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Phytoplankton in the Coastal Waters of Russky Island, Peter the Great Bay, Sea of Japan

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ABSTRACT

The article presents an annotated list of microalgal species in the coastal waters off Russky Island (Sea of Japan) based on original and literature data. A total of 254 taxa of microalgae from ten classes are identified. Descriptions and photographic illustrations are provided for the diatom species of the genus *Skeletonema* and prymnesiophyta *Pseudohaptolina sorokinii*, which are rare in the seas of Russia. Information on 20 species of potentially toxic microalgae observed in the study area is also provided.

Keywords: marine, phytoplankton, flora, ecology, Russky Island, Sea of Japan

РЕЗЮМЕ

Шевченко О.Г., Пономарева А.А., Шульгина М.А., Орлова Т.Ю. Фитопланктон прибрежных вод острова Русский, залив Петра Великого, Японское море. В работе представлен аннотированный список микроводорослей прибрежных вод острова Русский (Японское море), составленный на основе оригинальных сведений и данных литературы. Обнаружено 254 таксона микроводорослей, относящихся 10 классам. Приведены описания и даны фототаблицы редких для морей России видов диатомовых рода *Skeletonema* и примнезиофитовой водоросли *Pseudohaptolina sorokinii*. Включены сведения о 20 видах потенциально токсичных микроводорослей. Данная работа содержит сведения о составе фитопланктона исследованной акватории до начала ее активной эксплуатации.

Ключевые слова: морской фитопланктон, флора, экология, остров Русский, Японское море

Russky Island is located in Peter the Great Bay of the Sea of Japan, near the southern tip of the Muravyov-Amursky Peninsula. The island is washed by the waters of Amur Bay in the west and Ussuri Bay (both are smaller subordinate bays in Peter the Great Bay) in the east and in the south. The bays are connected by the Eastern Bosphorus Strait bordering Russky Island in the north. Amur Bay is one of the most studied areas of the northwestern Sea of Japan. More than 30 papers dealing with the research of phytoplankton from Amur Bay have been published since the beginning of the last century. The results of an almost hundred-year-long study of microalgal flora in this bay are summarized by Orlova et al. (2009). The phytoplankton of Ussuri Bay is significantly less studied; there are only two publications providing data on investigation of microalgae from this bay (Selina 1988, Begun 2004).

Species composition and abundance of phytoplankton are widely used for the assessments of the human impact on water areas and may serve as ecosystem indicators due to the ability of microalgae to promptly respond to changes in the aquatic environment (Cloern & Jassby 2010). The upcoming necessity to evaluate the anthropogenic pressures on the coastal waters off Russky Island makes inventorying the flora of this water area timely and relevant.

The purpose of our study was to summarize the data on the long-term research of phytoplankton from the coastal waters of Russky Island, as well as to compile a floral list with quantitative characteristics of each taxon for different seasons.

MATERIAL AND METHODS

Environmental conditions of the study area

The climatic conditions of the northwestern part of Russky Island differ from those in its southeastern part facing the open sea. During the summer monsoon period the southeastern part of the island is often exposed to fogs and colder than the northwest part. Most precipitation falls in summer. The mean air temperature ranges from 0°C to -12°C in winter and from 14°C to 21°C in summer. During winter, the temperature of the coastal waters off the island falls down to -1.9°C; the water reaches its highest temperature, up to 25°C, in August. Freeze-up usually begins in mid December; the coastal strip of the sea off Russky Island is covered with ice up to 1 m and more thick until the middle of March.

Data sampling and analysis

Phytoplankton was sampled in the coastal waters of Ussuri Bay and Peter the Great Bay around Russky Island

(Fig. 1, Table 1). In 2007 and 2008, sampling was conducted with the research vessel Larga; in 2012–2015, sampling was carried out by the research team of the Primorsky Aquarium, Branch of the National Scientific Center of Marine Biology, Far Eastern Branch of the Russian Academy of Sciences (NSCMB FEB RAS), at the monitoring stations. In winter, phytoplankton was sampled through a hole drilled in the sea ice. Samples were taken with a 5-liter Niskin bottle from the surface horizon. One liter of the sample was fixed with Utermöhl's solution and concentrated by sedimentation (Utermöhl 1958, Sukhanova 1983). The material was examined in a Nageotte counting chamber with a volume of 0.05 mL. A total of 497 phytoplankton samples were studied.

Microalgae were identified under a light microscope Olympus BX 41 (LM). The fine structure of valves was examined with a transmission electron microscope JEM-100 JEOL S (TEM) and a scanning electron microscope Carl Zeiss Leo 430 (SEM). Material for TEM was prepared according to the standard procedure (Hasle & Fryxell 1970, Shevchenko & Ponomareva 2015). Algae were considered to be blooming at concentrations exceeding 10^6 cells/L (Colijn 1992).

In this article we use the taxonomic classification proposed by Guiry & Guiry (2012). Species within the classes are alphabetically ordered (Table 2). The synonymy given here reflects all nomenclatural changes made since 2008.

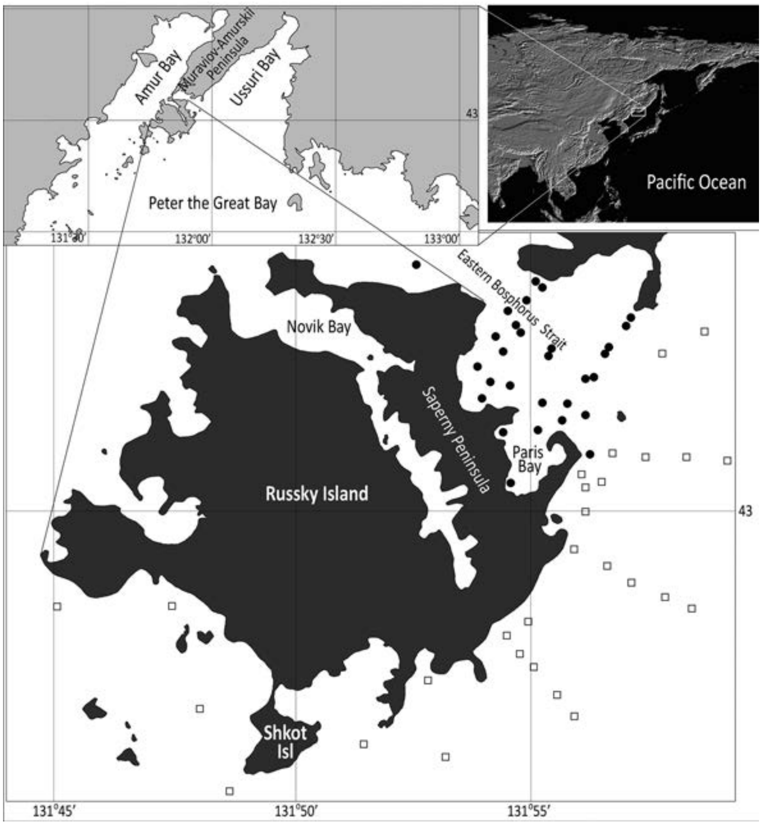

Figure 1 Map of phytoplankton sampling stations off Russky Island. Stations in Eastern Bosphorus Strait are indicated by circles; in Ussuri Bay, by squares

RESULTS

The original studies resulted in an annotated list of phytoplankton from the coastal waters of Russky Island. The list provides information on 254 species and intraspecific taxa of microalgae from ten classes (Table 2). The highest species diversity was recorded for Bacillariophyceae (133 species and 5 intraspecific taxa) and Dinophyceae (109). Other classes were represented by smaller numbers of species: Euglenoidea, 4; Dictyochophyceae, 4; Chlorophyceae, 3; Cryptophyceae, 2; Cyanophyceae, 2; Chrysophyceae, 1; Ebriophyceae, 1; and Prymnesiophyceae, 1 species. Among diatoms, the genus *Chaetoceros* was the richest in species (39 species and intraspecific taxa); among dinoflagellates, the genus *Protoperidinium* had the greatest variety of species (32 species).

During the study period, such species of planktonic microalgae as *Pseudohaptolina sorokinii* of the Prymnesiophycea and diatoms of the genus *Skeletonema*, which are rare in the seas of Russia, were recorded. When examining colonies of *Skeletonema* with electron microscopy, we identified *S. costatum*, *S. dohrnii*, *S. grethae*, *S. japonicum* and *S. marinoi* (Figs 2, 3). The article provides descriptions of the species of the genus *Skeletonema* and *Pseudohaptolina sorokinii* from the study area.

Table 1. Characteristics of the material collected.

Area	Date of sampling	Quantity		Longitude, E	Latitude, N
		stations	samples		
Eastern Bosphorus Strait	08.02.2007–28.02.2007	12	16	131°53′55″–131°56′03″	43°01′40″–43°03′25″
	13.04.2007	2	2	131°52′34″–131°55′36″	43°02′38″–43°04′08″
	03.05.2007	6	8	131°54′25″–131°57′22″	43°01′36″–43°03′53″
	02.09.2008; 04.09.2008	9	21	131°51′13″–131°56′38″	43°01′57″–43°03′39″
	14.12.2012–17.11.2015	2	335	131o54′20″–131o55′51″	43o00′27″–43o01′50″
Ussuri Bay	20.02.2007	3	3	131°56′15″–131°56′28″	43°00′17″–43°01′10″
	13.04.2007	8	8	131°45′17″–131°56′14″	42°55′46″–43°00′55″
	03.05.2007	12	16	131°53′07″–131°59′15″	42°55′42″–43°01′10″
	03.09.2008–04.09.2008	17	39	131°54′53″–131°59′03″	42°55′42″–43°01′10″
	26.03.2013–20.10.2015	1	49	131°56′12″–131°56′14″	44°00′54″–44°00′55″

Skeletonema costatum (Greville) Cleve, 1873 (Fig. 2: A, B)

Description. Cells cylindrical, 9–12 μm in diameter, joined into colonies by long straight fultoportula processes. Valves circular, slightly convex in the center, strongly silicified. Each fultoportula process with a large pore at its base. The intercalary fultoportula processes differ in shape from the terminal ones. The rimoportula is located inside the ring of the fultoportula processes in intercalary and terminal valves.

Distribution. Its distribution in the World Ocean needs to be clarified. The species is reliably reported from along the coast of Hong Kong Island (Greville 1866), Northern Queensland (Australia); in the Atlantic Ocean it occurs in the coastal waters of the USA, Uruguay, Brazil (Sarno et al.

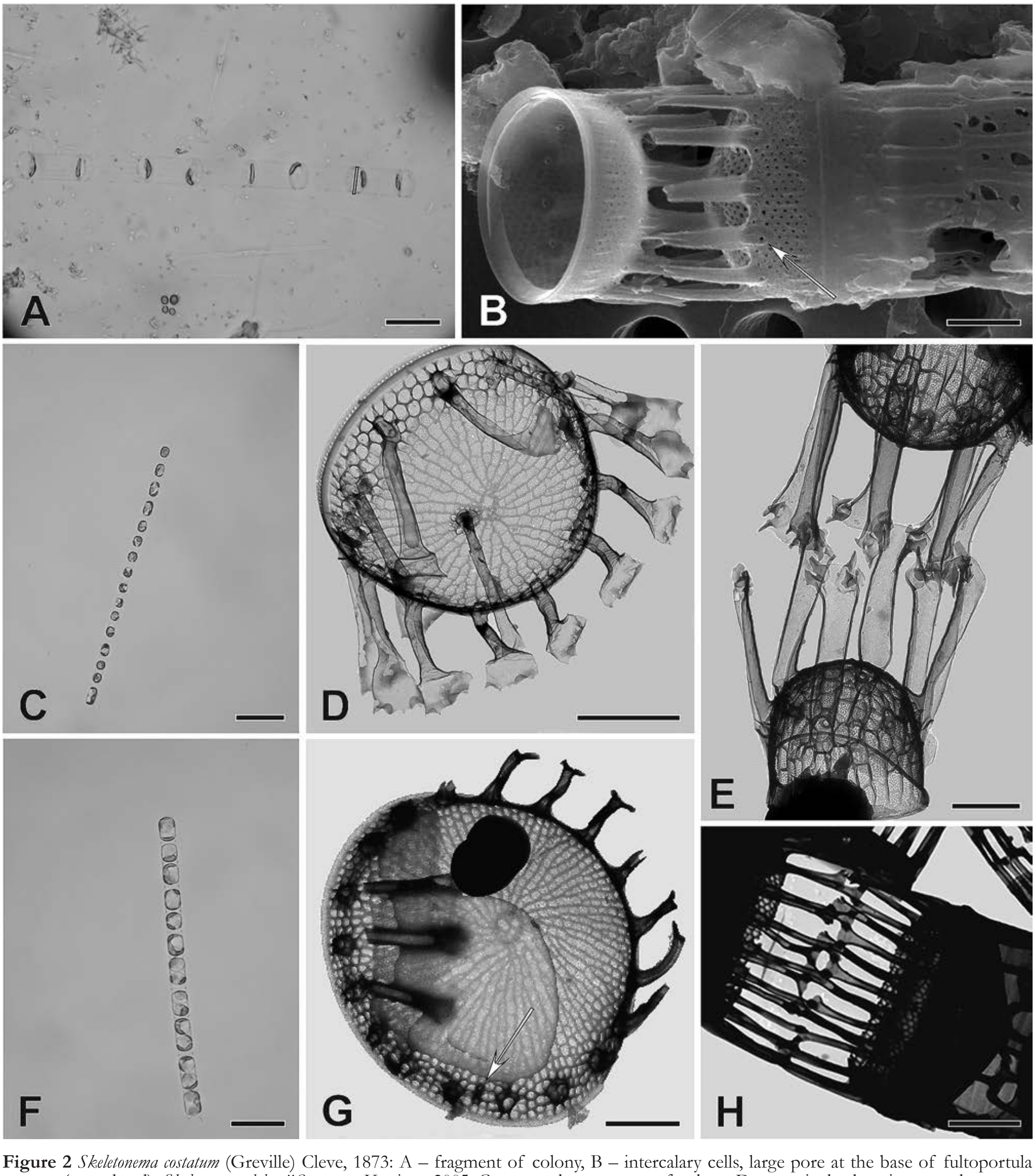

Figure 2 *Skeletonema costatum* (Greville) Cleve, 1873: A – fragment of colony, B – intercalary cells, large pore at the base of fultoportula process (arrowhead); *Skeletonema dohrnii* Sarno et Kooistra 2005: C – general appearance of colony, D – terminal valve, rimoportula process located close to valve center, E – two intercalary valves, shape of fultoportula processes; *Skeletonema grethae* Zingone et Sarno 2005: F – colony of cells, G – intercalary valve, rimoportula process (arrowhead), H –adjacent valves, linkage of fultoportula processes. A, C, F – LM, B – SEM, D, E, G, H – TEM. Scale: E = 1 μm, B, D, G, H = 2 μm, A, C = 10 μm, F = 20 μm

Table 2. List of planktonic microalgae in the coastal waters of Russky Island, Peter the Great Bay, Sea of Japan.

Species	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
DICTYOCHOPHYCEAE												
Dictyocha fibula Ehrenberg	1	1	2	1	0	0	1	2	2	3	3	1
Octactis speculum (Ehrenberg) Chang, Grieve et Sutherland	0	1	1	2	1	1	1	2	1	3	1	1
Octactis octonaria (Ehrenberg) Hovasse	0	0		1		0	0	2	2	2	0	0
Vicicitus globosus (Hara et Chihara) Chang = *Chattonella globosa* Hara et Chihara	0	0	2	0	0	0	0	0		3		6
CHRYSOPHYCEAE												
Dinobryon balticum (Schütt) Lemmermann	1	0	1	2	6	0	0	0	0	0	0	1
EBRIOPHYCEAE												
Ebria tripartita (Schütt) Lemmermann	0	0	1	1	1	0	2	2	2	2	1	0
BACILLARIOPHYCEAE												
Achnanthes longipes Agardh	0	0	0	0	0	0	0	1	0	0	1	0
Actinoptychus senarius (Ehrenberg) Ehrenberg	0	0	0	0	0	0	0	0	0	2	0	0
Amphora sp.	0	0	0	1	0	1	1	1	1	1	0	0
Asterionella formosa Hassal	0	2	0	1	1	0	0	0	0	2	0	0
Asterionellopsis glacialis (Castracane) Round	0	2	2	1	1	0	0	0	1	3	2	2
Asteromphalus flabellatus (Brébisson) Greville	0	0	0	0	0	0	0	0	0	1	0	0
Asteromphalus heptactis (Brébisson) Ralfs	0	0	0	0	0	0	0	0	0	2	0	0
Attheya longicornis Crawford et Gardner	0	3	1	1	0	0	0	0	1	1	0	0
Bacteriastrum furcatum Schadbolt	1		0	0	0	0	0	0	1	2	1	0
Bacteriastrum hyalinum Lauder	0	0	0	0	0	0	0	2	0	2	0	0
Bellerochea malleus (Brightwell) Van Heurck	0	0	0	0	0	0	0	0		1		0
Brockmanniella brockmannii (Husted) Hasle	0	0	0	0	0	2	2	2	0	0	1	0
Cerataulina dentata Hasle	0	0	0	0	1	1	3		3	3	2	1
Cerataulina pelagica (Cleve) Hendey	0	2	1	1	2	0	1	0	2	3	1	0
Chaetoceros affinis Lauder	3		0	0	0	1	2	3	3	3	1	0
Chaetoceros anastomosans Grunow	0	1	0	0	0	0	0	0	0	0	0	0
Chaetoceros atlanticus Cleve	0	2	1	0	0		1		0	0	0	0
Chaetoceros borealis Bailey	0	0	0	0	0	1	0	0	0	0	0	0
Chaetoceros concavicornis Mangin	0	0	0	0	0	0	0	0	0	2	1	0
Chaetoceros constrictus Gran	1		0	0	0		1		2	3	0	0
Chaetoceros contortus Schütt	0	2	2	3	2	2	0	2	2	4	0	0
Chaetoceros convolutus Castracane	0	1	2	2	1	0	1	0	1	2	1	0
Chaetoceros costatus Pavillard	0	0	0	0	0	0	0	0	0	2	0	0
Chaetoceros curvisetus Cleve	0	3	0	0	0	0	3	0	0	2	0	0
Chaetoceros danicus Cleve	1		0	1	0	0	0	1	1	0	0	0
Chaetoceros debilis Cleve	3	4	3	3	3	2	0	2	3	5	0	3
Chaetoceros decipiens Cleve	2	2	2	1	3	1	3	2	2	3	1	1
Chaetoceros diadema (Ehrenberg) Gran	0	3	0	1	0	1	0	0	0	3	0	0
Chaetoceros didymus Ehrenberg	0	3	2	2	1	1	2	3	4	3	2	1
Chaetoceros furcillatus Bailey	0	0	0	0	1	0	0	0	0	0	0	0
Chaetoceros ingolfianus Ostenfeld	0	0	0	0	1	0	0	0	0	0	0	0
Chaetoceros laciniosus F. Schütt	0	0	0	1	0		3		3	0	0	0
Chaetoceros lauderi Ralfs	0	0	0	0	0		1			3		0
Chaetoceros lorenzianus Grunow	0	1	0	0	0	0	0	0	0	1	0	0
Chaetoceros mitra (Bailey) Cleve	1	1	0	1	0	0	0	0	0	1	1	1
Chaetoceros paradoxus Cleve	0	0	0	0	0	0	0	0	2	0	0	0
Chaetoceros pendulus Karsten	0	0	0	0	0	0	0	0	0	1	0	0
Chaetoceros peruvianus Brightwell	0	1	0	0	0		1		1	1	0	0
Chaetoceros protuberans Lauder = *Chaetoceros didymus* var. *protuberans* (Lauder) Gran et Yendo	3		0	0	0	0	0	0	3	2	0	0
Chaetoceros pseudobrevis Pavillard	0	0	0	2	0	0	0	0	0	2	0	0
Chaetoceros pseudocrinitus Ostenfeld	0	4	0	4	2	0	0	0	0	0	0	0
Chaetoceros pseudocurvisetus Mangin	0	3	0	0	0	0	0	0	0	0	0	0
Chaetoceros radicans F. Schütt	0	1	0	0	0	1	0	0	0	3	0	0
Chaetoceros salsugineus Takano	0	2	0	2	0	0	0	0	0	2	0	0
Chaetoceros seiracanthus Gran	0	0	0	0	0	0	0	0	2	0	0	0
Chaetoceros similis Cleve	0	0	0	0	0	0	0	0	0	3	0	0
Chaetoceros simplex Ostenfeld	2	1	2	0	0	0	2	2	1	1	2	2
Chaetoceros socialis f. *socialis* Lauder	0	3	0	2	2	0	0	0	0	4	0	0
Chaetoceros socialis f. *radians* (F. Schütt) Proschkina-Lavrenko	0	0	0	3	0		1		0	0	0	0
Chaetoceros teres Cleve	0	0	0	2	0	0	0	0	0	0	0	1
Chaetoceros tortissimus Gran	0	2	0	0	0	0	0	0	0	0	0	0
Cocconeis distans Gregory	0	0	0	0	0	1	0	0	1	0	0	0
Cocconeis scutellum Ehrenberg	1	1	2	2	2	2	2	2	1	2	2	2
Corethron hystrix Hensen	0	0	0	0	0	0	0	0	0	1	0	0
Coscinodiscus granii Gough	0	1	2	0	0	0	0	1	0	3	0	0
Coscinodiscus oculus iridis Ehrenberg	1		1	1	1	0	1	1	2	2	2	0
Coscinodiscus perforatus Ehrenberg	0	0	0	0	0		1		0	0	0	0
Cyclotella sp.	0	0	0	0	1	0	0	0	0	2	0	0
Cylindrotheca closterium (Ehrenberg) Reimann et Lewin	1	2	1	2	2	2	1	1	1	3	3	2
Dactyliosolen fragilissimus (Bergon) Hasle = *Rhizosolenia fragilissima* Bergon	0	0	0	1	2	2	0	1	3	4	3	1
Delphineis surirella (Ehrenberg) Andrews	0	0	0	0	1	0	0	0	0	0	0	0
Diploneis lineata (Donkin) Cleve	0	0	0	0	0	0	0	0	0	0	1	0
Diploneis smithii (Brébisson) Cleve	0	1	1	1	1	1	1	2	1	2	0	1
Diploneis splendida Cleve	0	0	0	0	0	0	0	0	1	1	0	0
Ditylum brightwellii (West) Grunow	1	1	0	1	0	2	2	3	3	3	2	1
Entomoneis paludosa (W. Smith) Reimer = *Amphiprora paludosa* Smith	1	0		1		0	0	1	1	0	1	1
Eucampia cornuta (Cleve) Grunow	0	1		1		0	0	0	0	2	0	0
Eucampia zodiacus Ehrenberg	0	1		3			1		0	3	1	0
Fragilariopsis oceanica (Cleve) Hasle	0	1	0	1	0	0	0	0	0	2	0	0
Grammatophora marina (Lyngbye) Kützing	1	1	2	2	3	2	2	2	2	2	2	2
Guinardia delicatula (Cleve) Hasle = *Rhizosolenia delicatula* Cleve	0	2	0	0	0	0	0	0	2	2	0	1
Guinardia striata (Stolterfoth) Hasle = *Rhizosolenia stolterfothii* Peragallo	0	0	0	0	1	0	0	0	1	3	2	1
Gyrosigma fasciola Ehrenberg	0	1	0	0	1	0	0	0	0	2	0	0
Hemiaulus hauckii Grunow	1	1	0	1	0	0	0	1	3	3	0	1
Hemiaulus membranaceus Cleve	0	0	0	0	0	0	0	0		1		0
Hemiaulus sinensis Greville	1	1	0	0	0	0	0	0	1	2	0	0
Leptocylindrus danicus Cleve	0	2	0	2	1	2	0	4	1	4	2	0
Leptocylindrus mediterraneus (Peragallo) Hasle	0	0	0	0	0	0	0	3	0	3	0	0
Leptocylindrus minimus Gran	0	2	0	2	0	2	0	0	0	3	0	0
Licmophora abbreviata Agardh	2	2	3	3	2	3	1	2	2	2	2	2
Liriogramma sarcophagus (Wallich) Lan = *Asteromphalus sarcophagus* Wallich	0	0	0	0	0	0	0	0	0	2	0	0
Melosira moniliformis (Müller) Agardh	1	1	3	1	1	1	0	1	0	2	0	1
Navicula cancellata Donkin	0	0	0	1	0	0	0	0	0	0	0	0
Navicula directa (Smith) Ralfs in Pritchard	2	2	3	2	2	2	1	1	1	2	2	2
Navicula granii (Jørgensen) Gran	0	0	0	1	0	0	0	0	0	0	0	0
Navicula septentrionalis (Grunow) Gran	0	0	2	1	0	0	0	0	2	0	0	0
Navicula transitans var. *derasa* f. *delicatula* Heimdal	2	2	2	1	2	1	1	1	1	3	1	2
Navicula vanhoeffenii Gran	0	0	2	2	2	1	1	0	0	0	0	0
Nitzschia distans Gregory	0	0	1	0	1	0	0	0	0	0	0	0
Nitzschia fontifuga Cholnoky	0	0	0	0	0	1	0	0	0	0	0	0
Nitzschia frigida Grunow	0	0	2	0	0	4	0	0	0	2	0	0
Nitzschia hybrida Grunow in Cleve et Grunow	0	0	0	0	0	0	0	0	0	0	1	0
Nitzschia longissima (Brébisson) Ralfs	1		0	0	0	0	0	0		1		0
Nitzschia rectilonga Takano	1	1	2	1	0	2	0	0		1		0
Odontella aurita (Lyngbye) Agardh	1	2	4	2	1	2	1	1	1	2	1	1
Paralia sulcata (Ehrenberg) Cleve	0	0	0	0	1	0	0	0	0	0	0	0
Pleurosigma formosum Smith	1	2	2	1	2	2	1	2	3	3	1	2
Proboscia alata (Brightwell) Sundström	0	0	0	1	0	0	0	0	0	0	0	0
Pseudo-nitzschia americana (Hasle) Fryxell	0	2	0	2	1	0	0	0	0	0	0	0
*Pseudo-nitzschia calliantha** Lundholm, Hasle et Moestrup	0	1	0	0	2	0	0	0	0	4	2	0
*Pseudo-nitzschia fraudulenta** (Cleve) Hasle	0	1	0	1	0	0	0	0	0	0	0	0
*Pseudo-nitzschia multistriata** Takano	0	2	0	1	0	0	1	2	3	4	3	0
*Pseudo-nitzschia pungens** (Grunow ex Cleve) Hasle	0	2	1	1	1	1	0	3	2	4	3	2
*Pseudo-nitzschia pseudodelicatissima** Hasle	0	0		3			3			4		0
*Pseudo-nitzschia seriata** (Cleve) Peragallo	0	0	0	0	0	0	0	0	0	2	0	0
Pyxidicula nipponica (Gran et Yendo) Strelnikova et Nikolaev	1	1	1	0	0	0	0	0	0	0	0	0
Rhizosolenia hebetata f. hebetata Bailey	0	0	0	1	0	0	0	0	0	1	0	0
Rhizosolenia hebetata f. *semispina* (Hensen) Gran	0	0	0	0	0		1			1		0
Rhizosolenia pungens Cleve-Euler	0	1	0	0	0	0	0	0	1	3	0	1
Rhizosolenia setigera Brightwell	1	2	2	1	2	2	2	3	2	4	3	2
Skeletonema costatum (Greville) Cleve	0	0	0	0	0	3	0	0	0	0	0	0
Skeletonema dohrnii Sarno et Kooistra	0	0	0	0	0	1	2	3	5	0	0	0
Skeletonema grethae Zingone et Sarno	0	0	0	0	0	0	0	0	1	0	0	0
Skeletonema japonicum Zingone et Sarno	0	0	0	0	0	0	0	0	2	5	6	0
Skeletonema marinoi Sarno et Zingone	0	0	0	0	0	0	0	0	2	0	0	0
Skeletonema spp.	2	2	2	1	2	0	6	4	0	6	6	3
Stephanopyxis turris (Greville) Ralfs	0	0	0	0	0	0	1	0	0	0	0	0
Synedra sp.	0	0	1	0	0	0	0	0	0	0	0	0
Tabularia fasciculata (Agardh) Williams et Round	0	1	0	1	0	1	0	0	0	0	0	0
Thalassionema frauenfeldii (Grunow) Hallegraeff	2	2	3	2	2	3	3	3	3	4	3	2
Thalassionema nitzschioides (Grunow) Mereschkowsky	2	2	3	1	1	2	1	3	4	5	4	2
Thalassiosira gravida Cleve	0	1	0	0	1	0	0	0	0	0	0	0
Thalassiosira leptopus (Grunow ex Van Heurck) Hasle et Fryxell = *Coscinodiscus lineatus* Ehrenberg	0	0	0	0	0	0	0	0	1	0	0	0
Thalassiosira mala Takano	0	0	0	0	0	0	1	1	0	0	0	0

Table 2. Continued.

Species	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
Thalassiosira nordenskioeldii Cleve	3	5	4	2	2	0	0	0	0	0	0	4
Thalassiosira punctigera (Castracane) Hasle	0	1	0	0	0	0	0	0	0	3	0	0
Thalassiosira rotula Meunier	0	2	0	0	0		1			1		0
Thalassiothrix longissima Cleve et Grunow	0	1	0	0	0	0	0	0	0	0	0	0
CRYPTOPHYCEAE												
Plagioselmis prolonga Butcher ex Novarino, Lucas et Morrall = *Plagioselmis punctata* Butcher	0	2	2	4	4	0	3	1	2	1	0	2
Teleaulax acuta (Butcher) Hill = *Cryptomonas acuta* Butcher	0	0	0	1	2	0	0	0	0	0	0	0
DINOPHYCEAE												
Akashiwo sanguinea = *Gymnodinium sanguineum* Hirasaka	0	0	0	0	0	0	1	0	0	1	0	0
*Alexandrium insuetum** Balech	0	0	0	0	0	0	0	2	1	0	0	0
*Alexandrium ostenfeldii** (Paulsen) Balech et Tangen	0	0	0	0	1	0	0	0	0	0	0	0
*Alexandrium tamarense** (Lebour) Balech	0	1	1	0	0	1	0	1	1	0	0	0
Amphidinium crassum Lohmann	0	0	0	0	1	0	0	0	0	1	0	0
Amphidinium fusiforme Martin	0	0	0	1	1	0	0	0	0	0	0	0
Amphidinium longum Lohmann	0	0	0	0	0	0	1	0	0	0	0	0
*Amphidinium operculatum** Claparède et Lachmann	0	0	0	0	0	0	0	0	0	1	0	0
Amphidinium sphaenoides Wulff	0	1	0	0	1	0	1	0	0	2	0	1
Amylax triacantha (Jörgenson) Sournia	0	0	1	0	2	1	0	2	0	0	0	0
Cochlodinium sp.	0	0	0	0	1	0	0	0	0	0	0	0
*Dinophysis acuminata** Claparède et Lachmann	1	1	0	1	2	2	3	2	1	2	1	1
*Dinophysis acuta** Ehrenberg	1		0	0	1	1	1	1	1	0	1	0
Dinophysis arctica Mereschkowsky	0	0	0	1	0	0	0	0	0	0	0	0
*Dinophysis fortii** Pavillard	0	0	0	0	1	1	2	1	1	0	1	0
*Dinophysis infundibulum** Schiller	0	0	0	0	0	0	1	1	1	1	1	0
Dinophysis ovum Schütt	0	0	0	0	1	0	0	0	0	0	0	0
*Dinophysis rotundata** Claparède et Lachmann	0	1	1	1	0	1	1	1	2	1	1	0
Diplopelta asymmetrica (Mangin) Lebour	0	0	0	0	0	0	0	0	0	1	0	0
Diplopsalis lenticula Bergh	0	0	0	0	1	1	0	1	1	1	0	0
Diplopsalopsis orbicularis (Paulsen) Meunier	0	0	0	0	0	0	0	0	0	1	0	0
Dissodinium pseudolunula Swift, Elbrächter et Drebes	0	0	0	0	0	0	0	0	0	2	0	0
Glenodinium pilula (Ostenfeld) Schiller	0	0	0	1	0	0	0	0	0	0	0	0
Gonyaulax apiculata (Penard) Entz	0	0	0	0	1	0	0	0	0	0	0	0
Gonyaulax digitalis (Pouchet) Kofoid	0	0	0	0	1	1	1	1	1	1	1	0
*Gonyaulax spinifera** (Claparède et Lachmann) Diesing	0	0	0	1	1	2	1	1	0	1	0	0
Gonyaulax verior Sourina	0	0	0	1	1	0	1	2	0	0	0	0
Gymnodinium agiliforme Schiller	0	0	0	0	0	0	0	0	0	1	0	0
Gymnodinium blax Harris	1	1	1	2	2	1	2	2	2	2	3	1
Gymnodinium elongatum Hope	0	0	0	0	0	0	0	0	0	2	0	0
Gymnodinium galeatum Larsen	0	1	0	2	2	0	0	0	0	2	0	0
Gymnodinium simplex (Lohmann) Kofoid et Swezy	2	1	1	1	2	2	1	1	1	2	2	2
Gyrodinium falcatum Kofoid et Swezy	0	0	0	0	0	0	0	0	2	3	1	0
Gyrodinium fusiforme Kofoid et Swezy	2	2	1	1	2	1	2	2	2	2	2	2
Gyrodinium lachrymal (Meunier) Kofoid et Swezy	0	1	1	2	1	0	0	0	1	1	0	0
Gyrodinium pepo (Schütt) Kofoid et Swezy	0	0	0	0	1	0	0	0	0	0	0	0
Gyrodinium pingue (Schütt) Kofoid et Swezy	0	0	0	0	1	0	0	0	0	0	0	0
Gyrodinium spirale (Bergh) Kofoid et Swezy	2	2	2	2	2	1	1	2	3	2	2	2
Gyrodinium wulffii Schiller	0	0	0	0	1	0	0	0	0	0	0	0
Heterocapsa rotundata (Lohmann) Hansen	0	0	0	1	2	0	0	0	0	0	0	0
Heterocapsa triquetra (Ehrenbergh) Stein	1	1	1	1	2	2	2	2	2	2	0	1
Karenia mikimotoi (Miyake et Kominami ex Oda) Hansen et Moestrup	0	0	0	0	0	1	1	2	1	1	0	0
Katodinium glaucum (Lebour) Loeblich	0	0	0	1	2	1	0	2	1	1	0	1
Levanderina fissa (Levander) Moestrup, Hakanen, Hansen, Daugbjerg et Ellegaard = *Gyrodinium fissum* (Levander) Kofoid et Swezy	0	0	0	0	0	0	0	0	0	2	0	0
*Lingulodinium polyedra** (Stein) Dodge	0	0	0	0	1	1	1	0	0	0	0	0
Noctiluca scintillans (Macartney) Kofoid et Swezy	0	0	0	0	1	1	2	1	1	0	1	0
Oblea rotunda Balech et Sournia	1	1	1	1	2	2	2	2	1	3	1	2
Oxyrrhis marina Dujardin	0	0	0	0	0		1			1		0
Oxytoxum caudatum Schiller	0	0	0	1	1	0	0	0	0	0	0	0
Oxytoxum gladiolus Stein	0	0	0	1	0	0	0	0	0	1	0	0
Oxytoxum sceptrum Stein (Schröder)	2	2	2	2	1	1	1	1	1	1	1	2
Oxytoxum sphaeroideum Stein	0	0	0	0	0		1		0	0	0	0
Podolampas sp.	0	0	0	0	0	0	0	0	0	1	0	0
Pronoctiluca pelagica Fabre-Domer	0	0	0	0	0	0	0	0	0	2	0	0
Prorocentrum emarginatum Fukuyo	0	0	0	2	0	0	0	0	0	0	0	0
*Prorocentrum foraminosum** Faust	0	0	0	0	0	1	0	0	0	0	0	0
Prorocentrum micans Ehrenberg	0	0	0	0	0	1	3	3	2	2	2	1
*Prorocentrum minimum** (Pavillard) Schiller	0	1	1	1	1	2	3	4	3	2	1	1
Prorocentrum triestinum Shiller	0	1	0	0	1	0	3	4	3	2	1	0
*Protoceratium reticulatum** (Claparède et Lachmann) Butschli	0	0	1	0	1	1	1	2	2	1	0	0
Protoperidinium abei (Paulsen) Balech	0	0	0	1	0	0	0	0	0	0	0	0
Protoperidinium bipes (Paulsen) Balech	1	1	1	1	1	0	3	2	2	2	2	2
Protoperidinium brevipes (Paulsen) Balech	0	1	0	1	1	2	0	0	0	1	0	1
Protoperidinium claudicans (Paulsen) Balech	0	0	0	1	0	0	1	0	0	1	0	0
Protoperidinium conicoides (Paulsen) Balech	0	1	0	0	0	1	0	0	0	1	0	1
Protoperidinium conicum (Gran) Balech	1	0	0	1	1	1	2	2	1	2	2	1
Protoperidinium crassipes Kofoid	0	0	0	0	1	1	0	0	0	1	0	0
Protoperidinium curtipes (Jörgensen) Balech	0	0	0	0	1	0	1	0	0	1	0	0
Protoperidinium curvipes (Ostenfeld) Balech	0	0	0	1	0	1	1	0	0	1	0	1
Protoperidinium depressum (Bailey) Balech	0	1	1	0	1	0	0	0	0	0	0	1
Protoperidinium divaricatum (Meunier) Parke et Dodge	0	0	0	0	0	1	0	1	1	0	0	1
Protoperidinium divergens (Ehrenberg) Balech	0	0	0	0	1	1	1	1	1	1	1	0
Protoperidinium granii (Ostenfeld) Balech	0	0	0	1	1	0	0	0	1	0	0	0
Protoperidinium latidorsale (Dangeard) Balech	0	0	0	0	0	0	0	1	1	0	0	0
Protoperidinium leonis (Pavillard) Balech	0	0	1	1	1		1		1	1	0	0
Protoperidinium marukawai (Abé) Balech	0	0	0	0	1	0	0	0	0	0	0	0
Protoperidinium minutum (Kofoid) Loeblich	0	0	0	0	1	0	2	1	1	2	1	0
Protoperidinium mite (Pavillard) Balech	0	0	0	0	1	1	0	0	0	0	0	0
Protoperidinium monovelum (Abé) Balech	1	1	1	0	1	0	1	1	0	1	0	0
Protoperidinium oblongum (Aurivillius) Parke et Dodge	0	0	0	0	0	0	0	0	0	1	0	0
Protoperidinium obtusum (Karsten) Parke et Dodge	0	0	0	0	0	0	0	0	1	1	1	0
Protoperidinium oceanicum (Vanhöffen) Balech	0	0	0	0	0	0	0	0	1	1	0	0
Protoperidinium ovum (Schiller) Balech	0	0	0	0	0	0	0	0	0	2	0	0
Protoperidinium pallidum (Ostenfeld) Balech	0	1	0	1	1	0	1	0	0	0	0	0
Protoperidinium pellucidum Bergh	1	1	2	2	2	2	2	2	2	2	2	2
Protoperidinium pentagonum (Gran) Balech	0	0	0	0	1	1	1	1	1	1	0	0
Protoperidinium punctulatum (Paulsen) Balech	0	0	0	0	1	0	0	0	0	0	0	0
Protoperidinium pyriforme (Paulsen) Balech	1	1	1	1	2	1	2	2	1	2	1	1
Protoperidinium quarnerense (Schröder) Balech	0	0	0	0	0	0	0	0	1	0	0	0
Protoperidinium steinii (Jörgensen) Balech	0	0	0	0	1	1	0	1	1	2	1	0
Protoperidinium subinerme (Paulsen) Loeblich	0	0	0	0	1	0	0	0	1	1	0	1
Protoperidinium thorianum (Paulsen) Balech	0	1	1	1	1	1	1	1	1	1	0	0
Pyrocystis lunula (Schütt) Schütt	0	0	0	0	0	0	0	0	1	1	0	0
Pyrophacus horologium Stein	0	0	1	1	1	1	2	2	2	1	0	1
Pyrophacus steinii (Shiller) Wall et Dale	0	0	0	0	0	0	0	0		1		0
Scrippsiella trochoidea (Stein) Loeblich	0	1	0	1	2	2	3	3	2	2	1	1
Spatulodinium pseudonoctiluca (Pouchet) J. Cachon et M. Cachon	0	0	0	0	0	0	0	0	0	1	0	0
Torodinium robustum Kofoid et Swezy	0	0	0	0	1	0	0	0	0	1	0	0
Tripos eugrammus (Ehrenberg) Gȯmez = *Ceratium furca* var. *eugrammum* (Ehrenberg) Schiller	0	0	0	0	0	0	0	0	0	2	0	0
Tripos furca (Ehrenberg) Gȯmez = *Ceratium furca* (Ehrenberg) Claparède et Lachmann	0	0	0	0	0	0	0	0	0	2	0	0
Tripos fusus (Ehrenberg) Gȯmez = *Ceratium fusus* (Ehrenberg) Dujardin	0	0	0	0	1	0	2	2	2	3	1	0
Tripos kofoidii (Jörgensen) Gȯmez = *Ceratium kofoidii* Jörgensen	0	0	0	0	0	0	0	0	0	2	0	0
Tripos muelleri Bory = *Ceratium tripos* (Müller) Nitzsch	0	0	0	0	1	0	0	0	0	0	0	0
Tripos seta (Ehrenberg) Gȯmez = *Ceratium fusus* var. *seta* (Ehrenberg) Jörgensen	1			1		0	0	0		1		0

Table 2. Continued.

Species	1	2	3	4	5	6	7	8	9	10	11	12
CHLOROPHYCEAE												
Monoraphidium arcuatum (Korshikov) Hindák = *Ankistrodesmus arcuatus* Korschikov	0	0	0	0	0	0	0	0	0	1	0	0
Pyramimonas sp.	1		0	2	2	0	0	0	0	0	0	0
Scenedesmus quadricauda (Turpin) Brébisson	0	0	0	1	0		3		0	0	0	0
EUGLENOIDEA												
Eutreptia lanowii Steuer	2	2	2	2	3	1	1	2	5	1	1	1
Eutreptiella braarudii Throndsen	0	1	0	3	1	0	0	0	0	0	0	0
Eutreptiella eupharyngea Moestrup et Norris	0	1	0	0	2	0	0	0	0	0	0	0
Eutreptiella pascheri (Schiller) Pascher	0	1	0	1	0	1	0	0	0	0	0	0
CYANOPHYCEAE												
Microcystis sp.	0	0	0	0	0		1			1		0
PRYMNESIOPHYCEAE												
Pseudohaptolina sorokinii Stonik, Efimova et Orlova	0	3	6	0	0	0	0	0	0	0	0	0

Note: * – potentially toxic. "0" – absence of species in the sample, "1–6" – abundance of species (in combined cells with side borders – abundance of species in whole season) cells/L: "1" – less than 10^3, "2" – 10^3–10^4, "3" – 10^4–10^5, "4" – 10^5–$5x10^5$, "5" – $5x10^5$–10^6, "6" – greater than 10^6.

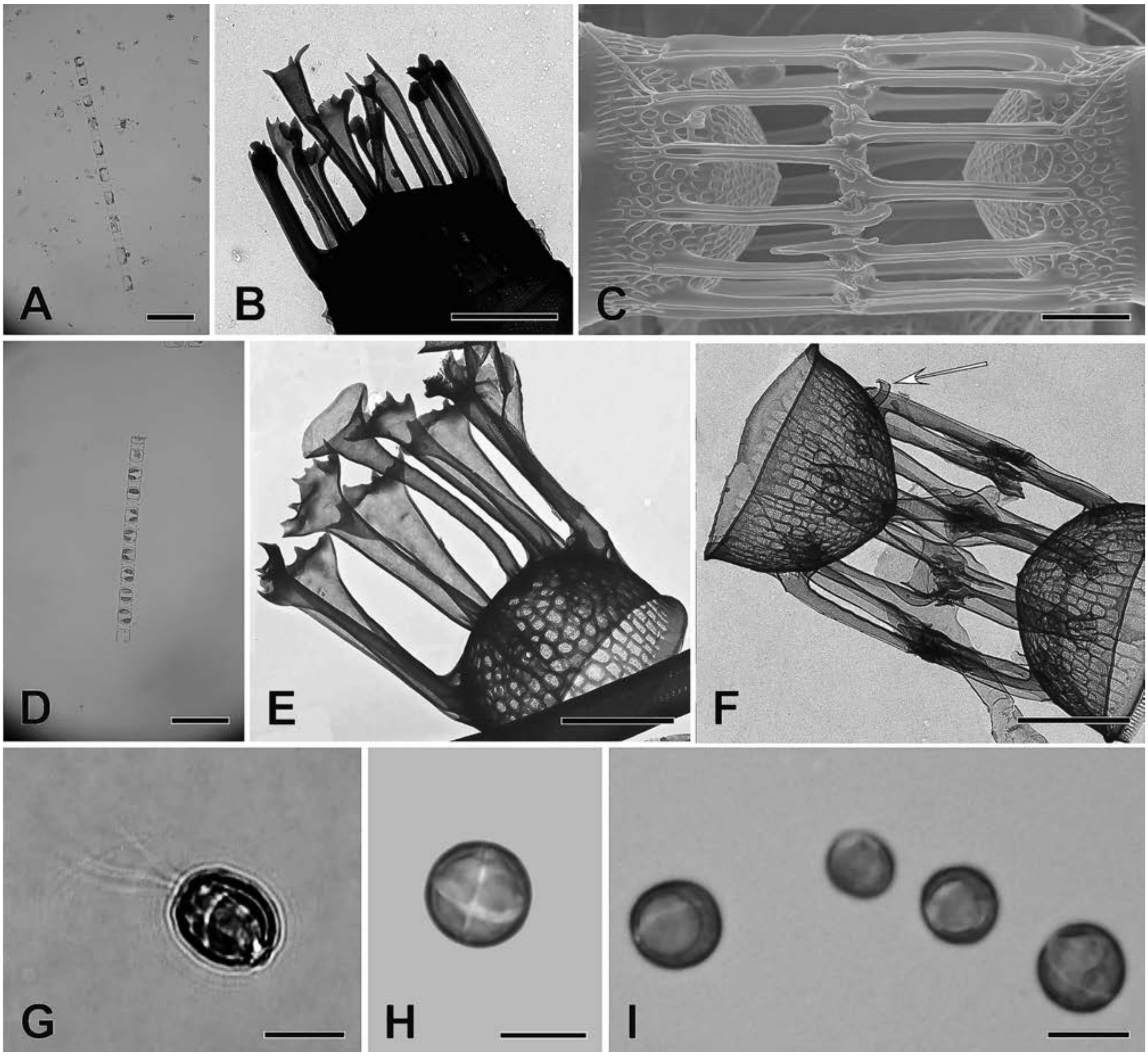

Figure 3 *Skeletonema japonicum* Zingone et Sarno 2005: A – general appearance of colony, B – terminal valve, long rimoportula process with denticles at edge, C – intercalary valves, linkage of fultoportula processes; *Skeletonema marinoi* Sarno et Zingone 2005: D – colony of cells, E – terminal valve, rimoportula process flared distally, F – intercalary valves, rimoportula process (arrowhead); *Pseudohaptolina sorokinii* Stonik, Efimova et Orlova 2016: G – cell with two flagella and one haptonema, H – cell with four chloroplasts, I – cells in plankton. A, D, G–I – LM, B, E, F – TEM, C – SEM. Scale: B, C, E, F = 2 μm, A, C, G–I = 10 μm, D = 20 μm

2007, Kooistra et al. 2008). In the Sea of Japan the species is known from off Kyushu Island (Yamada et al. 2010).

Skeletonema dohrnii Sarno et Kooistra 2005 (Fig. 2: C–E)

Description. Cells cylindrical, 2.7–10.8 µm in diameter, forming slightly curved colonies of 2–104 cells; with 1–2 chloroplasts per cell. Valves circular, slightly convex. Fultoportula processes straight, 6 to 29 on each valve. Terminal fultoportula processes widened, with denticles along the margin. The intercalary rimoportula process in the shape of a narrow low tube; situated near the valve margin. The terminal rimoportula process located close to the valve center.

Distribution. Widely distributed in the World Ocean, mainly in the temperate zone of the Pacific Ocean (from 52°N to 39°S); absent in tropical waters (Zingone et al. 2005, Kooistra et al. 2008). In the Sea of Japan first recorded from off the coast of Japan in Dokai Bay (Yamada et al. 2010).

Skeletonema grethae Zingone et Sarno 2005 (Fig. 2: F–H)

Description. Cells cylindrical, 5.5–10.3 µm in diameter, with 1–2 chloroplasts per cell. Colonies straight or slightly curved, consisting of 20–60 cells. Valves circular, convex. Fultoportula processes straight, long, 14 to 18 on each valve. Terminal fultoportula processes have a claw-like projection located distally. The intercalary rimoportula process in the shape of a short narrow tube; located close to the valve margin. The terminal valve bears an eccentrically situated rimoportula in the form of a long tube flared distally.

Distribution. Off the coast of Brazil and in Narragansett Bay (the Atlantic Ocean) (Sarno et al. 2005, Bergesch et al. 2009).

Skeletonema japonicum Zingone et Sarno 2005 (Fig. 3: A–C)

Description. Cells cylindrical, 3.0–7.6 µm in diameter, with 2–4 chloroplasts per cell, joined into straight colonies of 3 to 23 cells. Valves circular, slightly convex. Intercalary rimoportula process in the form of a narrow short tube; situated near the valve margin. Terminal rimoportula process is a long, distally widened tube located close to the center. Fultoportula processes straight, long, 6 to 37 on each valve. Terminal fultoportula processes slightly widened distally, with dentate margins.

Distribution. Mainly in the temperate zone of the Pacific Ocean and in the tropical upwelling zones (Kooistra et al. 2008). In the Sea of Japan it is found along the Korean Peninsula (Kooistra et al. 2008) and Kyushu Island (Yamada et al. 2010).

Skeletonema marinoi Sarno et Zingone 2005 (Fig. 3: D–F)

Description. Cells cylindrical, 2.0–7.0 µm in diameter, with 1–2 chloroplasts per cell, united into straight or slightly curved colonies of 15 to 30 cells. Valves rounded, slightly convex. The intercalary rimoportula process is a short narrow tube located close to the center of the valve. The terminal rimoportula process in the shape of a long tube flared distally; located close to the center of the valve. Fultoportula processes straight, long, 7 to 11 on each valve. Terminal fultoportula processes strongly widened distally.

Distribution. This cosmopolitan species, absent in the Antarctic waters, is reported from latitudes between 08ºS and 58ºN (Koostra et al. 2008). In the Sea of Japan it occurs off the coast of Japan in Dokai Bay (Yamada et al. 2010).

Pseudohaptolina sorokinii Stonik, Efimova et Orlova 2016 (Fig. 3: G–I)

Description. Cells rounded, 13–20 µm in diameter. Two flagella and one haptonema are of approximately equal length. Each cell contains four large chloroplasts, which can be well seen particularly at the moment when the cell dies.

Distribution. Amur Bay (the northwestern Sea of Japan) (Orlova et al. 2016).

Algal bloom of *Pseudohaptolina. sorokinii* and *Skeletonema japonicum* was documented in the coastal waters of Russky Island for the first time. Diatoms *Asteromphalus flabellatus*, *Liriogrammas arcophagus* and dinoflagellates *Dinophysis arctica*, *Gymnodinium elongatum*, *Protoperidinium divaricatum* were first reported from the northwestern Sea of Japan; their abundance did not exceed $1×10^3$ cells/L.

A total of 20 species of potentially toxic microalgae were identified from the study area (Table 2). Diatoms of the genus *Pseudo-nitzschia*, as well as dinoflagellates of the genera *Alexandrium*, *Dinophysis* and *Prorocentrum* were present in the phytoplankton all year round. Dinoflagellates *Amphidinium operculatum*, *Alexandrium ostenfeldii* and *Prorocentrum foraminosum*, in low concentrations, were observed in different seasons of the year; each of the species was reported once. The other species of potentially toxic microalgae were recorded mainly in summer.

DISCUSSION

The phytoplankton of the Ussuri Bay, before this study, was known only from Selina (1988), who carried out research from April to September of 1983 and provided the list of 80 microalgal species, and Begun (2004), who studied species composition and abundance of phytoplankton in 2001–2002 and recorded 119 taxa. In Amur Bay, 357 species from 8 orders were recorded in the course of a long-term research by Orlova et al. (2009).

During the study period, two species causing water bloom in the coastal waters of Russky Island (*Skeletonema japonicum* and *Pseudohaptolina sorokinii*) were identified. Massive growth of *Skeletonema japonicum* was recorded in November (t_{water} = 9°C, S = 33.5‰). According to the literature, at temperate latitudes species of the genus *Skeletonema* dominate in the plankton community mainly in winter, spring and summer (Borkman & Smayda 2009, Degerlund & Eilertsen 2010). Due to the difficulty in identification of *Skeletonema* cells at the species level with light microscopy, the quantitative data in Table 2 are given for a complex of species. In the coastal waters off Russky Island *Skeletonema* spp. occurred in the plankton throughout the year. The electron microscopic investigation of *Skeletonema costatum*, *S. dohrnii*, *S. grethae*, *S. japonicum* and *S. marinoi* indicated that morphology of the species from the study area, in general, corresponds with original descriptions (Sarno et al. 2005, Zingone et al. 2005).

A bloom of *Pseudohaptolina sorokinii* occured once, in March of 2013; its massive proliferation was observed when the sea ice of the study area started melting (t_{water} = -1.2 – -0.3°C, S = 13.8–32.5‰). *Pseudohaptolina sorokinii*, rather recently described from Amur Bay (Orlova et al. 2016), was recorded in the World Ocean for the second time. The mechanisms causing blooms of microalgae species, which are rare in any water area, are still understudied. Reliable records of cryptic phytoplankton taxa add to our knowledge of their distribution in the World Ocean.

At the same time, it should be noted that the abundance of the species occasionally blooming in adjacent Amur Bay, such as *Chaetoceros contortus*, *C. socislis*, *C. pseudocrinitus*, *Dactyliosolen fragilissimus*, *Nitzschia frigida*, *Pseudo-nitzschia calliantha*, *P. multistriata*, *P. pungens*, *P. pseudodelicatissima*, *Thalassionema nitzschioides*, *Thalassiosira nordenskioeldii*, dinoflagellates *Prorocentrum minimum*, *P. triestinum*, euglena *Eutreptia lanowii*, did not exceed 5×10^5 cells/L in the study area.

Data on species composition and quantitative characteristics of potentially toxic phytoplankton in the coastal waters of Russky Island are among the most important results of the study. Marine biotoxins from microalgae can accumulate in the tissues of filter-feeding shellfish and do no harm to them. But consumption of shellfish that are contaminated with toxins causes poisoning in endotherm animals, birds and humans (Hallegraeff et al. 2003). A total of 33 species of potentially toxic microalgae are known from the northwestern Sea of Japan (Orlova 2013), 28 species are recorded in Amur Bay, and our study provides information on 20 species: *Alexandrium insuetum*, *A. ostenfeldii*, *A. tamarense*, *Amphidinium operculatum*, *Dinophysis acuminata*, *D. acuta*, *D. fortii*, *D. infundibulum*, *D. rotundata*, *Gonyaulax spinifera*, *Lingulodinium polyedra*, *Prorocentrum foraminosum*, *P. minimum*, *Protoceratium reticulatum*, *Pseudo-nitzschia calliantha*, *P. fraudulenta*, *P. multistriata*, *P. pungens*, *P. pseudodelicatissima* and *P. seriata*. Though the list contains an impressive number of potentially toxic microalgal species reported in the study area, their abundance did not exceed the level safe for humans and marine organisms (Andersen 1996).

The present list should be regarded as a preliminary one. At the same time it can serve as a starting point for further monitoring of phytoplankton in the study water area.

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