LIFE-SUPPORTING ASIA-PACIFIC MARINE ECOSYSTEMS, BIODIVERSITY AND THEIR FUNCTIONING

Edited by
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Song Sun, Andrey V. Adrianov

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Phytoplankton of the coastal zone of Aniva Bay: seasonal change of the dominants and quantitative characteristics (Sakhalin Island, Russia)

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Sakhalin Island, the largest island in Russia, is located at the eastern Asia. In the north and east the island is washed by waters of the Okhotsk Sea, and in the west it is separated from the continent by the Tatar and Nevelskoy Straits, Amur Liman and Sakhalin Bay. In the south the La Perouse Strait separates Sakhalin Island from Hokkaido (Japan). Sakhalin Island has a meridian-stretched shape; it is 948 km long from Cape Krilion (south) to Cape Elizabeth (north). Its maximal width is 160 km, minimal 26 km within the Poyasok Isthmus, and square about 78,000 km^2. Sakhalin Island is characterized by a very diverse relief: middle-high mountains (500–800 m), low mountains, and lowlands. The West Sakhalin Ridge is the main watershed of Sakhalin which divides the river drainage into two groups. One group belongs to the basin of the Okhotsk Sea, another one to the basin of the Japan Sea. Sakhalin shores are weakly cut; large bays occur only in the southern and middle parts of the island (Resources of surface waters of the USSR, 1973).

Sakhalin climate is severe. Its winter is long (5–7 months), snowy and cold (up to −48°C), and its summer is short (2–3 months) and rainy. The average air temperature of the coldest month (January) in the north is −23°C, and in the south −8°C. The average air temperature of the warmest month (July) does not exceed 15–18°C (Resources..., 1973).

Sakhalin shelf is recognized as a rather rich territory on oil and gas deposits; the large projects on their production are realized there. Oil production on Sakhalin has been conducted since the beginning of the 20th century, but the most active developing of Sakhalin shelf began at the end of the 20th century that was related with the discovery of new oil and gas fields: Odoptu, Chayvo, Lunskoye, Piltun-Astokhskoye, and Arkutun-Dagi. Currently, two independent consortiums “Sakhalin-1” and “Sakhalin-2” have been concurrently working on the island, and oil products are transported via the two pipe lines.

The international consortium “Sakhalin-1” (Rosneft, ExxonMobil, SODECO, ONGC Videsh Ltd) is a grand branch-wise world project. Since 2006, “Sakhalin-1” has conducted the works on oil and oil products producing on the eastern shelf of Sakhalin Island and exported them via the 226 km pipe line across Sakhalin and Tatar Strait to the sea terminal in De-Kastri settlement located in the Khabarovsk territory.

“Sakhalin-2” (Gazprom, Shell Sakhalin Holdings, Mitsui Sakhalin Holdings, Diamond Gas Sakhalin), the most complicated engineering megaproject for complex development of the oil and gas fields, includes both technological assets for extracting and exporting crude oil and natural gas and a plant for liquefied natural gas (LNG) production. Sakhalin Energy Investment Company Ltd. is an operator of this project. In the course of the project realization, three sea platforms were settled along the eastern Sakhalin coast; a plant for liquefied natural gas (LNG) production was built in the south of the island (Aniva Bay coast). The length of the sub-sea pipe lines linking platforms with the shore is 300 km, and a total length of the onshore oil and gas pipe lines is 1600 km. Aggregated extractable reserves of “Sakhalin-2” stand at around 150 million tons of oil and 500 billion m³ of gas (Official site of “Sakhalin Energy”, 2016).

Because of the active development of oil and gas fields on Sakhalin shelf and increase in oil production and particularities of its transportation, a problem of the rising oil pollution for coastal waters of the northwestern, northeastern and southern parts of Sakhalin Island is intensified in the recent two decades. In such a situation, hydrobiological researches in the coastal waters with different levels of oil hydrocarbon pollution of the southern Sakhalin area are required to obtain comparative information within the monitoring of water biological resources and their habitat.

The aim of this study is to reveal hydrochemical peculiarities, species composition and quantitative characteristics of phytoplankton of the Aniva Bay coastal waters (southern Sakhalin) in the spring-summer-autumn period of 2015.

Materials and Methods

Hydrochemical and algological researches have been carried out on four testing areas of the southern Sakhalin Island: Taranai, Prigorodnoye, Arakul, and Busse (Aniva Bay) (Fig. 29.1). Water for chemical analysis and ground and phytoplankton have been sampled since February through October 2015 (Busse testing area – since June through October 2015) in the surface horizon at the coastal stations —1 m away from the shore, at a depth of 0.5 m.

Temperature, salinity and pH were measured on all of the testing areas when sampling algological and hydrochemical materials. The chemical analysis included definition of some parameters (dissolved oxygen, biological oxygen demand (BOD_5),

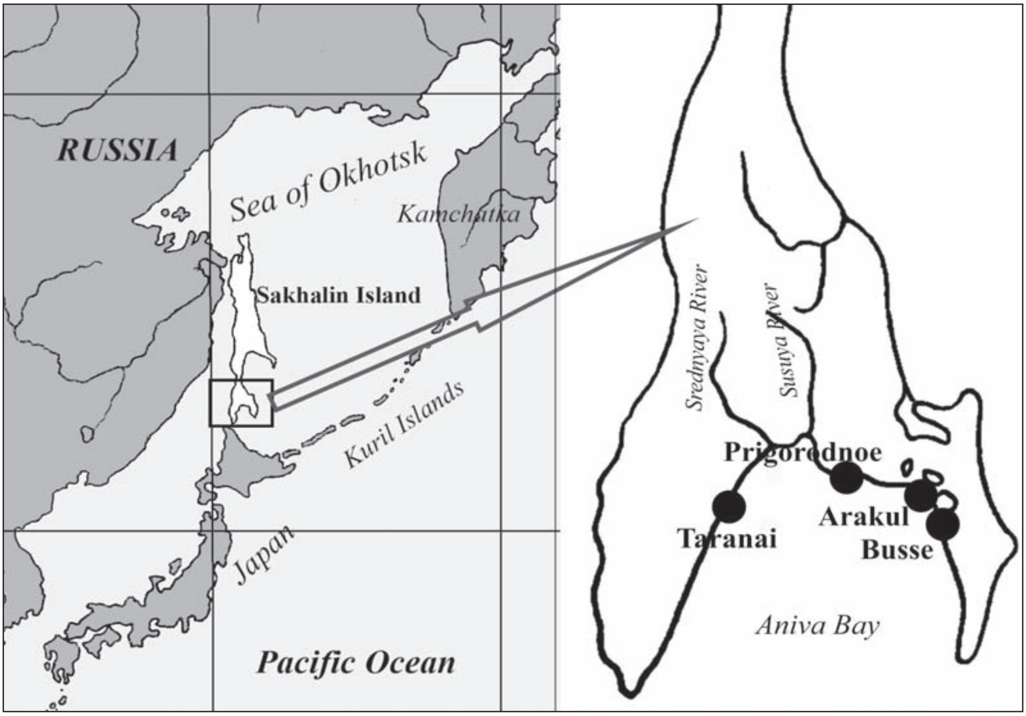


Fig. 29.1 Map of the sampling station.

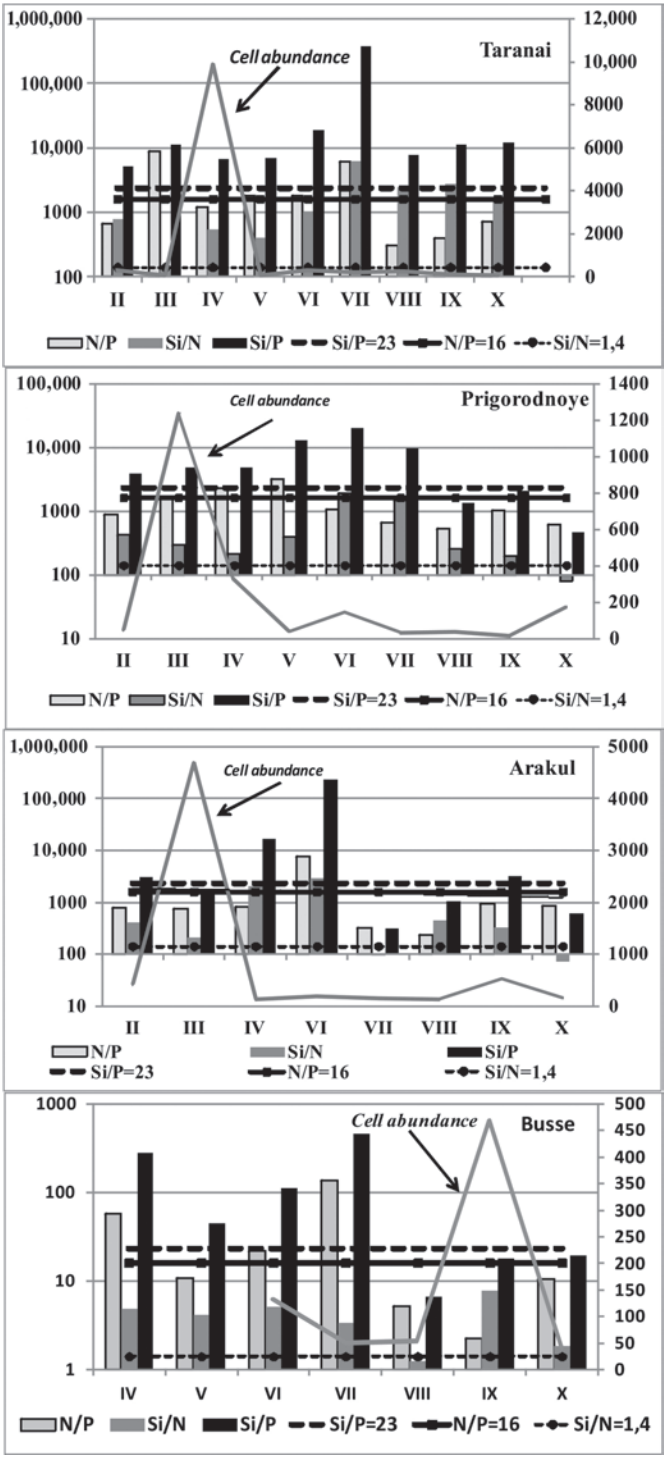
biogenic elements, suspended matters (SM), iron, petroleum products (PP)) and was done according to the standard certified methods (Manual on harmful marine microalgae, 1995; and others).

Phytoplankton was sampled, fixed, concentrated and treated using the commonly accepted methods (Vasser et al., 1989; and others). A taxonomic list of algae was prepared according to the modern classification (Guiry, Guiry, 2017). The taxa making 20% and more of the total phytoplankton number were referred to a dominant rank in the plankton communities and those making 5% and more to a subdominant rank.

Results and Discussion

Hydrochemistry

The results of hydrochemical studies on the three testing areas of southern Sakhalin in the summer-autumn period of 2015 appeared to be as follows. The maximal warming of water was recorded on the Taranai area in August and on Prigorodnoye and Arakul areas in July. The maximal values for salinity were observed in October at all of the surveyed coastal sites. The greatest freshening of waters was observed in September (15‰) and April (17.7‰) at the testing area Taranai. The maximum hydrogen index (pH) was recorded



on the testing areas Arakul and Prigorodnoye in August (8.15–8.54), on Taranai area in October (8.75). The minimum was recorded on Taranai area in June (7.22).

The high estimates of dissolved oxygen were revealed on the three testing areas of southern coast in June–September. They ranged between 11.83 mg/dm^3 (Arakul) and 17.76 mg/dm^3 (Taranai). The minimal estimates were observed on Arakul and Taranai areas in September and Prigorodnoye in August and October. The high values of the lightly oxidized organic matters in the coastal waters of Aniva Bay were recorded in the summer months: BOD_5 varied within <0.5–1.7 mg/dm^3 (Taranai), <0.5–2.18 mg/dm^3 (Arakul), <0.5–3.76 mg/dm^3 (Prigorodnoye), and 0.80–2.28 mg/dm^3 (Busse). In June,

Fig. 29.2 The dynamics of the phytoplankton cells abundant (N×10^3 cell/L) and the ratio of the content of biogenic elements in the coastal zone of the Aniva Bay (February–November 2015). Note. The ordinate axis (left) is the logarithm of the ratio of the values of biogenic elements, the ordinate axis (right) is the total phytoplankton abundance (10^3 cell/L). Optimum ratios Si/P=23, N/P=16, Si/N=1.4 are given according to the stoichiometric expression (Redfield, 1963).

BOD_5 exceeded a standard (3 mg/dm^3) as many as 1.3 times on Prigorodnoye area.

During the study period the maximal concentrations of suspended matters were observed on the Arakul, Busse and Prigorodnoye areas in October (45.2 mg/dm^3, 41.4 mg/dm^3, and 60.6 mg/dm^3, respectively), on Taranai area (32.6 mg/dm^3) in August. At the sampling sites of Prigorodnoye and Taranai areas the total iron concentrations varied from 0.062 to 0.165 mg/dm^3 in September–October, and in the area of Arakul River the total iron concentrations declined to <0.020–0.039 mg/dm^3. The excess of tentative allowable concentration (TAC) for total iron (1.1–3.3 times) was observed in several samples from the mouth of the Taranai River.

When analyzing phytoplankton provision with biogenic elements in the coastal zone of Aniva Bay, both their spatial heterogeneity and nitrogen and silicon shortage were observed in individual seasons. Nitrogen shortage was observed during the whole study period, except for July. Silicon shortage was recorded in the late summer and autumn at all coastal sites, except for the mouth of the large Taranai River (Fig. 29.2).

In Aniva Bay, no TAC excesses for PP and phenols were recorded. PP contents in the sea water samples were not high as well: on the Prigorodnoye testing area – from the detection limit <0.005 mg/dm^3 to 0.019 mg/dm^3. There were single cases when contents of petroleum products (PP) exceeded TAC. Phenol contents in sea water were lower than the detection limit (<0.0005 mg/dm^3) almost in all samples. There were not observed high phenol concentrations in bottom sediments.

Phytoplankton

A species composition of the coastal flora of Sakhalin Island since February through October 2015 was represented by 321 species, varieties and forms from eight divisions: Cyanobacteria (1), Bacillariophyta (256), Chlorophyta (8), Euglenophyta (2), Cryptophyta (8), Dinophyta (42), Haptophyta (1), and Ochrophyta (3).

Diatom (Bacillariophyta) and dinoflagellate (Dinophyta) algae appeared to be the most diverse by their species composition. In the systematic structure of algoflora the following families had the largest number of species, varieties and forms: Bacillariaceae – 40, Naviculaceae – 29, Fragilariaceae – 24, Chaetocerotaceae – 17, Thalassiosiraceae – 14 (diatoms), Protoperidiniaceae and Gymnodiniaceae – 12 each (dinoflagellates); and genera *Navicula* and *Nitzschia* – 23 each, *Chaetoceros* – 15, *Amphora* – 10 species and varieties.

A total of 38 species, varieties and forms were recorded as prevailed by abundance in phytoplankton communities; of them, only 7 algae appeared to be numerical dominants and subdominants, the rest algae were subdominants.

Taranai

In the spring season, the mass development of diatom algae composing more than 90% of the total number of flora in this area was observed within the mouth of Taranai River in the ice-free waters. In April, the water "bloom" was caused by development of some species: *Navicula directa* W. Smith, *Nitzschia* sp., *Odontellla aurita* (Lyngbye) Agardh, *Attea* sp., *Chaetoceros* spp. In the summer season (June–August), *Chaetoceros radicans* Schütt and *Skeletonema costatum* (Greville) Cleve together with several subdominants (*Chaetoceros didymus* Ehrenberg, *Chaetoceros socialis* Lauder, *Cylindrotheca closterium* (Ehrenberg) Lewin et Reimann, *Plagioselmis prolonga* Butcher ex Novarino, Lucas et Morrall, and others) dominated in phytoplankton. In comparison with the spring data, biomass increased more than three times under the insignificant increase in abundance (1.2 times). The base of abundance and biomass was formed by diatom algae. In autumn, there was a temperate development of phytoplankton represented only by the diatom algae in the coastal zone of Taranai testing area. The prevailing species were *Skeletonema costatum* (dominant), *Thalassionema frauenfeldii* Tempère et Peragallo, and *Asteroplanus karianus* (Grunow) Gardner et Crawford (subdominants).

Arakul

In March, there was "bloom" of the coastal waters of Arakul testing area caused by the development of diatom complex of *Chaetoceros* spp., *Phaeodasctylum tricornutum* Bohlin, *Fragilariopsis cylindrus* (Grunow) Helmcke et Krieger, and *Licmophora ehrenbergii* (Kützing) Grunow. In June, during the reconstruction of phytoplankton communities, the role of diatom algae was noticed to be lowered and that of cryptophytes was raised. In July, development of planktonic algae was temperate, their abundance remained at a low level and their biomass declined significantly because of the development of small-cell species. The phytoplankton composition was represented by diatom, dinoflagellate, cryptophyte, and green algae. The diatom *Skeletonema costatum* dominated both by abundance (36%) and biomass (39%), and the high biomass values were recorded for *Guinardia striata* (Stolterfoth) Hasle (20%) too. In September, there was observed an active vegetation of planktonic algae represented by diatoms, dinoflagellates, and chrysophytes. The total number of phytoplankton cells was 512.957×10^3cell/L (Fig. 29.2), and diatom algae dominated by the total abundance and biomass. The mass vegetation of *Teleaulax acuta* (Butcher) Hill, *Skeletonema costatum*, *Pseudo-nitzschia delicatissima* (Cleve) Heiden, *Phaeodactylum tricornutum*, and *Chaetoceros socialis* was observed.

Prigorodnoye

On the Prigorodnoye testing area, the "bloom" of coastal waters in March was caused by the development of diatom complex of *Chaetoceros* spp., *Phaeodactylum* *tricornutum*, *Fragilariopsis cylindrus*, and *Licmophora ehrenbergii*. In August, phytoplankton development was temperate; it was mainly represented by diatom algae. The dominants-by-abundance were not revealed. The small-cell colonial species of diatom *Skeletonema costatum* (16%) and also *Navicula directa* (8%) were recorded as subdominants. *Navicula directa* (52%) dominated by biomass. In September, diatom, dinoflagellate, and cryptophyte algae developed in plankton, but the basic contribution to the total abundance and biomass was made by diatoms. The mass vegetation of small-cell species *Phaeodactylum tricornutum* (diatoms) and *Plagioselmis* sp. (cryptophytes) were observed.

Busse

On the Busse testing area in September 2015, the mass phytoplankton development under the total abundance of 468.192×10^3cell/L was observed (Fig. 29.2). The species composition was represented by diatom, dinoflagellate, cryptophyte, and green algae. There was observed a mass vegetation of species *Skeletonema costatum, Dactylosolen fragilissimus* and *Plagioselmis* spp.

The seasonal dynamics of the mineral nitrogen compounds content is characterized by maximum values in the spring-summer and the late autumn periods and it is associated with the influence of a coastal flow in spring, and with the decay of organic matter formed during the vegetative season in the autumn. Seasonal maxima of phytoplankton development were observed in spring and summer. For the whole period of phytoplankton studies in the coastal zone of Aniva Bay, the spring peak of the phytoplankton abundance was recorded in April, the seasonal maximum – in September. The predominant mass development was observed for diatom algae in the summer season and for diatom, cryptophyte, and dinoflagellate algae in the autumn season. The total phytoplankton abundance varied: in spring period from 46.945×10^3 cell/L (February, Prigorodnoye) to 9883.636×10^3 cell/L (April, Taranai), in summer from 33.063× 10^3 cell/L (Prigorodnoye) to 280.428×10^3 cell/L (Taranai) and in autumn from 15.061× 10^3 cell/L (October, Prigorodnoye) to 512.957×10^3 cell/L (September, Arakul), biomass from 13.64 mg/m^3 (June, Arakul) to 908.20 mg/m^3 (August, Taranai) (Fig. 29.2). As a rule, diatoms prevailed by abundance in the local algal floras, the second were cryptophytes. The highest quantitative indices of planktonic algae were observed in the mouth of Taranai River.

Acknowledgements

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