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Kai PIIRSOO, Valli PORGASAAR*, and Malle VIIK**

ENVIRONMENTAL CONDITIONS, PHYTOPLANKTON AND CHLOROPHYLL *a* IN THE NARVA BAY (THE SOUTHERN PART OF THE GULF OF FINLAND)

Introduction

The indented coastline in the south of the Gulf of Finland constitutes a number of bays and inlets of different sizes. The largest of those is the Narva Bay, which has a very good exchange with the open waters of the Gulf. In the present paper, the Bay of Narva means an area in the Gulf of Finland bounded by the coastline in the south and in the east, with its northern and western boundaries falling within the respective coordinates of 59°55′ N and 26°35′ E (Fig. 1).

For the most part, the depth of the Bay is less than 50 m. A couple of deeper areas (up to 70 m) can occur near the islands of Tütarsaar. The southeastern part of the Gulf receives the Narva River — one of the largest in the catchment area— which also pours the sewage and industrial waste waters of the city of Narva into the Gulf. The waste water of the oil-shale industry in Kohtla-Järve is also carried into the Narva Bay through the sewage deep-sea outlet that has its opening 3 km off the coast, near Saka. The waste waters of industry in northeast Estonia are, likewise, poured into the Narva Bay through the sewage deep-sea outlets in Sillamäe and Aseri as well as through smaller rivers (the Purtse, the Pühajõgi, the Sõtke, et al.). Due to its geographic location in the east of the Gulf, the Narva Bay is also coming under the influence of the water from the Neva River. Thus, the Narva Bay is strongly affected by anthropogenic activity.

The aim of this research work was to study the hydrochemical and hydrobiological situation in the Narva Bay. The distribution of nutrients and chlorophyll *a* concentrations within the Bay as well as the relationships between these parameters are discussed. The paper will also provide information about the phytoplankton in regard to its species composition, abundance and biomass.

Material and methods

Research material was collected on board a research vessel "Arnold Veimer" in the years 1985, 1987—1990 (Table 1, 3). The plan of all sampling stations is presented in Fig. 1.

* Eesti Teaduste Akadeemia Zooloogia ja Botaanika Instituut (Institute of Zoology and Botany, Estonian Academy of Sciences). EE2400 Tartu, Vanemuise 21. Estonia.

Table 1

Phytoplankton abundance and biomass, chlorophyll *a* content and environmental factors of the water of the Gulf of Finland in spring (Numerator — mean values, denominator — variation ranges)

Sampling stations	Date	Depth m	*n*	Number of cells 10^6	Biomass mg/l	Chl a µg/l	T°	S ‰	PO_4—P µg/l	Tot—P µg/l	NO_3+ +NO_2—N µg/l
1—29	8.—11. 04. 1990	1	29	0.5 0.2—1.3	1.8 0.6—4.8	10.1 3.1—26.6	1.62 1.14—2.23	4.79 3.67—5.19	17 11—21	29 17—37	160 115—280
		near-bottom	29	—	—	5.8 1.0—21.2	1.53 1.09—2.25	5.02 3.67—5.66	21 11—30	29 20—40	170 115—280
30—40	12. 04. 1990	1	11	—	—	11.1 3.8—18.8	1.93 1.61—2.35	4.97 4.89—5.07	14 12—16	18 13—21	114 100—130
41—44	25.—26. 04. 1990	1	4	1.4 0.9—1.7	3.7 2.1—6.2	10.0 5.3—13.5	8.87 7.72—10.42	3.05 1.07—4.62	2 0—4	17 14—20	29 6—41
		near-bottom	4	—	—	8.0 6.3—16.2	1.70 1.41—1.90	4.99 4.82—5.26	7 3—9	15 12—17	39 7—57
76—79	12. 04. 1990	1	4	—	—	9.9 8.6—11.4	1.85 1.63—2.12	5.08 5.06—5.13	17 14—18	29 28—31	135 133—137
LL-3A	24. 04. 1990	1	1	—	—	20.9	4.48	5.12	8	40	3
		5	1	—	—	—	4.14	5.16	3	25	3
		10	1	—	—	12.0	3.36	5.19	5	19	5
		15	1	—	—	—	2.72	5.22	6	17	34
		20	1	—	—	4.0	1.85	5.30	12	25	119
		30	1	—	—	1.5	1.81	5.37	20	27	140
		55	1	—	—	—	1.73	5.71	27	31	140
80	24. 04. 1990	1	1	4.0	4.0	16.0	7.67	1.31	10	—	340
		5	1	—	—	—	3.54	1.60	12	—	340
		10	1	—	—	13.1	1.84	3.00	23	—	310
		20	1	—	—	15.4	0.94	3.66	23	—	280
		30	1	—	—	3.2	0.95	4.00	29	—	300
30—40	14. 05. 1989	1	11	3.0 2.0—5.3	14.8 7.2—25.5	—	—	—	—	—	—
45	27. 05. 1985	5	1	—	—	19.8	7.8	—	7	44	—

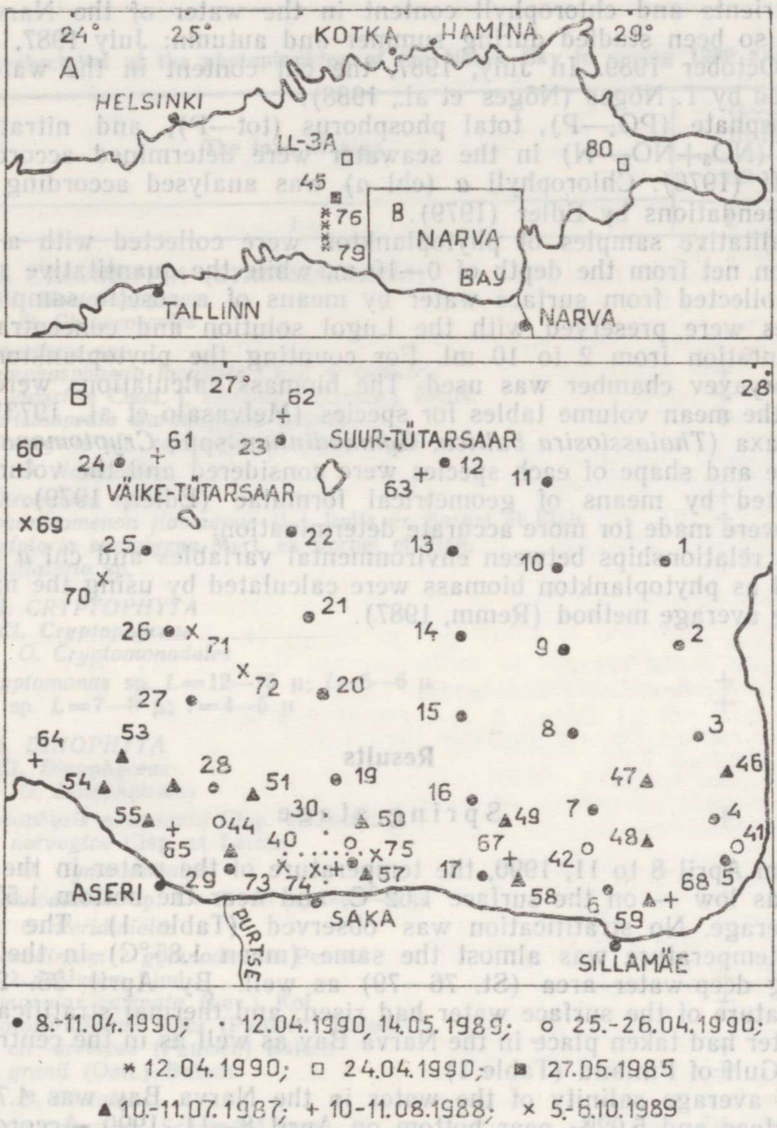

Fig. 1. The study area, sampling stations and date. A — Gulf of Finland; B — Narva Bay.

The most extensive research was carried out in April 1990. On April 8—11, samples were taken at 29 stations throughout the Narva Bay. On April 12, a more profound research of horizontal changes in nutrient and chlorophyll contents was done near Saka, in the area of the sewage deepsea outlet. Samples were taken at 11 stations located at the distance of 0.5—1 mile from each other. On April 25—26, recurrent sampling took place at 4 stations on the southern coast of the Narva Bay. Seawater was also sampled at several stations between the central part of the Gulf of Finland and its extreme east. Species composition of the phytoplankton, its abundance and biomass were determined at 11 stations near Saka also on May 14, 1989.

Nutrients and chlorophyll content in the water of the Narva Bay have also been studied during summer and autumn: July 1987, August 1988, October 1989. In July, 1987, the chl content in the water was analysed by T. Nõges (Nõges et al., 1988).

Phosphate (PO_4—P), total phosphorus (tot—P), and nitrate plus nitrite (NO_3+NO_2—N) in the seawater were determined according to Koroleff (1976). Chlorophyll *a* (chl *a*) was analysed according to the recommendations by Edler (1979).

Qualitative samples of phytoplankton were collected with a phytoplankton net from the depth of 0—10 m, while the quantitative samples were collected from surface water by means of a rosette sampler. The samples were preserved with the Lugol solution and concentrated by sedimentation from 2 to 10 ml. For counting the phytoplankton cells, the Goryayev chamber was used. The biomass calculations were made using the mean volume tables for species (Melvasalo et al., 1973). With some taxa (*Thalassiosira baltica*, *Gymnodinium* spp., *Cryptomonas* spp.) the size and shape of each species were considered and the volume was calculated by means of geometrical formulae (Edler, 1979). Diatom slides were made for more accurate determination.

The relationships between environmental variables and chl *a* content as well as phytoplankton biomass were calculated by using the modified moving average method (Remm, 1987).

Results

Spring stage

From April 8 to 11, 1990, the temperature of the water in the Narva Bay was low — on the surface 1.62 °C, and near the bottom 1.53 °C on the average. No stratification was observed (Table 1). The surface water temperature was almost the same (mean 1.85 °C) in the neighbouring deep-water area (St. 76—79) as well. By April 25—26, the temperature of the surface water had risen, and thermal stratification of the water had taken place in the Narva Bay as well as in the central part of the Gulf of Finland (Table 1).

The average salinity of the water in the Narva Bay was 4.79‰ in the surface and 5.02‰ near bottom on April 8—11, 1990. According to the horizontal distribution, water of the lowest salinity was recorded in the northeast of the Bay, which, evidently, can be ascribed to the influence of the Neva River. At the southern coast, including the areas close to the influx of the Narva River, the salinity was found to be higher. On April 25—26, 1990, the salinity of the water in the southern coastal area of the Narva Bay proved considerably lower (3.05‰) as compared to the results obtained at the first sampling. No marked difference was noticed between the salinity and temperature of the water at Saka and in the neighbouring areas (Table 1).

An abundance of inorganic phosphorus and nitrogen compounds could be recorded in the water of the Narva Bay despite the intensive development of the phytoplankton being under way from 8 to 11 of April, 1990. The PO_4—P concentration was within the ranges of 11—21 µgP/l and 11—30 µgP/l in the surface water and near the bottom, respectively. Total phosphorus concentration was recorded to be 17—37 µgP/l in the surface water and 20—40 µgP/l near the bottom, and it was observed to be irregularly changing throughout the Bay. The water of the Narva Bay was extremely rich in inorganic nitrogen compounds.

Table 2

The check-list of the phytoplankton of the Narva Bay in spring 1989 and 1990

The taxa of alga	Occurrence in the bay	
	1989	1990
1	2	3
PH. CYANOPHYTA (*CYANOBACTERIA*)		
Cl. Nostocophyceae		
O. Chroococcales		
1. *Gloeothece* sp.		+
2. *Gomphosphaeria lacustris* Chod. f. *lacustris*	+	+
3. *G. lacustris* Chod. f. *compacta* (Lemm.) Elenk.	+	+
4. *Merismopedia warmingiana* Lagerh.	+	
5. *Microcystis* cfr. *reinboldii* (Richter) Forti		+
O. Nostocales		
6. *Achroonema* sp.	+	+
7. *Aphanizomenon flos-aquae* (L.) Ralfs ex Bornet et Flah.	+	+
8. *Nodularia spumigena* Mert. ex Bornet et Flah.		+
9. *Oscillatoria* sp.	+	+
PH. CRYPTOPHYTA		
Cl. Cryptophyceae		
O. Cryptomonadales		
10. *Cryptomonas* sp. $L=12-15\ \mu$; $l=5-6\ \mu$	+	+
11. *C.* sp. $L=7-8\ \mu$; $l=4-5\ \mu$	+	+
PH. DINOPHYTA		
Cl. Dinophyceae		
O. Dinophysiales		
12. *Dinophysis acuminata* Clap. et Lachm.	+	+
13. *D. norvegica* Clap. et Lachm.		+
O. Gymnodiniales		
14. *Gymnodinium* sp. $L=9-10\ \mu$; $l=7-8\ \mu$	+	
O. Peridiniales		
15. *Glenodinium* ? *gymnodinium* Penard		+
16. *G.* ? *paululum* Lind.	+	
17. *Gonyaulax catenata* (Lev.) Kof.	+	+
18. *Protoperidinium bipes* (Paulsen) Balech		+
19. *P.* cfr. *brevipes* (Paulsen) Balech	+	
20. *P. granii* (Ostf.) Balech	+	+
O. Ebriales		
21. *Ebria tripartita* (Schum.) Lemm.	+	+
PH. PRYMNESIOPHYTA (*HAPTOPHYTA*)		
***Cl. Prymnesiophyceae* (*Haptophyceae*)**		
O. Prymnesiales		
22. *Chrysochromulina* sp.		+
PH. CHRYSOPHYTA		
Cl. Chrysophyceae		
O. Ochromonadales		
23. *Dinobryon* ? *balticum* (Schütt.) Lemm.		+
Cl. Diatomophyceae (*Bacillariophyceae*)		
O. Eupodiscales (*Centrales*)		
24. *Aulacosira granulata* (Ehr.) Simonsen		+
25. *Chaetoceros ceratosporus* Ostf.		+
26. *C. danicus* Cl.	+	+
27. *C. gracilis* Schütt		+
28. *C. holsaticus* Schütt	+	+
29. *C. wighamii* Bright.	+	+
30. *C.* sp.		+
31. *Coscinodiscus granii* Gough		+
32. *Melosira arctica* (Ehr.) Dickie		+

1	2	3
33. *M. nummuloides* (Dillw.) C. A. Agardh	+	+
34. *M. varians* C. A. Agardh		+
35. *Skeletonema costatum* (Grev.) Cl.	+	+
36. *Thalassiosira baltica* (Grun.) Ostf.	+	+
37. *T. levanderi* van Goor	+	+
O. Bacillariales (Pennales)		
38. *Achnanthes delicatula* (Kütz.) Grun. em Lange-Bertalot	+	
39. *A. taeniata* Grun.	+	+
40. *Amphora pediculus* (Kütz.) Grun.	+	
41. *Anomoeoneis sphaerophora* Ehr. Pfitz.		+
42. *Asterionella formosa* Hass.		+
43. *Bacillaria paxillifer* (O. F. Müll.) Hendey		+
44. *Campylodiscus clypeus* Ehr.		+
45. *Cocconeis pediculus* Ehr.	+	+
46. *C. placentula* Ehr.	+	
47. *C. scutellum* Ehr.	+	
48. *Cymatopleura solea* (Bréb.) W. Sm.		+
49. *Diatoma elongatum* (Lyngb.) C. A. Agardh	+	+
50. *D. vulgare* Bory	+	
51. *Epithemia sorex* Kütz.	+	
52. *Fragilaria ? brevistriata* Grun.		+
53. *F.* sp.	+	
54. *Gomphonema constrictum* Ehr.	+	
55. *Gyrosigma acuminatum* (Kütz.) Rabh.		+
56. *Licmophora* sp.		+
57. *Mastogloia smithii* Thwait.	+	
58. *Meridion circulare* (Grev.) C. A. Agardh var. *constricta* (Ralfs) V. H.		+
59. *Navicula capitata* Ehr. var. *hungarica* (Grun.) Ross		+
60. *N. cryptocephala* Kütz.	+	
61. *N. menisculus* Schum.	+	+
62. *N. peregrina* (Ehr.) Kütz.	+	
63. *N. salinarum* Grun.		+
64. *N.* sp.		+
65. *Nitzschia acicularis* W. Sm.	+	+
66. *N. cylindrus* (Grun.) Hasle	+	+
67. *N. frustulum* (Kütz.) Grun.	+	+
68. *N. ? kuetzingiana* Hilse in Cl. et Grun.		+
69. *N. sigmoidea* (Nitzsch) W. Sm.		+
70. *Opephora olsenii* Möller	+	+
71. *Pleurosigma elongatum* W. Sm.		+
72. *Rhoicosphenia abbreviata* (C. A. Agardh) Lange-Bertalot	+	+
73. *Surirella ? elegans* Ehr.		+
74. *S. ovalis* Bréb.		+
75. *S. striatula* Turp.		+
76. *Synedra acus* Kütz.		+
77. *S. pulchella* Ralfs		+
78. *S. tabulata* (C. A. Agardh) Kütz.	+	+
79. *Tabellaria fenestrata* (Lyngb.) Kütz.		+
PH. EUGLENOPHYTA		
Cl. Euglenophyceae		
O. Euglenales		
80. ? *Colacium vesiculosum* Ehr.		+
81. *Eutreptiella* sp. $L=14$ μ; $l=9$ μ	+	+
PH. CHLOROPHYTA		
Cl. Prasinophyceae		
O. Pyramimonadales		
82. *Pyramimonas* sp. $L=5$—6 μ; $l=4$—5 μ	+	+
Cl. Chlorophyceae		
O. Chlorococcales		
83. *Crucigenia quadrata* Morr.		+
84. *Dictyosphaerium pulchellum* Wood		+
85. *Micratinium pusillum* Fresen		+
86. *Monoraphidium contortum* (Thuret) Kom.-Legn.	+	+

1	2	3
87. *Oocystis borgei* Snow		+
88. *O. lacustris* Chod.	+	+
89. *Pediastrum boryanum* (Turp.) Menegh. var. *longicorne* Reinsch		+
90. *P. duplex* Meyen		+
91. *P. kawraiskyi* Schmidle		+
92. *Scenedesmus communis* Hegewald		+
93. *S. ecornis* (Ehr.) Chod.		+
94. *S. opoliensis* P. Richt		+
95. *Tetraedron minimum* (A. Br.) Hansg.		+
O. Ulotrichales		
96. *Planktonema lauterbornii* Schmidle		+

The value of NO_3+NO_2—N concentration varied within the range of 115—280 μgN/l both in surface as well as in near-bottom waters. The inorganic N : P ratio (weight) was high in the surface water (8—9 : 1).

During the recurrent sampling in April, 1990, the content of inorganic phosphorus and nitrogen in the surface water was declining. The PO_4—P content varied between 0—4 μgP/l, and NO_3+NO_2—N content was between 6—41 μgN/l in the water of the southern part of the Narva Bay. The PO_4—P concentration in the surface water of the central part of the Gulf of Finland did not exceed the 8 μgP/l mark, and that of NO_3+NO_2—N was marked as 3 μgN/l. In the easternmost part of the Gulf of Finland (St. 80), the influx of the Neva River composed a 5-m water layer in the surface, which, due to its low salinity and considerably higher temperature, could be easily distinguished from the rest of the water (Table 1). NO_3+NO_2—N concentrations were extraordinarily high both in the surface and near-bottom water (280—340 μgN/l), while PO_4—P content was low in the surface water (10 μgP/l) yet increased in the water near the bottom (29 μgP/l).

Phytoplankton research results and chl *a* content indicated that phytoplankton vernal bloom in the Narva Bay occurred already during the first observations (April 8—11, 1990). More numerously represented were the diatoms *Thalassiosira levanderi*, *Melosira arctica*, *Chaetoceros holsaticus*, *Skeletonema costatum*, the dinoflagellata *Gonyaulax catenata*, and flagellate from the order *Cryptomonadales*. *Gonyaulax catenata* had the highest biomass values at all the stations, making up about 70% of the total biomass. In 1990 the total number of taxa was 81 (Table 2), varying between 14 and 45 at different stations. The greatest number of species was found in the southeastern part of the Bay, near the influx of the Narva River (St. 4 and 5); it was composed of a number of freshwater and littoral species, such as the blue-green alga *Microcystis* cfr. *reinboldii*, the diatoms *Melosira nummuloides*, *Melosira varians*, *Asterionella formosa*, *Tabellaria fenestrata*, and green algae from the genera *Pediastrum* and *Scenedesmus*.

The number of the phytoplankton cells varied at different stations from 0.2—1.3 mln/l (0.5 mln/l on an average), its biomass occurred in the range 0.6—4.8 mg/l (average 1.8 mg/l). Chl *a* concentration in the surface water was 3.1—26.6 μg/l. Both the abundance and biomass of phytoplankton as well as the chl *a* concentration displayed irregular regional distribution (Fig. 2). Water with greater phytoplankton biomass was formed in the southeastern area of the Bay, also as a couple of "patches" in its open waters. Great differences in the chl *a* content of water in a small area were observed near Saka, but the range 3.8—18.8 μg/l holds for the Bay at large.

Table 3

Chlorophyll *a* content and environmental factors of the water of the Narva Bay in summer and autumn (Numerator — mean values, denominator — variation ranges)

Sampling stations	Date	Depth m	*n*	Chl *a* μg/l	T°	S ‰	PO_4—P μg/l	Tot—P μg/l	NO_3+NO_2—N μg/l
46—53	10.—11. 07. 1987	5	8	4.0 / 1.9—10.8	—	—	4 / 2—6	22 / 13—31	3 / 1—5
54—59	„	5	6	4.3 / 2.7—8.5	—	—	3 / 2—5	28 / 26—31	2 / 0—7
60—63	10.—11. 08. 1988	5	4	3.1 / 2.0—3.7	15.9 / 15.5—16.3	4.30 / 4.10—4.75	2 / 2—2	16 / 13—18	26 / 15—34
		20	4	1.1 / 0.5—3.0	7.7 / 4.1—13.0	5.10 / 4.77—5.32	7 / 2—16	—	77 / 64—100
		50	4	—	1.8 / 1.8—1.9	7.23 / 7.19—7.29	34 / 32—37	36 / 34—39	132 / 129—140
64—68	„	5	5	4.0 / 2.1—7.9	16.8 / 16.6—17.3	4.09 / 3.55—4.30	14 / 10—21	22 / 21—23	18 / 15—22
69—72	5.—6. 10. 1989	5	4	3.7 / 2.8—4.6	—	—	1 / 1—3	—	17 / 9—25
73—75	„	5	3	5.6 / 3.5—7.1	11.4 / 11.1—11.8	4.27 / 4.15—4.28	5 / 1—10	27 / 22—31	11 / 9—12
		near-bottom	3	5.9 / 5.7—6.2	—	—	3 / 1—4	31 / 30—31	11 / 9—12

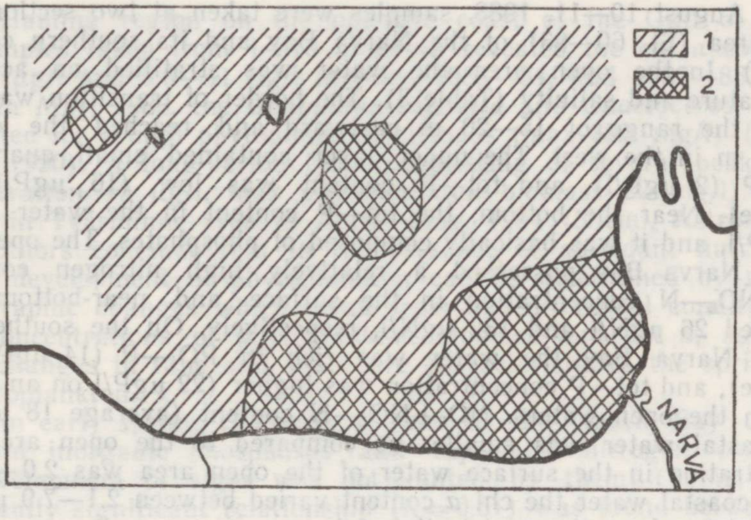

Fig. 2. Phytoplankton biomass and chlorophyll *a* content in the surface water of the Narva Bay 8.—12. 04. 1990. *1* — chl *a* content <10 µg/l and phytoplankton biomass <2 mg/l; *2* — chl *a* content >10 µg/l and phytoplankton biomass $\geqslant 2.0$ mg/l (excl. St. 5).

On April 25—26, 1990, the chl *a* content on the southern coast of the Narva Bay still remained high — being 10.0 µg/l on an average. The phytoplankton abundance and biomass had increased in the same area 1.6 and 1.2 times, respectively. The abundance of several cold-water diatoms (*Thalassiosira levanderi*, *Melosira artica*) had declined. The cells of the dinoflagellata *Gonyaulax catenata* revealed the tendency of decay. However, the abundance of flagellate had increased.

The intense vernal development of the phytoplankton occurred in the neighbouring areas as well. The chl *a* content in the surface water varied between 8.6—20.9 µg/l during the two weeks (Table 1).

In May, 1989, 47 phytoplankton species were found in the Narva Bay near Saka (Table 2). The number of taxa varied between 14 and 21. In most of the stations *Gonyaulax catenata* dominated, constituting about 50% of the biomass. Flagellates from the genera *Eutreptiella* and *Cryptomonas*, as well as the diatoms *Achnanthes taeniata*, *Chaetoceros holsaticus*, and *Chaetoceros wighamii* could be met with as co- or subdominants.

In 1989, the variation of phytoplankton abundance near Saka was recorded as 2.0—5.3 mln/l (3.0 mln/l on an average), the biomass was valued at 7.2—25.5 mg/l (average 14.8 mg/l). Great number of the cells of the *Gonyaulax catenata*, varying between 0.2 and 1.4 mln/l (average 0.5 mln/l) in the area studied was responsible for high biomass content. In April, 1990, the average abundance of that species in the Narva Bay was approximately 5 times lower.

Summer and autumn stages

On July 10—11, 1987, sampling in the Narva Bay was performed in two sections that lie parallel to the coastline (St. 46—53 and St. 54—59), both of which characterize coastal water (Fig. 1). Chl *a* content in the surface water varied regionally between 1.9—10.8 µg/l, increasing in the southeastern part of the Bay within the influx area of the Narva River. The water contained tiny amounts of PO_4—P (2—6 µgP/l) and NO_3+NO_2—N (0—7 µgN/l). Tot—P concentration (13—31 µgP/l) was unstable and relatively high for the summer stage.

On August 10—11, 1988, samples were taken at two sections of the open area (St. 60—63) of the Narva Bay and its southern coast (St. 64—68). In the open area the water was stratified on account of temperature and salinity (Table 3). The border of transition was located within the range of 15—20 m eastward and reached the depth of 25—30 m in the west. The upper layer contained small quantities of PO_4—P (2 μgP/l), and tot—P content was low (16 μgP/l on an average). Near the bottom, the tot—P content in the water averaged 36 μgP/l, and it was basically composed of phosphates. The open waters of the Narva Bay possessed a relatively high nitrogen content — NO_3+NO_2—N concentration in the surface and near-bottom waters averaged 26 μgN/l and 132 μgN/l, respectively. On the southern coast of the Narva Bay the water was rich in PO_4—P (14 μgP/l on an average), and tot—P concentration was higher (22 μgP/l on an average) than in the open waters. NO_3+NO_2—N content (average 18 μgP/l) in the coastal water was smaller as compared to the open area. Chl *a* concentration in the surface water of the open area was 2.0—3.7 μg/l. In the coastal water the chl *a* content varied between 2.1—7.9 μg/1, and it was rising from the west to the east.

On October 5—6, 1989, sampling took place in a NW—SE section of the open area (St. 69—72), and in the coastal area near Saka (St. 73—75). The surface water in the open area of the Narva Bay had a minimal content of PO_4—P (below 3 μgP/l), but the NO_3+NO_2—N content remained relatively high (17 μgN/l on an average). In the coastal waters, PO_4—P concentration (5 μgP/l on an average) increased, and NO_3+NO_2—N content (11 μgN/l on an average) declined as compared to the open area. Chl *a* content in the water varied between 2.8—4.6 μg/l in the open waters and 3.5—7.1 μg/l in the coastal area. Judging by the species composition of the phytoplankton community, transition from the late-summer to the autumn stage was under way (oral testimony by A. Randveer).

Discussion

Spring research in May, 1989, and April, 1990, coincided with the intensive period of phytoplankton development. During the first sampling in 1990 (April 8—11) the temperature of the surface water throughout the Narva Bay was low and varied in a small range (1.14—2.23 °C). However, the temperature of water affected both the distribution of chlorophyll ($R=0.72$) and that of phytoplankton biomass ($R=0.60$) in the Narva Bay. The correlation between phytoplankton biomass and chl *a* was very strong ($R=0.94$). The richest chlorophyll content was discovered in the shallow coastal area where the water was relatively warmer from the surface to the bottom. There the chl *a* content of the water reached 15 μg/l even in the near-bottom layer. In deeper areas, the chlorophyll-rich layer reached the depth of 25 m (according to the chlorophyll fluorescence data).

Even after a fortnight (April 24—26, 1990) the phytoplankton bloom could be observed. The chl *a* content of the surface water reached 10 μg/l in the coastal area in the Narva Bay and exceeded 20 μg/l in the central part of the Gulf of Finland. The temperature of the surface water had risen, and thermal stratification could be noticed, which, in turn, influenced the vertical distribution of phytoplankton in the open waters.

Intensive phytoplankton development in the open area of the Narva Bay has also been observed in late May. For example, on May, 27, 1985, the chl *a* concentration in surface water was valued at 19.8 μg/l. In

Kotka-Hamina region on the opposite coast of the Gulf of Finland, the samples taken from 1—10 m depth revealed the chl *a* contents of 14—37 μg/l and 5.6—41 μg/l in May, 1983—84, and 1987—88, respectively; in May, 1988, the *Gonyaulax catenata* and *Chaetoceros wighamii* accounted for a high phytoplankton biomass (max 38.1 mg/l) (Pitkänen et al., 1990). A long-period bloom consisting of several peaks (chl *a* concentration 40 μg/l, max phytoplankton biomass 22 mg/l) was observed in Tvärminne area in April—May, 1984 (Niemi, Åström, 1987). The authors conclude that in the presence of abundant nutrients the spring development of phytoplankton can be determined by means of hydrographic changes which result from meteorological conditions. The high concentrations of phytoplankton biomass and chl *a*, as well as sharp changes in time and space are characteristic of the spring stage of phytoplankton.

As in early spring, the surface water in the Narva Bay contained abundant inorganic phosphorus and especially nitrogen compounds; the development of algae was not limited by them (Table 4). The statistically significant relationship (R=0.61) was found between chl *a* and tot—P content. It must say, that on analysing the unfiltered seawater tot—P concentration also accounted for the phosphorus contained in phytoplankton cells.

Table 4

Statistics on the relationships between chlorophyll *a* content, phytoplankton biomass and environmental factors of the water of the Narva Bay in April 1990

Factors	n	P	R
Water temperature — chl *a*	28	>0.999	0.72
Water temperature — phytoplankton biomass	28	>0.999	0.60
Phytoplankton biomass — chl *a*	28	>0.999	0.94
PO_4—P — chl *a*	29	<0.95	0.19
Tot—P chl *a*	29	>0.95	0.61
NO_3+NO_2—N — chl *a*	29	<0.95	0.36
Water salinity — PO_4—P	29	<0.95	0.13
Water salinity — NO_3+NO_2—N	29	<0.95	0.20

n — number of samples, P — level of significance, R — correlation index.

There was no remarkable relationships between the nutrients content and the salinity of the water (Table 4) although the rivers of Narva and Neva discharge the nutrients into the Gulf. In April, 1990, the content of nutrients in the Narva Bay could be compared to the data obtained on the northern shore of the Gulf of Finland (near Kotka-Hamina) in spring 1987—88 (Pitkänen et al., 1990).

The scarce amount of phytoplankton in seawater in summer seems to be frequently caused by the lack of inorganic nutrients in the euphotic layer. The nutrient content of the water in the Gulf of Finland has increased in recent years (Baltic ..., 1987). Trophic degree increase in the water off the north coast in the eastern part of the Gulf, has been observed in the late summer and autumn of 1987 and 1988. In autumn 1987, it was evidenced by highly intensive blue-green algal bloom in the eastern part of the northern coast of the Gulf on Finland (Pitkänen et al., 1990).

During the sampling in summer and autumn 1987, 1988 and 1989 inorganic P- and N-compounds in the surface water of the Narva Bay could be found to a greater or lesser extent. Despite scattered data, the decline in nitrate-nitrite concentration and the increase of phosphate content in the coastal waters of the Narva Bay as compared to the surface water of the open area, should be mentioned. Variation of nutrients and chl *a* content in the water of the Narva Bay was similar to that observed near Kotka-Hamina in summer 1987—88 (Pitkänen et al., 1990). A few regular tendencies in the distribution of the chlorophyll concentration in the water of the Narva Bay can be elicited. Chl *a* content in the coastal waters was variable (1.9—10.8 μg/l in July, 1987, 2.1—7.9 μg/l in August, 1988, and 3.5—7.1 μg/l in October, 1989) and increased in the southeastern region of the Narva Bay. In the open waters of the Bay, the chl *a* content was lower and more stable (2.0—3.7 μg/l in August, 1988, and 2.8—4.6 μg/l in October, 1989).

As the life-span of the cells of phytoplankton is relatively short and their development is rapidly changing, the data obtained from the single sampling of chlorophyll content should be regarded as reliable at that particular period. In most cases the phytoplankton development and its seasonal successions are dependent on more than one agent, reflecting the net response to all factors, abiotic as well as biotic (Kautsky, 1988). So, in especially favourable weather conditions the summer bloom of phytoplankton can be possible in the Narva Bay, provided available are inorganic nutrients.

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Kai PIIRSOO, Valli PORGASAAR, Malle VIIK

KESKKONNATINGIMUSED, FÜTOPLANKTON JA KLOROFÜLL *a* NARVA LAHES (SOOME LAHE LÕUNAOSAS)

On esitatud andmed Narva lahe vee temperatuuri, soolsuse, biogeenide- ja klorofüllisisalduse ning fütoplanktoni liigilise koostise, arvukuse ja biomassi kohta 1985. ja 1987.—1990. aastal. Detailsem uurimine toimus 8.—11. aprillini 1990. Vee temperatuur varieerus pinnal 1,14—2,23 °C ja põhjas 1,09—2,25 °C. PO_4—P kontsentratsioon oli pinnavees 11—21 μgP/l ning põhjavees 11—30 μgP/l. Eriti rikkalikult (115—285 μgN/l) leidus NO_3+NO_2—N nii pinna- kui ka põhjavees. Pinnavees varieerus fütoplanktoni arvukus 0,2—1,3 mlj. rakku/l, biomass 0,6—4,8 mg/l, chl *a* kontsentratsioon 3,1—26,6 μg/l, kusjuures kõrgemad väärtused esinesid lahe kaguosas ning paari laiguna lahe avaosas. Arvukamad liigid olid *Thalassiosira levanderi*, *Melosira arctica*, *Chaetoceros holsaticus*, *Skeletonema costatum*, *Gonyaulax catenata* ja *Cryptomonas* spp.

1989. aasta mais varieerus fütoplanktoni arvukus 2,0—5,3 mlj. rakku/l, biomass 7,2—25,5 mg/l. Enamikus jaamades domineeris *Gonyaulax catenata*.

Suviste (VII 1987, VIII 1988) ja sügiseste (X 1989) vaatluste ajal leidus Narva lahe pinnavees peaaegu kõikjal PO_4—P (2—21 μgP/l) ja NO_3+NO_2—N (0—34 μgN/l). Toiteelementide jaotumuses võis märgata NO_3+NO_2—N kontsentratsiooni langus- ja PO_4—P sisalduse tõusutendentsi rannikuvees. Chl *a* sisaldus oli rannikuvees ebastabiilne (1,9—10,8 μg/l VII 1987; 2,1—7,9 μg/l VIII 1988 ja 3,5—7,1 μg/l X 1989), kusjuures kõrgem sisaldus esines lahe kaguosas. Lahe avaosas oli chl *a* kontsentratsioon madalam ja jaotus ühtlasem (2,0—3,7 μg/l VIII 1988; 2,8—4,6 μg/l X 1989).

Кай ПИЙРСОО, Валли ПОРГАСААР, Малле ВИЙК

УСЛОВИЯ СРЕДЫ, ФИТОПЛАНКТОН И ХЛОРОФИЛЛ *a* В НАРВСКОМ ЗАЛИВЕ (ЮЖНАЯ ЧАСТЬ ФИНСКОГО ЗАЛИВА)

Излагаются данные по температуре и солености воды, по содержанию биогенных элементов и хлорофилла *a*, а также по видовому составу, численности и биомассе фитопланктона в 1985 и 1987—1990 гг. В апреле 1990 г. концентрация фосфатов в поверхностной воде варьировала в пределах 11—21 мкг/л и в придонной воде 11—30 мкг/л. Вода была чрезвычайно богата минеральными соединениями азота. Содержание нитратного и нитритного азота как в поверхностной, так и в придонной воде варьировало в пределах 115—285 мкг/л. В поверхностном слое численность фитопланктона колебалась от 0,2 до 1,3 млн. клеток/л, биомасса от 0,6 до 4,8 мг/л, концентрация хлорофилла *a* от 3,1 до 26,6 мкг/л. Наиболее многочисленными видами были представлены: *Thalassiosira levanderi*, *Melosira arctica*, *Chaetoceros holsaticus*, *Skeletonema costatum*, *Gonyaulax catenata* и *Cryptomonas* spp.

В мае 1989 г. численность фитопланктона достигала 2,0—5,3 млн. клеток/л, биомасса 7,2—25,5 мг/л. В большинстве станций доминировал *Gonyaulax catenata*.

В июле 1987, в августе 1988 и в октябре 1989 г. содержание фосфатов поверхностной воды Нарвского залива колебалось в пределах 2—21 мкг/л и концентрация нитратов-нитритов 0—34 мкг/л. В воде прибрежной части залива было обнаружено повышение содержания фосфатов и уменьшение содержания нитратов-нитритов. Содержание хлорофилла *a* в прибрежной части залива было неоднородным (1,9—10,8 мкг/л в июле 1987 г., 2,1—7,9 мкг/л в августе 1988 г. и 3,5—7,1 мкг/л в октябре 1989 г.). Более высокие концентрации отмечены в юго-восточной части Нарвского залива. В воде открытой части залива содержание хлорофилла было меньше (2,0—3,7 мкг/л в августе 1988 г. и 2,8—4,6 мкг/л в октябре 1989 г.).