschia* sp. (H–K) *Pleurosigma* sp. (L) *Gyrosigma* sp. (M) *Rhizosolenia* sp. 1. (N) *Pseudo-nitzschia* sp.; (O–R) *Cylindrotheca* sp. (S, T) *Synedra* sp. (U, V) *Thalassiothrix* sp. (W) *Bacillaria paxillifera*; (X) *Licmophora* sp. (Y) *Rhoicosphenia* sp. (Z) *Plagiotropis* sp. (AA–AC) *Nitzschia* sp. (AD, AE) *Amphiprora* sp 1. (AF) *Achnanthes* sp. (AG, AH) *Navicula* sp. (AI) *Nitzschia* sp. (AJ) *Flagilariopsis* sp. (AK) *Nitzschia* sp. Scale bar = 20 μ m.

was found in this study (Table 1). Species in the same genus was also reported from a neighbouring country (Tan et al., 2013b). However, no blooms or fish kill events associated to this genus have been reported thus far.

***Ceratium* (Schrank, 1793).** In the dinoflagellate genus *Ceratium*, 53 species are recognized today. Species from this genus produce ichthyotoxins (Mijares et al., 1985) which can cause hypoxia and anoxia (Zingone & Enevoldsen, 2000; GEOHAB, 2001) and are also responsible for blooms that cause massive fish kills (Lim et al., 2012b). The occurrence of this genus has been reported from China, Vietnam, and Malaysia (Gómez et al., 2010; Lim et al., 2012b; Tan et al., 2013a; Chu et al., 2014). In this study, we identified *Ceratium furca* from the Singapore Strait (Table 1; Fig. 1).

***Cochlodinium* (Schütt, 1896).** The genus *Cochlodinium* consists of some 40 species distributed in the coastal waters of Southeast Asia, North America and Europe (Anton et al., 2008, Gobler et al., 2008, Kudela & Gobler, 2012). Species belonging to this genus produce ichthyotoxins as well as hemolytic toxins, which can cause fish mortalities in cage cultures (Kim et al., 1999, Gobler et al., 2008, Dorantes-Aranda et al., 2009, Kudela & Gobler, 2012). The same toxins also cause mortality in bivalves (Gobler et al., 2008), impact coral growth (Bauman et al., 2010), as well as affect other phytoplankton (Tang & Gobler, 2010) and zooplankton (Jiang et al., 2009; Jiang et al., 2010). Blooms of *Cochlodinium polykrikoides* have caused sea surface discoloration in Malaysia (Anton et al., 2008, Adam et al., 2011, Lim et al., 2012b), Brunei and the Philippines during the Northeast monsoon (Azanza et al., 2008), with cell densities reaching up to 6 million cells L^{-1} . This study

reports for the first time the occurrence of *C. polykrikoides* in Singapore waters (Table 1).

***Coolia* (Meunier, 1919).** The five recognised species in this genus were reported from French Polynesia, New Zealand, western Mediterranean, Southwestern Indian Ocean, Caribbean Sea, South China Sea, East China Sea, Japan and Southwest Pacific Ocean (Fukuyo, 1981; Faust, 1995; Rhodes & Thomas, 1997; Hage et al., 2000; Penna et al., 2005; Leaw et al., 2010). *Coolia* is associated with ciguatera fish poisoning. Its members also possess cooliatoxin that can induce hypothermia by affecting sodium channel activity, leading to respiratory failure in mice and enlargement of the spleen (Holmes et al., 1995, Rhodes et al., 2000, Rhodes et al., 2014), as well as mortality in *Artemia salina* (Rhodes & Thomas, 1997). Two species have previously been described and documented from Malaysia, namely *Coolia tropicalis* and *C. malayensis* (Leaw et al., 2010; Mohammad-Noor et al., 2013). However, only one species, *C. malayensis*, was identified in this study based on culture specimens collected from the Singapore Strait.

***Dinophysis* (Ehrenberg, 1839).** Among the 128 taxonomically accepted species, seven species are associated with diarrhetic shellfish poisoning (DSP). Commercially important bivalves are easily exposed to and contaminated by these toxic species as they share similar habitats. Human consumption of these bivalves will result in human intoxication. Patients intoxicated with *Dinophysis* toxins (DTXs) and okadaic acid (OA) experience gastrointestinal illness, diarrhea, nausea, vomiting, and both toxins are known to be tumor promoters (Suganuma, 1988, Vale & Sampayo, 1999, Vale & Sampayo, 2000). Between 1995 and 1997, six isomers of

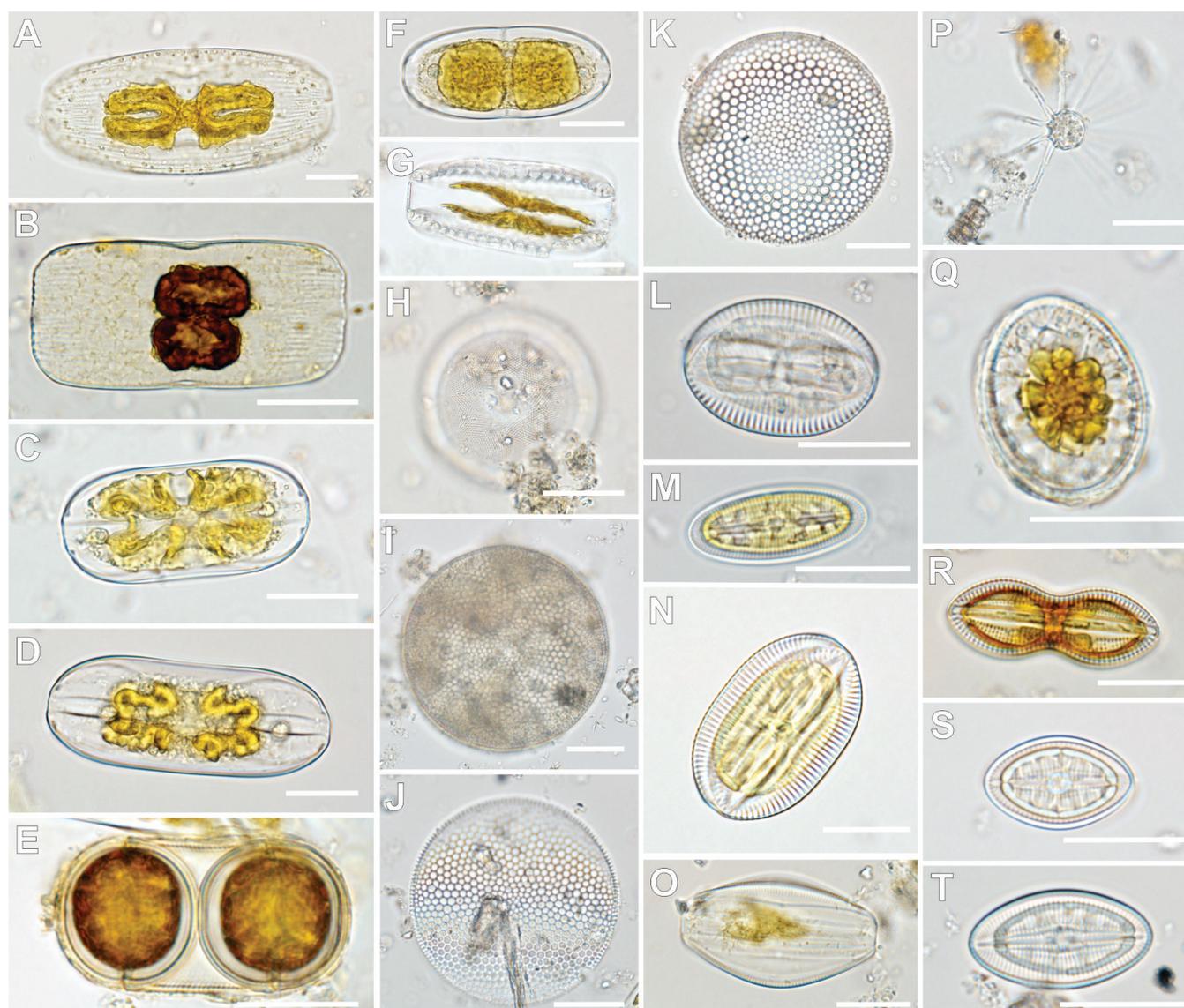


Fig. 3. Centric diatoms from the Singapore Strait. (A, B) *Thalassiosira* sp. (C, D) *Cyclotella* sp. (E) *Chaetoceros* sp. (F–K) *Cocconeidiscus* sp. (L–N) *Cocconeis* sp. (O) *Amphora* sp. (P) *Bacteriastrum* sp. (Q) *Cyclotella* sp. (R) *Diplomenora* sp. (S) *Diploneis* sp. (T) *Mastogloia* sp. Scale bar =20 μm

okadaic acid and five isomers of DTX were detected from samples collected from Johor Straits (Holmes et al., 1999). Two species of *Dinophysis* were detected from Singapore in this study. They were *D. caudata* and *D. rotundata* (Table 1; Fig. 1), with the former species associated with DSP (Marasigan et al., 2001). Two other species (*D. ovum* and *D. sacculus*) were reported previously from Singapore (Pham et al., 2011). Five species were previously reported from Malaysia (Usup et al., 2002c, Tan et al., 2013a).

***Gambierdiscus* (Adachi & Fukuyo, 1979).** This genus consists of 12 species, of which seven produce ciguatoxins (CTX) and maitotoxins (MTX) (Parsons et al., 2012). *Gambierdiscus* spp. are known to cause ciguatera fish poisoning (Yasumoto et al., 1979). Toxins are transferred to humans through consumption of contaminated reef fish (Holmes & Teo, 2002). Patients experience gastrointestinal uneasiness, cardiovascular and neurological signs and the most profound symptom that differs from other forms of seafood poisoning is the reversal of temperature sensation

(Lucas et al., 1997). Recovered patients may experience the reactivation of ciguatera toxin from time to time (Lehane & Lewis, 2000). *Gambierdiscus yasumotoi* was described from Pulau Hantu, Singapore (Holmes, 1998). In this study, high cell abundance of this toxic species was discovered in the sediment samples from Pulau Hantu (Table 1; Fig. 1). Two other undetermined species were also observed from the Singapore Strait. *Gambierdiscus yasumotoi* and *G. belizeanus* were also recorded from Malaysia (Leaw et al., 2011).

***Gonyaulax* (Diesing, 1866).** *Gonyaulax* is a genus with 71 taxonomically accepted dinoflagellate species. Some members of this genus are known to possess yessotoxin, which can contaminate shellfish (Draisci et al., 1999, Rhodes et al., 2006) and lead to diarrhetic shellfish poisoning (DSP). Numerous studies have been conducted for *G. spinifera*, *G. polygramma* and *G. polyedra*, all of which contain saxitoxin (Bruno et al., 1990) and yessotoxin (Rhodes et al., 2006) that can cause fish and shellfish mortality (Koizumi et al., 1996, Draisci et al., 1999). Blooms of this species resulted

Table 1. A checklist of marine dinoflagellates found in Singapore waters. The list is arranged alphabetically based on the scientific binominal name, with the species authority and family as in AlgaeBase (Guiry & Guiry, 2014). * New record in Singapore.

No	Taxon name	Family
1	<i>Alexandrium affine</i> (H.Inoue & Y.Fukuyo) Balech 1995*	Goniodomataceae
2	<i>Alexandrium leei</i> Balech 1985	Goniodomataceae
3	<i>Alexandrium tamiyavanichii</i> Balech 1994*	Goniodomataceae
4	<i>Alexandrium tamutum</i> M.Montresor, A.Beran & U.John 2004*	Goniodomataceae
5	<i>Amphidinium carterae</i> Hulburt 1957*	Gymnodiniaceae
6	<i>Ceratium furca</i> (Ehrenberg) F.Gomez, D.Moreira & P.Lopez-Garcia 2010*	Ceratiaceae
7	<i>Ceratium fusus</i> (Ehrenberg) F.Gomez, D.Moreira & P.Lopez-Garcia 2010*	Ceratiaceae
8	<i>Ceratium hirundinella</i> (O.F.Müller) Dujardin 1841	Ceratiaceae
9	<i>Ceratium tripos</i> (O.F.Müller) F.Gomez, D.Moreira & P.Lopez-Garcia 2010*	Ceratiaceae
10	<i>Cochlodinium polykrikoides</i> Margalef 1961*	Dinophyceae incerta sedis
11	<i>Coolia malayensis</i> Leaw, Lim & Usup 2010*	Goniodomataceae
12	<i>Dinophysis caudata</i> Saville-Kent 1881	Dinophysaceae
13	<i>Dinophysis ovum</i> Schütt 1895	Dinophysaceae
14	<i>Dinophysis rotundata</i> Claparède & Lachmann 1859	Dinophysaceae
15	<i>Dinophysis sacculus</i> Stein, 1883	Dinophysaceae
16	<i>Diplosalis</i> sp. 1*	Peridiniaceae
17	<i>Gambierdiscus</i> sp. 1*	Goniodomataceae
18	<i>Gambierdiscus</i> sp. 2*	Goniodomataceae
19	<i>Gambierdiscus yasumotoi</i> M.J.Holmes 1998	Goniodomataceae
20	<i>Goniodoma sphaericum</i> Murray & Whitting 1899	Goniodomataceae
21	<i>Gonyaulax spinifera</i> (Claparède & Lachmann) Diesing 1866*	Gonyaulacaceae
22	<i>Gymnodinium catenatum</i> H.W.Graham 1943	Dinotrichaceae
23	<i>Gymnodinium uberrimum</i> (G.J.Allman) Kofoid & Swezy 1921	Dinotrichaceae
24	<i>Gyrodinium spirale</i> (Bergh) Kofoid & Swezy 1921*	Gymnodiniaceae
25	<i>Hemidinium nasutum</i> F.Stein 1883	Glenodiniaceae
26	<i>Heterocapsa</i> sp. 1*	Heterocapsaceae
27	<i>Karenia</i> sp. 1*	Brachidiniaceae
28	<i>Ostreopsis ovata</i> Fukuyo 1981*	Goniodomataceae
29	<i>Prorocentrum concavum</i> Fukuyo 1981*	Prorocentraceae
30	<i>Prorocentrum emarginatum</i> Fukuyo 1981*	Prorocentraceae
31	<i>Prorocentrum gracile</i> Schütt 1895*	Prorocentraceae
32	<i>Prorocentrum lima</i> (Ehrenberg) F.Stein 1878	Prorocentraceae
33	<i>Prorocentrum micans</i> Ehrenberg 1834*	Prorocentraceae
34	<i>Protoperidinium</i> sp. 1*	Protoperidiniaceae
35	<i>Pyrophacus stenii</i> (Schiller) Wall & Dale 1971*	Pyrophacaceae
36	<i>Pyrodinium bahamense</i> var. <i>compressum</i> (Böhm) Steidinger, Tester & F.J.R.Taylor 1980*	Goniodomataceae
37	<i>Scrippsiella trochoidea</i> (Stein) Balech ex Loeblich III 1965*	Calciodinelloideae

in red discoloration of the sea, and this has been reported in Malaysia (Lim et al., 2014b). *Gonyaulax spinifera* (Claparède & Lachmann) Diesing 1866 was observed in the Singapore Strait for the first time in this study.

***Heterocapsa* (Stein, 1883).** This dinoflagellate genus comprises 19 species. Blooms of *Heterocapsa circularisquama* resulted in mass mortality of commercially important bivalves in Japan, such as the Pacific oyster, short-necked clam and blue mussel, incurring huge aquaculture losses (Matsuyama et al., 1997). Blooms cause bivalves to close their shells, contract their mantle and eventually leading to death (Horiguchi, 1995, Matsuyama et al., 1996, Nagai et al., 1996). In the South China Sea region, Hong Kong has experienced blooms of this species (Iwataki et al., 2002). One species, tentatively identified to *Heterocapsa* sp. 1, was found in Singapore.

***Karenia* (Hansen & Moestrup, 2000).** This genus is currently known to comprise 12 species. Toxins can be released into the environment as aerosols upon lysis of causative cells, causing humans to suffer respiratory problems (Ishida et al., 1996; Pierce et al., 2004). Recreational beaches have been forced to close due to blooms caused by members of this genus (Yang & Hodgkiss, 2004). Mortalities of fish, echinoderms, polychaetes and bivalves are also associated with such blooms (Yang & Hodgkiss, 2004, Silke et al., 2005). Consumption of bivalves contaminated with this genus may also result in neurotoxic shellfish poisoning (NSP) where patients experience headache, aching muscles, nausea, diarrhea and visual defects (Ishida et al., 1996). Blooms of *Karenia* have been reported from Japanese and Hong Kong waters in the western Pacific region (Yang & Hodgkiss, 2004). An undetermined species was observed from the Singapore Strait in this study.

Table 2. A checklist of marine diatoms found in Singapore waters. The list is arranged alphabetically based on scientific binominal name, with species authority and family as in AlgaeBase (Guiry & Guiry, 2014). * new record in Singapore.

No	Taxon name	Family
1	<i>Achnanthes brevipes</i> C.Agardh 1824	Achnantheaceae
2	<i>Achnanthes longipes</i> C.Agardh 1824	Achnantheaceae
3	<i>Achnanthes temperei</i> M.Peragallo in Témperé & Peragallo 1908	Achnantheaceae
4	<i>Achnanthes tenuistauros</i> A.Mann	Achnantheaceae
5	<i>Actinocyclus octonarius</i> Ehrenberg 1837	Hemidiscaceae
6	<i>Actinocyclus octonarius</i> var. <i>sparsus</i> (Gregory) Hendey 1954	Hemidiscaceae
7	<i>Actinocyclus platensis</i> F.C.Müller Melchers	Hemidiscaceae
8	<i>Actinoptychus senarius</i> (Ehrenberg) Ehrenberg 1843	Heliopeltaceae
9	<i>Amphicoconeis disculoides</i> (Hustedt) Stefano & Marino 2003	Achnantheaceae
10	<i>Amphiprora</i> sp. 1*	Amphipleuraceae
11	<i>Amphora acutiuscula</i> Kützing 1844	Catenulaceae
12	<i>Amphora angusta</i> var. <i>eulensteinii</i> (Grunow) Cleve	Catenulaceae
13	<i>Amphora angusta</i> var. <i>oblongella</i> (Grunow) Cleve	Catenulaceae
14	<i>Amphora angusta</i> var. <i>ventricosa</i> (W.Gregory) Cleve	Catenulaceae
15	<i>Amphora coffeiformis</i> (C.Agardh) Kützing 1844	Catenulaceae
16	<i>Amphora decipiens</i> Grunow	Catenulaceae
17	<i>Amphora graeffei</i> Cleve 1896	Catenulaceae
18	<i>Amphora holsatica</i> Hustedt 1925	Catenulaceae
19	<i>Amphora javanica</i> A.W.F.Schmidt	Catenulaceae
20	<i>Amphora normanii</i> Rabenhorst 1864	Catenulaceae
21	<i>Amphora ostrearia</i> Brébisson 1849	Catenulaceae
22	<i>Amphora proteus</i> Gregory 1857	Catenulaceae
23	<i>Amphora turgida</i> Gregory 1857	Catenulaceae
24	<i>Amphora wisei</i> (M.M.Salah) R.Simonsen	Catenulaceae
25	<i>Asterionella japonica</i> Cleve in Cleve & Möller 1882	Fragilariaceae
26	<i>Auliscus reticulatus</i> Greville	Triceratiaceae
27	<i>Azpeitia nodulifera</i> (A.W.F.Schmidt) G.A.Fryxell & P.A.Sims 1986	Hemidiscaceae
28	<i>Bacillaria paradoxa</i> J.F.Gmelin in Linnaeus 1791	Bacillariaceae
29	<i>Bacillaria paxillifera</i> (O.F.Müller) T.Marsson 1901	Bacillariaceae
30	<i>Bacteriastrum delicatulum</i> Cleve 1897	Chaetocerotaceae
31	<i>Bacteriastrum hyalinum</i> Lauder 1864	Chaetocerotaceae
32	<i>Biddulphia aurita</i> (Lyngbye) Brébisson 1838	Biddulphiaceae
33	<i>Biddulphia biddulphiana</i> (J.E.Smith) Boyer 1900	Biddulphiaceae
34	<i>Biddulphia petitiana</i> (G.Leuduger-Fortmorel) A.Mann	Biddulphiaceae
35	<i>Biddulphia vesiculosa</i> (Agardh) Kützing 1833	Biddulphiaceae
36	<i>Caloneis liber</i> (W.Smith) Cleve 1894	Naviculaceae
37	<i>Caloneis ventricosa</i> var. <i>minuta</i> (Grunow) F.W.Mills 1934	Naviculaceae
38	<i>Campylodiscus fastuosus</i> Ehrenberg 1845	Surirellaceae
39	<i>Campylodiscus ralfsii</i> W.Smith 1853	Surirellaceae
40	<i>Chaetoceros affinis</i> Lauder 1864*	Chaetocerotaceae
41	<i>Chaetoceros danicus</i> Cleve 1889	Chaetocerotaceae
42	<i>Chaetoceros decipiens</i> Cleve 1873*	Chaetocerotaceae
43	<i>Chaetoceros lorenzianus</i> Grunow 1863	Chaetocerotaceae
44	<i>Chaetoceros peruvianus</i> Brightwell 1856	Chaetocerotaceae
45	<i>Chaetoceros tetrastichon</i> Cleve 1897	Chaetocerotaceae
46	<i>Chattonella subsalsa</i> B.Biecheler 1936	Chattonellaceae
47	<i>Climacosphenia moniligera</i> Ehrenberg 1843	Climacospheniaceae
48	<i>Cocconeis dirupta</i> W.Gregory 1857	Cocconeidaceae
49	<i>Cocconeis heteroidea</i> Hantzsch	Cocconeidaceae
50	<i>Cocconeis pelta</i> A.Schmidt 1874	Cocconeidaceae
51	<i>Cocconeis placentula</i> Ehrenberg 1838	Cocconeidaceae
52	<i>Cocconeis pseudomarginata</i> var. <i>intermedia</i> Grunow	Cocconeidaceae
53	<i>Cocconeis speciosa</i> Gregory 1855	Cocconeidaceae
54	<i>Cocconeis sublittoralis</i> Hendey 1951	Cocconeidaceae
55	<i>Coscinodiscus argus</i> Ehrenberg 1839	Coscinodiscaceae

No	Taxon name	Family
56	<i>Coscinodiscus granii</i> Gough 1905	Coscinodiscaceae
57	<i>Coscinodiscus marginatus</i> Ehrenberg 1844	Coscinodiscaceae
58	<i>Coscinodiscus radiatus</i> Ehrenberg 1840	Coscinodiscaceae
59	<i>Coscinodiscus wailesii</i> Gran & Angst 1931	Coscinodiscaceae
60	<i>Craticula halophila</i> (Grunow) D.G.Mann in Round, Crawford & Mann 1990	Stauroneidaceae
61	<i>Cyclotella</i> sp. 1*	Stephanodiscaceae
62	<i>Cylindrotheca closterium</i> (Ehrenberg) Reimann & J.C.Lewin 1964	Bacillariaceae
63	<i>Cymatosira lorenziana</i> Grunow 1862	Cymatosiraceae
64	<i>Cymbella norvegica</i> Grunow in Schmidt 1875	Cymbellaceae
65	<i>Delphineis surirella</i> (Ehrenberg) G.W.Andrews 1981	Rhaphoneidaceae
66	<i>Denticula subtilis</i> Grunow 1862	Bacillariaceae
67	<i>Diademsis contenta</i> (Grunow ex Van Heurck) D.G.Mann in Round, Crawford & Mann 1990	Diademsidaceae
68	<i>Dictylum sol</i> Cleve 1900*	Lithodesmiaceae
69	<i>Diplomenora</i> sp. 1*	Rhaphoneidaceae
70	<i>Diploneis bombiformis</i> Cleve 1894	Diploneidaceae
71	<i>Diploneis bombus</i> (Ehrenberg) Ehrenberg 1853	Diploneidaceae
72	<i>Diploneis bombus</i> var. <i>densestriata</i> (A.Schmidt) Cleve 1894	Diploneidaceae
73	<i>Diploneis coffaeiformis</i> (Schmidt) Cleve 1894	Diploneidaceae
74	<i>Diploneis crabro</i> (Ehrenberg) Ehrenberg 1854	Diploneidaceae
75	<i>Diploneis exemta</i> var. <i>digrediens</i> Cleve	Diploneidaceae
76	<i>Diploneis gravelleana</i> R.Hagelstein	Diploneidaceae
77	<i>Diploneis incurvata</i> (Gregory) Cleve 1894	Diploneidaceae
78	<i>Diploneis interrupta</i> (Kützing) Cleve 1894	Diploneidaceae
79	<i>Diploneis interrupta</i> var. <i>gorjanovicii</i> (Pantocsek) Cleve	Diploneidaceae
80	<i>Diploneis littoralis</i> (Donkin) Cleve 1894	Diploneidaceae
81	<i>Diploneis oculata</i> (Brébisson) Cleve 1894	Diploneidaceae
82	<i>Diploneis puella</i> (Schumann) Cleve 1894	Diploneidaceae
83	<i>Diploneis smithii</i> var. <i>rhombica</i> Mereschkowsky 1902	Diploneidaceae
84	<i>Diploneis subovalis</i> Cleve 1894	Diploneidaceae
85	<i>Diploneis vetula</i> (A.Schmidt) Cleve 1894	Diploneidaceae
86	<i>Diploneis weissflogii</i> (A.W.F.Schmidt) Cleve 1894	Diploneidaceae
87	<i>Ditylum brightwellii</i> (T.West) Grunow in Van Heurck 1885	Lithodesmiaceae
88	<i>Eucampia</i> sp. 1*	Hemiaulaceae
89	<i>Flagilariopsis</i> sp. 1*	Bacillariaceae
90	<i>Fragilaria capucina</i> var. <i>vaucheriae</i> (Kützing) Lange-Bertalot 1980	Fragilariaceae
91	<i>Fragilaria schulzii</i> C.Brockmann 1950	Fragilariaceae
92	<i>Fragilariopsis cylindrus</i> (Grunow) Krieger 1954	Bacillariaceae
93	<i>Fragilariopsis oceanica</i> (Cleve) Hasle 1965	Bacillariaceae
94	<i>Frustulia</i> sp. 1*	Amphipleuraceae
95	<i>Gomphonema angustatum</i> (Kützing) Rabenhorst 1864	Gomphonemataceae
96	<i>Gomphonema angustatum</i> var. <i>[producta] f. indica</i> H.P.Gandhi	Gomphonemataceae
97	<i>Grammatophora marina</i> (Lyngbye) Kützing	Striatellaceae
98	<i>Grammatophora oceanica</i> Ehrenberg 1840	Striatellaceae
99	<i>Guinardia</i> sp. 1*	Rhizosoleniaceae
100	<i>Gyrosigma balticum</i> (Ehrenberg) Rabenhorst 1853	Pleurosigmataceae
101	<i>Gyrosigma distortum</i> (W.Smith) Griffith & Henfrey 1856	Pleurosigmataceae
102	<i>Gyrosigma fasciola</i> var. <i>sulcatum</i> (Grunow) Cleve 1894	Pleurosigmataceae
103	<i>Gyrosigma plagiostomum</i> (Grunow) Cleve	Pleurosigmataceae
104	<i>Gyrosigma rectum</i> (Donkin) Cleve 1894	Pleurosigmataceae
105	<i>Gyrosigma simile</i> (Grunow) Boyer 1916	Pleurosigmataceae
106	<i>Hantzschia virgata</i> (Roper) Cleve & Grunow 1880	Bacillariaceae
107	<i>Haslea crucigera</i> (W.Smith) Simonsen 1974	Naviculaceae
108	<i>Helicotheca tamesis</i> (Shrubsole) M.Ricard 1987*	Lithodesmiaceae
109	<i>Hemiaulus</i> sp. 1*	Hemiaulaceae
110	<i>Hyalodiscus stelliger</i> J.W.Bailey 1854	Hyalodiscaceae
111	<i>Isthmia enervis</i> Ehrenberg 1838	Biddulphiaceae
112	<i>Lauderia annulata</i> Cleve 1873*	Lauderiaceae
113	<i>Lemnicola hungarica</i> (Grunow) F.E.Round & P.W.Basson 1997	Achnanthidiaceae

No	Taxon name	Family
114	<i>Licmophora ehrenbergii</i> (Kützing) Grunow 1867	Licmophoraceae
115	<i>Licmophora gracilis</i> (Ehrenberg) Grunow 1867	Licmophoraceae
116	<i>Licmophora lyngbyei</i> (Kützing) Grunow ex Van Heurck 1867	Licmophoraceae
117	<i>Lyrella clavata</i> (Gregory) D.G.Mann in F.E. Round, R.M. Crawford & D.G. Mann 1990	Lyrellaceae
118	<i>Lyrella lyra</i> (Ehrenberg) Karajeva 1978	Lyrellaceae
119	<i>Lyrella praetexta</i> (Ehrenberg) D.G.Mann in F.E. Round, R.M. Crawford & D.G. Mann 1990	Lyrellaceae
120	<i>Martyana martyi</i> (Héribaud-Joseph) Round in Round, Crawford & Mann 1990	Fragilariaceae
121	<i>Mastogloia fimbriata</i> (T.Brightwell) Grunow 1863	Mastogloioaceae
122	<i>Melosira nummuloides</i> C.Agardh 1824	Melosiraceae
123	<i>Meuniera membranacea</i> (Cleve) P.C.Silva in Hasle & Syvertsen 1996*	Naviculaceae
124	<i>Navicula brasiliensis</i> Grunow	Naviculaceae
125	<i>Navicula discernenda</i> Pantocsek	Naviculaceae
126	<i>Navicula distans</i> (W.Smith) Ralfs in Prichard 1861	Naviculaceae
127	<i>Navicula elginensis</i> (W.Gregory) Ralfs in Pritchard 1861	Naviculaceae
128	<i>Navicula forcipata</i> var. <i>suborbicularis</i> (Grunow) Grunow in van Heurck	Naviculaceae
129	<i>Navicula gracilis</i> Ehrenberg 1832	Naviculaceae
130	<i>Navicula gruendleri</i> (Cleve & Grunow) Cleve	Naviculaceae
131	<i>Navicula menaiana</i> Hendey 1956	Naviculaceae
132	<i>Navicula monilifera</i> var. <i>constricta</i> Heiden	Naviculaceae
133	<i>Navicula niceaensis</i> H.Peragallo	Naviculaceae
134	<i>Navicula pennata</i> A.Schmidt in Schmidt 1876	Naviculaceae
135	<i>Navicula philippinarum</i> A.Mann	Naviculaceae
136	<i>Navicula pi</i> Cleve	Naviculaceae
137	<i>Navicula platessa</i> Cleve	Naviculaceae
138	<i>Navicula platyventris</i> Meister	Naviculaceae
139	<i>Navicula plicata</i> Bodeanu 1976	Naviculaceae
140	<i>Navicula ramosissima</i> (C.Agardh) Cleve 1895	Naviculaceae
141	<i>Navicula ramosissima</i> f. <i>caspia</i> (Grunow) Cleve	Naviculaceae
142	<i>Navicula reichardtii</i> (Grunow) Grunow in Cleve & Möller 1877	Naviculaceae
143	<i>Navicula rhapsoneis</i> (Ehrenberg) Ralfs	Naviculaceae
144	<i>Navicula rhynchocephala</i> Kützing 1844	Naviculaceae
145	<i>Navicula trituberculata</i> Prowse	Naviculaceae
146	<i>Navicula veneta</i> Kützing 1844	Naviculaceae
147	<i>Navicula yarrensensis</i> Grunow in Schmidt 1876	Naviculaceae
148	<i>Navicula zostereti</i> Grunow	Naviculaceae
149	<i>Nitzschia bilobata</i> var. <i>minor</i> Grunow 1881	Bacillariaceae
150	<i>Nitzschia brebissonii</i> var. <i>borealis</i> Cleve	Bacillariaceae
151	<i>Nitzschia closterium</i> (Ehrenberg) W.Smith 1853	Bacillariaceae
152	<i>Nitzschia commutata</i> Grunow in Cleve & Grunow 1880	Bacillariaceae
153	<i>Nitzschia constricta</i> (Gregory) Grunow 1880	Bacillariaceae
154	<i>Nitzschia hybridaeformis</i> Hustedt	Bacillariaceae
155	<i>Nitzschia lanceolata</i> W.Smith 1853	Bacillariaceae
156	<i>Nitzschia longissima</i> (Brébisson) Ralfs in Pritchard 1861	Bacillariaceae
157	<i>Nitzschia punctata</i> var. <i>coarctata</i> (Grunow) Hustedt 1921	Bacillariaceae
158	<i>Nitzschia sigma</i> (Kützing) W.Smith 1853	Bacillariaceae
159	<i>Nitzschia sigma</i> var. <i>rigida</i> Grunow ex Van Heurck 1880	Bacillariaceae
160	<i>Nitzschia sigmoidea</i> (Nitzsch) W.Smith 1853	Bacillariaceae
161	<i>Nitzschia vermicularis</i> (Kützing) Hantzsch in Rabenhorst 1860	Bacillariaceae
162	<i>Odontella aurita</i> (Lyngbye) C.Agardh 1832	Triceratiaceae
163	<i>Odontella mobiliensis</i> (J.W.Bailey) Grunow 1884	Triceratiaceae
164	<i>Odontella obtusa</i> Kützing 1844	Triceratiaceae
165	<i>Opephora pacifica</i> (Grunow) Petit 1888	Fragilariaceae
166	<i>Opephora schwartzii</i> (Grunow) Petit ex Pelletan 1889	Fragilariaceae
167	<i>Paralia sulcata</i> (Ehrenberg) Cleve 1873	Paraliaceae
168	<i>Petroneis monilifera</i> (Cleve) A.J.Stickle & D.G.Mann 1990	Lyrellaceae
169	<i>Petroneis transfuga</i> (Grunow ex Cleve) D.G.Mann 1990	Lyrellaceae
170	<i>Pinnularia cruciformis</i> (Donkin) Cleve 1895	Pinnulariaceae
171	<i>Plagiogramma staurophorum</i> (W.Gregory) Heiberg 1863	Plagiogrammaceae

No	Taxon name	Family
172	<i>Plagiotropis</i> sp1*	Plagiotropidaceae
173	<i>Planktoniella blanda</i> (A.Schmidt) E.E.Syvetsen & G.R.Hasle in Hasle & Syvetsen 1993*	Thalassiosiraceae
174	<i>Pleurosigma aestuarii</i> (Brébisson ex Kützing) W.Smith 1853	Pleurosigmataceae
175	<i>Pleurosigma delicatulum</i> W.Smith 1852	Pleurosigmataceae
176	<i>Pleurosigma elongatum</i> W.Smith 1852	Pleurosigmataceae
177	<i>Pleurosigma fasciola</i> (Ehrenberg) W.Smith 1852	Pleurosigmataceae
178	<i>Pleurosigma formosum</i> W.Smith 1852	Pleurosigmataceae
179	<i>Pleurosigma intermedium</i> W.Smith 1853	Pleurosigmataceae
180	<i>Pleurosigma majus</i> (Grunow) Cleve 1894	Pleurosigmataceae
181	<i>Pleurosigma marinum</i> Donkin 1858	Pleurosigmataceae
182	<i>Pleurosigma normanii</i> Ralfs in Pritchard 1861	Pleurosigmataceae
183	<i>Pleurosigma salinarum</i> (Grunow) Grunow in Cleve & Grunow 1880	Pleurosigmataceae
184	<i>Psammodictyon panduriforme</i> (W.Gregory) D.G.Mann in Round, Crawford & Mann 1990	Surirellaceae
185	<i>Psammodiscus nitidus</i> (W.Gregory) Round & D.G.Mann 1980	Psammodiscaceae
186	<i>Pseudo-nitzschia brasiliana</i> N.Lundholm, G.R.Hasle & G.A.Fryxell 2002*	Bacillariaceae
187	<i>Pseudo-nitzschia cuspidata</i> (Hasle) Hasle 1993*	Bacillariaceae
188	<i>Pseudo-nitzschia micropora</i> K.Priisholm, Ø.Moestrup & N.Lundholm 2002*	Bacillariaceae
189	<i>Pseudo-nitzschia multistriata</i> (Takano) Takano 1995*	Bacillariaceae
190	<i>Pseudo-nitzschia pungens</i> (Grunow ex Cleve) G.R.Hasle 1993	Bacillariaceae
191	<i>Pseudo-nitzschia seriata</i> (Cleve) H.Peragallo in H.Peragallo & M.Peragallo 1899	Bacillariaceae
192	<i>Pyxidicula africana</i> B.J.Cholnoky	Rhopalodiaceae
193	<i>Rhabdonema adriaticum</i> Kützing 1844	Rhabdonemataceae
194	<i>Rhaphoneis amphiceros</i> (Ehrenberg) Ehrenberg 1844	Rhaphoneidaceae
195	<i>Rhizosolenia</i> sp. 1*	Rhizosoleniaceae
196	<i>Rhoicosphenia abbreviata</i> (C.Agardh) Lange-Bertalot 1980	Rhoicospheniaceae
197	<i>Rhopalodia gibberula</i> (Ehrenberg) Otto Müller 1895	Rhopalodiaceae
198	<i>Rhopalodia gibberula</i> var. <i>producta</i> (Grunow) Otto Müller 1900	Rhopalodiaceae
199	<i>Rhopalodia gibberula</i> var. <i>vanheurckii</i> Otto Müller 1900	Rhopalodiaceae
200	<i>Rhopalodia musculus</i> (Kützing) Otto Müller 1900	Rhopalodiaceae
201	<i>Skeletonema</i> sp. 1*	Skeletonemataceae
202	<i>Shionodiscus oestrupii</i> (Ostenfeld) A.J.Alverson, S.H.Kang & E.C.Theriot 2006	Thalassiosiraceae
203	<i>Skeletonema costatum</i> (Greville) Cleve 1873	Skeletonemataceae
204	<i>Stauroneis membranacea</i> (Cleve) Hustedt 1959	Stauroneidaceae
205	<i>Stephanodiscus rotula</i> (Kützing) Hendey 1964	Stephanodiscaceae
206	<i>Stephanopyxis turris</i> var. <i>polaris</i> Grunow	Stephanodiscaceae
207	<i>Striatella unipunctata</i> (Lyngbye) C.Agardh 1832	Striatellaceae
208	<i>Surirella fastuosa</i> (Ehrenberg) Ehrenberg 1843	Surirellaceae
209	<i>Surirella fastuosa</i> var. <i>recedens</i> (A.Schmidt) Cleve	Surirellaceae
210	<i>Synedra amphicephala</i> Kützing 1844	Fragilariaceae
211	<i>Synedra crystallina</i> (C.Agardh) Kützing	Fragilariaceae
212	<i>Synedra formosa</i> Hantzsch 1863	Fragilariaceae
213	<i>Thalassionema nitzschioides</i> (Grunow) Mereschkowsky 1902	Thalassionemataceae
214	<i>Thalassionema</i> sp. 1*	Thalassionemataceae
215	<i>Thalassiosira angulata</i> (W.Gregory) Hasle 1978	Thalassiosiraceae
216	<i>Thalassiosira condensata</i> Cleve 1900	Thalassiosiraceae
217	<i>Thalassiosira decipiens</i> (Grunow) E.G.Jørgensen 1905	Thalassiosiraceae
218	<i>Thalassiosira eccentrica</i> (Ehrenberg) Cleve 1904	Thalassiosiraceae
219	<i>Thalassiosira rotula</i> Meunier 1910	Thalassiosiraceae
220	<i>Thalassiothrix</i> sp. 1*	Thalassionemataceae
221	<i>Toxarium hennedyanum</i> (Gregory) Pelletan 1889	Toxariaceae
222	<i>Trachyneis antillarum</i> (Cleve & Grunow) Cleve	Naviculaceae
223	<i>Trachyneis aspera</i> (Ehrenberg) Cleve 1894	Naviculaceae
224	<i>Trachyneis aspera</i> var. <i>intermedia</i> (Grunow) Cleve 1894	Naviculaceae
225	<i>Trachyneis aspera</i> var. <i>pulchella</i> (W.Smith) Cleve 1894	Naviculaceae
226	<i>Triceratium broeckii</i> G.Leuduger-Fortmorel	Triceratiaceae
227	<i>Triceratium dubium</i> Brightwell 1859	Triceratiaceae
228	<i>Trichocladia nostocoides</i> Zanardini 1872	Chordariaceae
229	<i>Tryblionella apiculata</i> Gregory 1857	Bacillariaceae

No	Taxon name	Family
230	<i>Tryblionella cocconeiformis</i> (Grunow) D.G.Mann in Round, Crawford & Mann 1990	Bacillariaceae
231	<i>Tryblionella compressa</i> (Bailey) M.Poulin in Poulin et al. 1990	Bacillariaceae
232	<i>Tryblionella granulata</i> (Grunow) D.G.Mann 1990	Bacillariaceae
233	<i>Tryblioptychus cocconeiformis</i> (Grunow) Hendey 1958	Surirellaceae

Karlodinium (Larsen, 2000). There are nine taxonomically accepted species in the genus *Karlodinium* (Daugbjerg et al., 2000). They possess ichthyotoxins and karlotoxins (de Salas et al., 2005, Adolf et al., 2009, Mooney et al., 2009, Peng et al., 2010) that are known to cause massive fish kills during blooms, significantly affecting aquaculture industries (Lim et al., 2014a). *Karlodinium veneficum* was first reported from the Tebrau Strait in Malaysia (Tan et al., 2013a). In February 2014, aquaculture finfishes amounting to some 50,000 individuals were killed. This was attributed to a massive bloom of *K. australe* when cell densities reached 1.25×10^6 cells L⁻¹ in the Johor Strait, Malaysia (Lim et al., 2014a). In this survey, no cells resembling *Karlodinium* spp. was detected. However, *Karlodinium* was found to be a common species in the Johor Straits (Lim et al., 2014a).

Ostreopsis (Schmidt, 1901). There are nine taxonomically accepted species in this genus. Members of this benthic genus possess palytoxins (PTX) and ovatoxins, which contaminate shellfish, crustaceans and several species of fish (Aligizaki et al., 2011). In 2005, around 200 people experienced respiratory symptoms when exposed to aerosols and 20 were hospitalized in Italy (Ciminiello et al., 2006; Tubaro et al., 2011). Patients experience fever, sore throat, cough, nausea, vomiting and in some cases have caused fatalities (Durando et al., 2007; Tubaro et al., 2011). When tested on mice, these toxins cause blindness, numbness and death (Aligizaki et al., 2011). Species from this genus have been reported from Malaysia, Indonesia and Vietnam (Leaw et al., 2001; Penna et al., 2012; Tan et al., 2013b). In this study, one species (*Ostreopsis ovata*; see Table 1) was found in the Singapore Strait.

Prorocentrum (Ehrenberg, 1834). There are 82 taxonomically accepted species in this dinoflagellate genus. Some species possess okadaic acid and pectentoxins (Murakami et al., 1982; Yasumoto et al., 1987; Lee et al., 1989; Zhou & Fritz, 1994), which are associated with blooms (Pybus, 1990) that may lead to ciguatera fish poisoning and diarrhetic shellfish poisoning (DSP) (Faust, 1991; Jackson et al., 1993; Heredia-Tapia et al., 2002). Some species can secrete diatom growth inhibitory and other substances with ichthyotoxic as well as hemolytic properties (Uchida, 1977; Yasumoto et al., 1987). Four *Prorocentrum* species were observed in this study (*P. concavum*, *P. gracile*, *P. lima* and *P. micans*) (Fig. 1; Table 1). One species, *P. lima*, is associated with DSP events (Bauder et al., 1996). Several species have been reported from Malaysia, including okadaic acid producers that affected shellfish industries (*P. lima*, *P. rathymum*; see Mohammad-Noor et al., 2007; Tan et al., 2012), and have

also caused massive fish kills (*P. minimum*; Usup et al., 2002c; Lim et al., 2012b).

Nitzschia (Hassall, 1845). *Nitzschia* is a common genus of diatoms in both freshwater and marine ecosystems. There are some 423 valid species in this large genus. Species of *Nitzschia* have not been responsible for any toxic blooms until 2000, when the first toxic *Nitzschia*, *N. navis-varingica* was reported to be responsible for a toxic bloom incident in Vietnam (Lundholm & Moestrup, 2000). The toxin was confirmed as domoic acid (DA) which causes amnesic shellfish poisoning (ASP). Following that, a new toxigenic species, *N. bizertensis* was reported as a DA producer (Smida et al., 2014). There have been few studies of *Nitzschia* in the Southeast Asia region. Screening had been conducted by Kotaki et al., 2006b in the region, and they reported toxic *Nitzschia* spp. in Thailand, Vietnam, Indonesia, Philippines and Malaysia (Kotaki et al., 2006a, Romero et al., 2008, Romero et al., 2011, Romero et al., 2012, Thoha et al., 2012). At the same time there were some non-toxic strains isolated from this region as well. In this study we identified some 15 non-toxic species of *Nitzschia* from the Singapore Strait.

Pseudo-nitzschia (Peragallo, 1900). *Pseudo-nitzschia* is a cosmopolitan genus of diatoms, consisting of 45 valid species, of which 16 are toxic. Recently, *P. kodamae* was shown to be the first toxic *Pseudo-nitzschia* species in Southeast Asia (Teng et al., 2014). Dao et al. (2014) reported the presence of toxic *P. cf. caciantha* from Vietnam. This species is believed to be associated with domoic acid occurrences in the spiny oyster *Spondylus versicolor* in Vietnam (Dao et al., 2006; Dao et al., 2009; Ha et al., 2014). However, no blooms of *Pseudo-nitzschia* associated with Amnesic Shellfish Poisoning (ASP) were reported in Southeast Asia thus far. Some 30 *Pseudo-nitzschia* spp. are found in the region, with ten of them being potentially toxic (Priisholm et al., 2002, Larsen and Nguyen-Ngoc, 2004, Bajarias et al., 2006, Yap-Dejeto et al., 2010, Lim et al., 2012a, Lim et al., 2013a, Teng et al., 2013, Teng et al., 2014). In this survey, five *Pseudo-nitzschia* species were recorded in Singapore waters (Lim et al., 2013b).

CONCLUSIONS

The biodiversity of marine phytoplankton is rich in Singapore waters. The risk of Singapore waters of having non-indigenous species is also high due to intense port activities. The marine phytoplankton list should be updated frequently and monitoring agencies should be aware of the bloom forming species as well as toxin producers, which might affect public health and seafood industries.

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