ANNEX II

MARINE RESEARCH CENTRE

THE ENVIRONMENTAL STATUS OF THE CURONIAN LAGOON

The Curonian Lagoon stretches along the densely populated coast of the Baltic Sea, where active economic activities are performed, therefore this waterbody experiences various ecological problems caused by them. The most important ecological problem in the Curonian Lagoon is ongoing eutrophication, which is caused by nutrient and organic substances flowing into the Lagoon with the water from the Nemunas and Minija and with the wastewater from Klaipeda city and settlements situated on the coast of the Lagoon. Unique hydrological features of the Curonian Lagoon – shallowness, limited water exchange with the Baltic Sea and strong inertia of natural processes stimulate eutrophication process, it’s consequences to the ecosystem. The interaction of natural processes and human economic activities influences intensive development of planktonic algae (water ‘blooming’), therefore a water body loses it’s esthetic and recreational value, changes it’s ecological state. The intensity of phytoplankton development determines water quality and productivity of a water body essentially.

1. PHYSICAL - GEOGRAPHICAL CHARACTERISTICS OF THE CURONIAN LAGOON

The Curonian Lagoon is a freshwater lagoon of the southeastern part of the Baltic Sea with a basin of a straight triangle (Fig. 1). A narrow (0.4-3.8 km width) Curonian Spit separates the Lagoon from the Baltic Sea. The total area of the Lagoon is 1584 km^2, the water volume is 6.2 km^3, and the total length of the coastline is 324.3 km. The lagoon is very shallow with an average depth of 3.8 m. Lithuania owns the northern part of the lagoon, the area of some 413 km^2 (or 26.1% of the total area). The length of the coastline of the Lagoon in Lithuanian territory is about 150 km. The rest part of the Lagoon is in the territory of the Kaliningrad district of Russian Federation.

The northernmost part of the Curonian Lagoon – Klaipeda Strait, which is up to 14 m depth and just 0.4 km width, has been strongly transformed by industrial activities (bottom deepening, expansion of the harbor area etc.) and it is considered to be a separate part (Žaromskis, 1996).

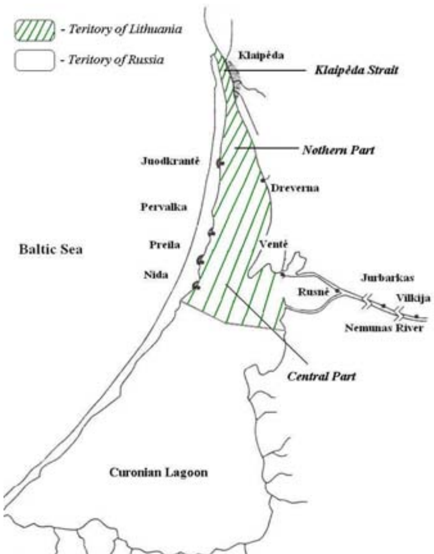


Fig. 1 Curonian Lagoon scheme

1.2. Hydrological characteristics

The circulation of water masses in the Curonian Lagoon, water temperature and salinity influence the speed and character of chemical reactions, which determine hydrochemical water composition and biological processes in the waterbody.

1.2.1. Water circulation

The hydrological regime of the Lagoon is formed by the rivers run-off and water exchange by the narrow Klaipeda Strait. River run-off reaches the Curonian Lagoon from the drainage area of 100 458 km^2 (5.8% of the Baltic Sea catchment), 98% of which is taken by the Nemunas basin. Annual fresh water input into the Lagoon is 23 km^3, although in different years it can range from 33 to 14 km^3/year (Gailiusis et al., 2001)

The most intensive water circulation takes place in the Klaipeda Strait. Due to the fresh water inflows prevailing under the inflows from the Sea into the Curonian Lagoon the inclination of the water surface towards the Sea is formed in the Klaipeda Strait. Therefore water from the Lagoon flows into the Sea, making quite a big area of it fresher. The storm winds of NW, W, N directions or high level of the sea water determine water flow from the Sea towards the northern Lagoon. Annually about 3-7 km^3 of the Baltic Sea water falls into the Curonian Lagoon. After the storm calms down this water flows back to the Sea forced by the river water and the Lagoon's water becomes fresh again.

The water balance of the Lagoon is: the river run-off into the Lagoon - 22.18 km^3, precipitation onto the water - 1.28 km^3, inflow from the Sea - 5.5 km^3, evaporation - 1.08 km^3, outflow into the Sea – 27.81 km^3. The water residence time of the Lagoon is 81 days (Gailiusis et al., 2001).

In the open part of the Lagoon the current regime (direction and speed of currents) is unstable as it is predetermined by winds. Currents in the Klaipeda Strait are mainly directed towards the Sea from the Lagoon. During the set-ups of the Sea water caused by strong W, NW and N winds water from the Baltic Sea flows towards the Lagoon. Also in many cases there are observed two-layer currents, when fresh or slightly saline lagoon's water flows in the surface layer to the Sea and, at the same time, there exists a flow, in the deep layer, from the Sea to the Lagoon.

1.2.2. Water temperature

As the Curonian Lagoon is shallow, temperature in surface water layer and near the bottom is similar. Sometimes insignificant gradients of temperature are observed, especially in spring. Most often temperature gradients are found in Klaipeda Strait due to the influence of the Baltic Sea on the northern part of the Lagoon.

The water temperature in the Curonian Lagoon varies from 0.0°C (in winter) to 20.0°C and above (in summer). According to the long-term (1992-2003) data of seasonal expeditions, the average surface water temperature in the Lagoon is 8.53 - 9.39°C (Fig. 2)

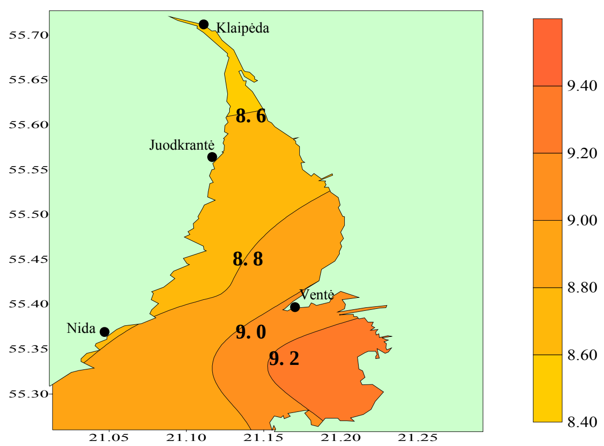
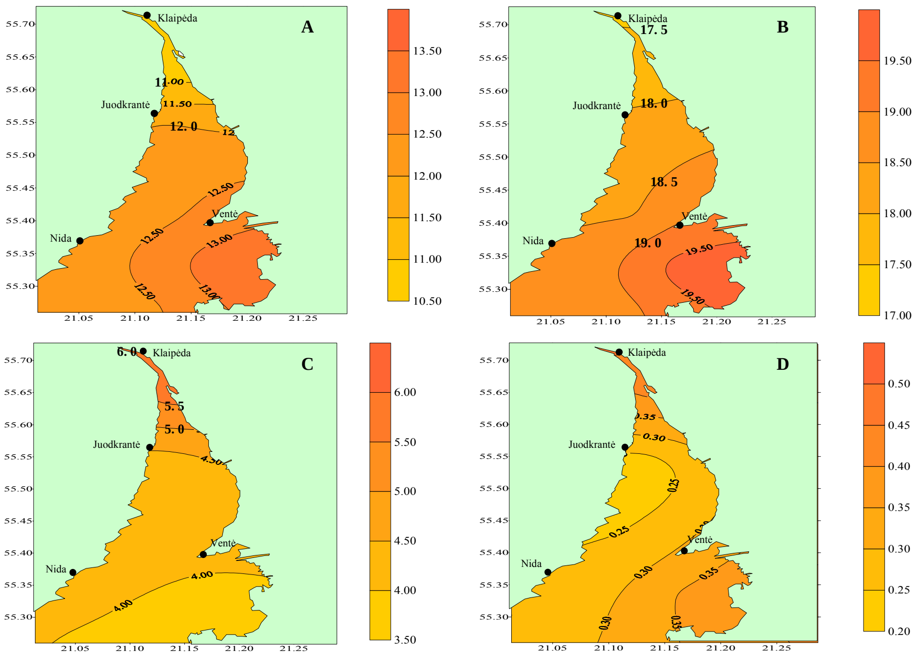


Fig. 2 Distribution of the long-term surface water temperature in the Curonian lagoon

In May when the weather becomes warmer water temperature rises up as well. Surface water temperature during that period various from 10.49 to 13.42^{o}C. In August the water in the Curonian Lagoon warms up to 19.74^{o}C. Both in spring and summer water temperature in Klaipeda Strait is lower than in the central part of the Lagoon. In October-November when the sun radiation decreases, the water temperature decreases to 4 - 6^{o}C. The higher temperature remains in the Klaipeda Strait, as it is under the marine water inflow, which becomes colder not so fast. In



February the temperature of the Lagoon water does not exceed 0.5^{o}C. Although in some years it significantly exceeds long-term average values. (Fig.3)

Fig. 3. Distribution of the long-term surface water temperature in the Curonian Lagoon A - in spring, B – in summer, C – in autumn, D – in winter

1.2.3. Water salinity

According to salinity distribution the Curonian Lagoon is divided into two parts: the northern which extends from the Klaipeda Strait to Juodkrante and the central. The highest salinity in Lagoon is observed in the Klaipeda Strait. Salinity decreases to the south (Fig. 4).

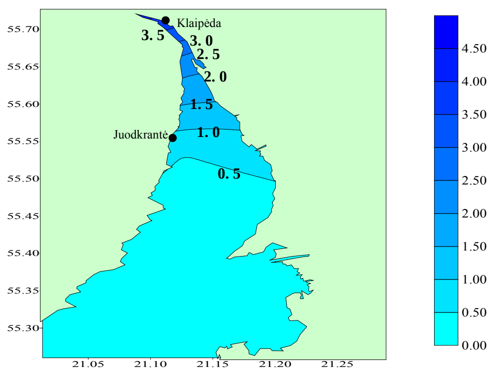


Fig. 4 Long-term distribution of the surface water salinity in the Curonian Lagoon

Usually the lowest (0.04 - 4.25 ‰) salinity in Curonian Lagoon is observed in the spring due to the high fresh water inflow from the rivers. In the summer the salinity in the Lagoon increases, as the inflow of the river water decreases. In the autumn the salinity is the largest due to the frequent sea water inflows into the Lagoon. During the longer lasting set-ups saline water reaches Juodkrante. In some years slightly saline water spreads all over the Lagoon. In winter water salinity in the Lagoon is 0.05-4.02 ‰. As usually, salinity in the Klaipeda Strait differs significantly from the salinity in other parts of the lagoon (1.47-4.02 ‰) (Fig. 5).

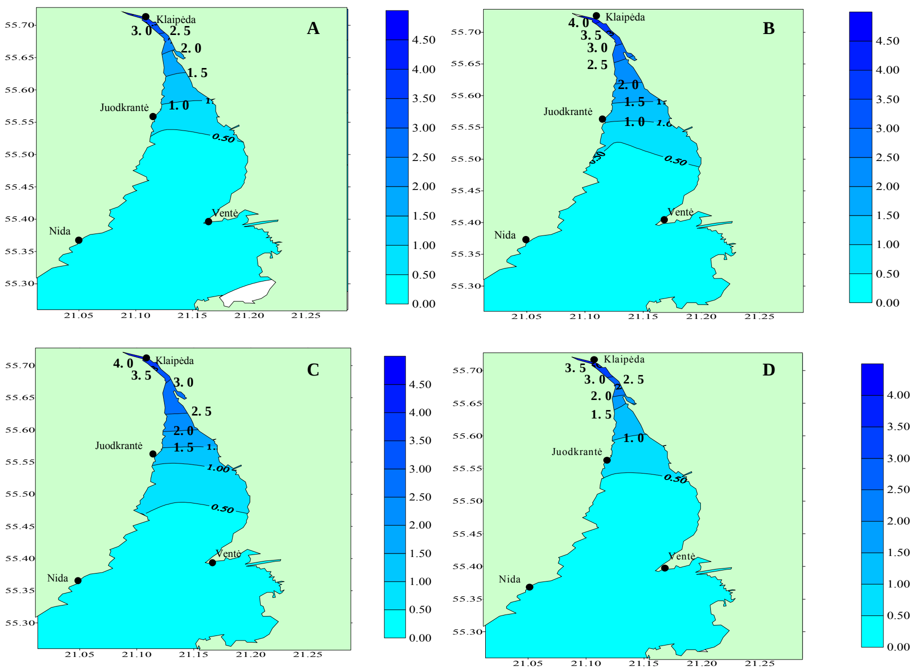


Fig. 5 Distribution of the long-term surface water salinity in the Curonian Lagoon
A - in spring, B – in summer, C – in autumn, D – in winter

According to the long-term data the salinity near the Juodkrante has slightly increased. During last decade it has increased by 0,31‰ (Fig. 6). The main causes of these changes are: deepening of the harbour, natural processes (increasing water level, changes in atmospheric circulation).

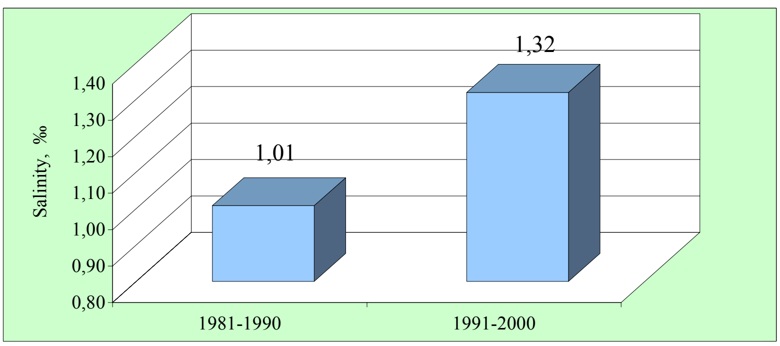


Fig. 6 The mean water salinity during the periods of 1981-1990 and 1991-2000 near Juodkrante

2. HYDRO-CHEMICAL CHARACTERISTICS

The conditions of dissolved oxygen in the Curonian Lagoon are good. Oxygen depletion only occurs episodically when the intensive consumption of oxygen for mineralization of large amount of died planktonic algae and water plants is going. Low oxygen concentrations in water leads to fish kills. It is observed episodically in the Curonian Lagoon.

The biochemical oxygen demand within seven days BOD_7 (i.e. the amount of dissolved oxygen which is necessary to oxidize biochemically organic substances) allows to determine the amount of organic substances in water. During the cold period of a year the water quality in the Curonian Lagoon according to the BOD_7 is good or very good (<4 mgO_2l), in spring and the beginning of summer - moderate (>6 - <10 mgO_2l). During the time of the decomposition of died water plants (August - September), when the amount of organic substances increases, water quality episodically in some parts of the Lagoon is poor (>10 mgO_2l).

During the last seven years the largest mean concentration of total nitrogen was in 2002, but in 2003 it significantly decreased. (Fig. 7)

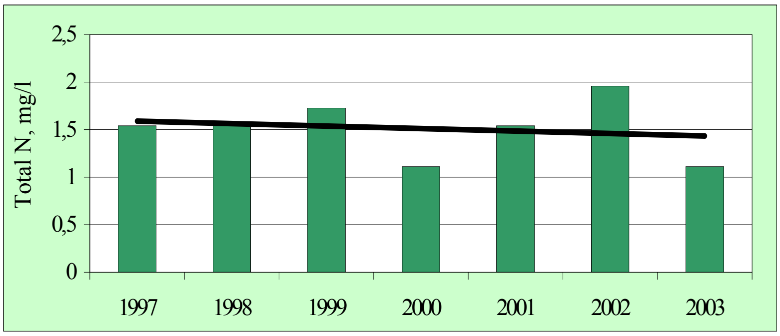


Fig. 7 The fluctuation of mean yearly concentrations of total nitrogen in the Curonian Lagoon in 1997-2003

The largest concentrations of total nitrogen in the Curonian Lagoon are often found during the cold period of a year in the mouth of the river Nemunas (Atmata, St. 12A) and Minija (St. 13), when about 60% of the total nitrogen constitutes mineral compounds (Fig. 8). According to the criteria of the classification of surface water bodies, with reference to the mean concentrations of total nitrogen (0.95 mg/l) during the vegetation period (01 May - 30 September) in 2003, the water quality in the Curonian Lagoon was moderate.

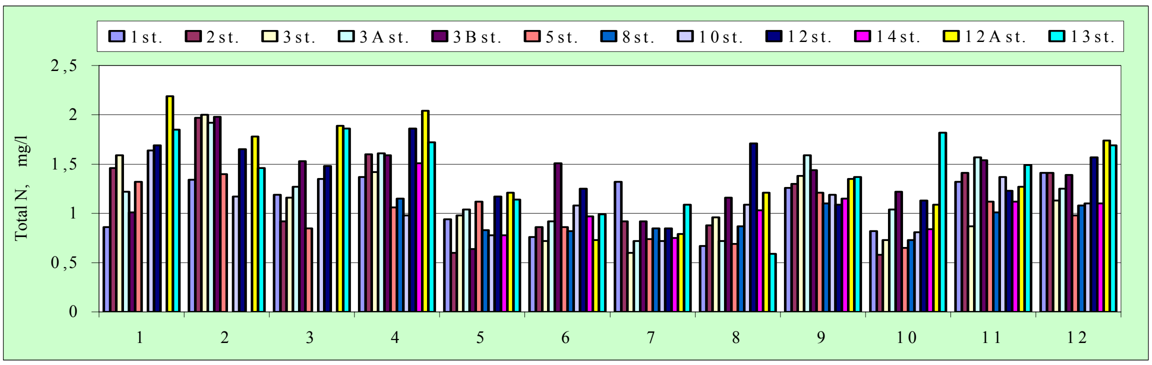


Fig. 8 The distribution of concentrations of total nitrogen in the Curonian Lagoon in 2003

During the cold period nitrate comprises the major part of total nitrogen in the Curonian Lagoon and their concentration often exceeds 1.0 mgN/l (Fig. 9). At the time of intense vegetation the concentrations of nitrate in some parts of the Lagoon decreases up to 100 times and organic nitrogen comprises the major part of total nitrogen.

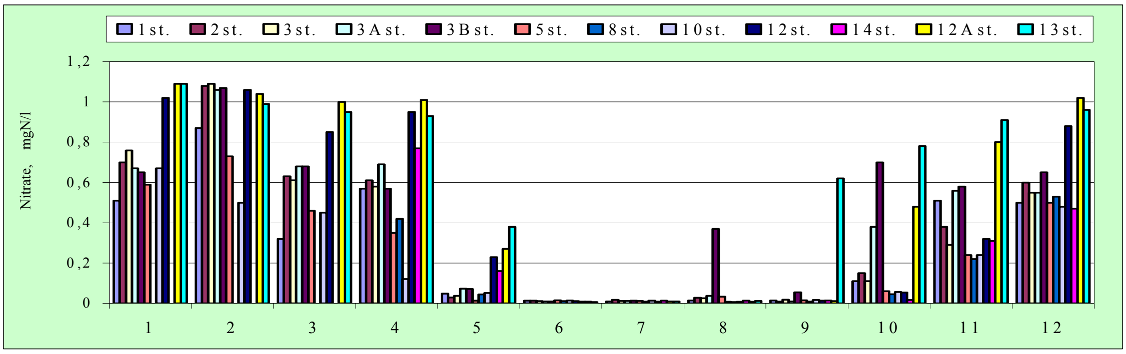


Fig. 9 The distribution of the concentration of nitrate in the Curonian Lagoon in 2003

The mean yearly concentration of nitrate in the Curonian Lagoon was decreasing till 1996, since 1998 the rising tendency has been observing. Within last 12 years the highest concentrations of nitrates (0.41 mgN/l) were observed in 2001, 2002 (Fig.10).

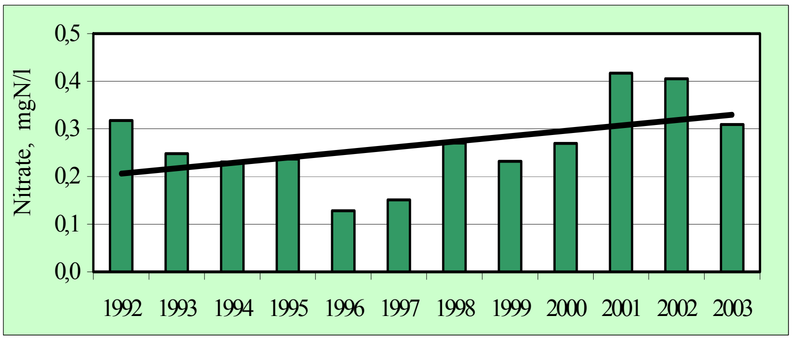


Fig. 10 The fluctuation of mean concentrations of nitrate in the Curonian Lagoon during 1992-2003 period

The long-term observations show that the concentrations of total phosphorus and phosphate are decreasing. In 2003, the mean concentration of total phosphorus in the Lagoon (0.071 mg/l) was the lowest during the last seven years (Fig. 11).

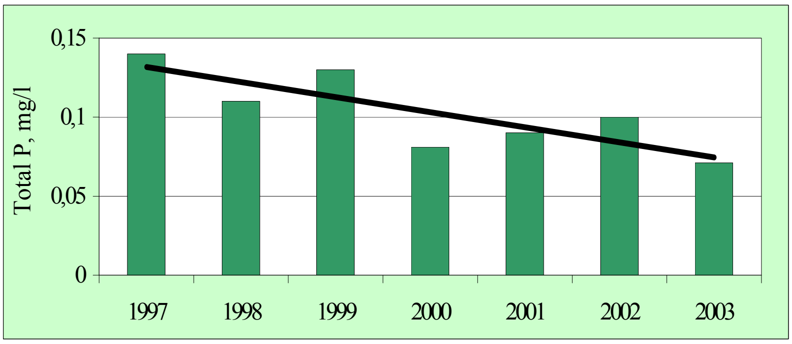


Fig. 11 The fluctuation of mean yearly concentrations of total phosphorus in the Curonian Lagoon in 1997-2003

High concentrations of total phosphorus exceeding maximum permissible concentration MPC (0.1 mg/l) are episodically found in the Nemunas delta (Atmata, St. 12A), the mouth of the river Minija (St.13), near the wastewater discharge of Klaipeda (St.3B) and in various parts of the Curonian Lagoon during the decomposition process of died water plants (Fig. 12). According to the criteria of the classification of surface water bodies, with reference to the mean concentration of total phosphorus (0.1 mg/l) during the vegetation period (01 May - 30 September) in 2003 the water quality in the Curonian Lagoon was poor.

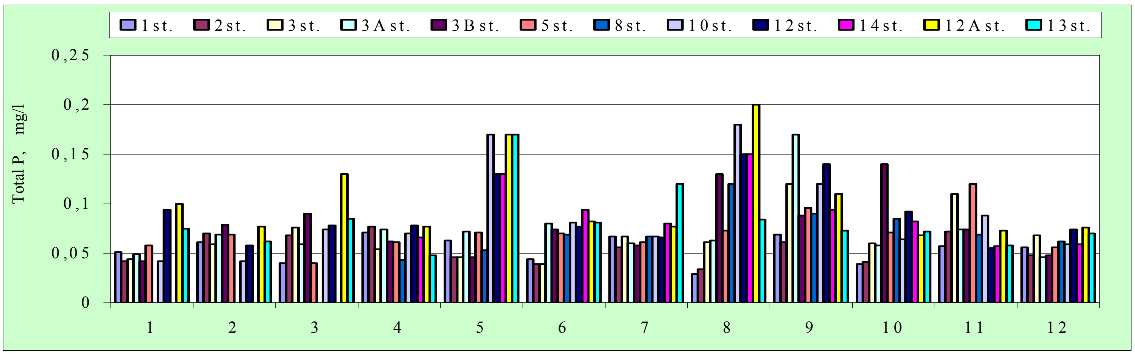


Fig. 12 The distribution of the concentrations of total phosphorus in the Curonian Lagoon in 2003

In winter mineral phosphorus dominates in the Lagoon, comprising 60 - 80% total phosphorus composition, organic phosphorus dominates during the other periods of a year.

The mean concentration of phosphate in 2003 (0.022 mgP/l) was the lowest during the last seven years. (Fig.13)

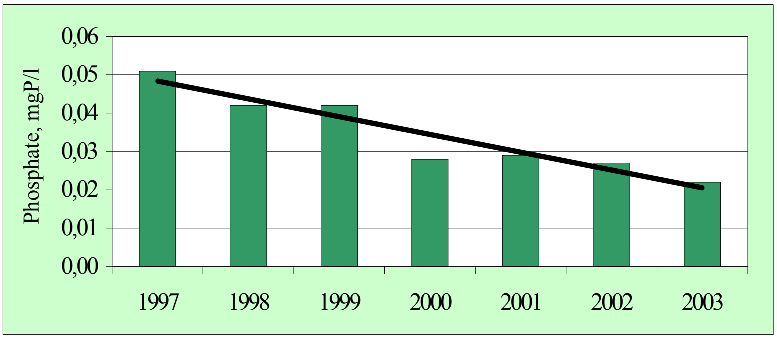


Fig. 13 The fluctuation of the mean yearly concentration of phosphate in the Curonian Lagoon in 1997-2003

In 2003 high concentrations of phosphate exceeding MPC (0.065 mgP/l) were observed in winter and early spring in the Nemunas delta (Atmata, St.12A) and in autumn near the wastewater discharge of Klaipeda (St. 3B; Fig. 14)

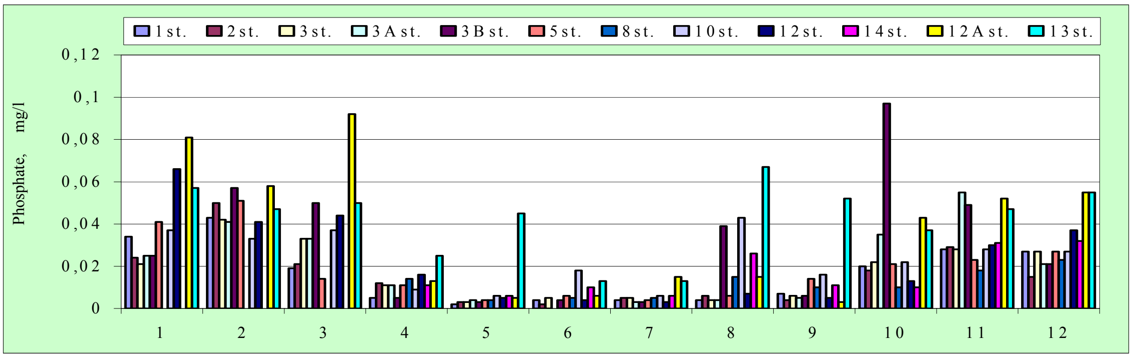


Fig. 14 The distribution of concentrations of phosphate in the Curonian lagoon in 2003

Seasonal changes of nutrients (nitrate, phosphate) concentrations in the Curonian Lagoon depend on the cycle of biological processes. During the vegetation period concentrations of nutrients significantly decrease.

3. HYDRO-BIOLOGICAL CHARACTERISTICS

The high concentration of nutrients in the Curonian Lagoon causes intensive water “bloom” - massive development of phytoplankton. The level of the water “bloom” is determined according to the Reimers scheme (Reimers, 1990) and it is divided into four levels:

- Weak - the biomass of algae fluctuates between 0.5 and 0.9 mg/l
- Moderate - 1.0 - 9.9 mg/l
- Intensive - 10.0-99.9 mg/l
- Hyperbloom - over 100.0 mg/l

The trophic level of the Curonian Lagoon waters was estimated according to the Vinberg scale (Vinberg, 1954) using chlorophyll-a concentrations and according to the Trifonova scale (Trifanova, 1990) using phytoplankton biomass (Table 1).

Table 1. Level of trophic conditions according to chlorophyll-a concentration and phytoplankton biomass.

Level of trophic status	Amount of chlorophyll-a, mg/m^3	Phytoplankton biomass, mg/l
Oligotrophic	Less than 1	Less than 1
Mesotrophic	1-10	1-5
Eutrophic	10-100	5-10
Hypertrophic	More than 100	More than 10

Water “bloom” in the Curonian Lagoon is an annual regular phenomenon. The ‘bloom’ is related with tremendous development of blue-green algae (*Cyanophyceae*) species. Algae bloom usually begins in June and lasts till November. Favourable water temperature (18-20°C) stimulates the reproduction of the blue-green algae cells and their biomass exceeds 10 mg/l. According to the Reimers’ scale it corresponds to intensive bloom. During June-September when the water warms up to 22-24°C the concentration of blue-green algae in the Lagoon reaches the hyperbloom level. The intensive-hyperbloom level of phytoplankton most often is observed till late autumn (October-November) and ends when the water temperature decreases down to 3-4°C.

The wind can drift a large amount of algae to the coastline where they intensely develop, rapidly use oxygen and emit toxins into the water. Lower layers of algae, which do not receive enough light, start to rot. The water quality worsens: the water gets unpleasant smell and it become less transparent.

Potentially toxic blue-green algae species *Aphanizomenon flos-aquae* and *Planktothrix agardhii*, with the largest biomass and abundance, cause water “bloom” in the Lagoon. Both species are the indicators of eutrophication. During the “bloom” period, the biomass of these species reaches over 90% of all the phytoplankton. Other potentially toxic blue-green algae species *Anabaena flos-aquae*, *A. lemmermannii*, *Microcystis viridis* and *M. wesenbergii* are of great importance (biomass exceeds 1 mg/l) in summer phytoplankton as well.

The lack of oxygen and the emission of poisonous products of toxic microalgae undoubtedly are some of the most important causes of fish decay in the Curonian Lagoon. In August 2002 the oxygen concentration near Nida and Preila was about 1,5-2 mg/l. Oxygen depletion resulted fish kills.

Intensive bloom is observed already for many years (Fig.15) and usually covers all the area of the Curonian Lagoon. The biomass of Cyanophyceae is lower in Klaipeda Strait (Stations 1, 2, 3, 5) due to the frequent inflow of saline water from the Baltic Sea.

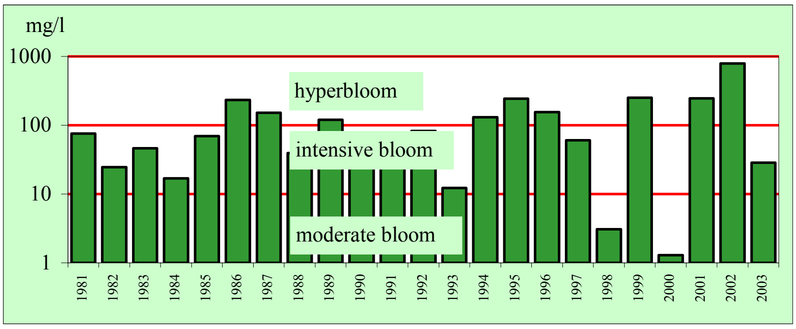


Fig.15 The long-term dynamic of the biomass and the bloom level of the potentially toxic blue-green algae *Aphanizomenon flos-aquae*

After analysing the seasonal dynamic of the phytoplankton biomass (Fig. 16, 17) and in accordance with the scale of water trophic level, the Curonian Lagoon corresponds to the status of a highly eutrophied water body: the monthly average amount of phytoplankton biomass exceeds 10 mg/l for 8 months a year. Just from December till March biomass of phytoplankton all over the Curonian Lagoon are lower, of mesotrophic level: in January-February it does not exceed 3 mg/l, December and March – 5 mg/l.

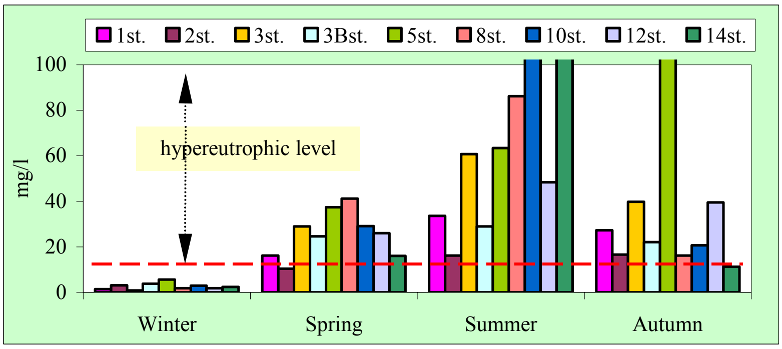


Fig. 16 Seasonal dynamic of the phytoplankton biomass in each sampling site of the Curonian Lagoon (average data for 1995-2003)

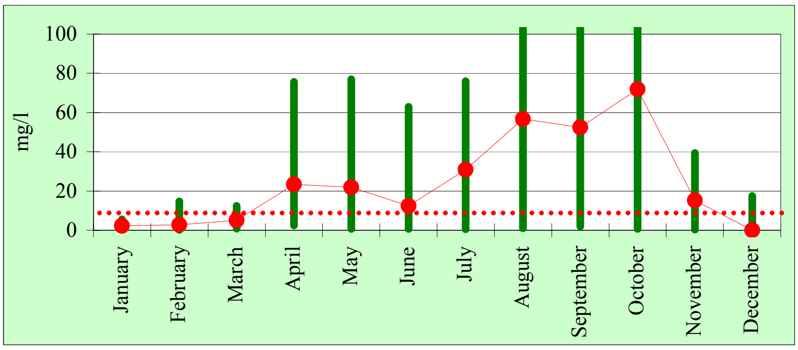


Fig. 17 Seasonal dynamic of the phytoplankton biomass in the Curonian Lagoon in 1995-2003 (red dot – average, vertical green line – detection limit)

The abundance of phytoplankton increases due to the increasing concentration of nutrients in the water of the Curonian Lagoon (Olenina, Olenin, 2002) (Fig. 18)

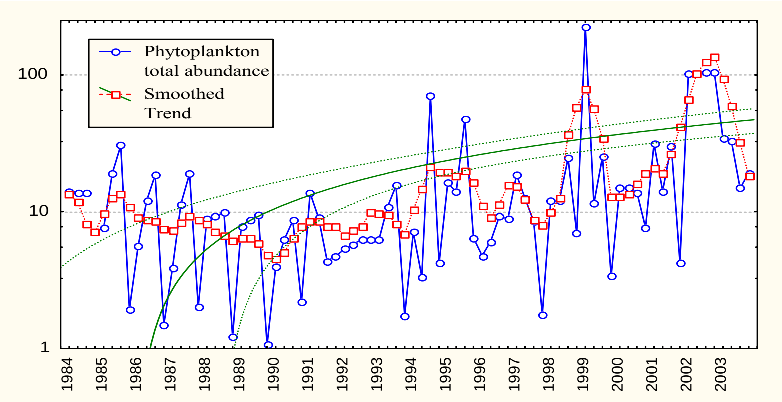


Fig 18. Trend in the total phytoplankton abundance (mln cells L^{-1}) in the central part of the Curonian Lagoon

The chlorophyll-a concentrations during a year changes from low in winter to high in summer-autumn (Fig.19). The lowest amounts usually are found in the Klaipeda Strait, when the inflow of marine water and it's mixing with the Lagoon's water is observed. In the rest part of the Lagoon higher chlorophyll-a concentrations dominates. It's mean depends on hydrometeorological conditions. A mesotrophic water level, which is often observed in winter, reaches an eutrophic level in spring and frequently hypertrophic level in summer and autumn.

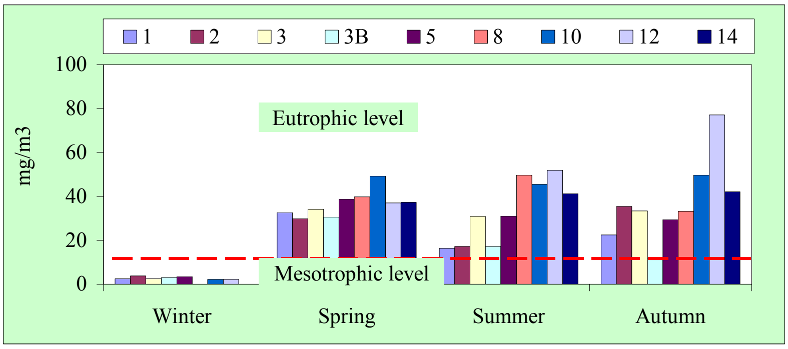


Fig. 19 Seasonal distribution of chlorophyll-a in each sampling site of the Curonian Lagoon in 2003

A significant decrease in the amount of chlorophyll-a was observed all over the Curonian Lagoon in 2003 compared to 2001 and 2002, but during the last decade the tendency of the amount of chlorophyll-a is increasing (Fig. 20).

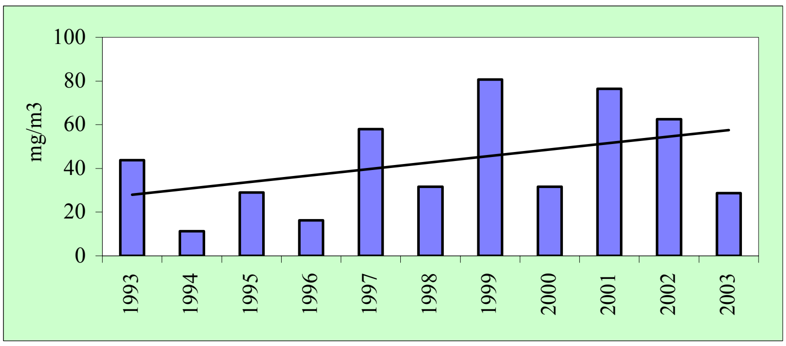


Fig. 20 Changes of chlorophyll-a amount averages (mg/m^3) during 1993-2003

CONCLUSIONS

1. The Curonian Lagoon is located on a densely populated southeastern coast of the Baltic Sea, where very intense economic activity goes on. Various ecological problems are very actual for this water body and one of the most important is the ongoing eutrophication.
2. The temperature of the Curonian Lagoon varies from 0.0^{o}C in winter to 20^{o}C and above in summer. According to data of 1992-2003, mean surface water temperature in the Curonian Lagoon is 8.53 - 9.39^{o}C.
3. According to salinity distribution the Curonian Lagoon is divided into two parts: the northern, which extends from the Klaipeda Strait to Juodkrante, and the central. During set-ups when marine water flows into the Lagoon the salinity in the Klaipeda Strait is much higher than in the central part of the Lagoon. According to the data of 1992-2003, the water salinity varies from 0.04 to 4.25 ‰.
4. The conditions of oxygen in the Curonian Lagoon are good. The lack of oxygen is observed episodically, when the water temperature is high (above + 20^{o}C) and there is large amount of planktonic algae.
5. The largest concentrations of total nitrogen in the Curonian Lagoon are often found during the cold period of a year in the mouth of the river Nemunas (Atmata, St. 12A) and Minija (St. 13), when about 60% of the total nitrogen constitutes mineral compounds (Fig. 8). According to the criteria of the classification of surface water bodies, with reference to the mean concentrations of total nitrogen (0.95 mg/l) during the vegetation period (01 May - 30 September) in 2003, the water quality in the Curonian Lagoon was moderate.
6. High concentrations of total phosphorus exceeding maximum permissible concentration MPC (0.1 mg/l) are episodically found in the Nemunas delta (Atmata, St. 12A), the mouth of the river Minija (St.13), near the wastewater discharge of Klaipeda (St.3B) and in various parts of the Curonian Lagoon during the decomposition process of died water plants (Fig. 12). According to the criteria of the classification of surface water bodies, with reference to the mean concentration of total phosphorus (0.1 mg/l) during the vegetation period (01 May - 30 September) in 2003 the water quality in the Curonian Lagoon was poor.
7. In accordance with existing long-term data and the scale of water trophic level, Curonian Lagoon corresponds to the status of a highly eutrophied water body: the monthly average amount of phytoplankton biomass exceeds 10 mg/l for 8 months a year.
8. Although Lithuania has made progress in reducing pollution from spot sources of pollution (modernized or built new water treatment facilities in big cities), natural processes are inert; therefore the ecological conditions of the Curonian Lagoon will not change significantly.

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