Transitional Waters Bulletin
TWB, Transit. Waters Bull. 1(2007), 27-37
ISSN 1825-229X, DOI 10.1285/i1825229Xv1n1p27
http://siba2.unile.it/ese/twb

RESEARCH ARTICLE

Long-term changes in diatom communities of phytoplankton and the surface sediments in the Curonian Lagoon (Lithuanian part)

Kasperovičienė[1] J., Vaikutienė[2] G.

[1]Institute of Botany, Žaliųjų Ežerų 49, LT – 08406 Vilnius, Lithuania, Fax: +370 5 2729950, teleph: +370 5 2701503, jurate.kasp@botanika.lt
[2]Vilnius University, Čiurlionio 21, LT – 03101 Vilnius, Lithuania

Abstract

1 - The aim of this study was to analyse spatial and temporal patterns among phytoplankton diatom communities for assessing water quality in the Curonian Lagoon, SE Baltic Sea. The study of diatoms in sediments was selected as a method to establish if these records are useful for reviewing the environmental conditions of a transitional water body because they represent a composite accumulation of species occurring throughout all the seasons.

2 - 137 phytoplankton diatom communities were analyzed seasonally in 1986–1987, 1991 and in summer 2003–2004. 34 diatom assemblages in surface sediments (0–5 cm) were studied in 1998–1999 in the Curonian Lagoon.

3 - 360 diatom species and 38 genera were identified. The high anthropogenic disturbance in the lagoon was reflected by the diatom communities in the phytoplankton. Species typical of eutrophic waters *Stephanodiscus hantzschii*, *S. minutulus*, *S. binderanus*, *Cyclostephanos dubius*, *Cyclotella atomus*, *C. meneghiniana* became dominant in 1986–1987 and 1991, accounting for more than 90% of total abundance. The dominant species of previous study periods have lost their advantage during the last two decades.

4 - Because of extensive dredging activities in the Klaipėda Strait, the brackish species *Actinocyclus normanii*, *Chaetoceros* spp., *Skeletonema costatum*, *Thalassiosira* spp. comprised a substantial part of the plankton diatom communities, especially during summer–autumn seasons also in the southern sites.

5 - Different Curonian Lagoon zones were defined according to the surface sediment diatom assemblages. Salinity was the main environmental factor regulating species occurrence. Predominance of brackish water planktonic diatoms was characteristic in the western part of the lagoon where salinity changes rapidly and irregularly. Freshwater benthic diatom taxa prevailed in the eastern part of the lagoon.

6 - Environmental reconstruction of the lagoon based on sediment diatom assemblages is problematic because they do not properly reflect species that are representative in water environments. Further investigations of the surface sediment diatom assemblages according to their habitat and salinity gradient in the lagoon are required in order to use them in the historical assessment of environmental changes in the transitional water.

Keywords: diatoms, phytoplankton, surface sediments, Curonian Lagoon, Lithuania

Introduction

Diatoms are an important component of the plankton and benthos primary producer communities in aquatic ecosystems. They are widespread in fresh, brackish and marine environments and are generally species-rich. Environmental conditions determine the quantitative association of the species. Diatoms have tolerance limits and optima with respect to environmental conditions such as nutrients, organic pollution, acidity and salinity (Van Dam *et al.*, 1994). They are commonly employed in monitoring efforts as sensitive biological indicators to determine the anthropogenic impact on aquatic ecosystems, and have for a long time been used in bio-assessments and historical reconstructions of modern and past changes of ecological conditions and climate (Cooper, 1999, Anderson, 2000, Miettinen *et al*., 2005).

Diatoms have been the subject of investigations of phytoplankton in the Curonian Lagoon (SE Baltic Sea) for over 60 years (Schmidt-Ries, 1940, Ūselytė, 1959, Jankavičiūtė, 1990, Olenina, 1998). Nevertheless, in the shallow transitional aquatic ecosystem sediments, resident benthic communities can be considered as the sensitive part of the aquatic ecosystem. Sedimentary diatom assemblages provide an extended temporal record of environmental conditions. Paleolimnological studies of the lagoons have rarely been attempted, as they typically have complex and variable sedimentation patterns in space and time, and resuspension of sediments can be a serious problem (Cooper, 1999). Despite the importance of the sediment biota, scientific investigations in Lithuania have mostly focused on water quality and benthic biological variables are neglected. Several studies have shown spatial variations of surface sediment diatom assemblages in the Curonian Lagoon in order to gather ecological information (Kasperovičienė, 1990, Vaikutienė, 2002).

The aim of this study was to analyse spatial and temporal patterns of changes in phytoplankton diatom species composition and abundance in order to assess water quality in the Curonian Lagoon. The study of diatoms in the surface sediments was selected as a method to determine whether diatom assemblages differ in distinct areas of the lagoon; these records are useful for reviewing environmental conditions of a transitional water body since they represent a composite accumulation of species occurring in plankton and benthos throughout all the seasons.

Methods

Study area. The Curonian Lagoon lies on the SE Baltic Sea coast of Lithuania and the Kaliningrad province of Russia. It is separated from the Baltic Sea by the narrow (1–3 km) sandy Curonian Spit. The total area of the lagoon is approximately 1584 km^2. The border between two countries divides the lagoon into a smaller northern part in Lithuania (413 km^2) and a southern part in Russia. The average depth of the Lithuanian part is 3.8 m, maximum 12–13 m in the harbour area of the Klaipėda Strait. The southern and central parts of the lagoon contain freshwater due to discharge from the Nemunas River and other smaller rivers, while the salinity in the northern part varies from 0 to 8 PSU. The duration and extent of the seawater inflows depend on the wind-caused rises in water level in the coastal zone of the sea (Žaromskis, 1996). The most common are the 1–2 days inflows of the Baltic Sea water, and the brackish water inflows are most frequent and prolonged from August to October, when 70% of the total annual inflows from the sea occur (Pustelnikovas, 1998). Extensive dredging activities in the harbour area of the Klaipėda Strait during the last two decades have caused occasional increases in water salinity in the southernmost sites.

Most (97.8%) of the surface sediments is comprised of (0.1–1 mm) sand fractions. The central and eastern parts are dominated by the Nemunas River drift material – fine sand. Coarse silt and fine silty mud tend to accumulate in the deepwater zones in the western and southern part of the lagoon (Trimonis *et al*., 2003).

Sampling and data analyses. Six stations (sites 1–6, Fig. 1) were sampled three times a year (May, July, October) in 1986–1987, ten stations (sites 1–6 and 9–12) in May, July, October 1991, and sites 1–2 and 6–12 in July 2003–2004. In total seventy-seven phytoplankton samples were collected with Ruttner bottles from the surface (0.5 m depth) and sixty from the near-bottom layer in 1986–1987 and 1991. In addition, thirty-four surface sediment (0–5 cm) samples were collected using an Ekman grab sampler in July-August 1998–1999 (Fig. 1). Sites 1–4 are situated in the northern part of the lagoon – the zone of Baltic Sea influence, sites 5–9 in the central and southern parts, and sites 10–12 in the zone of Nemunas River influence. These areas were defined by long-term phytoplankton biomass patterns observed at 17 sampling sites representative of the ecologically distinct parts of the lagoon specified by Olenina (1998).

The diatom frustules were oxidized by treatment with 30% hydrogen peroxide (Battarbee, 1986). Permanent slides were prepared, and diatoms were mounted with Naphrax. At least 500 diatom valves per slide were identified and counted along horizontal transects using a light Biolar microscope at ×1000 magnification, under oil immersion. Algae were identified to species level using the taxonomic works by Krammer and Lange-Bertalot (1986–1991). Identification of some diatoms was confirmed using a JEOL SEM microscope. Diatoms were divided into groups according to their ecological requirements (Van Dam et al., 1994). Surface sediment assemblage diversity and dominance were measured using the Shannon–Weaver (H') index, which was calculated from relative abundance and species richness. ArcViewer 8.0 was applied to compile a map and analyze data on the different ecological diatom species groups in the 0–5 cm sediment layer.

Physical characteristics (water temperature, pH, salinity) were measured in situ using a MultiLine F/Set-3 portable universal meter. Transparency was measured with a Secchi disk. Dissolved oxygen concentration was evaluated by the Winkler method. Nutrient (phosphorus and nitrogen) analyses were performed according to Merkienė and Čeponytė (1994). Phosphate-P was analysed by acid digestion followed by the molybdate ascorbic acid method, and the same procedure was followed for total-P, following persulfate-H_2SO_4 digestion. Nitrate-N was determined using potassium persulfate-$K_2S_2O_8$ following Cd reduction to NO2, and total-N was analysed in accordance with Kjeldahl.

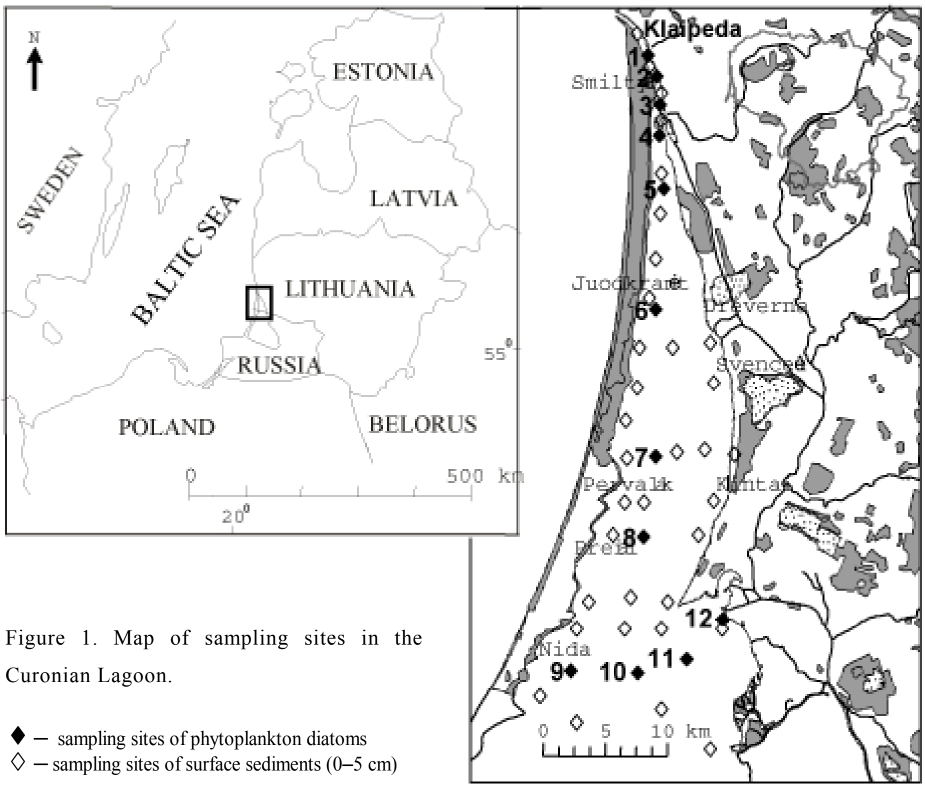

Figure 1. Map of sampling sites in the Curonian Lagoon.

♦ – sampling sites of phytoplankton diatoms
◇ – sampling sites of surface sediments (0–5 cm)

Results

Environmental variables. Some physical and chemical data for the Curonian Lagoon water (the upper 0.5 m water column) are presented in Table 1. Water temperature in the lagoon varied with season, but not with stations or depth. The range of recorded Secchi depths during 1956–1957 was wider than that observed in 2003–2004. There are rather small differences in the values of phosphate concentrations. Measured concentrations of ammonia and nitrate nitrogen fluctuated significantly during the investigated periods. The lack of some biogens (nitrogen, phosphorus, silica, etc.) measurements renders further analyses very difficult.

The study was carried out during calm weather conditions when hydrodynamic activity was minimal. Sites (1–4) in the northern part of the lagoon exhibited the highest influence of the Baltic Sea water during investigation periods (Tab. 2).

Table 1. Mean values of physical and chemical water parameters in the surface water layer (0–5 m) in the Curonian Lagoon during different periods of investigations.

Parameter	1956–1957*	1974–1975*	1987*	2003**			2004**		
				NP	SCP	NRIP	NP	SCP	NRIP
Water temper., t°C	8.0–22.6	10.5–23.2	9.1–19.0	22.4	20.8	20.2	18.9	18.9	20.5
Transparency, S_h, m	0.5–1.6	0.3–0.6	0.5–1.2	1.0	0.7	0.9	1.0	0.6	0.9
pH	8.1–8.9	7.5–9.03	7.5–9.0	8.5	8.7	8.4	8.4	8.5	8.2
O_2, mg l^{-1}	7.3–15.9	5.0–12.9	4.9–13.4	8.54	10.4	9.44	7.04	7.52	6.4
PO_4^{3-}-P, μgP l^{-1}	12–110	0.0–70	0.0–90	45	13	3.0	17	29	41
TP, μgP l^{-1}	–	47–116	–	190	110	63	87	110	140
NH_4^--N, μgN l^{-1}	–	0.0–5000	900–7000	45	23	14	43	23	86
NO_3^--N, μgN l^{-1}	11–34	–	40–1100	280	140	140	370	100	200
NO_2^--N, μgN l^{-1}	0.0–5.0	0.0–145	5.0–800	5.0	8.0	8.0	3.7	1.0	1.0
TN, μgN l^{-1}	–	–	–	2600	1500	1700	2900	3100	4100
SiO_3^{2-}, mg l^{-1}	1.5–3.2	0.02–4.1	–	–	–	–	–	–	–

– no data; * data were taken from Jankavičiūtė, 1990, ** summer season data in the northern part (NP), central and southern parts (CSP), the Nemunas River influence part (NRIP)

Table 2. Salinity values (PSU) in the Curonian Lagoon surface and near-bottom water layers.

Date	Areas of the Curonian Lagoon, sampling sites		
	Northern part (1–4 sites)	Central, southern part (5–9 sites)	Nemunas River influence part (10–12 sites)
1986	0.0–5.0/0.0–3.6	0.0–1.5/–	–
1987	0.0–4.1/0.0–4.8	0.0–3.7/–	–
1991	0.0–2.4/0.3–2.7	0.0–0.6/–	0.0/–
2003	1.0–1.3/–	0.3–2.7/–	0.0/–
2004	0.0–1.3/–	0.0/–	0.0/–

– no data

Species diversity. 360 diatom species and 38 genera were identified in the phytoplankton and surface sediment samples from the Curonian Lagoon. Pennate diatoms prevailed, and 18% (65 species) of identified taxa were centric.

The list of species included a great number of rare sporadic species – approximately 70% were encountered on only a few occasions during the study.

Phytoplankton diatom communities. Curonian Lagoon phytoplankton diatoms showed a similar annual development in 1986–1987. The total abundance reached high amounts (0.7×10^6–14.2×10^6 valves l^{-1}) in the surface water layer at six sampling sites included in this study (Tab.

3). The highest total abundance of diatoms was in May. The Spring diatom community was comprised of species characteristic of eutrophic waters *Stephanodiscus hantzschi* Grun., *S. minutulus* (Kütz.) Cleve & Möller, *S. parvus* Stoermer & Håkansson (Fig. 2).

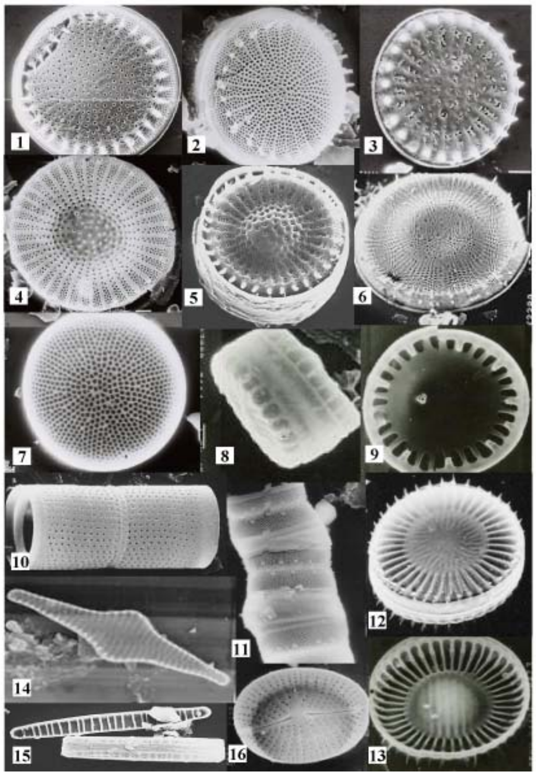

Figure 2. The dominant diatom species in plankton and surface sediments of the Curonian Lagoon. – 1. *Stephanodiscus hantzschii*, ×6600; 2. *S. hantzschii* f. *tenuis*, ×6600; 3. *S. parvus*, ×11000; 4–5. *S. minutulus*, ×7800–×5960; 6. *S. rotula*, ×2200; 7. *Actinocyclus normanii* f. *subsalsa*, ×2600; 8–9. *Cyclotella atomus*, ×13000; 10. *Aulacoseira islandica*, ×7000; 11. *Stephanodiscus binderanus*, ×4000; 12–13. *Cyclotella meneghiniana*, ×4000–×4400; 14. *Fragilaria inflata* var. *istvanffyi*, ×4800; 15. *Diatoma moniliformis*, ×3820; 16. *Navicula scutelloides*, ×2600.

They were present in phytoplankton through the whole vegetation period with the highest abundance reaching 70–90% in spring. Other typical taxa of this period, although with lower abundance, were *Aulacoseira islandica* (O. Müll.) Simons., *Cyclostephanos dubius* (Fricke) Round, *Diatoma tenuis* Ag., and *Fragilaria heidenii* Østrup (Fig. 2 and Appendix 1).

The total abundance of diatoms decreased by 1.5 to 13 times at different sites in July. In summer, the dominant small *Stephanodiscus* algae were complemented by *S. binderanus* (Kütz.) Krieger and *Cyclotella meneghiniana* Kütz. Despite some variations in algal density among the investigated sites, diatom abundance in October phytoplankton slowly increased in comparison to summer. *Cyclotella atomus* Hust. became numerous in the communities of the central part (sites 5–6) of the Curonian Lagoon.

Similar alternation of the phytoplankton diatom community was found in 1991. Generally, algal abundance in the southern sites (9–10) and the river mouth sites (11–12) was greater than in the sites of the northern and central lagoon (Tab. 3). The dominant species in 1986–1987 were accompanied by *Asterionella formosa* Hassal, *Aulacoseira islandica* (O. Müller) Simonsen and *Chaetoceros wighamii* Brightwell during investigations in different study sites (Appendix 1).

The major shift in plankton diatom communities occurred in summer 2003–2004. The total abundance decreased and did not reach 1×10^6 valves l^{-1} in almost all sites (Tab. 3). Large *Actinocyclus normanii* algae became dominant, accounting for 71% of relative diatom abundance. *Stephanodicus* and other algae characteristic of eutrophic waters almost disappeared or occurred in small numbers in phytoplankton (Appendix 1).

Each lagoon area was characterized by quantitative changes in diatoms in the near-bottom layer during different seasons and years (Tab. 3). The dominant algae were almost the same as in the surface layer. The characteristic feature was a pronounced salinity effect on diatom community structure in the near-bottom layer. A considerable portion (30–40%) of diatoms encountered was comprised of brackish *Chaetoceros*, *Skeletonema* and *Thalassiosira* species due to the Baltic Sea water inputs in July–October. They were typically seen in the deepest (9–11 m) sites (1–4 sites) in the Klaipėda Strait. In other sites their abundance was negligible.

Table 3. Total amount of phytoplankton diatoms (×10^6 valves l^{-1}) in the surface/near-bottom water layer in the Curonian Lagoon.

Date		Sampling sites					
		1	2	3	4	5	6
1986	14 May	5.5/4.2	9.4/11.1	7.2/7.1	6.5/9.7	7.4/4.0	6.9/3.9
	08 July	2.1/1.0	0.7/1.3	1.4/2.9	3.1/6.1	1.9/0.5	0.8/1.1
	13 October	2.2/1.4	3.4/1.5	1.3/1.0	3.9/2.8	3.7/4.3	2.1/2.9
1987	13 May	2.7/15.2	9.9/11.6	12.0/5.0	8.7/8.4	14.2/5.1	7.6/3.3
	14 July	5.1/1.8	6.7/13.9	4.9/6.7	6.2/5.4	4.8/4.5	5.3/3.1
	14 October	3.0/1.3	1.6/1.5	5.9/6.2	5.2/4.3	5.3/3.3	5.3/4.4
1991	27 May	3.3/6.2	7.5/9.4	7.2/43.7	4,0/3,7	8,4/4,1	4,5/5,2
	17 July	2.6/5.9	3.4/3.9	1.2/3.6	–	–	–
	17 October	3.2/1.7	4.1/5.8	3.6/3.8	–	–	–
15 July 2003		–	–	–	0.34/–	5.43/–	0.26/–
27 July 2004		0.1/–	0.02/–	–	–	–	–
Date		Sampling sites					
		7	8	9	10	11	12
1986	14 May	–	–	–	–	–	–
	08 July	–	–	–	–	–	–
	13 October	–	–	–	–	–	–
1987	13 May	–	–	–	–	–	–
	14 July	–	–	–	–	–	–
	14 October	–	–	–	–	–	–
1991	27 May	–	–	12.6/6.8	6.9/3.3	11.2/5.4	19.3/13.1
	17 July	–	–	4.0/1.8	9.4/2.7	29.4/15.0	29.8/20.0
	17 October	–	–	11.1/8.5	4.8/7.1	47.2/10.2	29.8/43.2
15 July 2003		0.12/–	0.06/–	0.19/–	0.15–	0.52/–	0.61–
27 July 2004		0.4/–	0.4/–	0.1/–	0.3/–	0.4/–	2.0/–

Surface sediments. 120 diatom taxa were recorded in the 0–5 cm layer of the sediments. Benthic diatoms were dominated by pennate species in the assemblages, and 17% (20 species) of identified taxa were centric. Species achieving a cumulative importance of more than 2% of richness varied from 10 in the central and southern areas of the Curonian Lagoon to 20 in the northern and the Nemunas River influenced areas. The following 5 taxa, planktonic diatom *Actinocyclus normanii* (55%), epipsamic species *Fragilaria heidenii* (9%), *Martyana martyi* (Héribaud) Round (26%), and epipelic *Navicula scutelloides* W. Smith. (80%), *Amphora pediculus* (Kütz.) Grunow (6%), occurred in all diatom assemblages, and accounted for between 80 and 90% of the total abundance.

Shannon-Weaver species diversity (H') varied from 1.37 to 2.07. H'-values for diatom assemblages in the Nemunas River influenced area was smaller compared with other parts of the lagoon. The Shannon-Weaver species diversity index showed no clear dependency upon salinity changes in different parts of the lagoon (Fig. 3). The Median of diversity was higher for the northern part, where the most frequent and prolonged total annual brackish water inflows occur and tended to slowly decrease in the sites situated in central, southern and the Nemunas River influenced parts of the lagoon.

Different Curonian Lagoon zones were defined according to diatom assemblages in the 0–5 cm surface sediments with reference to the data obtained in 1998–1999 (Fig. 4 A). The largest amounts of planktonic species (60–80%) accumulated in the sediments in the western part of the lagoon. *Actinocyclus normanii*, *Aulacoseira islandica* and *Stephanodiscus rotula* (Kütz.) Hendey prevailed in the sediments of 0–5 m depth. Benthic diatoms were present as common components in diatom assemblages in a wide range of habitats. However, an anomalous abundance (60–80%) of the benthic algae *F. heidenii*, *Martyana martyi* and *Navicula scutelloides* in the sediments of the central part suggest the importance of hydrodynamic processes in the formation of diatom assemblages.

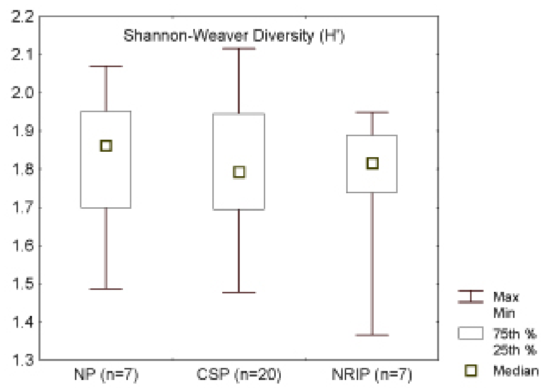

Figure 3. Boxplots of Shannon-Weaver diversity values of the surface sediments (0–5 cm) diatoms in the northern part (NP), central and southern parts (CSP), the Nemunas River influence part (NRIP).

The majority of high density occurrences of brackish diatoms appeared in the sediment samples close to the western shorelines (Fig. 4 B). The Baltic Sea brackish water inflow mainly occurs in this part of the lagoon. Planktonic *Actinocyclus normanii* was presented in the highest density and reached 55% of relative diatom abundance in the sediments of this zone. The shift from the assemblages dominated by brackish species to ones dominated by freshwater algae towards the eastern shore was determined.

Discussion

Based on data obtained during half a century of investigations (Schmidt-Ries, 1940, Ūselytė, 1956, Jankavičiūtė and Jankevičius, 1978) we can assume that the Curonian Lagoon has undergone different periods of algal community productivity. Taxa with high Si/P requirements (Van Donk and Kilham, 1990) such as *Asterionella formosa*, *F. crotonensis* Kitton were the most abundant during the initial period of investigations. *Aulacoseira granulata* (Ehrenb.) Simons and *A islandica* were also among the dominant algae. According to Trifonova (1998) *A. islandica* prevails in aquatic basins during the first stages of eutrophication and their abundance decreases in highly eutrophic waters. Thus mesotrophic plankton flora indicating moderate productivity of the water basin and the first stage of eutrophication (Hall and Smoll, 1992) was found.

High abundance of diatoms was recorded during the growing season in 1986–1987 and 1991 when the seasonal observations of plankton diatoms were carried out. Evident changes took place in the dominant species composition. Small algae, such as *Stephanodiscus hantzschii*, *S. minutulus*, *S. parvus*, *Cyclostephanos dubius*, *Cyclotella meneghiniana* and *C. atomus* – the reliable indicators of eutrophic conditions (Hall and Smoll, 1992) – dominated in diatom communities. A significant increase in *Stephanodiscus* spp. since 1980 was also observed by Jankavičiūtė (1990) and Olenina (1998). Almost all diatom species mentioned as characteristic components in previous phytoplankton studies were lacking or were not particularly abundant. Thus diatom structure in the lagoon phytoplankton showed a succession characteristic of many anthropogenically eutrophicated water bodies (Willèn, 1992). It is well known that eutrophication of water basins favours green algae and cyanoprocaryotes over diatoms. The proportions in which nutrients are loaded to a system can exert a strong influence on which algal species will thrive (Kilham and Heckey, 1988). Changes to plankton diatom communities in the Curonian Lagoon suggested increased nutrient availability. Besides N and P, Si is also an essential nutrient for diatoms. The importance of Si in structuring phytoplankton communities has been well-established and high dissolved Si/P ratios have been shown to favour diatoms over other algae (Egge and Aksnes, 1992, Humborg *et al*., 2000). *Stephanodiscus* has a very low Si/P optimum and the dominance changes in diatom communities in the lagoon may reflect further enrichment of phosphorous. Unfortunately, the silica budget of the lagoon has been neglected since 1987.

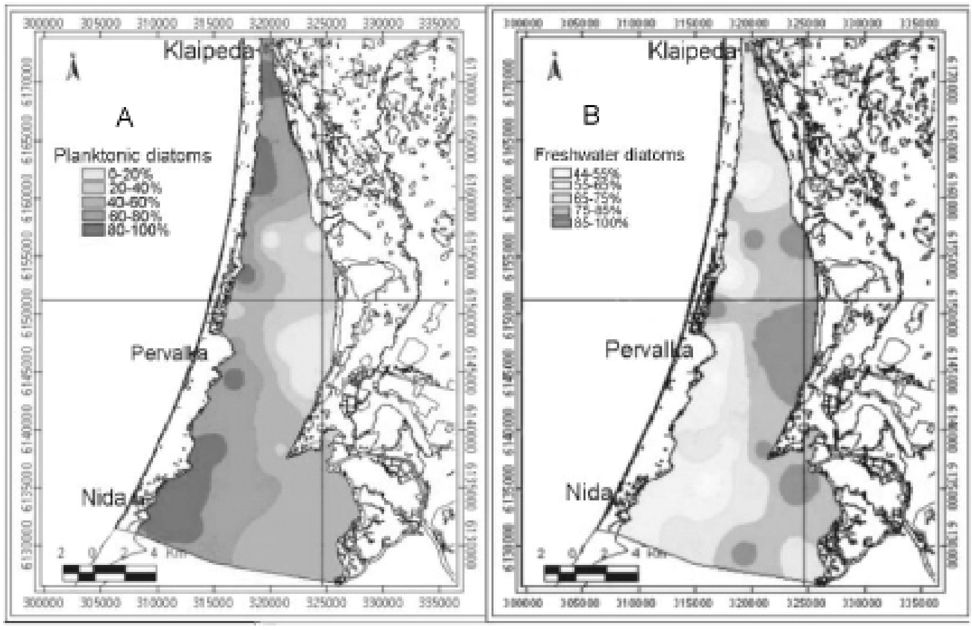

Figure 4. Distribution of planktonic (A) and freshwater (B) diatoms in the surface sediments of the Curonian Lagoon.

Because of extensive dredging activities in the Klaipėda Strait, since 1986 the brackish species *Actinocyclus normanii*, *Chaetoceros* spp., *Skeletonema costatum*, and *Thalassiosira* spp. have continued to constitute a substantial part of diatom abundance, especially during the summer period, as far south as the Klaipėda Strait and have recently become dominant in the lagoon. Whereas *A. normanii* appears to thrive in a wide range of salinity it is supposed that its distribution is not directly controlled by available chlorine (Belcher and Swale, 1979). This species seems to be confined to waters rich in nutrients.

Different zones of the Curonian Lagoon defined according to diatom assemblages in the surface sediments showed a close relationship between them and bottom relief and fresh and brackish water inflow areas. Brackish diatoms dominated in the western, deepest part of the lagoon. Freshwater diatoms prevailed in the shallow eastern part of the lagoon, where the Nemunas River outflow has a great influence. Hydrodynamic processes influenced the occurrence of diatoms in surface sediments. Evidence of this is a large percentage of benthic diatoms found in the central part of the lagoon. Algae are transported from nearshore habitats, where light for photosynthesis is available, to the offshore regions.

The main factor determining diatom structure and abundance in the sediments is their productivity in the overlying waters. Haworth (1980) found excellent temporal agreement between the phytoplankton records and sediment diatom assemblages and a reasonable relationship between the total number of *Stephanodiscus* in the sediments and mean number in the overlying water column. Unfortunately, these species, despite their resistance to dissolution, are poorly preserved in the Curonian Lagoon sediments. On the other hand they are dominant in the surface sediments (0–1 cm) in the Lithuanian coast areas (Bubinas *et al*., 1998). It seems that planktonic species are being discharged from the lagoon into the coastal areas.

Conclusions

Quantitative assessment of phytoplankton diatom development changes indicates that the Curonian Lagoon is naturally productive and became eutrophicated significantly in the late 20th century. This study of algal communities draws attention to the low water quality of the lagoon caused by human activities.

The species composition of the diatom assemblages in sediments seems to be related to the peculiarities of water dynamic processes in the transitional waters. The penetration of the brackish Baltic Sea water has an influence on diatom assemblages in the Curonian Lagoon. Unfortunately, environmental reconstruction of the lagoon is problematic as the diatom assemblages in the sediments do not properly reflect the species representative in the water environment. Further investigations on diatom assemblages in the surface sediments according to their habitat and salinity gradient in the Curonian Lagoon are required in order to use them in the historical assessment of environmental changes in the transitional water.

Acknowledgement

We wish to thank Dr. Galina Khursevich from the Institute of Geological Science (Minsk, Belarus) for SEM photographs and Prof. E. Trimonis and Dr. S. Gulbinskas from the Institute of Geology and Geography (Vilnius) for sediment samples. We are grateful to anonymous referees who improved the manuscript significantly. Dr. Z. Gudžinskas kindly revised the English of the manuscript.

References

Anderson NJ. 2000. Miniview: Diatoms, temperature and climatic change. *Eur. J. Phycol*. 35: 307-314.

Battarbee RW. 1986. Diatom analysis. In: Berglund B. (ed.), *Handbook of Holocene Paleoecology and Paleohydrology*: 527-570. Wiley & Sons, Chichester.

Belcher JH, Swale EMF. 1979. English freshwater records of Actinocyclus normanii (Greg.) Hustedt (Bacillariophyceae). *Br. Phycol. J.* 14: 225-229.

Bubinas A, Kasperovičenė J, Repečka M. 1998. Distribution of diatoms and zoobenthos in the bottom sediments of the nearshore aquatory of the Baltic Sea between Klaipėda and Šventoji. *Ekologija* 3: 40-49. Vilnius, Lithuania.

Cooper SR. 1999. Estuarine paleoenvironmental reconstructions using diatoms. In: Stoermer EF, Smol JP. (eds.), *The Diatoms: Applications to the Environmental and Earth Sciences*: 352-373. Cambridge University Press, Cambridge.

Egge JK, Aksnes DL. 1992. Silicate as a regulating nutrient in phytoplankton competition. *Mar. Ecol. Prog*. Ser 3: 83-91.

Hall RI, Smoll JP. 1992. A weighted-averaging regression and calibration model for inferring total phosphorous concentration from diatoms in British Columbia (Canada) lakes. *Freshwater Biol*. 27: 417-434.

Haworth EY. 1980. Comparison of continuous phytoplankton records with the diatom stratigraphy in the recent sediments of Blelham Tarn. *Limnology and Oceanography* 25: 1093-1103.

Humborg C, Conley DJ, Rahm L, Wulff F. 2000. Silicon retention in river basins: Far-reaching effects on biogeochemistry and aquatic food webs in coastal marine environments. *Ambio* 29: 45-50.

Jankavičiūtė G, Jankevičius K. 1978. Plankton organisms physiological-biochemical evidence in the northern part of Kuršių Marios: 33-61. Vilnius, Lithuania.

Jankavičiūtė G. 1990. Phytoplankton species composition in the Curonian Lagoon. *Ekologija* 1: 5-21. Vilnius, Lithuania.

Kasperovičienė J. 1990. *Diatoms in Lithuanian water bodies*. PhD Thesis. Vilnius, Lithuania.

Kilham P, Heckey RE. 1988. Comparative ecology of marine and freshwater phytoplankton. *Limnology and Oceanography* 33: 776-795.

Krammer K, Lange-Bertalot H. 1986–1991. *Süßwasserflora von Mitteleuropa*. 2 (Teil 1–4). *Bacillariophyceae*. Ettl H, Gerloff J, Heynig H, Mollenhauer D. (eds.). VEB Gustav Fischer Verlag, Stuttgart/Jena, Germany.

Merkienė R, Čeponytė V. 1994. *Unified sewage and surface waters quality assessment methods*. P. Kalibato IĮ, Vilnius, Lithuania.

Miettinen JO, Kukkonen M, Simola H. 2005. Hindcasting baseline values for water colour and total phosphorous concentration in lakes using sedimentary diatoms implications for lake typology in Finland. *Boreal Environment Research* 10: 31-43.

Olenina I. 1998. Long-term changes in Kuršių Marios Lagoon: eutrophication and phytoplankton response. *Ekologija* 1: 56-65. Vilnius, Lithuania

Schmidt-Ries H. 1940. Utersuchungen zur Kenntnis des Pelagials eines Strandgewässers (Kurisches Haff). *Zeitschriftfur für Fischerei und deren Hilfswissenschaften* Band XXXVII, Helf 2: 183-322.

Pustelnikovas O. 1998. *Geochemistry of sediments of the Curonian Lagoon (Baltic Sea)*. Mokslo Aidai, Vilnius, Lithuania.

Trifonova IS. 1998. Phytoplankton composition and biomass structure in relation to trophic gradient in some temperate and subarctic lakes of north-western Russia and the Prebaltic. *Hydrobiologia* 369/370: 99-108.

Trimonis E, Gulbinskas S, Kuzavinis M. 2003. The Curonian Lagoon bottom sediments in the Lithuanian water area. *Baltica* 16: 13-20. Vilnius, Lithuania.

Ūselytė S. 1959. Das phytoplankton des Kurischen Haffes und seine saisonmässige dynamik. In: *Kurisches Haff*: 139-167. Biologisches Institut, Vilnius, Lithuania.

Vaikutienė G. 2002. Diatoms distribution in superficial sediments of northern part of the Curonian Lagoon. *Geologija* 37: 56-66. Vilnius, Lithuania.

Van Dam H, Mertens A, Sinkeldam J. 1994. A coded checklist and ecological indicator values of freshwater diatoms from the Netherlands. *J. of Aquat. Ecol*. 28: 117-133.

Van Donk E, Kilham SS. 1990. Temperature effects on silicon- and phosphorus-limited growth and competitive interactions among three diatoms. *J. of Phycology* 26: 40-50. DOI:10.1111/j.0022-3646.1990.00040.x

Willén E. 1992. Long-term changes in the phytoplankton in large lakes in response to changes in nutrient loading. *Nordic Journal of Botany* 12: 575-587.

Žaromskis R. 1996. *Oceans, Seas and Estuaries*. Debesija, Vilnius, Lithuania.

Appendix 1. Dominant phytoplankton diatom species (max relative abundance, %) in the surface water layer of the Curonian Lagoon

Date		Areas of the Curonian Lagoon, sampling sites		
		Northern part (1–4 sites)	Central, southern part (5–9 sites)	Nemunas River influence part (10–12 sites)
1986	14 May	*Stephanodiscus hantzschii* (64%), *S. minutulus* (14%), *S. parvus* (14%)	*S. hantzschii* (55%), *S. minutulus* (18%)	–
1986	08 July	*S. hantzschii* (25 %), *S. minutulus* (10 %), *Skeletonema costatum* (18 %), *Thalassiosira* spp. (11 %)	*S. hantzschii* (29 %), *S. minutulus* (11 %), *Skeletonema costatum* (16 %),	–
1986	13 October	*Stephanodiscus hantzschii* (34%), *S. minutulus* (9%), *Cyclotella meneghiniana* (13%), *Thalassiosira* spp. (12%)	*Stephanodiscus hantzschii* (37%), *S. minutulus* (15%), *Cyclotella meneghiniana* (14%), *C. atomus* (12%)	–
1987	13 May	*Stephanodiscus hantzschii* (49%), *S. minutulus* (17%), *Diatoma tenuis* (14%)	*Stephanodiscus hantzschii* (41%), *S. minutulus* (12%), *D. tenuis* (14%)	–
1987	14 July	*Stephanodiscus hantzschii* (38 %), *S. minutulus* (9%), *Cyclotella meneghiniana* (12%), *Thalassiosira* spp. (12%), *Skeletonema costatum* (7%)	*Stephanodiscus hantzschii* (40%), *S. binderanus* (14%), *S. minutulus* (9%), *Skeletonema costatum* (11%)	–
1987	14 October	*Stephanodiscus hantzschii* (54%), *S. minutulus* (19%)	*S. hantzschii* (64%), *S. minutulus* (14%), *S. binderanus* (14%)	–
1991	27 May	*S. hantzschii* (48%), *Chaetoceros wighamii* (20%), *Diatoma tenuis* (14%)	*S. hantzschii* (47%), *Asterionella formosa* (17%)	*S. hantzschii* (43%), *A. formosa* (15%), *Actinocyclus normanii* (11%)
1991	17 July	*S. hantzschii* (48%), *Fragilaria heidenii* (14%), *Nitzschia palea* (5%)	*Cyclotella atomus* (44%), *A. normanii* (23%), *S. hantzschii* (19%)	*S. hantzschii* (36%), *C. atomus* (21%)
1991	17 October	*Stephanodiscus hantzschii* (38%), *Skeletonema. costatum* (28%)	*Stephanodiscus hantzschii* (17%), *Cyclotella atomus* (15%), *Aulacoseira islandica* (10%)	*Stephanodiscus hantzschii* (22%), *Cyclotelal atomus* (19%), *A. islandica* (9%)
15 July 2003		*Actinocyclus normanii* (71%), *F. heidenii* (12%), *Cyclotella* spp. (14%)	*A. normanii* (42%), *Stephanodiscus rotula* (14%), *Cyclotella* spp. (9%)	*A. normanii* (55%), *Stephanodiscus rotula* (25%), *Aulacoseira islandica* (10%)
27 July 2004		*Actinocyclus normanii* (63%), *Cyclotella* spp. (8%)	*A. normanii* (71%), *Cyclotella* spp. (16%)	*Cyclotella* spp. (26%), *Stephanodiscus hantzschii* (25%), S. *minutulus* (7%)

