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The Vistula Lagoon

Current knowledge base and knowledge gaps

Fishing harbour in Piaski on the Vistula Spit (Photo: Małgorzata Bielecka)

Title
The Vistula Lagoon – Current knowledge base and knowledge gaps
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Contents

Summary

This report is a ‘snapshot’ of the current condition of the Vistula Lagoon. It consists of two major chapters. The first one describes physical conditions of the lagoon, climate, natural resources and land use patterns and the main problems related to the ecology and environmental protection. The second chapter deals with the management issues concerning socio-economic and political issues and the legal and management frameworks in the Polish and the Russian parts of the lagoon. Detailed information on administrative units, international conventions applied to the Vistula Lagoon, overview of legislative acts dealing with environmental issues in Russian system of legislation is contained in Annexes.

The main environmental problems in the lagoon area are linked to flood danger in low-lying areas, increase of salinity and salt-wedge intrusions into discharging rivers, high level of eutrophication, problem of nutrients recycling from sediment and invasion of alien species. All of them may become more severe due to climate changes in the area. The most obvious management problems are: overfishing, absence of joint monitoring program both in the Polish and the Russian parts of the lagoon, disproportionality in development of different municipalities around the lagoon and different sectorial activities. Despite existence of formal mechanisms of transboundary cooperation between Poland and Russia, there is an obvious gap in practical transboundary cooperation and cooperation between stakeholders themselves at all levels, both in the Polish and the Russian parts of the lagoon. This fact is reflected in the report where some inconsistent information related to the Polish and the Russian parts of expertise, is submitted.

Some important knowledge gaps were identified. Regarding the socio-economic segment, detailed environmental and economical assessment of construction of the passage across the Polish part of the Vistula Spit and the navigational canal running entirely in the lagoon towards the City of Elbląg, is missing. Also, there is an absence of joint assessment and harmonization of economic plans and intentions in the Polish and the Russian parts of the lagoon. Any efforts of harmonization of Polish and Russian legislation concerning coastal zone management and nature preservation (NATURA 2000) as well as advancing the development of recreational and economic activities in different parts of the lagoon shore are absent. Finally, insufficient communication and indifference was identified between communities living on the Polish part of the Spit and those living on its southern shores; they belong to different major administrative units and find little common interest in joint efforts.

1. Introduction

The Vistula Lagoon is located in the South Baltic and is the second largest lagoon in this area after the Curonian Lagoon (Fig. 1.1). The lagoon is separated from the Gulf of Gdansk by the Vistula Spit and its extension on the Russian side called the Baltiyskaya Kosa.

As it is shared by Poland and Russia the lagoon has two different names: On the official political and navigational maps, the Polish part is called Vistula Lagoon (Zalew Wiślany) and the Russian part is called Kaliningrad Lagoon (Kaliningradskij Zaliv). These names are official and obligatory according to international conventions (http://www.kulinski.zagle.pl/zw/02_zalew_wislany_charakterystyka_akwenu.htm).

Anyhow, among scientists the names Vistula Lagoon and Vistula Spit are used for the whole lagoon. This decision was introduced in a fundamental monograph written in the 1970s by Polish and Russian scientists, and published in Polish (Lazarenko, Majewski, 1975) and Russian languages (Lazarenko, Maevski, 1971) with only slightly different content. In this report we will therefore only refer to Vistula Lagoon and Vistula Spit, as these names are already widely used in English literature. In exceptional cases we will add the Polish or Russian names in brackets to make some specific clarifications.

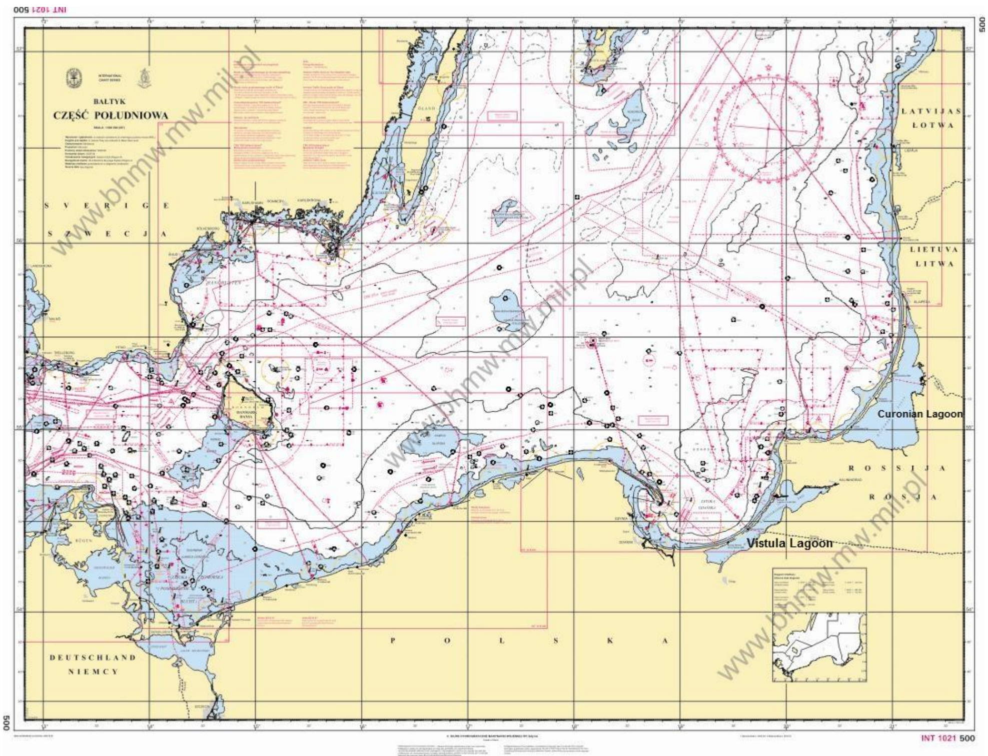


Figure 1.1. Map of South Baltic. Source: http://bhmw.mw.mil.pl/mapy2.php

The lagoon has one connection with the Gulf of Gdansk which is located in the Russian part of the lagoon and that is called the Rinna Baltiyskaya (in Polish) or Kaliningradskij Morskoy Canal (in Russian) or Kaliningrad Marine Canal (will be further use, in English) (http://www.kulinski.zagle.pl/zw/02_zalew_wislany_charakterystyka_akwenu.htm). In the scientific literature this inlet is called the Baltiysk Strait, and it is a passage for marine waters to enter the lagoon and for the lagoon's waters to discharge into the Baltic Sea.

Geologically speaking, the Vistula Lagoon started to form around 7 500 years ago (Lazarenko, Majewski, 1975) by a slow process of separating coastal shoals with sandy dunes. Until the 16th century the Vistula Lagoon was under the influence of freshwater discharging from the Vistula River. The Nogat River, the eastern branch of the Vistula River delta (Fig. 1.2), took over 86% of the water of the Vistula River at that time.

Figure 1.2. The Vistula River delta during 1300 (approximately). Source:
http://www.kulinski.zagle.pl/zw/02_zalew_wislany_charakterystyka_akwenu.htm

The intensive inflow of freshwater was accompanied by the accumulation of significant amounts of sediment, which led to a shallowing of the lagoon. Since the 16th century regulation of Vistula River and Nogat River started. In 1610, the first control structure was built in the Nogat River reducing its discharge to 75% of the Vistula River discharge. In 1848, a weir was constructed in Piekło resulting in a distribution of the water between the Vistula and Nogat Rivers of 4:1 (25%). After a series of serious floods in Żuławy (the lowland west of the lagoon), the decision was taken to construct an artificial Vistula River outlet in Świbno. The investment was realized during the period from 1890 to 1895. In 1900 the inflow from the Vistula River to the Nogat River was cut-off by the Białogóra lock. The Nogat River was regulated with three weirs and, presently, it takes only 3% of water from the Vistula River. Since this cut-off, the Vistula Lagoon started to change its character from a mainly freshwater basin into a brackish water coastal lagoon. This resulted in significant changes in the lagoon's aquatic ecosystem. With respect to salinity, the lagoon is considered a transitional water area.

2. The Physiogeographical Story

2.1 Physical conditions of the lagoon and the drainage basin

The Vistula Lagoon (Fig. 2.1.1) is one of the largest inner marine water basins in Europe and is the second largest after Curonian Lagoon in the Baltic Sea. It covers an area of 838 km^2 and has a drainage basin of 23,870 km^2.

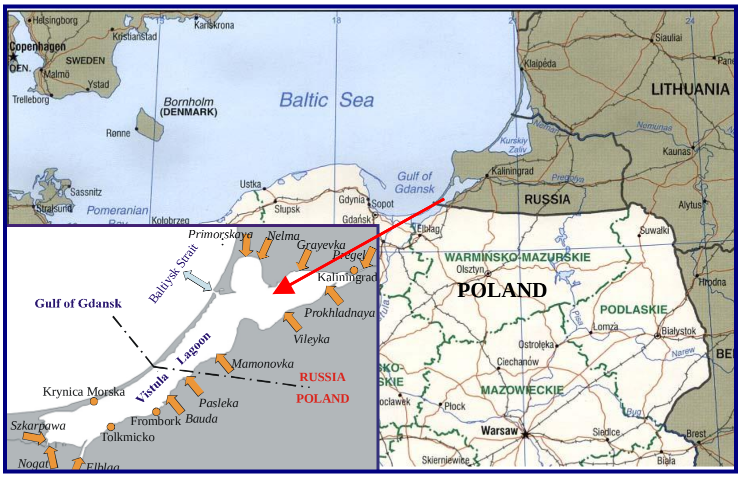


Figure 2.1.1 Location of the Vistula Lagoon and the main discharging rivers.

It is shared between one EU-state (Poland) and one non-EU state (Russia) with 473 km^2 belonging to Russia and the remaining part to Poland. It has a single inlet, the Baltiysk Strait, located in the Russian part of the lagoon. The lagoon has an elongated shape running from south-west to north-east and a total length of 91 km. The average width of the lagoon is about 9 km; the widest point measures 13 km. The lagoon's coastline is about 270 km long, and the volume of water is about 2.3 km^3. It is a shallow coastal ecosystem. The average depth of the lagoon is 2.7 m, and the maximum natural depth is 5.2 m close to the Baltiysk Strait (Fig. 2.1.2).

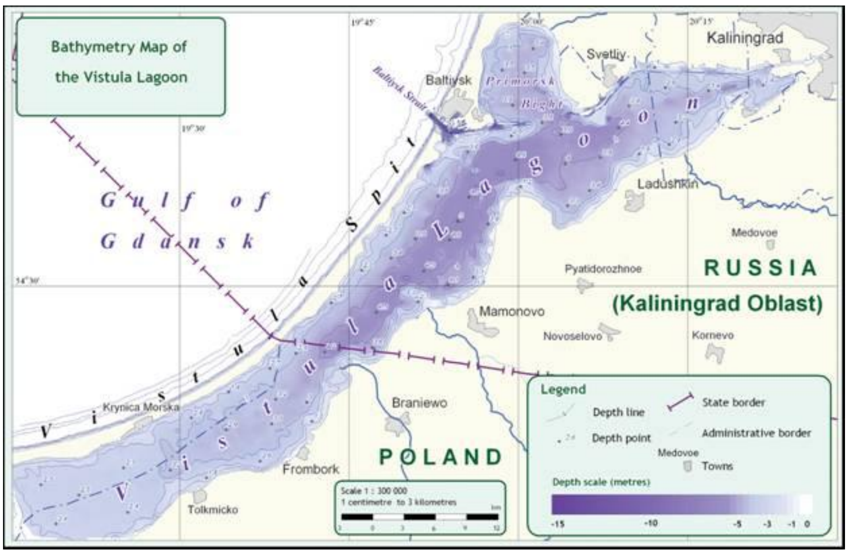


Figure 2.1.2. Bathymetry map of the Vistula Lagoon. (Chubarenko, 2008)

Vistula Lagoon is separated from the Baltic Sea by the Vistula Spit - a sandy, 55 km long peninsula (Fig. 2.1.3). The Spit dunes are mainly covered with pine and mixed forests which have been planted to reinforce the dunes, and to protect the Spit's infrastructure from the prevailing winds blowing in from the Gulf of Gdansk.

Figure 2.1.3. The Vistula Spit – Krynica Morska. Source: http://www.zalew.org.pl/album2.phtml.

The Lagoon exchanges water with the Gulf of Gdansk through the Baltiysk Strait, which has a width of approximately 400 m, a length of two kilometres and an average depth of 8.8 m.

A navigation canal leads from the Baltiysk Strait up to the harbour of Kaliningrad; this canal is twice as deep as the largest natural depression in the lagoon. Despite its relative narrowness, the canal plays an important role in transporting sea water from the Baltic Sea to the lagoon.

2.1.1 Salinity

With respect to salinity the Vistula Lagoon is considered a transitional area. Average salinity (1950 - 1965) for the eastern part of the lagoon (spring-autumn) is 2.5-4.3 PSU, for the central part 3.9-5.0 PSU, and for the southern part 1.0-3.4 PSU. This is a result of salt water inflows from the Baltic Sea that influence all aquatic areas of the lagoon, including the mouth of the Pregola River, the largest river in the catchment. At the Baltiysk Strait salinity may reach up to 7 PSU.

Hydrological regimes of the Vistula Lagoon have changed dramatically in the beginning of 19th century. Before 1916, the Nogat only brought up to 2200 m3/sec of water to the Vistula Lagoon during spring freshet. The sediments flux was up to 0.3-0.4 millions of m3. The Nogat delta increased by 15 hectares per year. Marine water intrusions were very seldom and not intensive. In 1916 the discharge of the Nogat River was regulated and today it equals to 25 m^3/s in average. After the lagoon became marine water dominated, salinity has increased till today's values [Lasarenko, Maevski, 1971].

Seasonal salinity changes are caused by variations in balance between marine and river drain influences. The minimum salinity in the lagoon (0.5–4.5 psu) is in the late spring after the maximum of the river runoff occurs (March and April). Then, from May till August, salinity increases to 3.5–6.5 psu, the river runoff is very low and the marine influence prevails. In autumn, smooth desalinization starts, and finally, in winter, the ratio between the fresh and salt water in-fluxes stabilizes during ice coverage and the lagoon comes to equilibrium between salting and refreshing processes [Chubarenko I., et al., 2004]. During the winter the significant amount of salt comes from the developed ice into the water column, mixes it totally, and may cause an increase of the lagoon water salinity by 10–25 percent [Chubarenko B., et al., 2005].

The canal and deep lower segment of the Pregola River (from its mouth towards the centre of Kaliningrad City) form an estuary part of the river, where permanent mixing of marine waters and river fresh waters occurs. The mixing zone seasonally migrates 10−20 km distance both upstream and downstream, as well as becomes longer or shorter. In winter and the early spring the mixing zone shrinks up to 3−5 km in length along the river and is localized in the Kaliningrad harbour. At this time characteristic values of the vertical and horizontal gradients are ca. 0.3−0.35 psu per m and per km respectively. Spring increasing of the river runoff spreads the gradient up to 10−25 km in length along the river and pushes the mixing zone towards the inlet (Fig. 2.1.4). The centre of the zone is 10−20 km from the river mouth, the horizontal and vertical gradients are of ca. 0.05−0.15 psu per m and per km. In the beginning of summer the river runoff significantly decreases, and any water level rise near the inlet immediately induces the salt water near-bottom intrusion upstream the canal (Fig. 2.1.5). As a result, a salt-wedge with maximum salinity of 4.5−5 psu reaches the Pregola River mouth, but upper water layer remains fresh. Vertical gradients increase up to 0.5 psu per m. Autumn winds and active mixing of both water in the lagoon, and between the lagoon and the canal, destroy vertical gradients in the canal, and the mixing zone finally is kept in the harbour area (Fig. 2.1.6) [Chubarenko B., 2008].

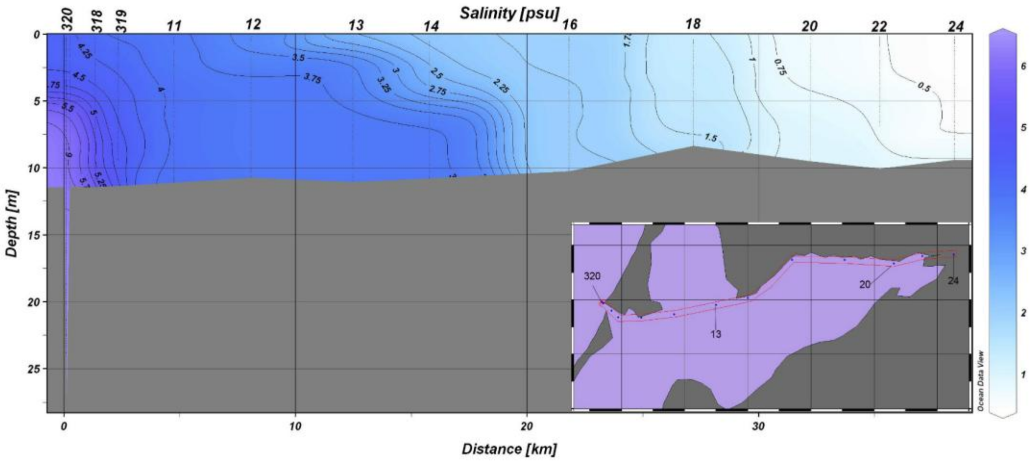


Figure 2.1.4 Vertical structure of salinity distribution along the Kaliningrad Marine Canal (spring situation). Location of the canal is marked in pink on the schematic chart of the northern (Russian) part of the Vistula Lagoon. (Pilipchuk, Chubarenko, 2012)

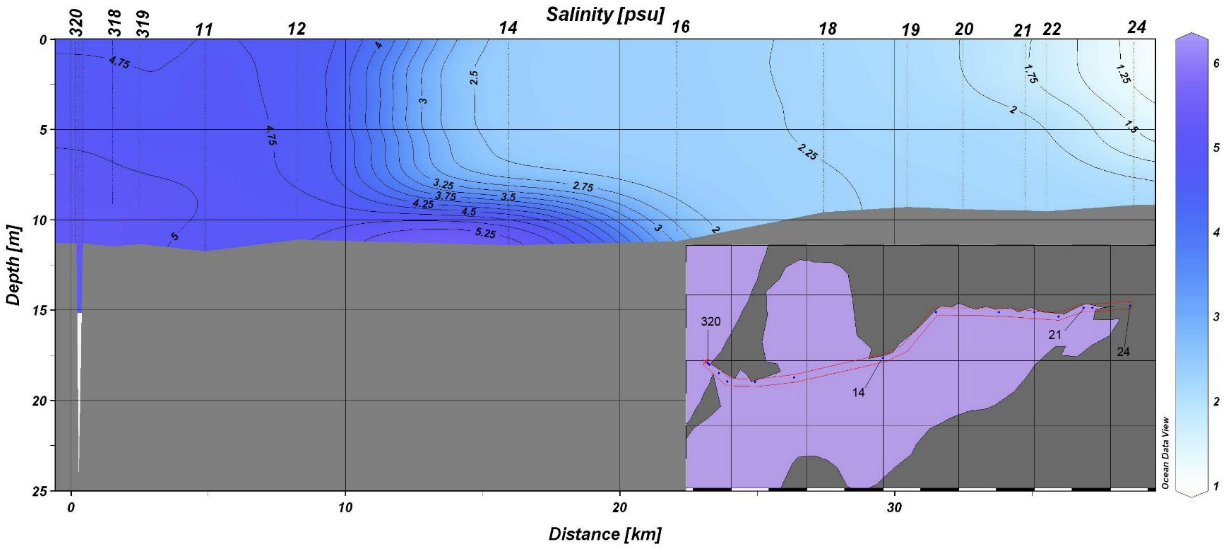


Figure 2.1.5 Vertical structure of salinity distribution along the Kaliningrad Marine Canal (summer situation). Location of the canal is marked in pink on the schematic chart of the northern (Russian) part of the Vistula Lagoon. (Pilipchuk, Chubarenko, 2012)

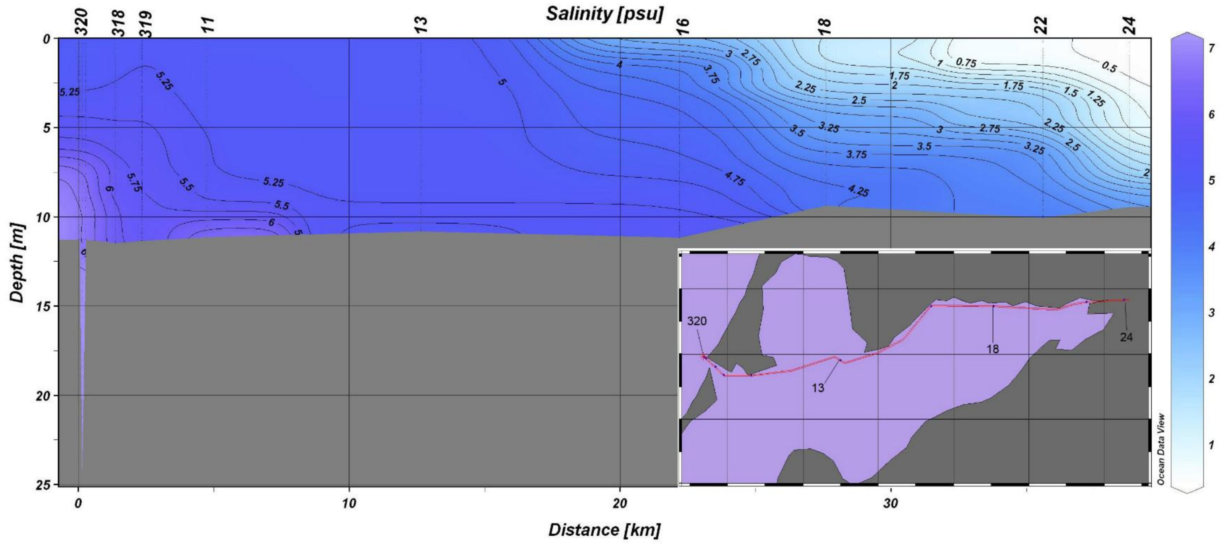


Figure 2.1.6. Vertical structure of salinity distribution along the Kaliningrad Marine Canal (autumn situation). Location of the canal is marked in pink on the schematic chart of the northern (Russian) part of the Vistula Lagoon (Pilipchuk, Chubarenko, 2012)

The process of water exchange follows by plumes of the lagoon waters in the adjacent marine coastal area. Satellite images allow making formmetric estimations of discharged plums (Fig. 2.1.7).

Figure 2.1.7. Plume of lagoon waters in the off-shore area near the Baltiysk Strait (04.09.2009) by Landsat 5TM. (http://www.usgs.gov/)

2.1.2 Surface temperature in the Vistula Lagoon

The thermal regime of Baltic Sea waters has changed through the last hundred years [Assessment..2008, Meier H.E.M. 2006; Siegel, Gerth, Tschersich, 2006; Stigebrandt, Gustafsson 2003]. Identified trends of sea surface temperature (SST) are consistent with regional climate changes and are expected to continue into the future. Scientists predict a further warming of the climate over the Baltic Sea, but indicate a regional diversity in this respect [Meier H.E.M., 2006, Siegel, Gerth, Tschersich, 2006]. The local hydro-meteorological conditions are the major factor of regime shift for the areas of Curonian and Vistula lagoons [Chubarenko, Chubarenko 2002].

The southern part of the Baltic Sea is characterized by general principles of the long-term changing of the annual mean SST. The SST increase of 0.3 °C is observed in the South-Eastern Baltic in the last decade [Siegel, Gerth, Tschersich, 2006].

SST *in-situ* measurements for the period 1997-2007 carried out by Atlantic Branch of P.P.Shirshov Institute of Oceanology in the area of Kosa Village (Baltiysk City), located on the Vistula Spit ending close to the Baltic Strait, present a positive trend in the annual mean SST with an increase of 0.17 °C [Stont, Chubarenko, Goushchin, 2010].

Satellite data of ocean colour scanner MODIS (on Aqua and Terra satellites) with a spatial resolution of 1×1 km have been widely used for climatological investigations. SST, derived from MODIS data for the period 2003-2011, was used for the analysis of thermal regime changes in Vistula Lagoon and identifying of potential trends. The area of investigation shown in Fig. 2.1.8 includes a transect consisting of 5 points through the central part of the lagoon.

A positive linear trend of SST with an increase of 0.01-0.02 °C per year occurred in the lagoon (Tab. 2.1.1).

The transect satellite data also show that SST has increased by 0.06–0.14 °C for the period of investigation. A minimum increase of SST occurred at the 5-th point that is located in the north-eastern part of the lagoon (ship-canal, Pregola River mouth). However, the positive trend of SST in the lagoon is weaker than the trend which is observed in the south-eastern part of the Baltic Sea and means the increase of 0.2-0.3 °C/period.

According to the results of (Jurgelėnaitė, Kriaučiūnienė, Šarauskienė, 2012) for the period 1991-2010 the increase of SST and air temperature in the area of Curonian lagoon rivers is 0.04 and 0.06 °C/warm period, respectively. Thus, air temperature is one of the most significant factors affecting SST. SST trends in Vistula lagoon include the cold period, what could be a reason for a lower rate of surface warming.

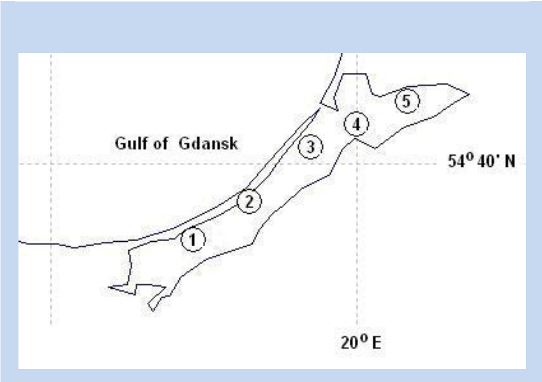


Figure 2.1.8. Locations of points of satellite monitoring in the Vistula Lagoon (Bukanova, Stont, personal communications, 2012)

Table 2.1.1. Average surface temperature (SST), their linear trends and increase (according to the trends) in the Vistula Lagoon by data MODIS from 2003 to 2011.

Measurement point	***Average ±σ***	***Trend***		***Increase, °C/period***	***t-student/N****
		°C/day	***°C/year***		
P. 1	12.97±6.69	0.00029	0.02	0.14	0.926/482
P. 2	13.04±6.60	0.00021	0.01	0.10	0.678/490
P. 3	12.73±6.82	0.00014	0.01	0.07	1.149/561
P. 4	12.59±6.81	0.00026	0.01	0.13	0.798/500
P. 5	12.75±6.87	0.00013	0.007	0.06	0.746/489
Average	12.82	0.00021	0.011	0.10	
±σ	0.18	7.09E-05	0.010	0.084	

* N – number of measurements

Table 2.1.2. Average surface temperature (SST), their linear trends and increase (according to the trends) on seasons in the Vistula Lagoon by data MODIS from 2003 to 2011.

Measurement point	***Increase, °C/period***			
	Winter	***Spring***	***Summer***	***Autumn***
P. 1	-0.001	0.08	0.15	-0.07
P. 2	0.002	0.09	0.06	-0.08
P. 3	-0.01	0.09	0.12	-0.04
P. 4	-0.003	0.12	0.12	0.01
P. 5	-0.004	0.12	0.06	-0.04
Average	-0.003	0.096	0.11	-0.044
±σ	0.004	0.025	0.040	0.035

During the investigation period (2003-2011) an average increase of SST in the Vistula Lagoon is 0.011 ± 0.010 °C per year (Tab. 2.3.4). A maximum increase occurs in warm periods: spring - 0.10 °C/period, and summer - 0.11 °C/period (Tab. 2.1.2). Winter time is characterized by slightly negative trend 0 °C (-0.003 °C/period). A maximum negative trend occurs in autumn: - 0.044 °C/period. A negative trend of the winter and autumn periods is 2.5 times lower than positive trends in the spring and summer months.

Thus, the investigation period is characterized by a positive trend in the annual mean SST of the Baltic Sea, with an increase of 0.1 °C in 9 years. Summer and spring dominate this positive trend. The winter and autumn periods show a negative trend. Evidently, the SST positive trend will keep growing in the future, generally due to the increase of maximum temperatures of water and air, and a consequent warming of the surface water layer in the summer period, and declining of warming rates in the cold period.

2.1.3 Water level rise

Observations clearly show a constant increase of average annual levels in the Russian sector of the Vistula Lagoon, with a rate of 1.7 mm/year (Baltiysk, 1840-2006), 1.9 mm/year (Kaliningrad1901-2006) (Navrotskaya, Chubarenko 2012 a) . A speed up of the water level increase was noticed in the second part of 20th century (1950-2006, 1959-2006, 1961–2003, 1975-2006, 1980–2005) up to 2.2–4.5 mm/year, especially after 1975 (Table 2.1.3, 2.1.4, Fig. 2.1.9, 2.1.10). The highest rate of the level increase was observed after 1993, more than 10 mm/year. These changes correspond to long-term level increase of the Global Ocean, with a rate of 1.7-1.8 mm/year in the previous century, and a speed up to 3.1 mm/year in the end of that century and the beginning of the next one (Climate Change 2007; Malinin et al. 2010).

Table 2.1.3. Rate of sea level rise for World Ocean, and locations around the Vistula Lagoon (Navrotskaya, Chubarenko 2012 b*)*

Lagoon	Measurement point	Trend of level rise, mm/year			
		1901-2000	1961-2003	1980-2005	1993-2003
World Ocean		**1.7-1.8**	**1.8**	**1.8**	**3.1**
Vistula Lagoon	Baltiysk	1.8	3.2	3.9	11.7
	Kaliningrad	1.7	3.1	2.7	9.6
	Krasnoflotskoye	-	3.5	2.2	3.5

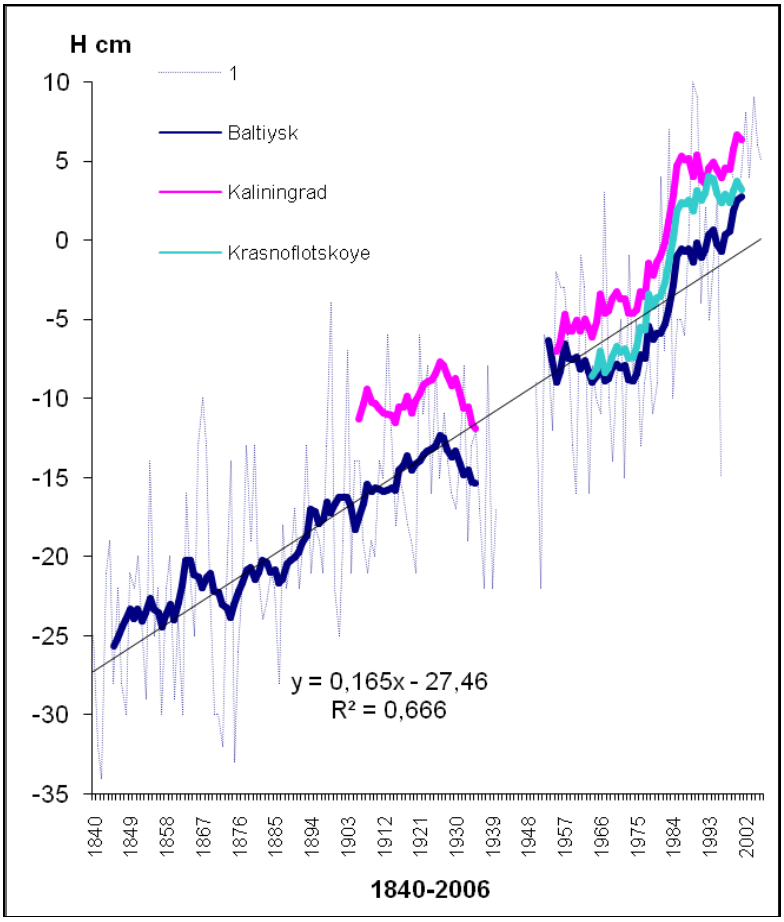


Figure 2.1.9. Average annual sea level (smoothed by 11-year running average) at the points of the Vistula Lagoon (Baltiysk, from 1840; Kaliningrad, from 1901; Krasnoflotskoye, from 1959) for the period of 1840-2006. The yearly data are presented by thin line (1) for illustration of year-to-year variations for Baltiysk (trend is of 1.65 mm/year). (Navrotskaya, Chubarenko 2012 b*)*

The positive linear trend of the average annual level changes in 1959-2006 (3.6-3.7 mm/year) is a result of an increase of minimal levels (3.9-5.0 mm/year), fluctuations of which are connected with general tendencies of level growth due to the climate changes of hydrological factors forming the climate (Table 2.1.3). But the maximal levels mostly reflect tendencies in wind regimes 0.4-3.2

mm/year). The archived results illustrate a response of level change in the lagoon on the global climate warming and regional changes in climate forming factors, which provide wind and rainfall regimes in water collecting basin.

In the second half of 20th century the mean long annual sea level rise (1959-2006) in Kaliningrad was about 3-5 cm, and in Krasnoflotskoye it was about 1-2 cm over that in Baltiysk (Fig. 2.1.9, Table 2.1.4). The slope of the water surface in the lagoon from north-east coast (Kaliningrad and Krasnoflotskoye) in the direction of Baltic Strait is the result of the most frequent active western winds (set-up winds is the most in the mouth of the Pregola River, Kaliningrad) (Navrotskaya, Chubarenko 2011).

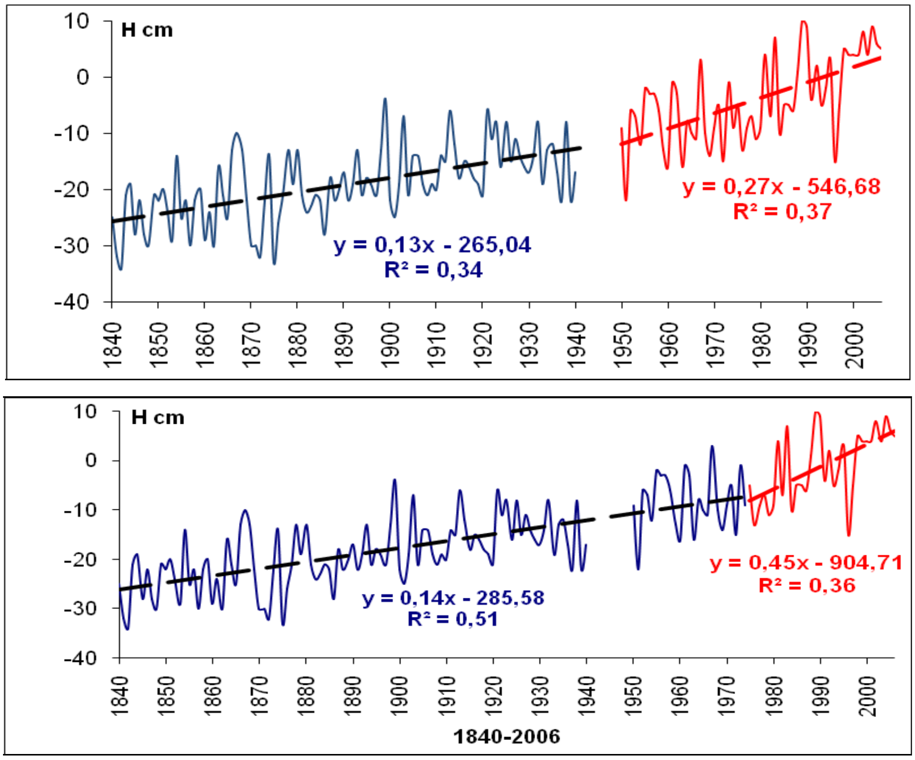


Figure 2.1.10. Mean annual sea level changes (and its trends) measured at Baltiysk: blue solid line – sea level changes in the period 1840-1940 (1.3 mm/year) and 1840-1974 (1.4 mm/year); red solid line - sea level changes in the period 1950-2006 (2.7 mm/year) and 1975-2006 (4.5 mm/year). (Chubarenko et al. 2012)

Table 2.1.4. Linear trends and increase due to trends for annual average, maximal and minimal sea levels at the points of the Vistula Lagoon for periods of 1959-2006. (Navrotskaya, Chubarenko 2012a)

Measurement point	Mean long annual level, cm	Mean annual level		Maximum level		Minimum level		Annual amplitude	
		Trend, mm/ year	Increase, cm/pe-riod	Trend, mm/ year	Increase, cm/pe-riod	Trend, mm/ year	Increase, cm/pe-riod	Trend, mm/ year	Increase, cm/pe-riod
Kaliningrad	1	3,7	17,4	3,2	15,0	4,3	20,2	-1,8	-8,5
Krasnoflotskoye	-2	3,6	16,9	0,4	1,9	3,9	18,3	-3,5	-16,4
Baltiysk	-4	3,6	16,9	2,2	10,3	5,0	23,5	-2,7	-12,7

Interannual variations of average sea level occur with high correlation (0.96) for the stations located on the Vistula Lagoon, but extreme values are not reached simultaneously: coefficients correlation 0.74-0.84 (minimal level) and 0,44-0,75 (maximal level). (Navrotskaya, Chubarenko 2012 a). That means, that the lagoon can be considered to be a homogeneous one from the general tendencies of interannual changing point of view, but significantly inhomogeneous for realization of extreme conditions.
Water level increase in the lagoons and intensification of that increase during the last years makes obvious the necessity to develop measures for adaptation to local consequences of climate changes for onshore zone of the Kaliningrad region - Russian territory in that part of the Baltic Sea.

2.1.4 Drainage basin

The catchment area of the Vistula Lagoon amounts to 23,871 km^2 and the average retention time of water inside the lagoon, due to the river drain, is about 6-7 months.

Water balance of the lagoon is presented in Tab. 2.1.5.

Table 2.1.5. Water balance of the Vistula Lagoon (1951-1965, [km^3], [%]), (Silicz, 1975)

	Ingoing (km^3)	%
Water from the rivers	3.62	17.1
Marine inflow	17.00	80.2
Atm. precipitation	0.50	2.4
Ground water	0.07	0.3
Total	**21.19**	**100.0**
	Outgoing (km^3)	%
Flowing to the sea	20.48	96.9
Evaporation	0.65	3.1
Total	**21.13**	**100.0**

The main inflow (80%) is coming through the Baltiysk Strait as marine waters. The total volume of marine water inflowing to the lagoon during 24 hours is estimated as 23 million cubic meters, which makes about 1% of the total water body of the lagoon (Chubarenko B.V. & Chubarenko I.P., 1998). 17% of the inflow is coming from the catchment.

Atmospheric precipitation and underground discharge make up about 3% and are almost equal to the part of the balance originating from the evaporation. Thus, the major contributor to the water balance of the Vistula Lagoon is the water exchange through the Baltiysk Strait. The second contributor is the river runoff. There are more than 20 rivers discharging directly into the Vistula Lagoon. Among them the most important ones are Pregola, Elbląg, Pasłęka, Nogat, Prokhladnaya, Mamonovka, Bauda, Primorskaya and Szkarpawa (Fig. 2.1.1). The main part of the annual fresh water inflow (41%) is coming from the Pregola River (Tab. 2.1.6).

Table 2.1.6. Characteristics of the rivers discharging to the Vistula Lagoon

River	Length in km	Catchment area in km^2	Mean discharge in mln m^3/year (Kruk, 2011)	Mean discharge in m^3/ (Kruk, 2011)	Mean discharge in m^3/s for years 1998-2000
Pregola	123	15 500	2728	87	58
Elbląg	18	No data	826	26	31
Pasłęka	211	2 295	528	17	21
Nogat	62	1 330	224	7	16
Prokhladnaya	65	No data	161	5	11
Mamonovka	35	215	109	3	6
Bauda	54	340	85	3	3
Primorskaya	No data	No data	80	3	No data
Szkarpawa	25	780	74	2	No data

Formation of the Vistula Lagoon watershed occurs in Poland and in the Kaliningrad Oblast of Russia. The main river of the lagoon is the Pregola River. Its catchment area is 13.7 ths. km^2. The lower part of the Pregola catchment (49%) is located in the Kaliningrad Oblast and the upper part of the watershed (51%) – in Poland (Domnin, Chubarenko, 2007). The figures for the catchments area are different according to different literature sources (for example, Lasarenko, Mayevski, 1971; Domnin, Chubarenko, 2007). This is a result of different methods applied for estimation of the catchment areas. It is essential to make the joint Polish-Russian study on these issues using modern approaches of remote sensing techniques and GIS analysis which considerably advanced during the last years.

All main tributaries of Pregola River (Lava/Lyna, Angrapa/Wangorapa, Pissa) begin in Poland within the Warmia and Vyshtynetskaya uplands. A small part of the catchment (about 60 km^2) is located in Lithuania around Vishtynets Lake (Figures 2.1.11). Other rivers discharging waters into the Vistula Lagoon are: rivers of the Polish side are Pasłęka (catchment area is 2.4 ths. km^2), Nogat (4 ths. km^2) and rivers of the Russian side are Prokhladnaya (1.1 ths. km^2), Mamonovka (0.3 ths. km^2), Nelma (0.2 ths. km^2), Primorskaya (0.1 ths. km^2). The total area of the Vistula Lagoon watershed is 22.5 ths. km^2.

In general, the drainage network is formed in the south and east of the catchment, where the altitude marks are 150-300 m above the sea level, and water flows have northern and western directions (Figures 2.1.12). The analysis of watershed structure in a transboundary context is given in the Figure 2.1.13 (Chubarenko, 2008).

The Pregola River drainage basin brings about 1.53 km^3 of water per year to the Vistula Lagoon (it is 44 percents of the full discharge), all other rivers contribute 1.96 km^3 of water per year to lagoon (56 percents) (Silich, 1971).

The mainstream of the Pregola River divides into two branches in Gvardeysk (56 km upstream the mouth). The first branch, the Pregola River, brings 60 percents of water to the Vistula Lagoon, and the second stream, Deyma River, draws about 40 percents of the water volume to the Curonian Lagoon (Markova, 1999). Mean discharge of the Pregola is 86 m^3 per second (or 2.7 km3 per year) (Figure 2.2.5). Measurement discharges of other rivers are Primorskaya – 0.9 m^3 per second, Nelma – 1.7 m3 per second, Mamonovka – 4.3 m^3 per second, Pasłęka – 14 m^3 per second.

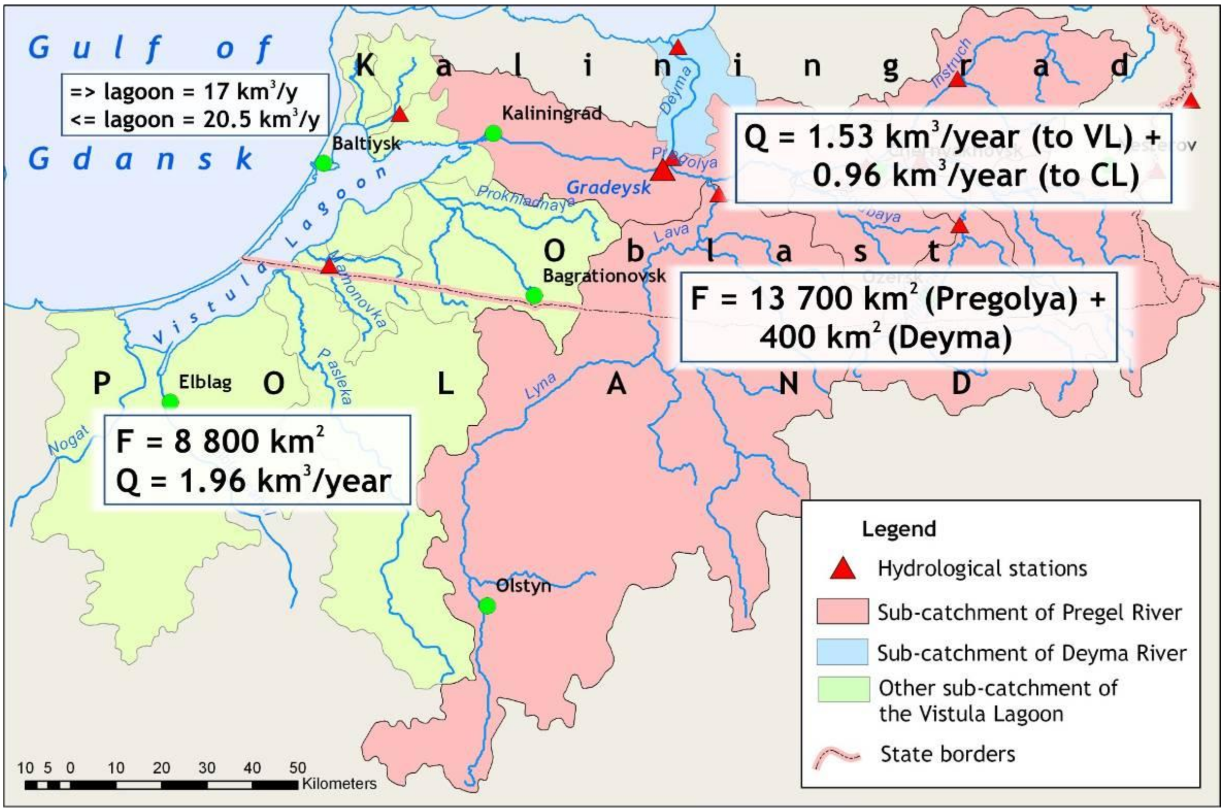


Figure 2.1.11. The Vistula Lagoon river catchment. (Map is compiled by D. Domnin using GIS tool on the basis of Polish and Russian sources of data about river catchments) (Domnin, 2011)

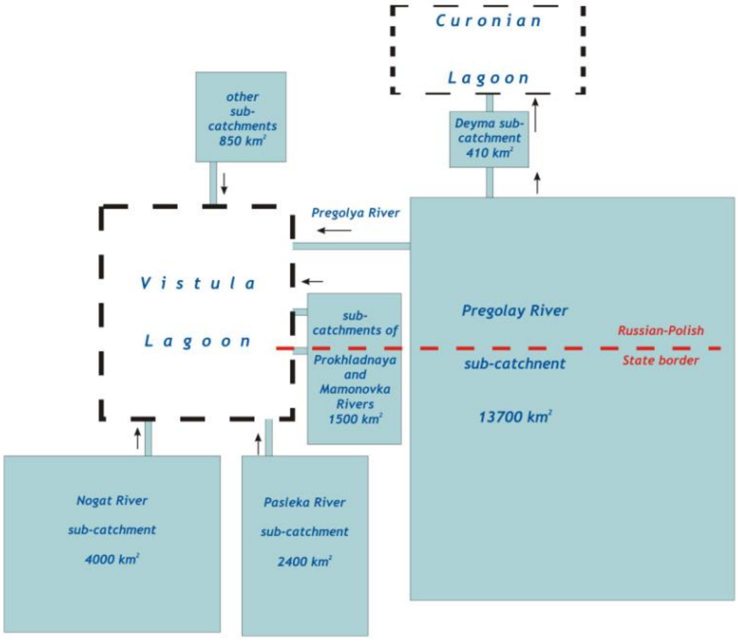


Figure 2.1.12. Principal structure of the Vistula Lagoon catchment (Domnin, 2011)

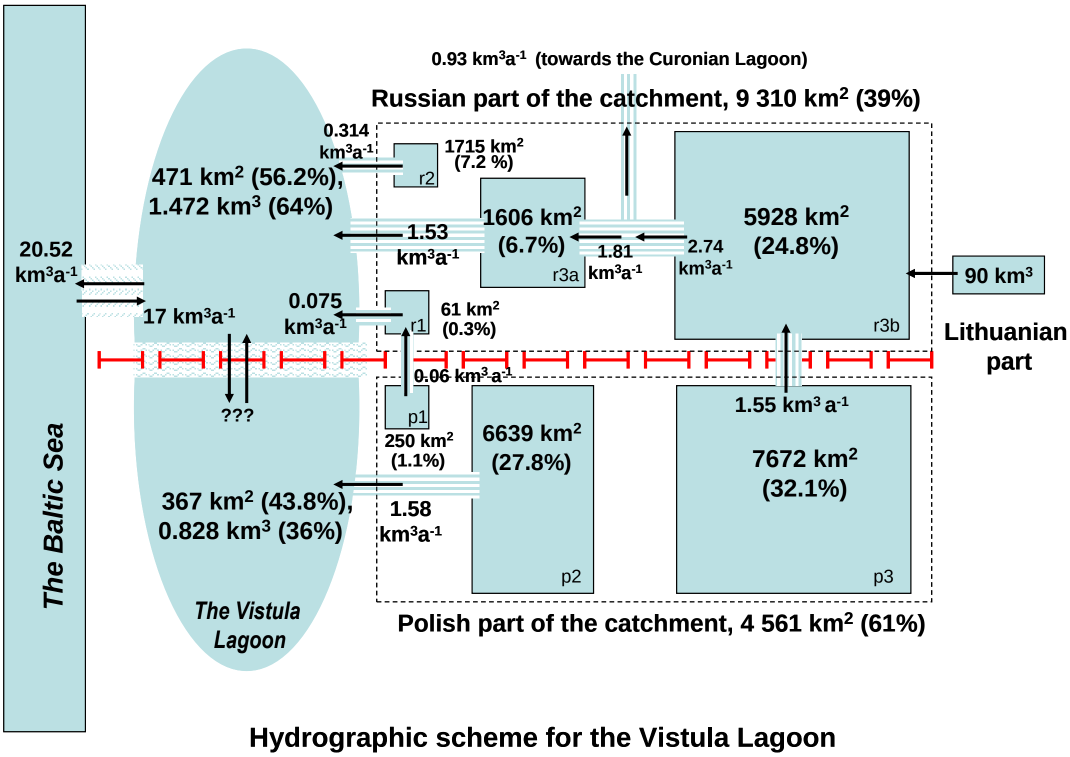


Figure 2.1.13. Principal hydrographic scheme of the Vistula Lagoon catchment. The red line symbolizes the state border which divides Polish (southern) and Kaliningrad (northern) parts of the Vistula Lagoon and its catchment. Each national sub-catchment consists of pure national (e.g., p2 and r2) or transboundary watersheds (e.g., p1-r1, p3-r3 – the Pregola River). The Vistula Lagoon comprises two national parts and has one inlet connecting the lagoon with the Baltic Sea (Chubarenko, 2008).

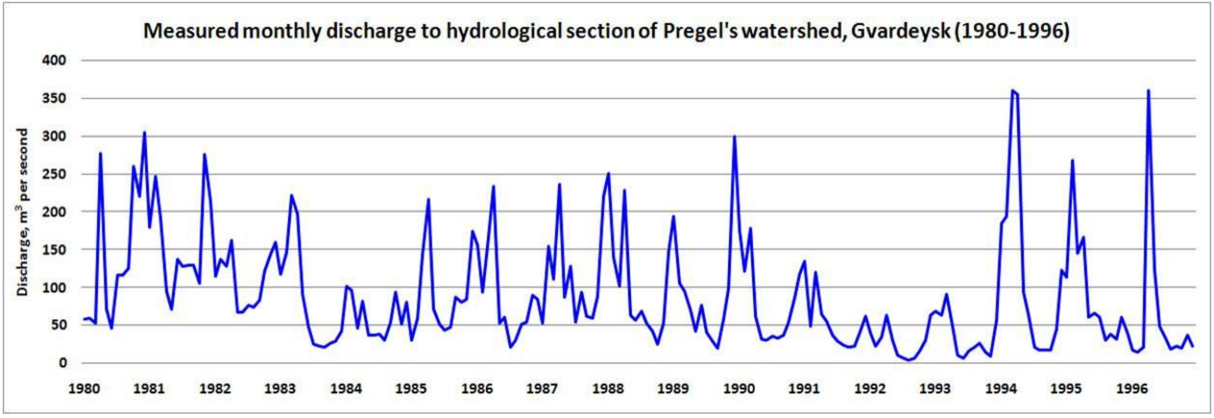


Figure 2.1.14. Monthly average river discharge measured at hydrological section Gvardeysk (the Pregola River watershed) for 1980-1996. (Domnin, 2011)

2.1.5 Ice cover

Usually, the Vistula Lagoon is covered by ice during several months. During very cold winters, a permanent ice cover remains from December to March. In warm winters, the ice cover lasts during a short period only, or no permanent ice cover is observed at all. Due to recent climate changes this period gets shorter and is not stable in time. Ice periods enable active self cleaning of the lagoon's waters. At that time there is no wind influence on the lagoon's waters and all air pollution is accumulated by ice. During the ice cover the lagoon's water gets refreshed by marine waters inflow, as well as by fresh water inflow from rivers. At the same time, the sedimentation process, undisturbed by wind mixing, allows for absorbing chemicals present in the water column. All those processes may lead to "self cleaning" of the lagoon's waters. However, if the ice period is shorter and fractioned in time the self cleaning process is not so efficient. This implies great changes in the ecosystem functioning (Chubarenko, 2008).

2.1.6 Bottom sediments in the Vistula Lagoon

The comparison (Chechko, 2008) of a bottom sediment scheme (Fig.2.1.15) developed first in (Chechko, Blazhchishin, 2002) with the one published 35 years ago (Wypych, Nieczaj, 1975) allows an estimation of the ratio of areas, covered by different types of sediments in 1960-th and in 1990-th. The most valuable changes occurred in the redistribution of areas, covered by clayey silt, i.e. the finest sediments. As before, this type of sediments dominates in the south-western part of the lagoon, however, its area had been considerably reduced – from 29 to 20%.

The bottom area adjacent to the lagoon inlet (Baltiysk Strait) is characterized by serious changes in the distribution of the bottom sediments. In accordance with the scheme (Wypych, Nieczaj, 1975), silt covered the bottom of the central part of the lagoon uninterruptedly (except of a narrow coastal band). At present, it has become much narrower near the inlet, and is almost completely replaced by coarse sediments – sandy silt and sand. At the same time, silt appeared in deeper parts of the bottom of the north-eastern part of the lagoon and the Primorskaya Bight.

Areas covered by sandy silt, are generally reduced – from 23 to 17%. As before, this type of sediments is the most widespread in the north-eastern part of the lagoon and the Primorskaya Bight. Areas covered by sand have increased – from 21 to 29%. Coastal areas and the zone opposite the lagoon inlet are subjected to such changes, i.e. places where active wave impact on bottom sediments re-suspends and removes fine material, leaving only the coarser one.

Comparison of the two schemes showed that re-deposition of sediments, i.e. sorting and redistribution of material within the basin in accordance with its hydrodynamic state, is characteristic of contemporary sediment accumulation in the Vistula Lagoon (Chubarenko et all, 2005). Coarse fractions are located in energetically most active areas of the lagoon proper – in shallows and in the coastal zone, while a fine material is accumulated in deeper, calmer areas. Deep area near the inlet is covered by a coarse material because of fine sediments being brought out into the sea by water exchange currents.

Basic changes in the spatial distribution of the bottom sediments in the Vistula Lagoon are caused by regulation of the Vistula River drain in the beginning of 19th century, that resulted in the change of evolution of the Vistula Lagoon as a single whole system and, in particular, in its natural regime of sedimentation.

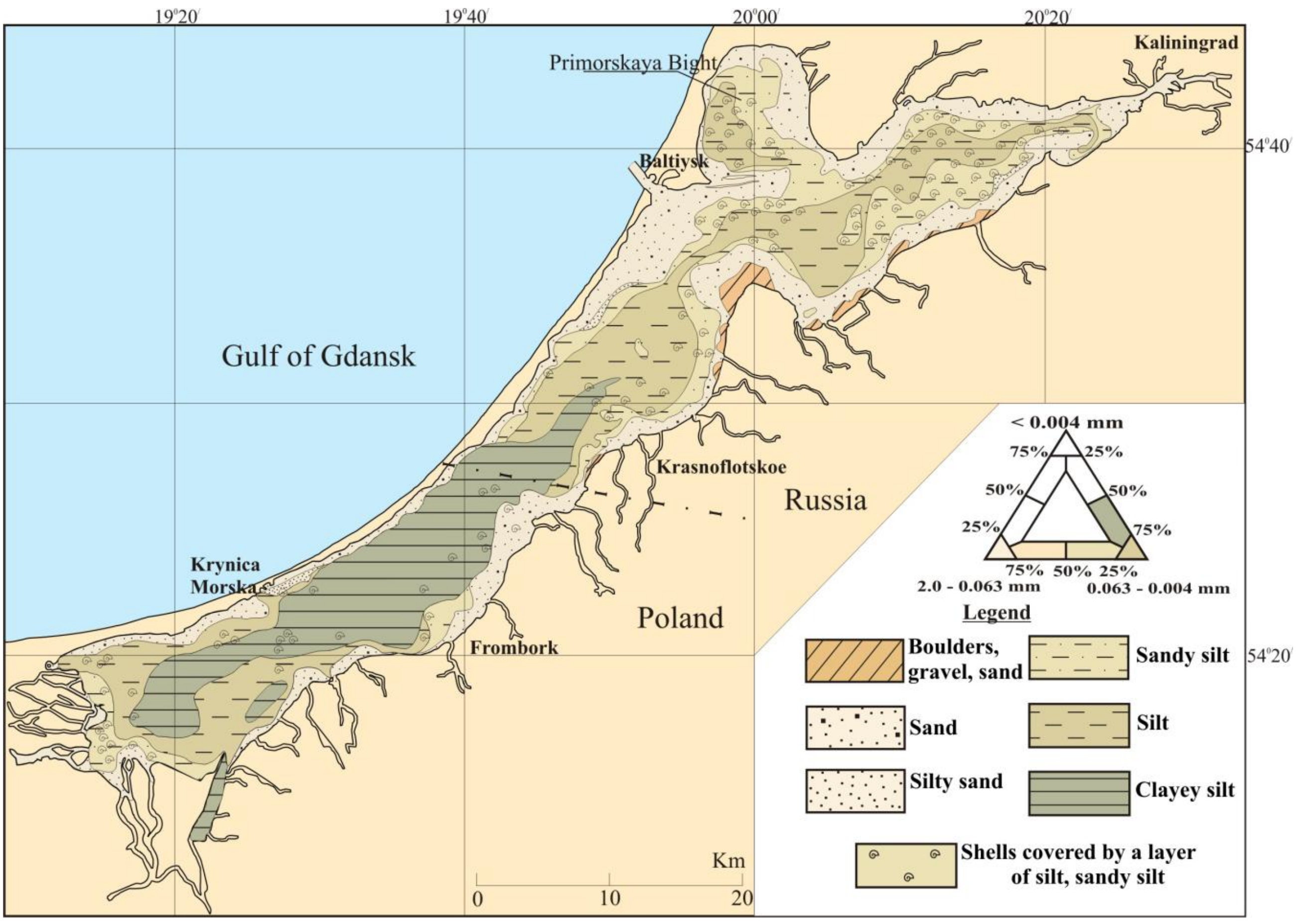


Figure 2.1.15. Joint scheme of distribution of the surface (0-5 cm) sediment types in the Vistula Lagoon in a whole in 1990th developed according to Shepard's classification. Polish part of the lagoon was compiled from (Zachowicz&Uscinowicz, 1995).

2.1.7 Shore line of the Russian part of the Vistula Lagoon

The length of the coastal line of the Russian part of the Vistula Lagoon (called on Russian maps as Kaliningrad Bay) is 148 km. There is some variety in present morphology, genesis and existing coastal processes along the coastline.

The eastern shore is relatively aligned. Only the surrounding of the North Cape (the Cap Severnyi) formed by moraine protrudes into the lagoon.

The shore is relatively high at the segment from Mamonovo to Krasnoflotskoe, cliffs are bordered by narrow beaches, which are folded by large-scale sediments with multiple enclosures of boulders (Fig. 2.1.16, a). From Krasnoflotskoe to the North Cape the cliff is active (Fig. 2.1.16, b), despite the fact that the shore is protected by a wide boulder bench. The rate of erosion there is of 0,1-0,4 m/year (Bobykina, Boldyrev, 2007). More areas of the similar rate of erosion occur north to Ushakovo.

East from the North Cape the most part of the low-lying and high mainland shores are blocked by reed bushes of different area (Fig. 2.1.17). Thus, the stable reed shores are prevailing. This area is low-lying, swampy, completely overgrown by bulrush and reeds, and rather stable.

(a)

(b)

Figure 2.1.16. (a) The abrasion shore between Mamonovo and the North Cape. Photo by V. Bobykina
(b) The active cliff between Balga and village Krasnoflotskoye. Photo by V. Bobykina

Figure 2.1.17. Reed (stable) coast north of promontory Severny. Photo by V. Bobykina

The northern shore of the Vistula Lagoon is separated from the lagoon area by the artificial Kaliningrad Marine Navigation Canal, which goes from the Baltiysk to the mouth of the River Pregola. The islands of dam bordering the canal from the lagoon side were artificially constructed together with the canal (shore is man-made). Their shore faced to the lagoon is under intensive erosion and partly protected by stones or reeds.

There are several large capes, such as Vysokiy, Glavny, Ostry, Krayniay, Gdansky, Razmyty, Chayachy, along the western shore of the lagoon, i.e. along the shore of the Vistula Spit. The shore is eroded, stable man-caused (reed), and accumulative (Fig. 2.1.18).

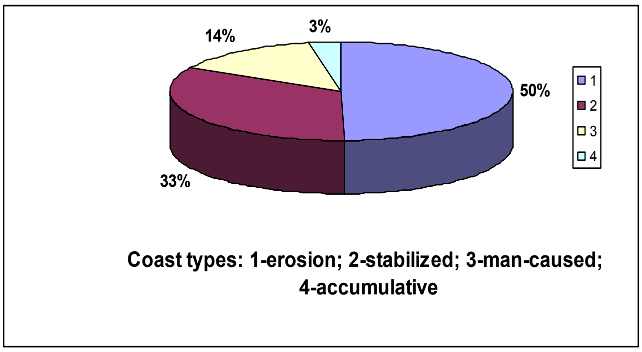


Figure 2.1.18. Percentage of the main types of the lagoon shores of the Vistula Spit (Bobykina, 2002).

Figure 2.1.19. Washing-out slopes of the ancient dunes. Photo by V. Bobykina

Almost 50% of the lagoon coast of the Vistula Spit are now eroded (Fig. 2.1.19) (Bobykina, 2002; Boldyrev, Bobykina, 2005). Reed is developed in the shore and bottom in places where sediments are formed by loams and lagoon-silt. They reliably protect the coast from waves, and make coast mostly stable (Fig. 2.1.20). Erosion of open segments is caused by the combination of wind surge and wind wave influence. The maximum values of surges can reach 1.2-1.8 m here. The water reaches the eroded base of forested dunes, which leads to slice of unconsolidated sand formations that form the shore. In addition, there is flooding of low-lying areas of the shore which are not higher than 1.5 m.

Coastal erosion of the Spit shore is associated with waves caused by the wind of east directions, and the mainland - western directions.

Long-term observations of coastal dynamics of the Vistula Spit are missing. They were started by the Atlantic Branch of P.P.Shirshov Institute of Oceanology of Russian Academy of Sciences only since 1999 (Bobykina, 2008).

Basing on quantitative observations of the dynamics of the lagoon shore of the Vistula Spit since 1999, average annual erosion rate varies from 0.5 to 2 m (Fig. 2.1.21). The maximum rate of erosion is observed at the northern and southern segments of the Russian part of the Spit. In the years with significant surges and waves (for example, the period of 2004-2005) the magnitude of erosion of individual sites can be up to 3 m (Fig. 2.1.21).

Conclusions: Eastern, western and northern shores of the Vistula lagoon are different according to their geomorphology. Northern shore is artificially man-made. Stable segments covered by reeds are dominated at the east shore. West shore (the Vistula Spit) is characterised by dominated eroded sore segments (50%), stable segments with reed (33%), and man-made and accumulative segments (17%).

There is a reduction of the spit width through the recession of the shore of the lagoon at the open segments, with the rate of 0.5 – 2 m per year. Erosion of ancient dunes at the lagoon shore of the Vistula Spit supplies the significant amounts of sand material to the underwater slope, while erosion of moraine sequences at the mainland shore supplies clay.

Short series of shore monitoring does not allow to draw any conclusions on dynamics of the coast resulted from climate change

Prospect: The rate of erosion will increase due to positive trend in the water level of the lagoon (more than 11 mm/year) in the period after 1993 (Navrotska, Chubarenko, 2012). The similar reason was for formation of new natural straits in the body of the spit which took place in the history (there were 9 straits, including modern, in the historical period from 890 A.D. (Shalaginova et al, 2009).

Figure 2.1.20. The stable shore protected by reeds. Photo by V. Bobykina

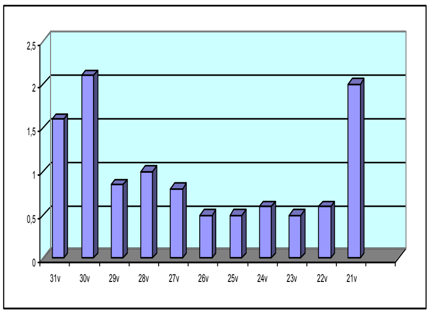


Figure 2.1.21. Average annual velocities of erosion along of the Vistula Spit lagoon coast for the period 2000 -2005 (V. Bobykina, 2008)

Outlook: positive trend in the level of the Gulf (more than 11 mm /year) in the period after 1993 (Navrotska, Chubarenko, 2012) should be expected due to the activation of abrasion and wash-out of the shores. Over time, it could happen with the formation of new natural straits in the body of the spit. Known sequences of formation of 9 straits, in the historical period beginning in 890 and including modern times, (Shalaginova et al, 2009). This in turn will cause large-scale environmental change of the bay ecology.

Advisable: to make a joint quasi-simultaneous inspection of the shores state of the Vistula Lagoon. To analyze the potentially flooded areas under existing trend of water level rise.

2.2 Climate, natural resources and land-use

The Vistula Lagoon region can be divided into three areas with different climatic characteristics (Lazarenko and Majewski, 1975):

- The Vistula Spit (separating the lagoon from the sea) has maritime climate with both spring and autumn delayed when compared with other areas. Maximum temperatures calculated for all months (e.g. from 9.1°C in January to 34.8°C in July measured in Krynica Morska) are relatively low but the minimum values recorded here are higher than those measured along the southern coast of the lagoon. The period with temperatures above the freezing point lasts on average 203 days and the mean annual rainfall equals 521 mm. Compared to conditions at the southern coast, fogs are more frequent here, and snow covers the area for a longer period of time.
- The south-western narrow coastline is the area with the highest average annual air temperature and annual amplitude of 65°C. Spring and autumn start relatively early here. Winds are strong and rains are observed during 164 days a year with the average annual rainfall reaching 650 mm.
- The north-eastern part of the lagoon is the coolest area with an apparent continental influence. The absolute minimum and maximum air temperatures range from -31°C to 36°C. Snow cover and rainfall are observed during 70 and 170 days a year, respectively. Wind speed is on average lower when compared with the two other areas.

The highest air temperature dynamics are recorded during winter season and a difference of up to 8 °C might be recorded between average air temperatures of subsequent winters. A significant difference in rainfall intensity is observed, especially during autumn.

As summarised by Chubarenko and Margoński (2008), the most probable wind directions are in the sector between south and north-west (60%). The strongest winds blow from the south-east and east. The average wind speed for the marine coast (6.1 m s^{-1}) exceeds that observed at the inner lagoon coast: 5.6 m s^{-1} in Tolkmicko and 4.3 m s^{-1} in Momonovo, both located along the southern coast of the lagoon (Bogdanov et al. 2004).

The wind wave action is higher on the eastern lagoon coast; the wave energy fluxes calculated at 2 m depth are 104–105 Ts^{-1} for the onshore component and 102–103 Ts^{-1} for the alongshore component (1 Ts^{-1} = 104 J) (Bogdanov et al. 2004).

2.2.1 Climate

General characteristic. The Northern Europe belongs to the Atlantic-Arctic area (extra humid and moderately warm) of the temperate zone. Specific features of climatic conditions are determined by its location between the Atlantic Ocean and Eurasia. The climate here is transitional: from the marine to moderately continental, and is characterized by small amount of an annual air temperature variations (~ 20 °C), high humidity (~ 80 %), and rich precipitation (annual sum is up to 800 mm).

The radiation balance is positive during more than half of the year (from April to October). Its mean-annual value fluctuates in a range from 1500 to 1630 MJoul/m². An annual value of the sum solar radiation varies from 3400 to 3450 MJoul/m² [Barinova 2002].

Atmospheric transfer. Western and south-western winds prevail, its speeds are increasing during cold period over the region. A lack of orographic obstacles initiates a transit of the anticyclones and has an influence on a wind regime and distribution of winds on water area (Fig. 2.2.1). The main part of the western transfer [Abramov R., Stont J. 2004] changes its direction by 90° (i.e. from zonal W-E to meridional S-N), following along the coast.

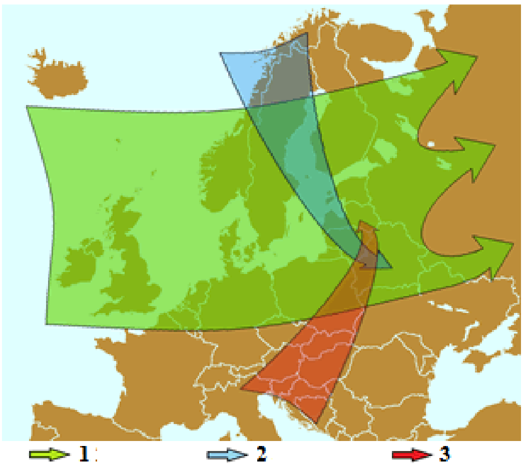


Figure 2.2.1. Trajectories of the cyclones forming weather in Southeast Baltic: 1 – western; 2 – northern; 3 - southern [www.meteo.lt]

Wind. The Figure 2.2.2 shows that the wind rose has an oblong shape in SW – NE direction. Half of all the winds (49 %) are from southern directions (SW 21 %, SE 16 %, S 12 %). The winds from western directions (total 47 %: SW 21 %, W 16 %, NW 10 %) form another large group. The smallest group is composed of winds of the northern direction – 25 %. Calm weather was observed in 9% of all cases [Handbook…, 1966].

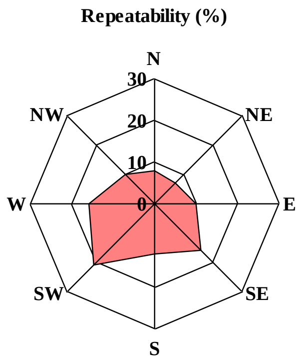


Figure 2.2.2. Repeatability (%) of wind directions for all winds (Chubarenko, Navrotskaya, Stont, 2012)

Gales reach the biggest repeatability (20-35%) from October to February. On the base of data [Handbook…1966], the number of days with strong winds (15 m/s and more) varies from 22 to 38, in particular years it is up to 45-60 days on coasts and spits of the Gulf of Gdansk.

There are more than half stormy days in particular months (XII, I). The wind speed is about 12 – 15 m/s; it sometimes comes up to 20-25 m/s.

Gales more often come from S, SW and SE, however, there is a possibility of gales from northern directions.

The gales duration is usually limited by one day and comes up to 2-3 days very seldom. The thermobaric conditions of cyclones formation and development and their trajectories were considered in [Hydro-meteorological regime …1971].

The cloudiness is significant with the predominance of a cumulus clouds. The largest number of days a month with the cloudy weather is in December – 20; the lowest (7-10) – in June. The average duration of the sun radiance varies from 4 to 7 hours over the Baltic Sea [Handbook… 1969].

There is a high humidity over sea (70-95 %). There are fogs in all seasons; in the heating period - marine fog; in autumn and winter – fogs due to evaporation. The largest number of days with fogs is from December to March; the lowest – from June to September; their repeatability may come up to 20-25 % in particular months [Handbook… 1969].

The specific feature here is a significant precipitation: in winter – snow; in summer – rain. The quantity of the precipitation is around 700 mm/year, their maximum occurs in July-August; minimum – in January-March [Handbook… 1968].

The winter air temperature fluctuates near 0 °C; in summer - 16÷20 °C. The average temperature of the eastern Baltic is by 6-7^{o}C larger than the mean-latitude temperature in January; in July – it is only by ~2^{o}C larger. The mean-annual air temperature is 4°C larger than the mean-latitude temperature. The air temperature annual amplitudes are around 20° on the coast, which may be comparable with the amplitudes in the Western Europe regions with marine climate [Barinova 2002].

The specific feature of the climate near the coast is the long frost-free period. Its duration is around 200 days. Thaws are very frequent. The freeze-up is not observed in particular years at all.

The climate of the temperate zones (where the south-eastern Baltic coast is situated) is characterized by an annual cycle of atmospheric processes, which is revealed by changes of climatic seasons.

Winter – is gentle, with prevalence of the cloudy weather and frequent precipitation. The severe frosts are seldom and short-term. Southern, south-western and western winds are characterized by the biggest repeatability, reaching storm winds quite often. The maximum-speed winds have a probability of 1 time in 4-5 years. The ordinary gales are short-term, however, the stormy weather is observed during 4-5 days.

The winter starts in December, the snow coverage appears at the end of the month, and mean-daily temperatures are negative. There are severe frosts in the middle of the winter, reaching -30 ÷ -33^{o}C in particular cases. The average height of the snow cover is not high and is around 10-20 cm on the coast.

The beginning of the spring is cold, long-term and occurs in March. In comparison with the typical winter, winds speed goes down and the repeatability of gales decreases. In the middle of April the precipitation events are seldom in comparison with winter; however, the possibility of fogs is rather high; the repeatability of the cyclonic weather increases. The frosts stop in the middle of May; however, they repeat in late spring and even at the beginning of June 1 time in 10-15 years. The days when the air temperature crosses 0^{o}C occur in March.

The summer, as a rule, is chilly, the repeatability of the north-western and north winds goes up. The summer starts in June, when the mean-month air temperature crosses 15^{o}C. The mean air temperature is around 20^{o}C, sometimes 8-17 days are observed with temperatures of 30-35^{o}C. The hot weather is seldom, and lasts not long. At the end of summer, precipitation increases, falling down as heavy showers. The highest temperatures are observed in July-August.

The autumn is warm, wet and windy. The wet cloudy weather prevails with the frequent long-term precipitation. Fogs and stormy winds of western directions are observed. The number of cloudy and rainy days goes up. The snow coverage occurs at the end of November, when the air temperature crosses 0°.

2.2.2 Local climate changes in atmospheric forcing during 1981 – 2010

The change in the climate of the South-Eastern Baltic is a reality. The precipitation is increased, especially it is observed in the summer time. The air temperature increase (averages and extreme values) proves that the global warming becomes an obvious fact in the recent years. The wind regime has changed. Adaptation to the climate change is a problem demanding decision. Below there is a summary of the analysis for 1981-2010 (last thirty years as climate period) which was selected from the analysis of longer period in (Chubarenko, Navrotskaya, Stont, 2011).

***Data employed*.**

In order to estimate the variability of meteorological parameters in the Kaliningrad region we used contact measurements which were obtained on Kaliningrad weather station (Airport Devau):

Kaliningrad (Airport Devau) - weather station 26702 (UMKK), latitude 54°42′ N; longitude 20°37′ E; 21m height above sea level. Observation period is from 1981 to 2010. The following data were used: atmospheric pressure and air temperature (monthly mean and mean-annual data, extreme values); monthly and annual precipitations amount; monthly mean and mean annual wind speed, maximum monthly wind speed and the number of days per month with wind speed more than 12 m/s (≥ 42 km/h).

According to the recommendation of the World Meteorological Organization, the thirty-year period of 1961-1990 was adopted as a regulatory one to determine further trends. Data analysis allows us to define trends of the main meteorological parameters on sliding 30-year periods starting from 1921 (Table 2.2.1).

The Table 2.2.1 shows that air temperature increased by 1 °C during last 30 years (1981-2010); it is the largest temperature rise during 90 years. The greatest rise of precipitation was in the middle of the 20th century (1951-1980); later it started to decrease gradually and it reduced 3 times larger during 1981-2010 in comparison with the regulatory period. The atmospheric pressure has the lowest level of fluctuations: it has increased by 0.1 hPa since 1971.

Table 2.2.1. Average meteorological parameters, their linear trends and increase (according to the trends) on the base of a data obtained from Kaliningrad weather station (UMKK 26702) from 1921 to 2010.

Ta, °C				
Years	***Average***	***The time rate of temperature rise, °C/period***	***Trend °C/year***	R^2
1921-1950	7.2±1.00	0.42	0.014	0.02
1931-1960	7.2±1.00	-0.45	-0.015	0.02
1941-1970	6.9±0.88	-0.21	-0.007	0.01
1951-1980	7.0±0.80	0.09	0.003	0.00
1961-1990	7.2±0.98	0.84	0.028	0.07
1971-2000	7.5±0.98	0.93	0.031	0.08
1981-2010	7.9±0.93	1.02	0.034	0.11
Pr, mm				
Years	***Average***	***The time rate of precipitation rise, mm/ period***	***Trend, mm/year***	R^2
1921-1950	743 ±101	-45	-1.5	0.02
1931-1960	723 ± 96	21	0.7	0.00
1941-1970	731±131	102	3.4	0.05
1951-1980	754±142	159	5.3	0.11
1961-1990	786±149	141	4.7	0.07
1971-2000	817±146	105	3.5	0.04
1981-2010	841±143	48	1.6	0.01
Pressure, hPa				
Years	***Average***	***The time rate of pressure rise, hPa/ period***	***Trend, hPa/year***	R^2
1961-1990	1014.5	-0.6	-0.02	0.00
1971-2000	1014.4	0.03	0.001	0.00
1981-2010	1014.5	0.00	0.00	0.00
Wind, km/h*				
Years	***Average***	***The time rate of wind speed rise,*** $km\cdot h^{-1}$***/ period***	***Trend,*** $km\cdot h^{-1}$***/year***	R^2
1961-1990	11.7±3.33	-2.4	-0.08	0.00
1971-2000	11.6±2.61	-8.1	-0.27	0.81
1981-2010	10.0±1.94	4.2	0.14	0.39

Wind speed module has started to decrease since 1961. The most significant changes occurred in the period of 1971-2000, when the time rate of wind speed rise decreased by 8.1 $km\cdot h^{-1}$/ period. Next 30-year period (1981-2010) was characterized by a positive trend (0.14 $km\cdot h^{-1}$/ year) and the time rate of wind speed rise was 4.2 $km\cdot h^{-1}$/ period.

The present research focuses on the following parameters based on the above mentioned data: air temperature changes, precipitations and wind speed during 1981-2010; local fluctuations within particular periods of measurements; the intensification of the fluctuations of meteorological parameters in recent years due to the global climate change. The estimations of these parameters were carried out for the 30-year period of 1981-2010.

* transfer coefficient km/h to m/s: 1 [km/h]* 0.278 = 0.278 [m/s]

We can conclude that specific features of variability of meteorological parameters in the Kaliningrad region during 1981-2010 are the following:

***Air temperature** c*hanges (mean annual, monthly mean maximum and minimum of temperatures) have been characterized by positive linear trends 0.02-0.05 °C/year and a temperature rise by 0.3-1.5 °C since 1981. It is observed that a time rate of monthly mean maximum temperature rise is 1.7 times larger than the monthly mean equivalent. Time rate of monthly mean minimum temperature rise is around 0 °C in 1981-2010. Thus, a positive trend of the mean annual air temperature is mainly caused by the temperature rise in a warm season and, by contrast, decayed between seasons (which are under review). The air temperature rise is likely to continue in future, mainly due to temperature maximum rise in summer period.

The time rate of winter mean temperature rise (0.04 °C/year) and spring temperature rise (0.04 °C/year) has been observed. The rate of the summer temperature rise is even larger (0.05 ° C/year). The minimal rate (two times less than for other seasons) is observed for time rate of spring temperature rise (0.02 ° C/year). Thus, the maximum mean air temperature rise (1.5 °C) within 30 years (1981-2010) is observed in summer (annual maximum temperature is in Kaliningrad in July and August); it is similar for winter and spring according to the trend (1.4 °C), but slightly less than in summer. Average autumn temperature has the lowest for 30 years – 0.6 °C.

Precipitation. A positive trend of annual precipitation was observed during the period 1981-2010, its value was 4.9 mm/year, and precipitation rise according to the trend was ~ 147 mm (or 18% of average value during the 30-year period). An increase in precipitation was observed in spring and summer - 1.2-4.0 mm/year, a decrease – in winter and autumn. It caused precipitation rise by ~160 mm during the warm period of year during the whole 30-year period. The maximum precipitation rise was observed in summer. It is related to intensification of storm rainfall. The trend was 4.0 mm/year; it was 3 times larger than in spring and winter. The increase amounted to 120 mm; it was also 3 times larger than in other seasons. There are no changes in precipitation in winter: the trend was -0.013 mm/year, the precipitation was extremely low. Thus, it was due to intensification of summer storm rainfall. It is possible to divide the period of 1981-2010 into 2 conventional sub-periods according to the time rate of precipitation rise. In the first sub-period (1981-1995) the trend was 163 mm; in the second (1996-2010) the process slowed down, the rate was -0.8 mm/year.

Wind. Temporary change of average wind speed during the period analyzed is characterized by a very slight positive linear trend (0.14 km/h/year, or 0.04 m/s/year), the time rate of wind speed rise amounted to 4.2 km/h or 1.2 m/s in 1981-2010.

The intensity of the maximum wind speed was not constant in 1981-2010. In 1981-1994 there was a decrease in the maximum speed (the trend was -0.6 km/h per year, the time rate of wind speed rise was - 8.0 km/h per period) as well as a decrease in the number of stormy days (the trend was -0.1 days per year, while the increase was -1.3 days per period). In 1995-1998 almost no gale-force winds were observed. Since 1999 the processes have changed: the number of days with strong winds increased (the trend was 0.08 days per year, the increase made up 0.9 days per period), maximum speed increased (the trend was 0.25 km/h per year, while the increase made up 2.8 km/h per period).

The most intensive average wind speed increase started in 1997. The positive trend (0.4 km/h/year, or 0.11 m/s/year) 3 times surpassed the negative trend of preceding years by absolute value. The increase for 13 years (1997-2010) amounted to 1.6 km/h or 0.45 m/s. It is possible to trace a connection between periods of increase in wind speed and decrease in atmospheric pressure: determination of periods of average wind speed coincides with periods of atmospheric pressure with a one-year shift (Fig. 2.2.3).

a b

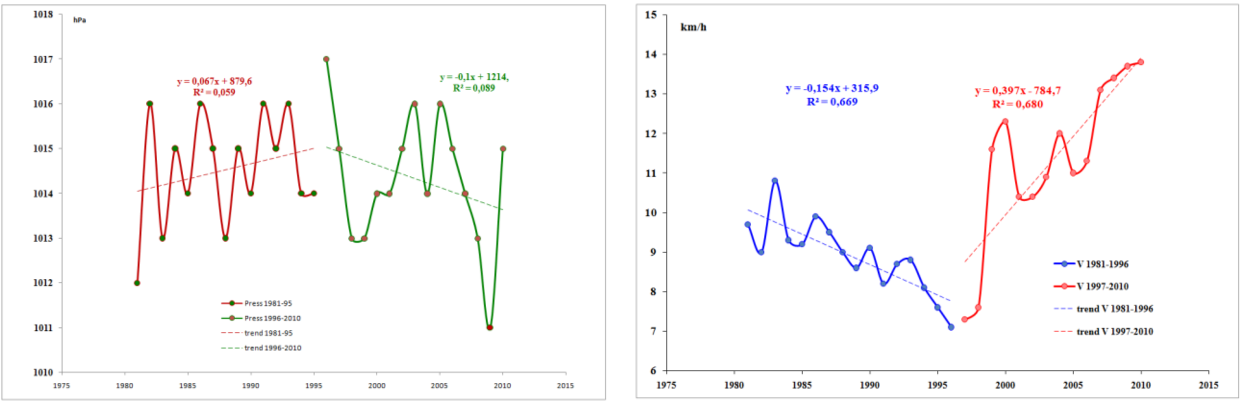


Figure 2.2.3. Variability of atmospheric pressure (a) and of annual mean wind speed (b) in Kaliningrad in 1981-2010 according to the periods. Dotted lines show the linear trends.(Chubarenko, Navrotskaya, Stont, 2012)

***Conclusions*.** The analysis of meteorological parameters measured on the coast of the Kaliningrad region in 1981-2010 showed that there was intensification of atmospheric processes over the south-eastern Baltic Sea area. An increase in air temperature, average and maximum wind speed, especially in winter, was observed.

2.2.3 Population, water use and economic activities in the catchment

Population in the Vistula Lagoon coastal areas is uneven. The main concentration of inhabitants is around Kaliningrad, which is the largest city in the Vistula Lagoon region. Border areas between Russia and Poland in south and west of the Vistula Lagoon are populated relatively poorly. In all these regions the average population density rarely exceeds 20 people per km^2 (Figure 2.2.4).

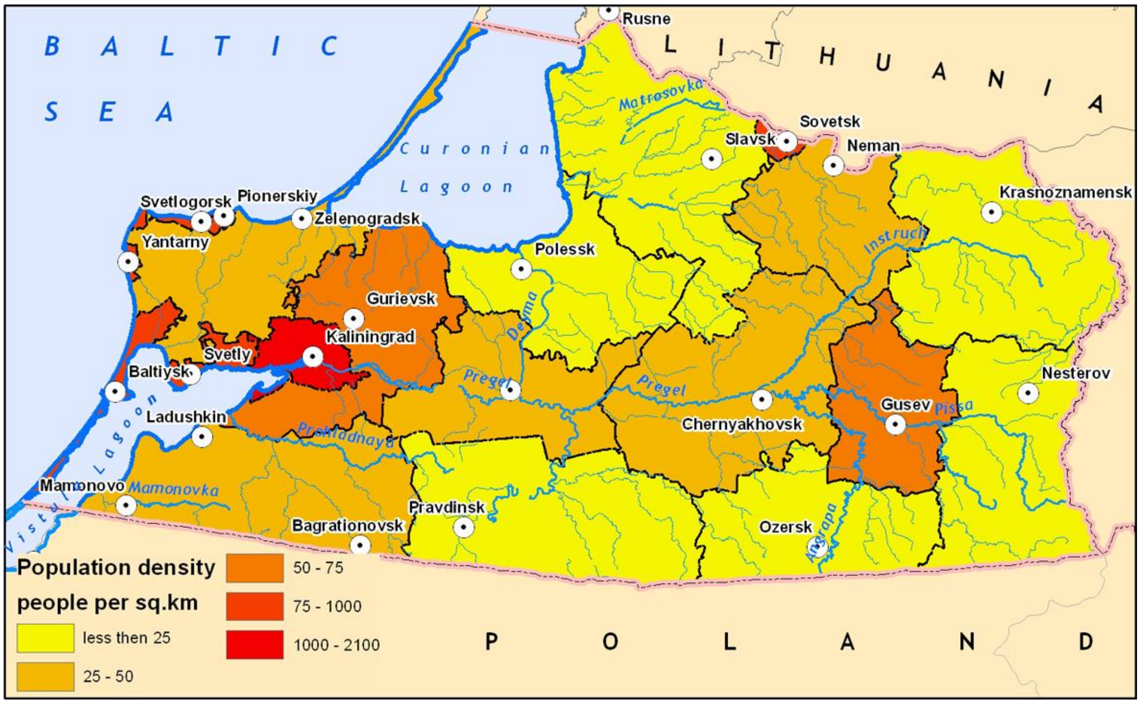


Figure 2.2.4. Population density of the Kaliningrad Oblast (State of the Coast ..., 2008)

Table 2.2.2. Population quantity for municipalities and cities/towns of Kaliningrad Oblast

City/town	People, ths.	City/town	People, ths.
Kaliningrad	419.2	Pionerskiy	12.0
Sovetsk	42.6	Yantarnyy urban district	5.3
Ladushkin urban district	3.9	Mamonovo urban district	7.8
Baltiysk district (37.0 ths.)			
Baltiysk	34.1	Primorsk	2.1
Svetlogorsk district (13.6 ths.)			
Svetlogorsk	11.2	Primorie	0.7
Svetlyy district (29.3 ths.)			
Svetlyy	22.3	Vzmorie	2.1
Bagrationovsk district (33.2 ths.)			
Bagrationovsk	6.6	Yuzhnyy	2.7
Gvardeysk district (28.5 ths.)			
Gvardeysk	13.0	Znamensk	4.3
Gurievsk district (54.4 ths.)			
Gurievsk	12.1	Vasilkovo	4.8
Gusev district (37.3 ths.)			
Gusev	28.1	Mayakovskoe	0.9
Zelenogradsk district (32.5 ths.)			
Zelenogradsk	12	Pereslavskoe	1.3
Krasnoznamensk district (11.7 ths.)			
Krasnoznamensk	3.4	Dobrovolsk	1.6
Neman district (21.7 ths.)			
Neman	12.0	Zhilino	1.0
Nesterov district (17.0 ths.)			
Nesterov	4.6	Chernashevskoe	1.2
Ozersk district (16.1 ths.)			
Ozersk	5.0	Sadovoe	0.6
Polessk district (19.4 ths.)			
Polessk	7.6	Zalesie	1.2
Pravdinsk district (21.7 ths.)			
Pravdinsk	7.3	Zheleznodorozhnyy	2.9
Slavsk district (21.6 ths.)			
Slavsk	5.0	Bolshkovo	2.3
Chernyakhovsk district (51.2 ths.)			
Chernyakhovsk	39.8	Mezhdurechie	0.7

The largest number of employed population is observed in the Kaliningrad and Svetly (up to 70%), whereas in other territories population employment is low - about 20%.

The population is mainly engaged in manufacturing, health care, education, transport and trade (more than 60 %). Employment in all other sectors is less than 20 % (Fig.2.2.5).

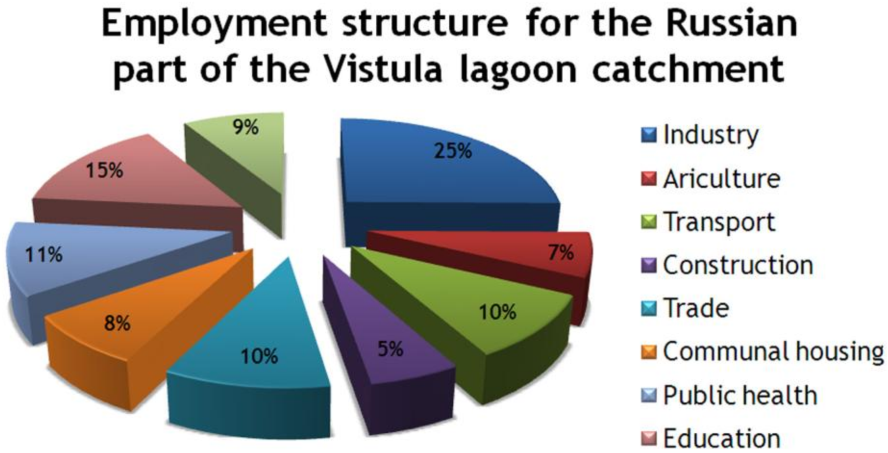


Figure 2.2.5. Employment structure for the Russian part of the Vistula lagoon catchment (State of the Coast ..., 2008)

Water consumption of the Kaliningrad Oblast is from surface and underground water sources (Fig.2.2.6).

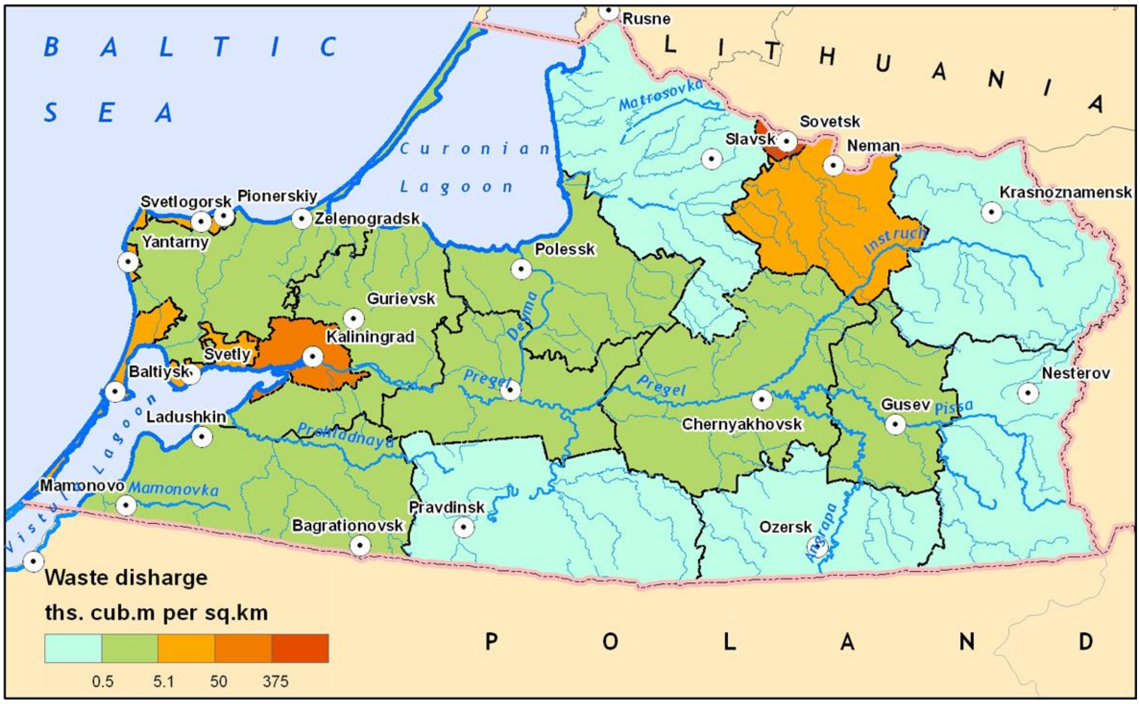


Figure 2.2.6. Waste discharge by municipalities of the Kaliningrad Oblast, 2006 (Domnin, 2012)

Table 2.2.3 Main indicators of the actual water use in the Kaliningrad Oblast, mln. m^3

	Bodies for water supply				**Supply of fresh and marine waters**	**Full water supply**	**Irretrievable water supply**
	Total						
		Surface fresh waters	**Marine waters**	**Underground waters**			
1	2	3	4	5	6	7	8
2006	200	121	12	67	164	488	45
2007	172	88	16	68	146	427	32
2008	169	77	22	70	135	424	35
2009	143	59			116	396	29

Table 2.2.4. Main indicators of wastewater discharge in the Kaliningrad Oblast, mln. m^3

Indicator	**2006**	**2007**	**2008**	**2009**
Sewage to surface water bodies	155	140	133	114
1. polluted	131	116	103	87
without cleaning of them	111	96	80	68
2. insufficiently cleaning	21	21	26	23
3. cleaning	3	3	4	4
Sewage to surface land	5	5	5	5

Corresponding information on Polish side of the lagoon may be found in ANNEX 1.

2.2.4 Land use

Agricultural areas cover less than half (46%) of the Russian part of the Vistula Lagoon catchment. Coniferous and deciduous and mixed forests cover 8% and 16, 5% respectively. More than 22% is other crop land. Lakes and other non-crop lands are occupied by less than 1%. Urbanization land up just over 5.5%. (Fig.2.2.7, 2.2.8).

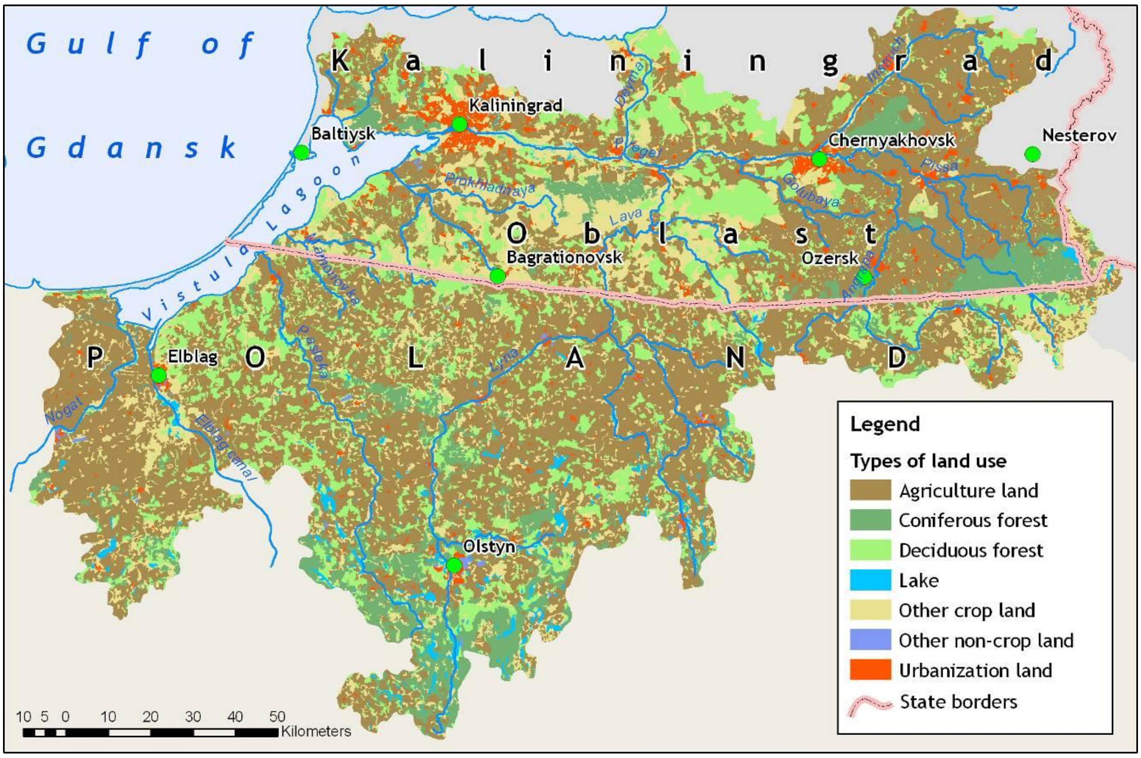


Figure 2.2.7. Land use scheme of the Vistula Lagoon catchment[2]

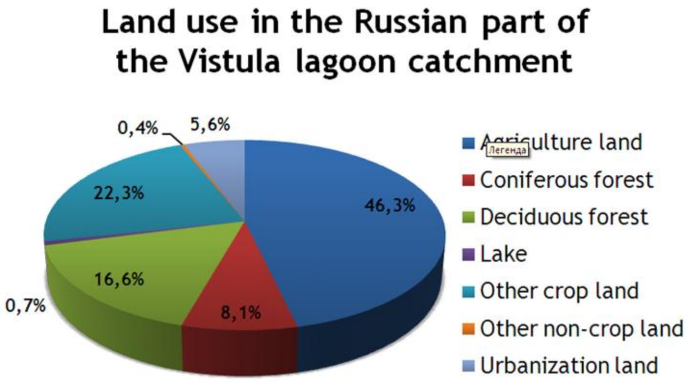


Figure 2.2.8. Structure of uses of land for the Russian part of the Vistula lagoon catchment. (Domnin, 2011)

[2] Report of RFBR grant 08-05-92421-BONUS_a Advanced modeling tool for scenarios of the Baltic Sea ecosystem to support decision making – ECOSUPPORT, Kaliningrad, 2011

In the Polish part of the Vistula Lagoon drainage area different categories of arable land, pastures and forests dominate (Fig.2.2.9).

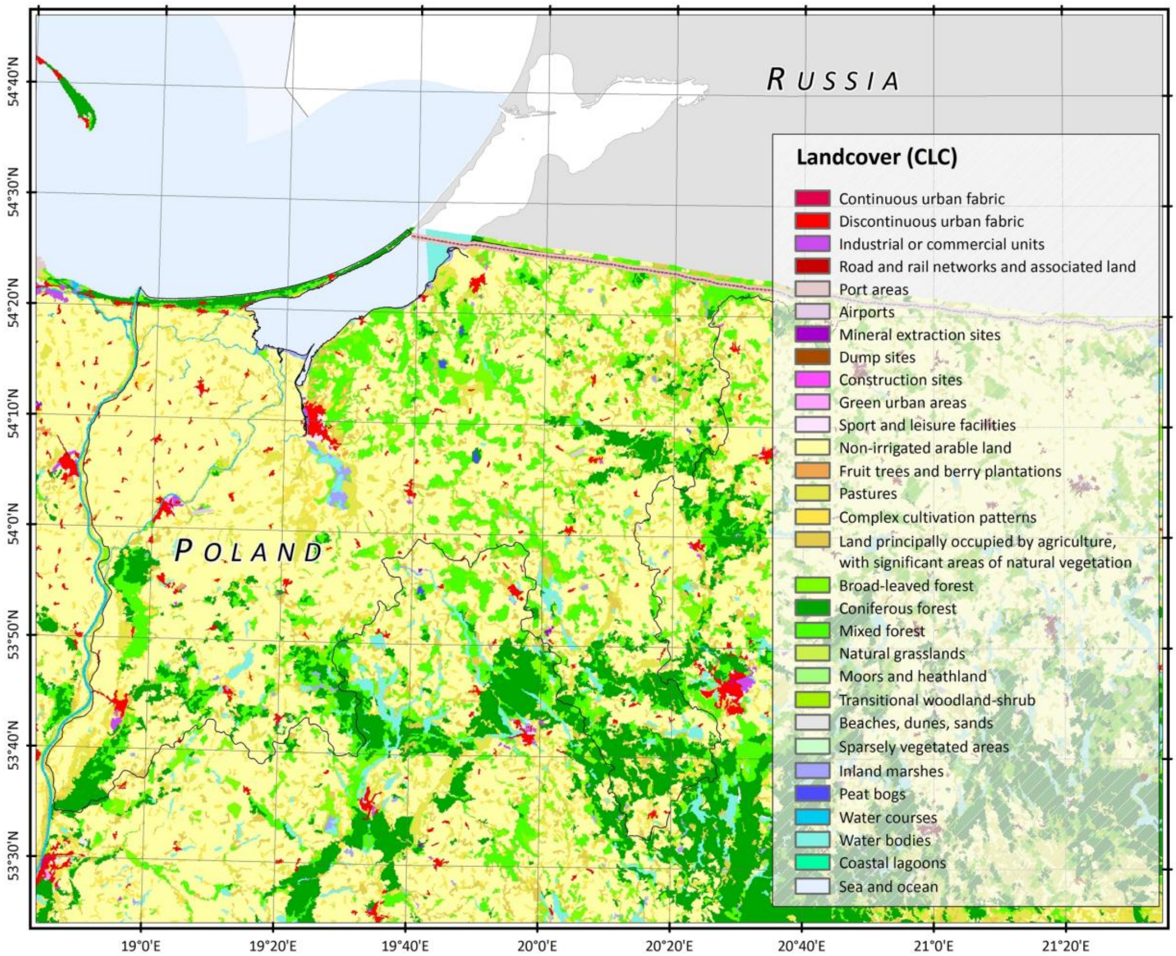


Figure 2.2.9. Landcover (CLC) classification in the Polish part of the Vistula Lagoon drainage area (prepared by Lena Szymanek based on data downloaded from the European Environment Agency (EEA) - http://www.eea.europa.eu/themes/landuse/interactive/clc-download

In the most western part (the original Vistula River delta system) a substantial part is located below sea level. These wetlands are drained and used for agriculture. Forests are covering the hills along the south-western coast as well as most of the area on the Vistula Spit. Population density is rather low and villages and small towns therefore dominate the Polish part. The biggest city is Elbląg with the population approaching 130 000 inhabitants. Total population of the Polish part in 2010 was 199 151, and 158 559 could be considered as urban population, 21 035 as semi urban population and 19 557 – as rural population.

Fishery is the most important human activity in the lagoon; shipping and tourism are less developed.

Tourism on land is spatially unbalanced - it is extremely important on the Vistula Spit, where Baltic Sea sandy beaches are the main attraction in summer and much less developed on the south side of the lagoon. More information available in ANNEX 1.

Polish part of the Vistula Lagoon entirely belongs to NATURA 2000 regions; however it is not under Ramsar convention. There are also many other protected areas there and nature reserves. For details refer to ANNEX 1.

The waters of the Kaliningrad Oblast do not include any areas protected under the NATURA 2000 programme and Ramsar convention. There are four reserves in the Russian part of the Vistula Lagoon catchment, namely the Novoselovsky, Kamensky, Maysko-Krasnopolaynsky State Nature Reserves and Vishtynecky Nature Park. The Vistula Spit has been designated as a nature conservation area.

Natural potential of inland waters of the Kaliningrad Oblast predicts increased production of aquaculture in ten times (now about 30 tons of commodity fish are grown in inland waters).

Some aspects concerning water quality and natural resources of Vistula Lagoon will are described below based on Chubarenko and Margoński (2008) with necessary additions and modification.

2.2.5 Water Quality

Eutrophication is one of the major issues in the lagoon. This water body is especially vulnerable to eutrophication due to the large drainage area and limited water exchange with the Baltic Sea. Water quality is regularly monitored on both sides of the lagoon from spring to autumn. Winter nutrient concentrations are measured very seldom. This short overview is based on Chubarenko and Margoński (2008).

The horizontal distribution of water quality parameters in Vistula Lagoon is strongly influenced by hydrological and meteorological factors. Of these, the exchange of water masses between the Gulf of Gdansk and the lagoon constitutes one of the most important factors. As a consequence, the lagoon area close to the Baltiysk Strait is ventilated by permanent inflow of marine waters and the concentrations of nutrients in this area are lower in comparison to those in remote parts of the lagoon.

Renk et al. (2001) reported high spatial and temporal variations in nutrient concentrations in the Polish part of the lagoon during the 1999 vegetative season, and especially during the spring phytoplankton bloom, the concentrations of some nutrients decreased below detectable limits. Phosphate concentrations were relatively high and ranged from 0.25 to 1.96 μmol l^{-1}. The lowest values were observed in April, while winter phosphate concentrations exceeded 4 μmol l^{-1} in February 2000 (M. Zalewski, personal communication). The average concentrations of various forms of inorganic nitrogen oscillated around the following values: nitrites 0.11 μmol l^{-1}; nitrates 0.75 μmol l^{-1}; ammonia nitrogen 0.58 μmol l^{-1} (April–October 1999). However, winter maxima were much higher: nitrites 3.49 μmol l^{-1}; nitrates 130.42 μmol l^{-1}; ammonia nitrogen 16.63 μmol l^{-1} (February 2000, M. Zalewski, personal communication). The ratio of inorganic nitrogen to phosphorus was very low during the vegetative season. It decreased to below 1 from the second half of May to the end of September. The only exception was the average in the second half of July (1.81), which coincided with the blue-green algal bloom. In February 2000, the ratio of inorganic nitrogen to phosphorus even reached a level of 40–50 (M. Zalewski, personal communication). The silicate concentrations were very high; the average value for the Polish part oscillated around 84.5 μmol l^{-1} from April to August, while the average for the September–November period was 107.6 μmol l^{-1}. Winter maxima were higher than 180 μmol l^{-1} (M. Zalewski, personal communication). The average chlorophyll a (Chl a) concentrations in the 0–1.5 m layer were high at 41.2 mg m^{-3} in 1998 and 43.5 mg m^{-3} in 1999. The highest recorded values exceeded 150 or even 200 mg m^{-3} during blooms in July and August. The light attenuation coefficients varied significantly from 1.5 m^{-1} to 7 m^{-1}.

Monthly water quality averages for the 1981–2001 periods in the Russian part of the lagoon were reported by Senin et al. (2004). Oxygen concentrations were usually very high (9.8–12.7 mg l^{-1}), but biochemical oxygen demand over a 5 day period (BOD5) ranged between 3.3 and 6.4 mg l^{-1}. Phosphate concentrations varied between 15 and 104 μg l^{-1} (0.48–3.36 μmol l^{-1}) throughout the season, with peaks in spring and summer. The highest nitrate concentrations were observed in early spring, only to drop significantly during the vegetative season (from 865 to 26 μg l^{-1} or from 62 to 1.86 μmol l^{-1}). The Chl a concentrations ranged from 36 to 52 mg m^{-3} (41.7 mg m^{-3}, on average).

All those values indicate a high trophic level of both parts of the lagoon.

Water transparency is very low. Although the average Secchi depth is 0.4–0.6 m in the Polish and Russian parts, it very often falls to 0.3–0.4 m during the vegetation period. On cloudless days, the maximum value of photosynthetically active radiation (PAR) penetrating into the water is 2,500–2,600 µmol m^{-2} s^{-1}. Half of this is lost in the top 25 cm, and about 1% of it reaches to a depth of 1.5 m. The vertical distribution of PAR is well approximated by a simple one-exponential fold, in which a light attenuation coefficient varies seasonally, because of algae vegetation and wind resuspension, between 2.5 (March) and 3.5 (July, November) (Rasmussen 1997; A.F. Kuleshov 2007, personal communication).

Eutrophication processes are influenced not only by riverine loads (Tab. 2.2.5) but also by nutrient exchange between the water and sediments as well as by water exchange with the Gulf of Gdansk.

Table 2.2.5 Riverine loads to the Vistula Lagoon in 2008 (Kopiec, 2008)

River	Mean Q	BOD5		Total org. carbon		Total N		Total P	
	m^3/s	mean conc. (mg/l)	Load (Mg/y)	mean conc. (mg/l)	Load (Mg/y)	mean conc. (mg/l)	Load (Mg/y	mean conc. (mg/l)	Load (Mg/y)
Elbląg	8,6	3,10	843,1	15,7	4269,7	3,900	1060,6	0,215	58,5
Pasłęka	16,75	2,50	1324,2	13,2	6991,7	2,608	1381,4	0,139	73,6
Nogat	7,1	2,30	516,4	13,7	3075,9	2,461	552,5	0,126	28,3
Bauda	2,7	2,24	191,5	11,7	1001,1	4,499	384,1	0,325	27,7
Narusa	0,3	2,50	23,7	8,8	83,2	4,137	39,2	0,338	3,2
Stradanka	0,22	3,80	26,4	13,8	96,0	2,370	16,5	0,252	1,8
Grabianka	0,12	7,50	28,5	24,0	91,1	23,200	88,0	2,200	8,3
Dąbrówka	0,085	4,13	11,1	10,0	26,9	8,771	23,6	0,484	1,3
Kamionka	0,08	2,95	7,5	9,0	22,7	1,420	3,6	0,159	0,4
Olszanka	0,06	2,27	4,3	7,5	14,2	2,755	5,2	0,346	0,7
Suchacz	0,045	3,09	4,4	7,0	10,0	3,427	4,9	0,909	1,3

According to Kwiatkowski (1996), significant sources of nitrogen and phosphorus are accumulated and released from silty bottom sediments. As a consequence of water mixing, the redistribution of labile inorganic nutrients from the upper layer of bottom sediments to the water column is almost continuous (Ezhova et al. 1999). Witek et al. (2010) assess, based on modelling results that on an annual scale, between 15 and 20% of the sedimented nitrogen and between 25 and 40% of the sedimented phosphorus were "re-exported" to the water column due to resuspension. Therefore, there is a high internal potential for eutrophication. Kwiatkowski (1996) estimated that as much as 138,600 tons of nitrogen and 55,800 tons of phosphorus have accumulated in the 10 cm sediment layer. Approximately 22% of the nitrogen and 35% of the phosphorus loads are exported to the Gulf of Gdansk (Kwiatkowski et al. 1996). A different modelling approach presented by Witek at al. (2010) assessed that the riverine transport was the main source of nitrogen and phosphorus to the lagoon, and outflow to the Baltic Sea was the main sink (Fig. 2.2.10). Nitrogen fixation by cyanobacteria might influence nitrogen budget of the lagoon to a various degree. In the warm year, nitrogen fixation constituted about 1/5 of the riverine inflow. In colder years, nitrogen input via nitrogen fixation was negligible. Denitrification was an important nitrogen sink, removing about 50% of the riverine input. Favourable conditions for denitrification enabled 35%-retention of nitrogen in the lagoon in total, despite lack of nitrogen accumulation in bottom sediments. No phosphorus retention was observed.

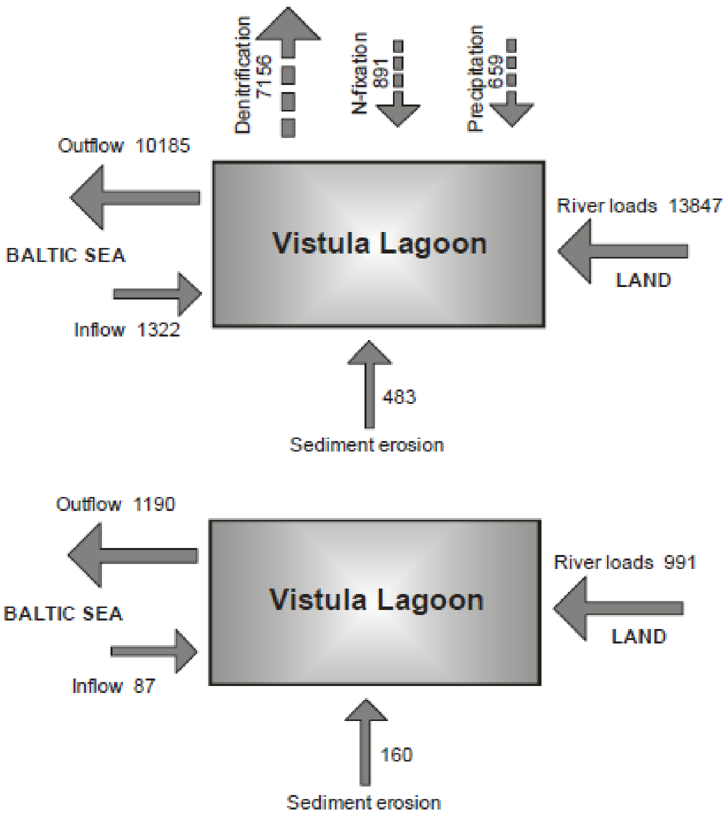


Figure 2.2.10. Nitrogen (upper panel) and phosphorus (lower panel) budget for the Vistula Lagoon – 1998÷2000 (tonnes yr^{-1}) (Witek et al. 2010)

2.2.6 Limitation of Primary Production

Light and nutrient availability are among the most important factors controlling primary production. Light limitation is caused mostly by the amount of suspended matter in the water column. Total suspended matter (TSM) was measured only in the Polish part of the Vistula Lagoon (Witek et al 2010). In general, increasing trend of concentrations was noted during the vegetative season: from 20 to 40 g m^{-3} with peak values, exceeding 60 g m^{-3} noted mostly in the second part of the vegetative season, sometimes reaching even 120 g m^{-3} at some stations. Model simulations indicated that, under long periods of ice cover, suspended matter concentration dropped below 20 g m^{-3}. Such large amounts of suspended solids result from frequent resuspension of bottom sediments, which is typical of shallow water bodies exposed to winds, such as the Vistula Lagoon (Witek et al 2010). The vast majority of lakes studied within the scope of the OECD project (OECD 1982) fall into the category of phosphorus-limited lakes; however, on the contrary, Vistula Lagoon rather seems to be a nitrogen-limited water body. Phytoplankton growth limitation estimated with modelling tools confirmed that phosphorus limitation occurs only during early spring. Throughout the rest of the vegetative season, nitrogen is the main limiting factor (Ezhova et al. 1999; Kwiatkowski et al. 1997).

2.2.7 Phytoplankton

Taxonomic composition of phytoplankton and long-term changes in composition and abundance are relatively well described. Trends as well as similarities and differences between Polish and Russian parts of the lagoon are presented here based on Chubarenko and Margoński (2008).

Three phytoplankton groups dominate in terms of abundance in the Polish part of Vistula Lagoon (Chubarenko and Margoński 2008) (Fig. 2.2.11): Cyanobacteria, green algae, and diatoms. Cyanobacteria comprise over 80% of the total abundance. Species from the genera *Anabaena* and *Merismopedia*, *Aphanizomenon flos-aquae*, and representatives of the subfamily Gomphosphaerioideae are present among the dominants. The composition of dominating species of Cyanobacteria noted in 1953 was similar (Szarejko-Łukaszewicz, 1957). In 1999, the highest biovolume of Cyanobacteria was observed in August, when the mass occurrence of filamentous species from *Anabaena* genus and *Aphanizomenon flos-aquae* was noted. Blooms of these species were observed from June to September in the central and north-eastern regions of the Polish part of Vistula Lagoon (Szarejko-Łukaszewicz 1957; Plinski and Simm, 1978, Chubarenko and Margoński 2008).

Green algae (Fig. 2.2.11) comprised from 10 to 15% of the total phytoplankton abundance in the 1970s and 1990s (Plinski and Simm 1978, Chubarenko and Margoński 2008). The filamentous green alga *Planktonema lauterborni*, which was not reported in samples taken in 1953, dominated the green algae abundance in spring samples from the 1974–1975 and 1999 periods. On the other hand, representatives of Volvocales – *Volvox aureus, Pandorina morum*, and *Eudorina elegans* – were not noted in the 1970s or 1990s (Szarejko-Łukaszewicz 1957; Plinski and Simm 1978, Chubarenko and Margoński 2008).

The share of diatoms in the phytoplankton abundance is lower than 2% (Fig. 2.2.11). Typically marine species such as *Chaetoceros danicus, Ch. holsaticus*, and *Bacillaria paxillifera* were noted among dominants, and the mass occurrence of *Coscinodiscus commutatus* was observed in 1953 only (Szarejko-Łukaszewicz 1957). Although *C. commutatus* and *C. granii* were noted in the 1970s, they did not occur later on (Plinski and Simm 1978, Chubarenko and Margoński 2008). On the other hand, *Skeletonema subsalsa* appeared in the late 1990s. As this species prefers waters of low salinity, it formed diatom blooms in the central region of the Polish part of the lagoon in 1999 along with *Melosira varians*. The biovolume of diatoms during the mass occurrence of *M. varians* in the western part of lagoon reached values comparable with those of the highest Cyanobacteria blooms close to the Russian–Polish border (Chubarenko and Margoński 2008)

As in the Polish part of the lagoon, Cyanobacteria also dominate in the Russian part (Chubarenko and Margoński 2008) (Fig. 2.2.11). The percentage of Cyanobacteria with respect to total phytoplankton abundance is very similar in both parts of the lagoon. Species from the genera *Merismopedia* and *Aphanocapsa*, and representatives of the subfamily Gomphosphaerioideae dominate in terms of abundance. Species from the *Anabaena genus* and *Aphanizomenon flos-aquae* do not occur among the dominants; nevertheless, their share in the total biovolume could be significant. At present, Cyanobacteria blooms are observed annually in the Russian part of the lagoon, while such blooms were noted only sporadically in the 1970s (Krylova and Naumenko 1992).

Significant differences in the phytoplankton composition between the Polish and Russian parts of the lagoon could be observed in the share of dinoflagellates and cryptophytes during the late 1990s. In the Polish part, under conditions of lower salinity, cryptophytes were more abundant, while in the Russian part, with higher salinity, dinoflagellates were more frequent (Chubarenko and Margoński 2008).

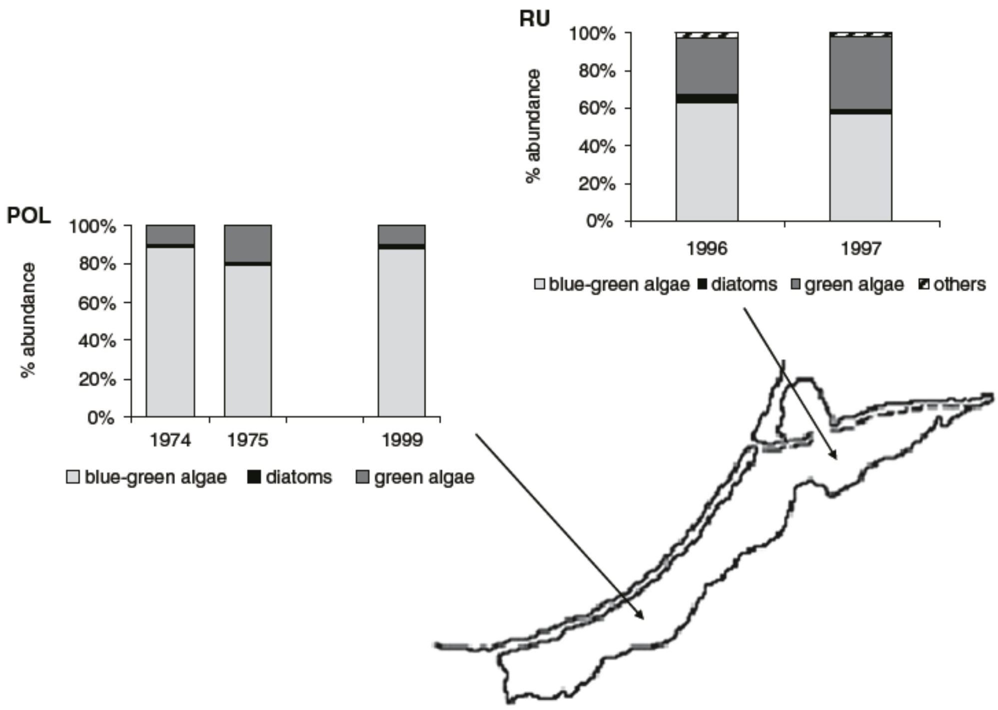


Figure 2.2.11. Proportion of main phytoplankton groups in Vistula Lagoon: POL - Polish part, RUS - Russian part (Chubarenko and Margoński, 2008)

2.2.8 Zooplankton

Research on zooplankton community structure, abundance, biomass, and seasonal as well as long-term changes has a long history in both parts of the Vistula Lagoon. This summary was prepared based on Chubarenko and Margoński (2008).

Significant changes in the zooplankton community occurred after 1915 when the Nogat River was cut off by flood-gates. This caused a three-fold decrease in the freshwater discharge into the lagoon. Until this time, the lagoon had been inhabited mainly by freshwater species (Wiktor and Wiktor 1959). As a consequence of the construction and the subsequent increase in water salinity, the zooplankton became comprised of freshwater euryhaline and brackish water species (Rozanska 1967, 1972). The permanent changes in salinity created unfavourable conditions for zooplankton development, thus the majority of species were unable to reach their maximum abundance (Biernacka 1956).

Differences in zooplankton abundance, biomass, and species composition between the Russian and Polish parts of the lagoon are influenced primarily by different salinity regimes. Rotifers play a much more important role in the Polish part than they do in the Russian part, which is dominated by copepods (Fig. 2.2.12).

The highest species diversity of zooplankton was observed close to the Pregola River estuary (84 species) and in the south-western area of the Polish part, while the lowest diversity was close to the Baltiysk Strait (Adamkiewicz-Chojnacka and Majerski 1980; Krylova 1985; Naumenko 1999; Tsybaleva et al. 2000). As regards abundance and species diversity, the dominating group of zooplankton was Rotifera (Adamkiewicz-Chojnacka and Radwan 1989); as they were represented primarily by weakly euryhaline, freshwater species, their abundance and biomass decreased as salinity increased (Rozanska 1963; Adamkiewicz-Chojnacka and Lesniak 1985).

The composition of dominating species in the Polish and the Russian parts of the lagoon was similar. The dominant rotifer species in the Russian part in terms of biomass are *Filinia longiseta, Brachionus calyciflorus, Keratella quadrata, Brachionus angularis, and Brachionus urceus*. In terms of abundance they are *F. longiseta, Keratella cochlearis, K. quadrata, Brachionus calyciflorus*, and *B. angularis.* Important changes in the dominating cladoceran species have occurred in recent years: *Diaphanosoma brachyurum* has been replaced by *Cercopagis pengoi*. The invader came to dominate with regards to biomass, but in terms of abundance *D. brachyurum* still plays the most important role. Other abundant species include *Bosmina sp., Leptodora kindtii, and Podon sp.* The dominant copepods are *Eurytemora affinis, Acartia tonsa, A. bifilosa, and Acanthocyclops viridis* (Chubarenko and Margoński 2008).

The dominating rotifer species in the Polish part of the lagoon in terms of biomass are *B. calyciflorus, F. longiseta, B. angularis, Euchlanis dilatata*, and in terms of abundance *F. longiseta, B. angularis, K. cochlearis, B. calyciflorus, and K. quadrata*. Among copepods the most important is *Eurytemora affinis*, the much less abundant *A. tonsa* and Cyclopoida. The dominating cladocerans include *Bosmina longirostris, D. brachyurum, and L. kindtii* (A. Krajewska, 2007, personal communication).

The seasonal dynamics of zooplankton abundance and biomass are similar in the two parts of the lagoon (Adamkiewicz-Chojnacka and Rozanska 1990), and are characterised by two peaks that are usually coincident in spring (April–May) and summer (August). This is typical of eutrophic waters (Naumenko 2004).

In August 1999, a new predatory Cladocera species, *Cercopagis pengoi* (Ostroumov 1891) appeared in Vistula Lagoon. It originated from the Ponto-Caspian basin and invaded with ballast waters. The highest abundance, at a density range of 17–533 ind m^{-3}, was observed in the Russian part near the Baltiysk Strait (Naumenko and Polunina 2000a, 2000b; Polunina 2001). In spring 2000, its abundance in the Russian part was ten-fold higher (average value 634 ind m^{-3} and maximum 3,000 ind m^{-3}) (Polunina 2001). In August 1999, it constituted 3.6% of the zooplankton biomass, while it had increased its share to 36.8% and 54.4%, respectively, by May and June 2000. In September 1999, it appeared in the Polish part of the lagoon at an average abundance of 220 ind m^{-3}, which accounted for 0.4% of the zooplankton biomass. In June 2000, with an average abundance of 160 ind m^{-3}, it constituted 1.3% of the total zooplankton biomass (A. Krajewska, 2007, personal communication).

The zooplankton of Vistula Lagoon is vulnerable to the salinity gradient. Moreover, as it is subject to the trophic pressure of juvenile Baltic herring, the naturalisation of the additional predator can negatively affect zooplankton structure as well as initiate significant changes in the trophic chain (Naumenko and Polunina 2000b).

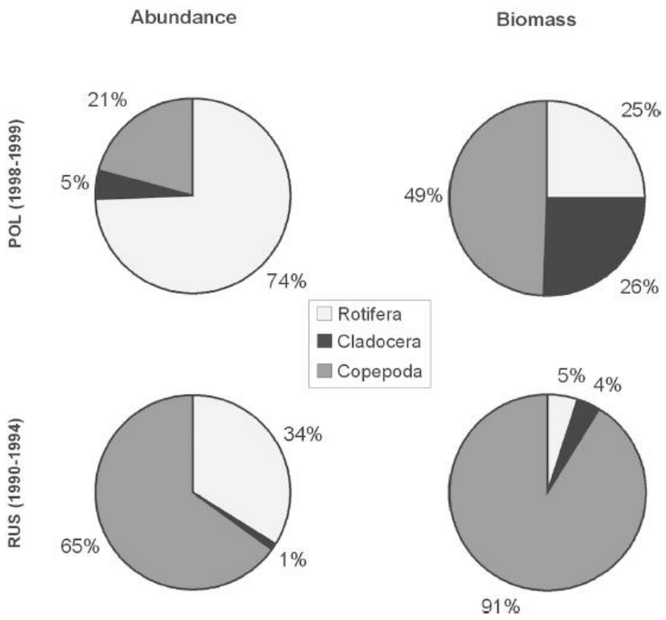


Figure 2.2.12. Proportion of main zooplankton groups in the Vistula Lagoon: POL - Polish part, RUS - Russian part (Chubarenko and Margoński, 2008)

2.2.9 Macrophytes

Macrophytes are playing an important role as habitat builders and therefore any changes (positive or negative) in their spatial extent and structure are extremely important for the whole lagoon ecosystem.

There are six known belts in the distribution of aquatic flora in the Russian parts of the Curonian Lagoon and Vistula lagoon (BERNET 2000):

- Microphytes belt – includes numerous small algal species and certain tall algae, e.g. *Cladophora*;
- Macrophytes belt – pronounced mainly in locations sheltered from wind and dominated by *Chara*, *Tolypellopsis*, *Stelligera*, and *Fontinalis*;
- Broad-leaved pondweed belt – comprised of several pondweed species *Potamogeton sp.*, water-milfoil *Myriophyllum sp.*, and *Batrachium sp*; sometimes stretches a distance of 200–500 m or more inside the lagoon;
- Water lily belt – the yellow water-lily Nuphar lutea, white water-lily *Nymphaea alba*, fringed water-lily *Nymphoides peltata*, broad-leaved pondweed *Potamogeton natans*; interrelated with reed belt and partially overlapping; particularly widespread in sheltered places at depths of 0.5–1.5 m; width usually ranges from 75 to 200 m;
- Rushes belt – dense stands form at depths of 0.5–1.5 m; stretches up to widths of 200 m; at some sites rush stands spread along the shallows far into the lagoon; dominants include common club-rush *Scirpus lacustris, Scirpus tabernaemontana*, and in some locations bulrush *Typha latifolia* and lesser bulrush *T. angustifolia*;
- Common reed *Phragmites australis* belt – in strips of 20–50 m in length; locally 150–200 m wide; normally proceeds onto the water surface; occasionally a belt of small aquatic vegetation separates it from the coast.

The structure of communities and the spatial distribution of the higher aquatic plants in Vistula Lagoon are similar to that of Curonian Lagoon. Vistula Lagoon is distinguishable from Curonian Lagoon by the additional common reed and common club-rush communities that occupy a major part of the lagoon coast along the Vistula Spit (BERNET 2000).

According to Plinski et al. (1978), the basic phytosociological units in the Polish part of the lagoon included *Scirpo-Phragmitetum* and pure aggregations of *Phragmites communis*, *Myriophyllo-Nupharetum*, *Parvopotamo-Zannichellietum*, and *Potametum lucentis*. The total area covered by plants was 2,197.4 ha, which constitutes 6.86% of the total area of the Polish part of the lagoon. Approximately 40% of the plant cover there were aggregations of *Phragmites communis* and an association of *Scirpo-Phragmitetum* with *Phragmites communis*, which comprised 93% of the overall plant biomass in the lagoon. The same authors compiled a list of recorded species with their abundance and distribution characteristics. Later studies (Plinski 1995) showed that significant changes have occurred, i.e. a decrease in the area covered by vegetation and an especially drastic decrease in the surface covered by narrow-leafed cattail and plants with submerged and floating leaves. Apparently, in some areas, submerged plants and plants growing further away from the coastline were disappearing, probably due to increased turbidity limiting photosynthesis and changes in the structure of bottom sediments. Those changes, however, did not affect homogenous reed aggregations, which remained nearly unchanged.

2.2.10 Macrozoobenthos

Extensive research on macrozoobenthos allows us to summarize the current status of this ecosystem component in the Vistula Lagoon and describe the community response to various external forcing factors including the appearance of non-indigenous species. This summary is provided based on Chubarenko and Margoński (2008)

The macrozoobenthos of Vistula Lagoon is dominated by euryhaline organisms of marine and freshwater origin. During the late 1990s, sixty zoobenthos species and groups (Ostracoda and Chironomidae) were identified in the Russian part of the lagoon. They belonged to the following 12 higher taxonomic groups: Hydrozoa, Bryozoa, Nemertini, Turbellaria, Oligocheata, Hirudinea, Polychaeta, Insecta, Malacostraca, Bivalvia, Gastropoda, and Arachnida (Ezhova et al. 2004). The current number of species is significantly lower in comparison to observations from the early twentieth century (Riech 1928) and the 1960s (Aristova 1965, 1973). In addition to the reduction in taxonomic composition over the last 80 years, other changes have also been identified. The majority of species currently noted are of marine origin, and the role of invasive species has increased dramatically (Ezhova et al. 2004) (Fig. 2.2.13). The reduction in taxonomic composition has been caused by the disappearance of freshwater species and, since 1988, the active colonisation of the lagoon by *Marenzelleria neglecta* (Rudinskaya 2000a, 2000b).

At the end of the 1990s the biomass of *M. neglecta* stabilised at a level (4–5 g m^{-1}) lower than that found in the 1989–1996 period (20 g m^{-1}). Polychaeta accounts for approximately 35% of the total biomass. The highest abundance and biomass of Polychaeta is observed close to the Baltiysk Strait. Freshwater benthic organisms occupy primarily the north-eastern part of the lagoon, and, until the 1980s, comprised 70% of the biomass; this value has now dropped to 46% (Ezhova et al. 2004).

There are three main assemblages in the Russian part of the lagoon: *Macoma*, *Marenzelleria*, and *Chironomidae-Ostracoda*. Approximately 20–25 marine and brackish water species constitute the *Macoma* assemblage, which inhabits the area of maximum salinity (5–7 psu) adjacent to the lagoon inlet. This is the richest community in terms of species composition and its average biomass ranges from 32 to 70 g m^{-2} (maximum 376 g m^{-2}). The *Marenzelleria* community is completely new to the lagoon. It occupies most of the Russian part and consists of 14–18 groups and species (70% saline and brackish water species; 30% freshwater species). It attains an average biomass range of 8–290 g m^{-2}. Polychaete biomass decreases during the autumn–winter period. The *Chironomidae-Ostracoda* community is typical of more freshwater areas, i.e. close to the Pregola River mouth and near the Polish–Russian border. Approximately half of the 12–14 species are freshwater species (Ezhova et al. 2004).

During the late 1990s, the zoobenthos biomass in the Russian part of the lagoon ranged from 0.2 to 452 g m^{-2}. The lowest values were calculated for the area close to the Pregola River mouth and in the eastern part of Primorskaya Bay (0.4–10 g m^{-2}), while the highest levels were noted in the area adjacent to the lagoon inlet (70–452 g m^{-2}). The annual zoobenthos production in the Russian part of the lagoon has decreased at the end of the last century to 23.2 kcal m^{-2} in comparison with results of 35.2 kcal m^{-2} from 1959–1988 and 40.7 kcal m^{-2} from 1989–1996. Although this trend was observed in all groups, it was extremely pronounced with freshwater species (Ezhova et al. 2004).

In the Polish part of the lagoon the vast majority of benthic organisms are freshwater taxa that are characteristic of eutrophic waters. Only polychaetes and most of the crustaceans are euryhaline, marine, or brackish fauna, such as *M. neglecta, Neomysis integer, Gammarus zaddachi, G. salinus, Rhithropanopeus tridentatus*, and the rare *Balanus improvisus*. In the open lagoon, the mean macrozoobenthos biomass did not exceed 22 g m^{-2} in 1988, whereas in the early 1990s it increased to 81–103 g m^{-2}. This increase was even more pronounced in the near-shore area where, in the same periods, it rose from 42 g m^{-2} to almost 300 g m^{-2} (Zmudzinski 2000).

In the western part of the lagoon, several brackish water species have disappeared since the 1950s, e.g. *Corophium lacustre, C. volutator, and Potamopyrgus antipodarum*. A drastic decrease of the previous dominating species, *Chironomus f. l. semireductus* and oligochaetes, has also been noted (Zmudzinski 2000) (Fig. 2.2.13). Invasive species have played an important role in these changes in taxonomic composition, abundance, and biomass. Alien species include the new gammarid species *Gammarus tigrinus, Pontogammarus robustoides*, and *Obesogammarus crassus* (Jazdzewski et al. 2002), and the polychaete *M. neglecta*, which has become a dominant species in nearly the entire area. In some biotopes it has exceeded 90% of the total biomass. This invasion caused a significant increase in the total zoobenthos biomass (Zmudzinskii 2000).

Zmudzinski (1957) described three main assemblages of benthic fauna. The Chironomidae assemblage (*Chironomus f. l. semireductus, Procladius sp. Microchironomus conjugens* and *Cryptochironomus defectus*), with oligochaetes, and crustaceans (*Corophium volutator* and *Rhitropanopeus harrissi tridentatus*), was characteristic of the muddy bottom. The *Dreissena polymorpha* assemblage, with chironomids, oligochaetes, and crustaceans (*Corophium spp*. and *Rhitropanopeus harrissi tridentatus*), was abundant at the muddy and sandy bottom border. Oligochaetes predominated in the third assemblage, consisting of species associated with the shallow, sandy bottom. Other important taxa were Chironomidae, Nemertini, Bivalvia (*Dreissena polymorpha*), and Crustacea (*Rhitropanopeus harrissi tridentatus*).

In Vistula Lagoon, benthic fauna in various parts of the lagoon is mostly related to different physical conditions rather than to anthropogenic factors. Moreover, opposite tendencies in taxonomic composition changes in both sides of the lagoon are observed: the increasing role of brackish and marine-water species in the Russian part and extinction of some marine species in the Polish part (no overall trend).

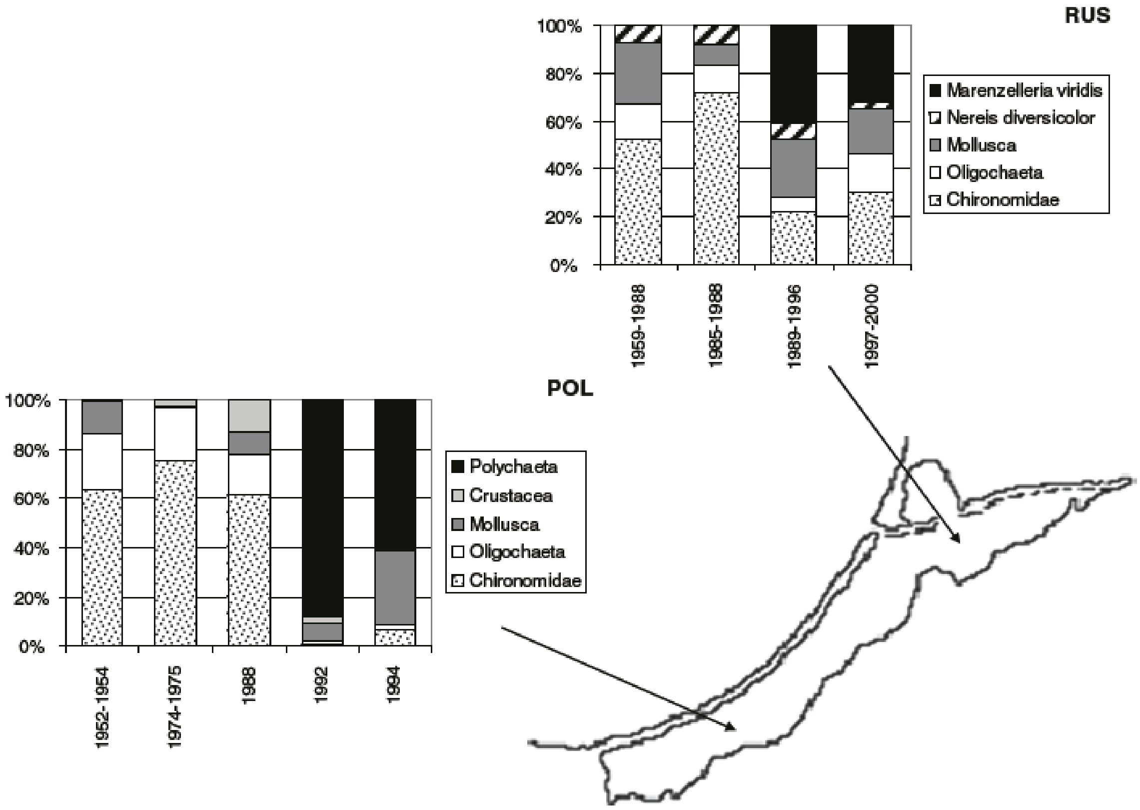


Figure 2.2.13. Proportion of the main macrozoobenthos groups in Vistula Lagoon (Brzeska 1995; Cywinska and Rozanska 1978; Ezhova et al. 2004; Fall 1993; Marut 1990; Zmudzinski 1957). POL - Polish part, RUS - Russian part (Chubarenko and Margoński, 2008)

2.2.11 Ecological status

Monitoring of the Vistula Lagoon according to WFD requirements started only in 2007. First preliminary assessment of its status was carried out based on monitoring data of years 2007 and 2008.

Biological assessment was performed based on chlorophyll "a" concentrations. In 2007 that corresponded to moderate status and in 2008 – **poor** status. However, in some other publication (http://www.gios.gov.pl/stansrodowiska/gios/pokaz_artykul/pl/front/stanwpolsce/srodowisko_i_zdrowie/jakosc_wod) in 2008 the status was **bad** with respect to chlorophyll "a" concentrations (Fig. 2.2.14).

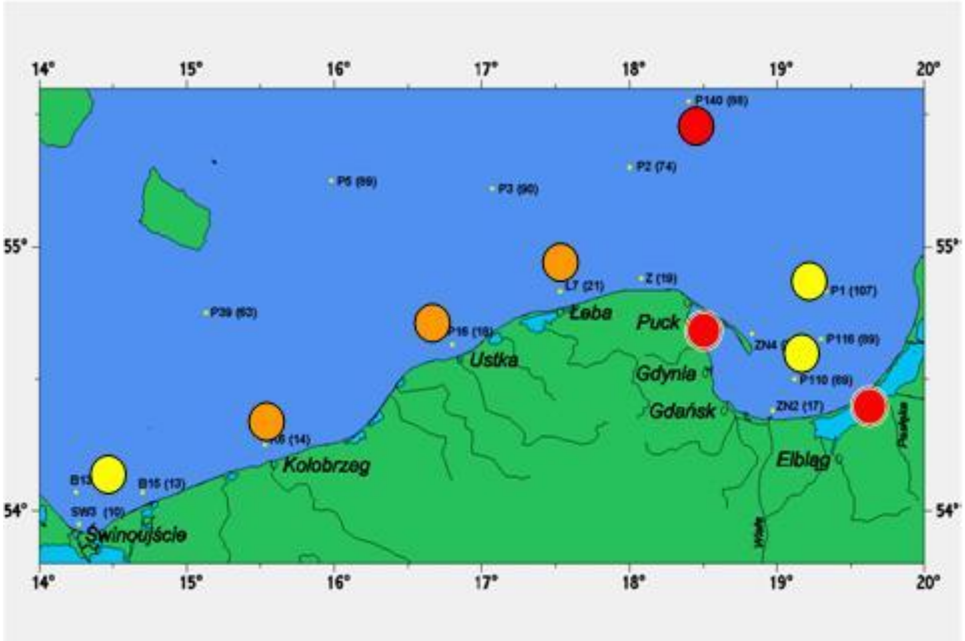


Figure 2.2.14. Classification of marine waters' status for the Polish South Baltic area carried out in 2008 with respect chlorophyll „a" concentrations; yellow – moderate status, orange – poor status, red – bad status (Source: GIOŚ/PMŚ - http://www.gios.gov.pl/stansrodowiska/gios/pokaz_artykul/pl/front/stanwpolsce/srodowisko_i_zdrowie/jakosc_wod)

With respect to biological EQR the lagoon was classified in 2007 as moderate and in 2008 as poor.

With respect to chemical status the lagoon was assessed as both in 2007 and 2008 as good.

Overall evaluation of the ecological status of the lagoon indicates bad status of lagoon's waters (Kopiec, 2008).

According to Kopiec (2011) since 2008 till 2010 overall ecological status of the lagoon remained bad.

2.2.12 Fish and Fisheries

Due to its productivity, Vistula Lagoon provides favourable conditions for many fish species. The dominant freshwater species are accompanied by fewer brackish water species. Catch statistics indicate that 30 fish species were caught during the 1889–1920 period (Bartel et al. 1996). These included the following:

Marine species:
herring (*Clupea harrengus*)
flounder (*Pleuronectes flesus*)
cod (*Gadus morhua*)
eelpout (*Zoarces viviparous*)

Migratory species:
Atlantic salmon (*Salmo salar*)
sea trout (*Salmo trutta*)
sturgeon (*Acipenser sturio*)
river lamprey (*Lampetra fluviatilis*)
eel (*Anguilla anguilla*)
vimba (*Vimba vimba*)
shad (*Alosa fallax*)

Freshwater species:
ruffe (*Gymnocephalus cernuus*)
crucian carp (*Carassius carassius*)
prussian carp (*Carassius auratus gibelio*)
bream (*Abramis brama*)
tench (*Tinca tinca*)
perch (*Perca fluviatilis*)
roach (*Rutilus rutilus*)
pikeperch (*Sander lucioperca*)
pike (*Esox lucius*)
rudd (*Scardinius erythrophthalmus*)
carp (*Cyprinus carpio*)
smelt (*Osmerus eperlanus*)
burbot (*Lota lota*)
sabre carp (*Pelecus cultratus*)
bleak (*Alburnus alburnus*)
asp (*Aspius aspius*)
white bream (*Blicca bjoerkna*)
gudgeon (*Gobio gobio*)
wels (*Silurus glanis*)

Species no longer noted in catches are Prussian carp, rudd, sturgeon, bleak, gudgeon, eelpout, wels, and shad (Bartel et al. 1996).

The lagoon provides spawning grounds for typically marine species, such as herring as well as various freshwater species, including pikeperch, bream, roach, and perch (Psuty 2012).

The total annual catch in the lagoon fluctuates strongly depending on the abundance of the herring that enters the shallow lagoon waters to spawn. The mass entrance of herring spawners is usually observed in February–March and finishes in May. The beginning of the spawning migration is significantly impacted by hydrological conditions, mainly the disappearance of ice cover. With the exception of the 1957–1964 period, the share of herring in the catches has always been considerable, exceeding 70% of the total fish biomass in most years. During the 1993–2002 period, it has oscillated between 68% and 90%. Most herring are caught in the Russian part of the lagoon; this is primarily due to its closer proximity to the Baltiysk Strait. Variation in herring catches (2,000–13,000 tons annually) has had an impact on total catches (3,000–15,000 tons) over the last 30 years. In addition to herring, the most important fish species are eel, pikeperch, and bream. In order to optimise the exploitation of fish productivity of the lagoon, annual catches of pikeperch and bream are regulated by the Polish–Russian Commission for the Management of Fish Resources in Vistula Lagoon (Chubarenko and Margoński, 2008).

With the exception of herring catches, the total catch in the Vistula Lagoon has remained on a comparable level of 600-800 tons for many years at an annual mean for the 1948-2010 period of 678 tons. The structure of the catch, however, has shifted towards species that command lower prices, which means they are less satisfactory to the fishers. Eel fishery is no longer a primary source of income for Polish fishers because of drastic decreases in biomass and the cessation of stocking resulting from the lack of an agreement with the Russian side. This situation should change soon since stocking cultured eel started again in 2005 in the Polish part of the lagoon, and since 2011 additional measures have been implemented as part of the European Eel Management Plan establishing measures for the recovery of the stock of European eel. Currently, roach, bream, and perch comprise the bulk of the catch with decreasing contributions of pikeperch and eel (Table 2.2.6.) (Psuty 2012).

As summarized by Psuty (2012) the Vistula Lagoon fisheries administration developed a relatively effective management system which permitted it to adapt to changing environmental and economic conditions. It is currently based on the following measures:

- limiting fishing effort – number of vessels, maximum number of fishing gear per vessel, length of net sets and fyke nets;

- designating minimum protected fish size and the associated minimum mesh size in gillnets;
- requiring the installation of protective sieves in the last chamber of fyke nets from 1 June to 31 December;
- limiting regions in which small-mesh gillnets (perch-roach nets) can be used;
- designating gear-free zones in waters known as mass fish migration corridors;
- designating spawning ground and river mouth protected areas;
- designating closed seasons for pike, pikeperch, bream, sea trout, salmon, and eel;
- establishing of Total Allowable Catch (TAC) for bream and pikeperch set by the Polish-Russian Joint Commission.

Table 2.2.6 Composition of catches registered in 2010 in both parts of the lagoon (Psuty 2010).

	Catches in the Polish part of the lagoon [kg]	Catches in the Russian part of the lagoon [kg]	Share of Polish catches in the total catches in the Vistula Lagoon [%]
Eel	9 793	15 479	38.8
Pikeperch	65 122	135 000	32.5
Bream	109 339	273 395	28.6
Ziege	19 174	68 165	
Perch	80 199	30 570	72.4
Roach	95 772	72 832	56.8
Smelt	401		
Pike	113	169	
Tench	529		
Crucian carp	14 474		
White bream	15 538		
Burbot	701	332	
Round goby	634		
Flounder	9 720		
Herring	1 637 003	1 997 453	45.0
Other		11 098	
Salmon [indiv.]	17		
Sea trout [indiv.]	241		
Total	2 317 157	2 604 493	
Total without herring	680 154	607 040	52.8

For more information regarding the legal and social aspects of fisheries see also section 3.1.

2.2.13 Cormorants in Kąty Rybackie Colony

According to the Helsinki Commission sources (http://www.helcom.fi/BSAP_assessment/ifs/ifs2011/en_GB/Cormorant/) "the vast majority of the cormorants breeding in the Baltic are nesting in colonies located near to the coast. The breeding sites are quite often islets where the birds build their nests on the ground or on trees.

Great cormorant. Photo by P. Margonski

The highest concentration of cormorants is found around the highly eutrophic estuaries of the large rivers of the southern Baltic: Vistula Lagoon (11 500 bp in 2006 in a colony on Vistula Spit in Kąty Rybackie, Poland; Figure 2.2.15), Odra Lagoon (10 750 bp in 2006 in five colonies in Mecklenburg-Western Pomerania and Poland), and Curonian Lagoon (11 300 bp in 2006 in two colonies on the Lithuanian and the Kaliningrad side of the lagoon)."

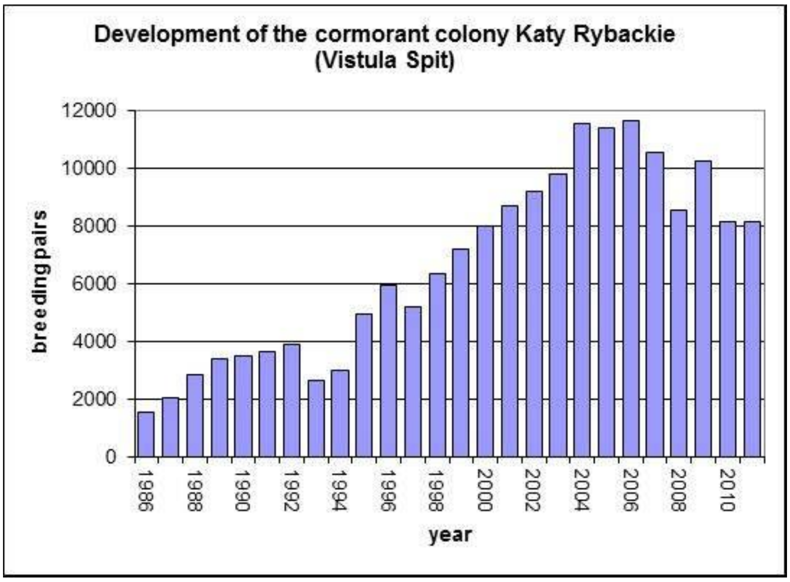


Figure 2.2.15: The development of the largest European Cormorant colony on Vistula Spit, Poland, 1986-2009. Data from Przybysz (1997), Mellin et al. (1997), Goc et al. (2005), Goc (2006) and M. Goc & P. Stępniewski (pers. com).

High eutrophication of the Vistula Lagoon explains intensive expansion of those birds in this area since 1987 till 2006. Since then the concentration of cormorants in Kąty Rybackie dropped to 8000 bp in 2010 and stays at this level. This may be associated with improving water quality of the lagoon or some minor actions limiting the cormorants' population like: oiling or pricking of eggs and scaring the birds. Shooting of cormorants was not allowed so far in this area. But still, this is too high concentration and according to local fishermen, creates serious problems for them. Fishermen state that cormorants catch more fish (also the valuable species) than they can catch. This also results from

legal restrictions: fishermen can catch fish only in specific periods set by the Ministry of Agriculture and Rural Development, however cormorants enjoy full freedom in catching fish – they do not have time restrictions and catch quotas.
Regarding transboundary perspective of this issue, this is rather local, Polish problem especially with respect to damage made to forests. However, with regard to impact on fish stocks it may also influence the Russian side.

2.3 Main ecological and environmental problems

The main environmental problems in the lagoon area are listed below. Many of them may become more severe due to climate changes in the area. That is why it is so important to assess impact of climate changes on the Vistula Lagoon hydrology and ecosystem.

This short overview of the problems is based on review of many publications and on Stakeholder cooperation agreement between the stakeholders in Russia and Poland on the implementation of reinforcement of the environmental integrity of the Vistula Lagoon as a pert of cross-border South Baltic transitional waters, developed during ARTWEI project (www.kucorpi.lt).

- Eutrophication
  It is a major environmental problem for the lagoon state and functioning. Eutrophication is caused by the rapid urbanization and development of industry and tourism in the drainage area which was not accompanied by the proper investments in waste water management. Diffuse sources mainly from agriculture contribute as well. Lagoon is especially vulnerable to eutrophication due to the large drainage area and limited water exchange with the Baltic Sea.
- Recycling of nutrients from sediments
  This is most probably responsible for a limited response of the water quality to nutrient load reduction. Due to almost continuous wind driven resuspension, nutrient fluxes between water column and sediments are very dynamic.
- Increased salinity due to continuous dredging of the Baltiysk Strait and salt intrusions upstream the Pregola River during wind surges cause temporary problems for the supply of drinking water to Kaliningrad (it will be discussed in depth below).
- Overuse for recreational purposes of the Polish part of the Vistula Spit during the summer season beyond the carrying capacity of resources. However, the Russian part of the Spit as former military area is in the pristine conditions and undeveloped, therefore suitable even for green tourism.
- Fishing pressure.
  A combination of high fishing pressure and eutrophication resulted in significant changes in fish stock size and their condition. Changes in level of fish exploitation depend mainly on human activities: international regulations (common bream & pikeperch); prices at the market (herring, partly); and low level or lack of stocking (eel). However, there are also natural conditions influencing the fishing pressure such as year-to-year variation in intensity of herring spawning migrations. There is also a fishing pressure related to the Cormorants activity in Kąty Rybackie colony.
- Appearance of alien species.
  There are various mechanisms responsible for the appearance of non-indigenous species (NIS): "natural" ones being a consequence of climate change (partly also induces by the human activity) and "anthropogenic" ones where the transportation with ballast waters plays the most significant role. The Baltic Sea area (including its lagoons) is especially vulnerable for NIS appearance and usually significant changes in the native community structure are expected influencing the existing food web.
- Flood danger in low-lying areas due to poor technical conditions of flood-prevention and drainage infrastructure. The drainage system requires revitalization of mosts locks, culverts,

drainage ditches, pumping stations and flood embankments preventing rapid storm surges in case of north-easterly winds.

2.3.1 Intrusion of the salt-bearing wedge into the mouth of the Pregola River

Morphological and hydrological features of the Kaliningrad Marine Canal and the ones of the mouth part of the Pregola River watercourse (Fig. 2.3.1) from the point of the river confluence into the lagoon to the point of conjunction of two branches of the river are similar - a certain level of depth (8-11 m) is maintained for navigation. Navigable depth in the Kaliningrad Marine Canal is of 9-11m, width is 50 m for bottom part and 150 m on the surface. Average depth does not exceed 4 m upstream the conjunction point of the river.

Active interaction of the Baltic waters (salinity 6.5-7 ‰) and fresh river water occurs throughout the Kaliningrad Marine Canal and estuarine part of the Pregola River (fig. 2.3.1) [Chubarenko, 2007]. According to research held in 1994-1997 [Chuabrenko, Shkurenko, 1999], the boundary between fresh and salt water in the estuary part of the Pregola River climbs up the river every autumn [Chubarenko and Chubarenko, 1997] and reaches the centre of the urban part of the river. It happens due to natural features of water dynamics in the estuary part of the Pregola River including the whole Kaliningrad Marine Canal and the urban part of the river (Fig. 2.3.2) [Chubarenko, Shkurenko, 2001].

Furthermore, exactly in this period the combination of interacting driving factors results in frequent surges and intensive penetration of salting estuarine waters upper the river every year (Fig. 2.3.3). As the result water intakes of pumping stations (UVS-1 and UVS-2) which are located upstream from the city are blocked by water with anomalous salinity. It can lead to a break in the water supply of the City of Kaliningrad. Backing storage reservoir can provide the city with fresh water for 2-4 days only.

Increase of the water level which is caused by the global climate change can provoke the deeper and longer intrusion of salt water in the urban part of the Pregola River. For early warning of this situation additional numerical investigations should be carried out using long-term meteorological and hydrological forecasts for the local region.

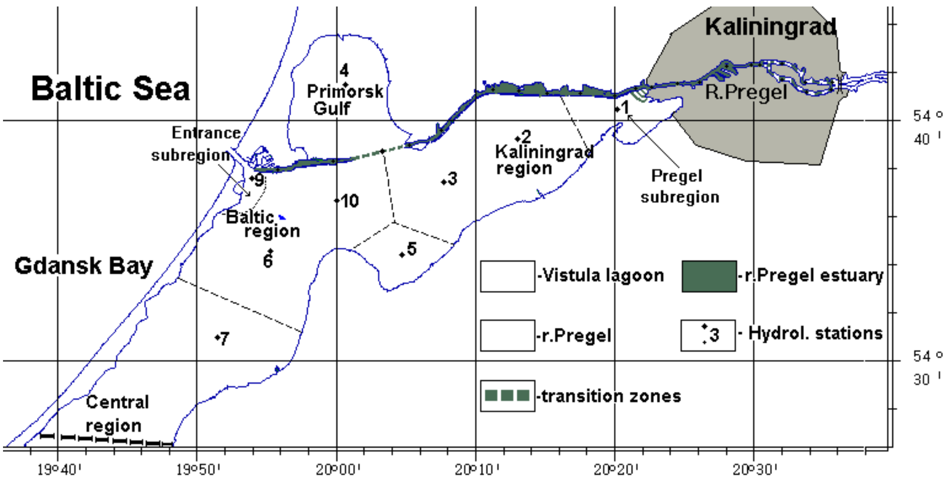
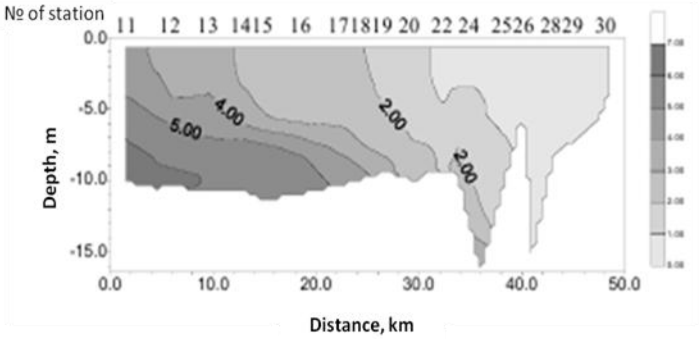


Figure 2.3.1. Estuarine part of the Pregola River (Kaliningrad Marine Canal and urban part of the river) and the Russian part of the Vistula Lagoon (Chubarenko, 2007)

Distribution of salinity (ppm) along the Kaliningrad Marine Canal and the Pregola River, 19.09.1998



Distribution of salinity (ppm) along the Kaliningrad Marine Canal and the Pregola River, 18.11.99

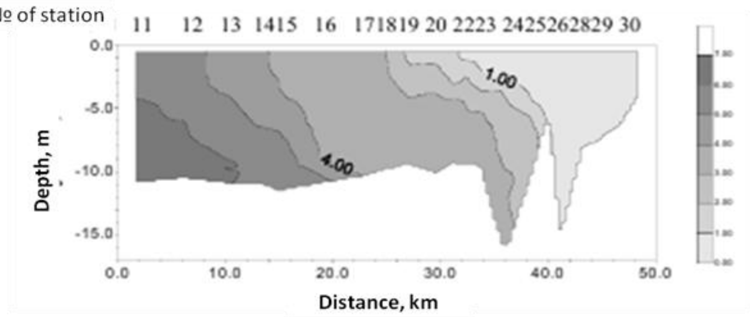


Figure 2.3.2. Typical distribution of salinity in the estuarine part of the Pregola River on the eve autumn surge (Chubarenko, 2007)

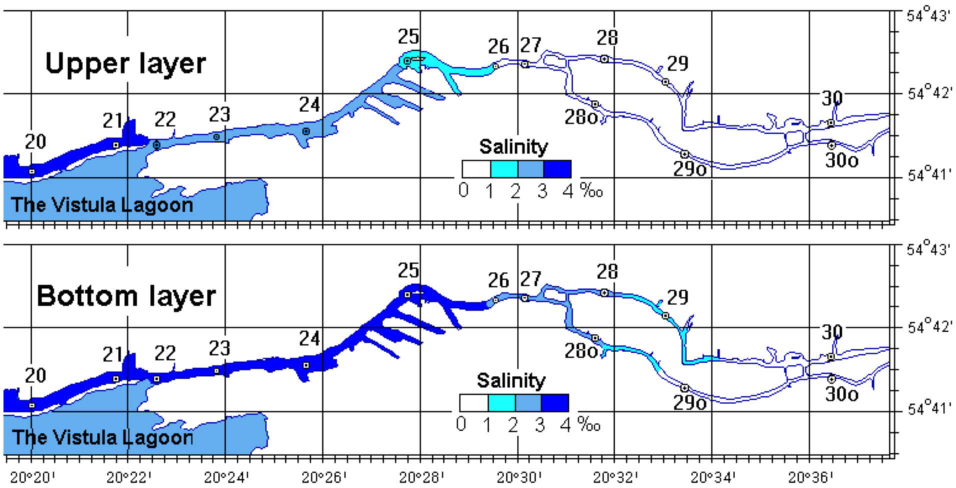


Figure 2.3.3. Scheme of the most probable location of the boundaries of water with different salinity on the eve of the autumn storm period on surface and bottom layers. Drinking water supply stations UVS-1 and UVS-2 are located at the points 29o and 30o. (Chubarenko, 2007)

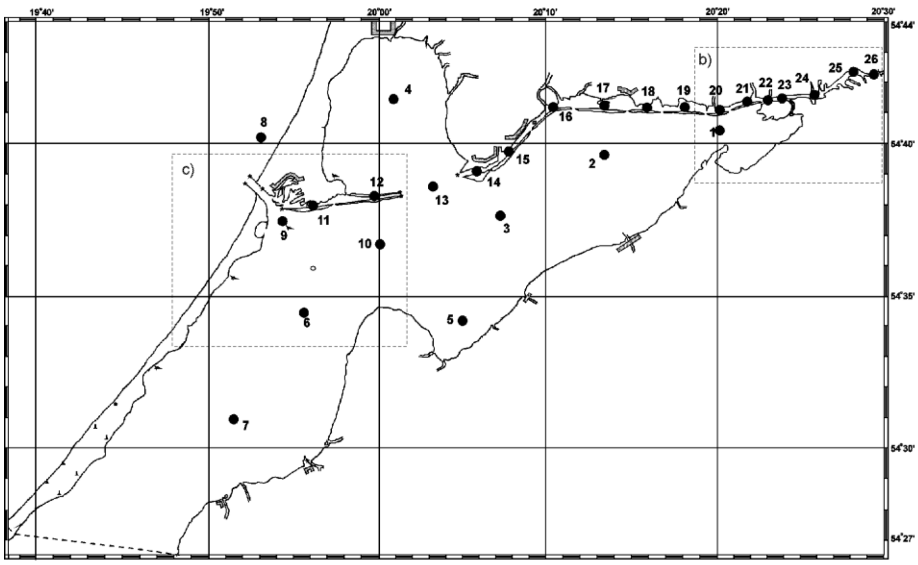
2.4 Knowledge gaps

To describe the current status of the lagoon and its possible response to various climatic and economic scenarios we need to gather all the necessary information as well as understand the key processes driving the lagoon ecosystem functioning. Even though the lagoon area is regularly monitored, it is difficult to assess the dynamics of many atmospheric and hydrological parameters and use monitoring data for modelling purposes (Chubarenko et al., 2008). First of all the so called “regular monitoring” is carried out here in the following way:

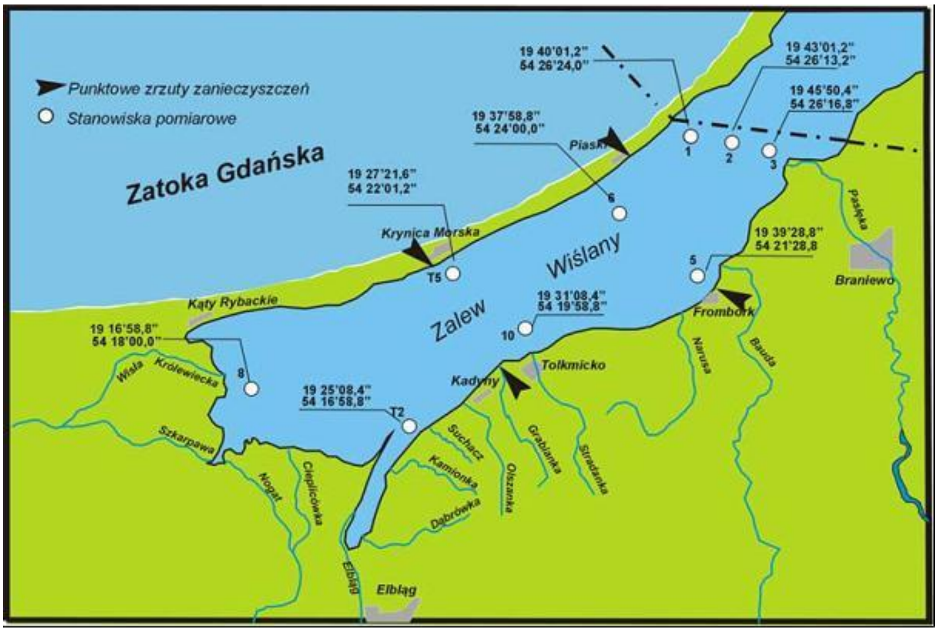
1) ecological parameters in rivers discharging to the lagoon are monitored every year, from March to October on a one day in a month; but this may be any day of the month and it is not in any way connected to monitoring of other areas (like Vistula Lagoon) or monitoring of the discharges of those rivers; since November till February data are generally missing – there is no monitoring, even though rivers are not covered with ice; only two rivers on the Polish side are monitored from January till December (Pasłęka and Bauda) and in some cases twice a month (Pasłęka); basing on such information it is not possible to determine if the measured concentrations are typical for the month or are just incidental and sometimes related to some accidental dumping of sewage, manure in the river basin areas; besides, there is no information on winter concentration which would be valuable for assessing nutrients concentration in periods when there is no vegetation; the lack of monitoring in winter months disables also a proper set up of water quality modelling tools; therefore all predictions produced on such a basis are uncertain and always indicate some errors;

2) discharges in rivers are regularly monitored only in some of them: Pasłęka, Bauda on the Polish side and Pregola, Mamonovka and Nelma on the Russian side; other Polish rivers (Elbląg, Nogat, Szkarpawa) and a relatively big river – Prokhladnaya - on the Russian side are not monitored at all and information on their discharges has to be assessed basing on some indirect information; this situation prevents reliable assessment of riverine discharges to the lagoon, as well as nutrient and pollution loads to the lagoon; again, as above, all predictions of water hydrodynamics and water quality in the lagoon are not fully reliable and great effort is required to make them realistic;

3) ecological parameters in the lagoon are monitored on selected stations (9 of them on the Polish side and 26 on the Russian side including outlet of the Pregola River from April till October at the Polish part of the Lagoon (Fig. 2.4.1), however only temperature and salinity are measured in the Kaliningrad Marine Canal and the Pregola River; as far as the number of stations could be considered as satisfactory, the sampling periods and frequency is not good enough to make proper calibration and validation of hydrodynamic and ecological modelling tools used for predicting future changes in the lagoon;



a)



b)

Figure 2.4.1. Location of monitoring stations in: a) the Russian side (Chubarenko, B.V., personal communications) and b) the Polish side of the Lagoon in 2007 -2008 (Kopiec, 2008)

4) meteorological parameters are monitored regularly but in Poland only on the south side of the lagoon and in Russia on the north side of the lagoon; access to the data is difficult due to their high cost; this again prevents perfect mathematical models set up, calibration, validation and prediction of changes of hydrodynamic and ecological parameters in the lagoon.

The above proves also that the monitoring of the lagoon is not synchronized in time with the rivers monitoring, as well as the monitoring of the Polish part of the lagoon and the rivers is not synchronized in time with monitoring of the Russian part of the lagoon and the rivers. Therefore, in this case “regular” means rather “repetitiously” but absolutely not synchronized in time and not necessarily on the same date every year, every month.

Generally speaking, two fundamentally different systems of monitoring program are implemented at the Polish and the Russian sides of the Vistula Lagoon – targeted and baseline monitoring respectively (Chubarenko, 2007). Monitoring stations in the Polish part are mainly associated with cities and include anthropogenic influence, while stations in the Russian part are located outside possible anthropogenic sources and show mainly background or natural conditions.

Generally, information on main meteorological, hydrological and water quality parameters for both Vistula Lagoon and the river catchments is very scarce and incomplete. It can even be misleading. For example, according to the report by GIOŚ of 2010 in years 2007 – 2008 water temperature in the lagoon was higher than normally. This situation was not a result of natural processes but simply the fact that sampling started later than normally! (http://www.gios.gov.pl/zalaczniki/artykuly/Ocena_srodowiska_morskiego_Baltyku_za_rok_2010.pdf). It may be considered as a minor problem, however in case of calibration and validation of numerical models, it may become a major issue.

The number of meteorological stations is not sufficient, type specific concentrations for soils are unknown, and the CORINE Land Cover database does not cover Russian territory. This becomes especially apparent when tackling transboundary problems. There is a need for free data acquisition and improved data access. In addition, a synchronization of sampling campaigns, in terms of sampling time, frequency and techniques, would be necessary. Since there is no monitoring of ecological parameters in months November – March, even though ice cover on the lagoon is not so long lasting and monitoring of the rivers is incomplete, the monitoring programs need to be adjusted to the requirements of modelling tools used for predicting changes in the lagoon's water hydrodynamics (e.g. changes in salt distribution and assessment of possible salt intrusions into rivers, as well as assessment of currents and water levels variations with special focus on flood risk) and water quality (e.g. possible intensification of toxic algal blooms).

For modelling purposes it is also very important to consider the atmospheric nutrient deposition and nutrient exchanges between the water column and the sediments. In our case this information is only approximated based on in situ measurements from other areas (e.g. Łeba city on the open Baltic coast of Poland). Since the modelling tools are more and more intensively used by water managers for predicting future changes and impacts in the lagoon and in river basins, it is necessary to provide reliable sets of data for their set up, calibration and validation. As it was discussed above, definitely monitoring programs need to be substantially improved and synchronized locally and across the border. Only then will we be able to achieve reasonable decision making in the fields of water and coastal zone management.

3. The Management Story

3.1 Socio-economic, livelihood and political issues

3.1.1 Administrative districts in the Polish part: some characteristics

As a result of past history, the environs of Vistula Lagoon are scarcely populated; relocation of the population after the Second World War, division of the lagoon area over two countries and a long-term blockage of the Baltiysk Strait in the Kaliningrad region can be mentioned as the main reasons. Nowadays, serious economic problems such as high unemployment and inadequate infrastructure persist, being largely attributable to the aftermath of a centrally planned economy and volatile political relations between two countries. The area is primarily divided between Poland and the Kaliningrad region of the Russian Federation. The Polish part of the lagoon is shared by two provinces, i.e. major administration units: Warmia-Masuria (capital Olsztyn) and Pomerania (capital Gdańsk). Two smaller units (counties) in the Warmia-Masuria and one in the Pomerania Province border the lagoon. In the following, basic facts on the urbanization of the Vistula Lagoon region are provided.

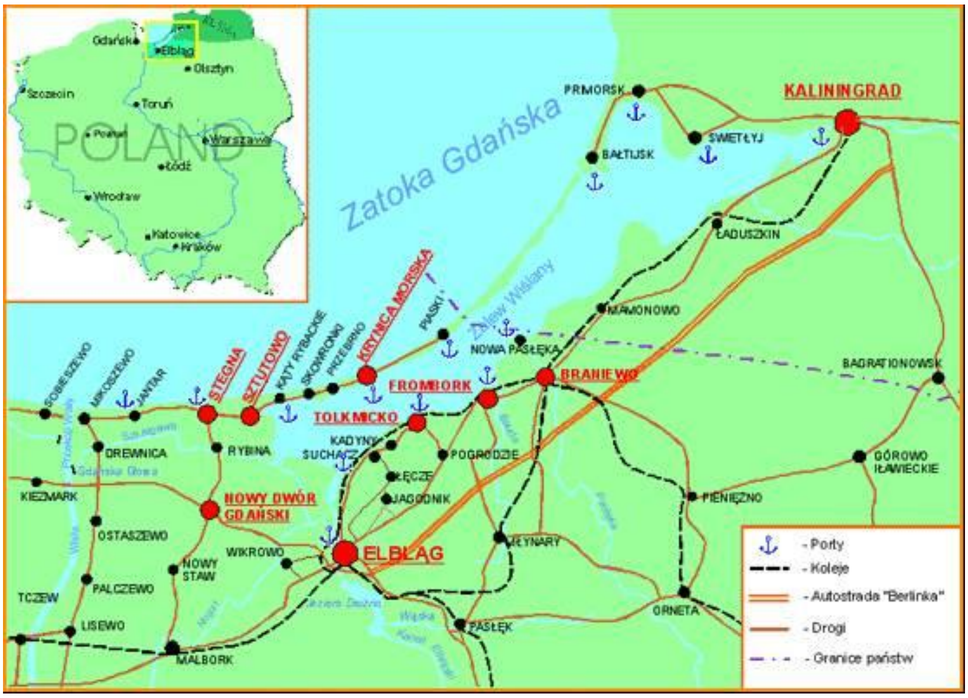


Figure 3.1 Location of the Vistula Lagoon and main cities. Source: http://www.zalew.org.pl/lagomar/index.htm

Warmia-Masuria Province (województwo warmińsko-mazurskie)
City of Elbląg

Elbląg, the second largest city of Warmia-Masuria Province, is situated in the south-west corner of Vistula Lagoon; it is the largest city in the Polish part of the lagoon (see Fig. 3.2). The city covers 7,952 ha with 1,975 ha belonging to urbanized areas, 1,989 ha to parks and forests, 2,726 ha to agricultural land, 102 ha to water bodies (rivers, lakes and ponds) and 1,021 ha to other areas. The total number of inhabitants amounts to 127,954; this value slightly decreased with respect to the peak value of more than 130,000 inhabitants in 2000. The average *per capita* gross monthly income in the business sector equals 2,521 PLN, which is considerably less than the national average with 3605 PLN.
The decreasing population and the rather low average monthly income reflect the city's economic difficulties related to a severe reduction of employment in some of the area's key businesses such as Alstom factory and the local brewery. The rate of unemployment remains above the national average and equalled 16.6% in February 2012 compared to 13.2% for the entire country. On the other hand, the city's unemployment rate is well below the average value for Warmia-Masuria Province, 21.1%, the highest unemployment rate for all 16 provinces in Poland.

Elbląg County (powiat elbląski)

Elbląg County belongs to Warmia-Masuria Province and covers 141,558 ha (see Fig. 3.2). The average population density equals 40 people per km^2, while it is 59 for the entire province. In 2010, Elbląg County had 56504 inhabitants; they have been suffering from high unemployment (27.5%). The average gross monthly *per capita* income is 2563 PLN. The county has three smaller towns: Tolkmicko (pop. 2,850), situated on the lagoon coast, Pasłęk (pop. 12,000), belonging to the lagoon catchment through river Pasłęka, and Młynary (pop. 1,900) also within this catchment. The remaining part of the county is dominated by rural areas, forests and water bodies; forests and water cover about

40% of the county’s area. The urbanization index (percentage of population living in towns and cities) is low and equals ca. 30%.

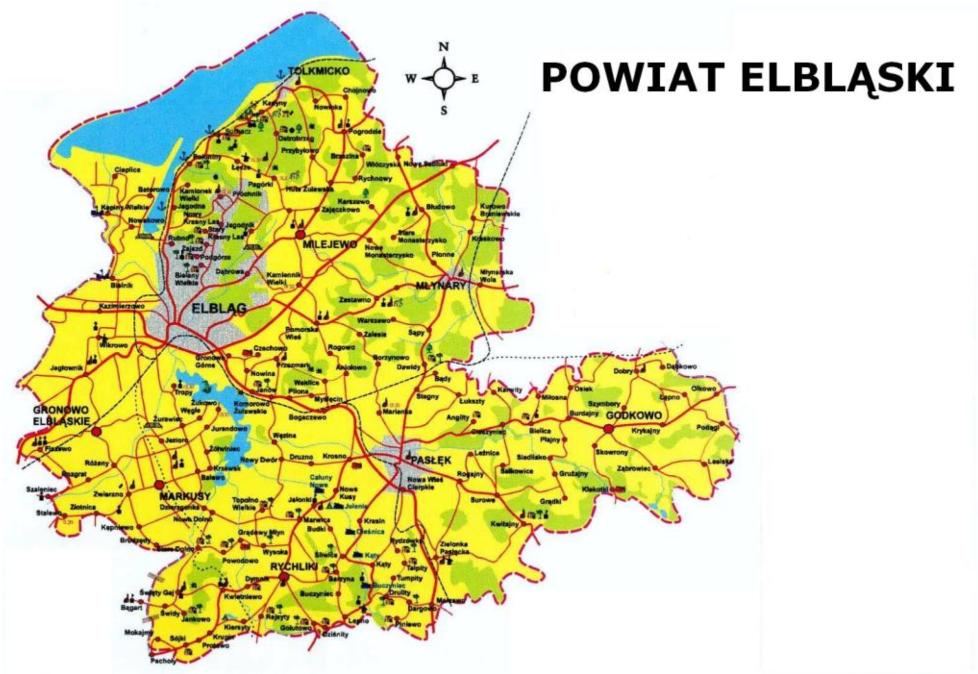


Figure 3.2 City of Elbląg and Elbląg County. Source: http://zdp-elblag.internetdsl.pl/

Braniewo County (powiat braniewski)

Figure 3.3 Braniewo County. Source: http://olsztyn.is.gov.pl/2803/index.php?option=com_content&view=article&id=46&Itemid=57

This county is also situated in Warmia-Masuria Province and occupies 120,454 ha (see Fig. 3.3). The population density is lower than in Elbląg County and equals 36,6 people per km^2. The total population in 2010 was 42,633 and shows a decreasing trend. The rate of unemployment is very high and equals 31.6%. The average monthly *per capita* income is 2641 PLN. The county lies in the lagoon catchment. The county's capital Braniewo, situated on Pasłęka River near the frontier to the Kaliningrad region, has a surface of 1,236 ha of which 28% is used by agriculture. Currently, Braniewo has 17,500 inhabitants, which is slightly less than the record from June 2004 with 18,068 inhabitants. The closure of a major employer, a local brewery, created high economic tensions in the town. Other key employers are the army and a prison, administered by the government (Ministry of Defence and Home Office). Local businesses feature mainly small and medium enterprises, operating on the local scale market. Other smaller towns are Frombork (pop. 2,500) and Pieniężno (pop. 2,900). Despite an urbanization index of 53.4%, the county retains a predominantly rural character, mainly due to the low population density.

Pomerania Province (województwo pomorskie)
Nowy Dwór County (powiat nowodworski)

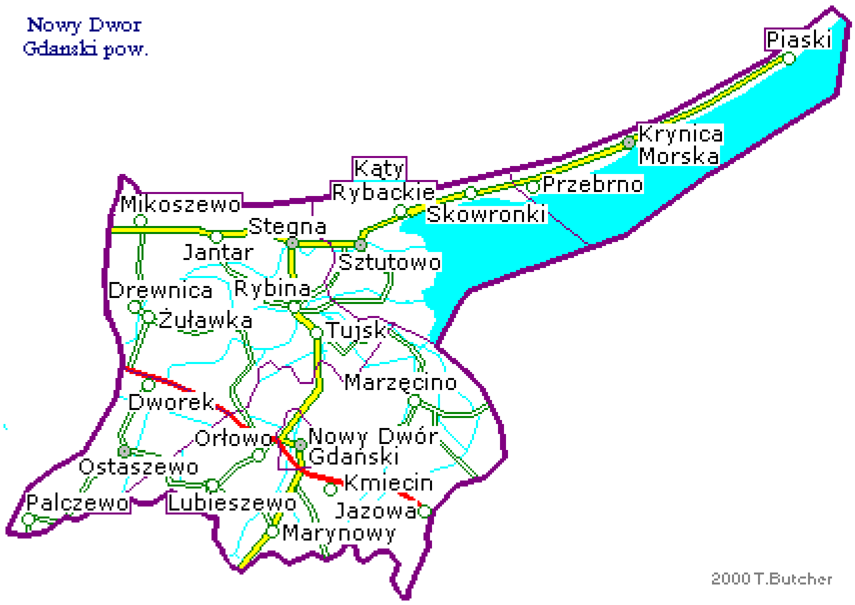


Figure 3.4 Nowy Dwór County. Source: http://www.rootsweb.ancestry.com/~polpomor/p-nowygd.htm

Nowy Dwór Gdański County belongs to Pomerania Province and occupies 67153 ha with a relatively stable number of 35700 inhabitants (see Fig. 3.4). The average population density is 53 people per km^2, which is lower than the average value of 122 inhabitants per km^2 in the province. The rate of unemployment (27.5%) is typical for counties in the Vistula Lagoon area, but is strikingly when compared with the entire Pomerania Province (13.2%). The average gross monthly *per capita* income is similar to the two other Lagoon counties and equals 2811 PLN. Higher incomes result from the proximity to Gdańsk, where many residents of this county work and an improved transportation infrastructure. The urbanization index is low (31.55%), since there are only two towns, namely Nowy Dwór Gdański (county capital, pop. 9,900) and Krynica Morska, pop. 1,360, situated on the Vistula Lagoon Spit, where numerous temporary residents appear during the summer.

3.1.2 Infrastructure in the Polish part of the lagoon

The information on infrastructure around the Polish side of Vistula Lagoon was collated on the assumption that it is consistent with both administration units and physical environment around the lagoon. Therefore, the description of infrastructure includes the counties described in the urbanization section together with the city of Elbląg. Importantly, these counties belong entirely to the lagoon catchment, so developments there can affect the evolution of Vistula Lagoon.

The scrutiny of infrastructure reveals the fact that, if compared to a number of other areas in Poland, the studied area is impoverished due to persistent and high unemployment. Undoubtedly, one can see positive elements, such as high percentage of population with access to running water, recently constructed waste water treatment facilities, or initiation of segregation of solid wastes. However, the screening of business sector shows that it is dominated by small ventures, operating mostly on local market and weak in terms of credit worthiness. The major problem is the lack of large investors that could secure multiple jobs and generate a synergistic effect of extra jobs from companies that usually follow a respectable investor. In recent year rather a different trend was observed; large companies were closing their branches, e.g. in Elbląg city, causing high waves of job losses there. Another problem is the volatile condition of harbour at Elbląg. Separated from open sea it solely relies on navigation in Vistula Lagoon and trade with Russia. This trade is vulnerable to general Polish-Russian relations, which resulted in almost entire closure of operations of the harbour between 2006 – 2009. Also, socio-political situation in Poland can adversely affect the harbour, i.e. termination of (cheap) coal delivery from Kaliningrad to power plants in Elbląg and Gdańsk, forced by Polish trade unions to sustain jobs of coal mining industry in south Poland. The current output of this port is still a small fraction of operations from mid 1990's. Finally, a serious infrastructural malfunctioning of flood protection in south-west corner of the lagoon persists. The drainage system requires revitalization of the most of the locks, culverts, drainage ditches, pumping stations and flood embankments preventing rapid storm surges in case of north-easterly winds. Also, the connection of Vistula River and Vistula Lagoon through Szkarpawa branch is available only for small vessels up to 500 tonnes. It demonstrates why Elbląg is virtually isolated from the rest of Polish maritime economy. This large set of problems can only be successfully addressed by large infrastructural programs on government level, including EU subsidies. Long-term plans were put together in form of the comprehensive program of rehabilitation of the entire Vistula river delta under the name 'Żuławy 2030'; it anticipates that adequate flood protection can be attained not earlier than by 2030.

Detailed description of infrastructure of the Polish part of the lagoon, including the city of Elbląg and three adjacent counties is provided in Annex I.

3.1.3 Fisheries in the Polish part of the Vistula Lagoon

The Polish part of Vistula Lagoon belongs to Poland's internal marine waters, therefore the fishing sector is regulated by the Fishery Act of Parliament of 19th Feb. 2004. One of the main provisions of this act is licensing policy; an annual license is issued by the Regional Sea Fisheries Inspectorate in Gdynia; applications must be submitted by 31st Oct. of the previous year. The second major provision is the threshold for the overall capacity of fishing boats; currently, there are 52 vessels united in the Fisheries Local Action Group - the total number of fishing boats in the Polish sector of the lagoon is ca. 70 compared to 220 in 2004. This large decline was caused by a falling productivity of the lagoon, discarded stocking with juvenile eels, and EU-related policies of paying compensations for boat scrapping and profession change.

The fishing business is usually run by individual family ventures, where the fish is caught, processed and sold at local markets. The largest processing centres are situated in Frombork, Nowa Pasłęka, Tolkmicko and Krynica Morska. Other fishing ports include Kąty Rybackie and Piaski (both on the Spit) plus some other smaller locations. Fishermen based on the Spit can operate both on the lagoon and in the (Baltic) Sea after the passage through the Vistula river mouth and the Szkarpawa branch.

The most economically vital species caught in the lagoon is herring; it is usually fished in (early) spring just after the ice melt when the shoals migrate into the lagoon to spawn. Over the last six years, about 1,000 tons of herring were caught in the Polish sector of the lagoon. The remaining species amount to 200 tons. In this group the most prominent species are pikeperch and bream. According to fishermen from Fisheries Local Action Group, uniting Polish community of fishermen in the lagoon, their catches are limited by the Polish-Russian bilateral commission on fish stocks management. However, no information on any activities of this commission is available online, so it was not possible to determine on what problems it works and how important the recommendations and decisions it produces are for the Polish and Russian government. As regards eel, it is the most precious species, but its landings depend heavily on (rather erratic) stocking policies.

Currently, the greatest concern associated with fisheries on the lagoon is the growing population of cormorants, which consume large amounts of juvenile fish, particularly during the cormorants' breeding season.

3.1.4 Economic activities and use of the Russian part of the lagoon area

The Vistula Lagoon is used for fishery, water discharge, navigation, tourism, dredging and dumping. Other uses are not developed.

Navigation and fishing have been, and are certain to remain, major industries in the region, while navigation is an important factor in the development of the coastal zone (Andriashkina, Domnin, Chubarenko, 2008). The tourism and recreation are some of the promising areas of the Kaliningrad Oblast and the lagoon in particular, though at the moment the tourism sector is in its initial stages, and has to be developed further to meet high European and Russian standards.

Fishery. One of the main sources of commercial fish in the Kaliningrad Oblast is the Vistula lagoon, where fishing is performed mostly with net gear. The commercial species caught in the Vistula Lagoon are pikeperch, roach, eel, perch, and sabrefish abound. Another productive species is bream. In 1996, slightly more than 200 t of bream were caught in the Vistula Lagoon, and by 2003 the catch volume rose to 250 t, with its peak in 2002 (about 300 t) (State of the Coast ..., 2008).

Aquaculture in the Russian part of the Vistula lagoon catchment is represented by commodity fish-breeding (arkoProduction of trout and sturgeon is carried out by the company "Kaliningrad Centre "Aquaculture" in the urban village of Pribrezhny. Fish are grown in cages installed in flooded quarry hatchery with water enriched with oxygen and low temperature conditions. The farm produces 9.5 tons of trout, as well as 2.5 tons of sturgeon annually. Sales market is a network of shops and restaurants in Kaliningrad (newkenigsberg.ru)

The company "KMP Aqua" was established in the city of Svetly in 2007. It is based on the fish processing plant "Kaliningrad seafood" (Inker, 2008). The company is engaged in fish-breeding in a closed water supply installations. The total plant area is 11 ths. m^2. The company produces sturgeon, tilapia, catfish and eel for sale. The company plans to sell their products in Russia and abroad, but now all the grown commercial fish is sold in the domestic market of the Kaliningrad Oblast.

Waste water discharge. Most waste water in the Vistula Lagoon comes from point sources located inland (Kaliningrad, Baltiysk, Svetly, Ladushkin, Mamonovo). Run-off from agricultural industry enters the lagoon through a network of smaller rivers, streams and canals. Mechanically treated wastewaters from the Kaliningrad City (about 450 thousands inhabitants) are directed to the Primorskaya Bay of the Vistula Lagoon by the bypass open collector (Kaliningrad Sewage Runaround Canal). In addition, wastewater from the cities and enterprises located upstream flows into the Pregola River after its mechanical treatment (Velikanov, Proskurnin, 2003).

Sanitary conditions are good enough for bathing in the lagoon due to self-cleaning capability of the river system and the lagoon. The largest hot spot, the Kaliningrad Sewage Runaround Canal, will be closed soon after opening of a Kaliningrad's new treatment plant in winter 2013.

Tourism. The tourism-related infrastructure of the lagoon waters of the Kaliningrad Oblast has not been sufficiently developed, hence there is a potential for a significant growth. At present, angling is developed. Yachting and beach rest are not developed enough. Also at present, international routes on internal waterways between Poland and Lithuania through the territory of the Kaliningrad Oblast are practically unused. In order to develop this type of recreation, it is necessary to provide a detailed assessment of the natural conditions of this water area and develop coastal infrastructure.

Dredging and dumping. Dredging operations are constantly held in the Kaliningrad Sea Canal. These works are needed to maintain and improve the entrance of the Canal. Dumpings of clean medium sands are in the water area of the Baltic Sea. Fine-grained soil of varying degree of contamination is used to strengthen internal parts of the island of the protective dam of the Kaliningrad Sea Canal (Blazhchishin, Boldyrev, 1999).

Navigation. Officially, the Kaliningrad Oblast has one port of Kaliningrad, composed of four harbours (Kaliningrad, Svetly, Baltiysk, and Pionersky). Three of them are situated in the Vistula Lagoon.

In recent years, the port of Kaliningrad has witnessed steady cargo turnover with a notable growth in spring and winter, although passenger transfers have not been developed to the desired level. Currently, the harbour of Baltiysk has a passenger terminal that processes about 12,000 passengers per year. According to 2005-2006 data, there is a slow increase in the numbers of passenger transfers on the internal route between the ports of Kaliningrad and Sankt-Petersburg of about 11% (State of the Coast ..., 2008).

The further development of ports and anchoring facilities for small ships is required, as is the growth of cargo turnover and passenger transfers. In addition, official navigation routes are scarce; in fact, there are three navigation routes on the waters of the Baltic Sea including the entrance to the ports of Baltiysk and Kaliningrad and short navigation routes in the Vistula Lagoon.

3.1.5 Plans of future economic development and use of the Russian part of the lagoon area and land

The municipalities in the catchment of the Vistula Lagoon include all the municipalities of the Kaliningrad Oblast except Slavsk, Polessk and Svetlogorsk metropolitan regions (or municipal districts) and Pionersky and Yantarny urban districts.

Analysis of social and economic development strategies for municipalities around the Vistula Lagoon in the Kaliningrad Oblast for the period to 2016 showed that strategic directions of varying degrees of priority are:

- Industrial production,
- Agriculture,
- Transport,
- Recreation and tourism,
- Environmental protection.

Each municipality adopts the strategic development directions depending on its economic and geographical situation and social conditions (Fig.3.5).

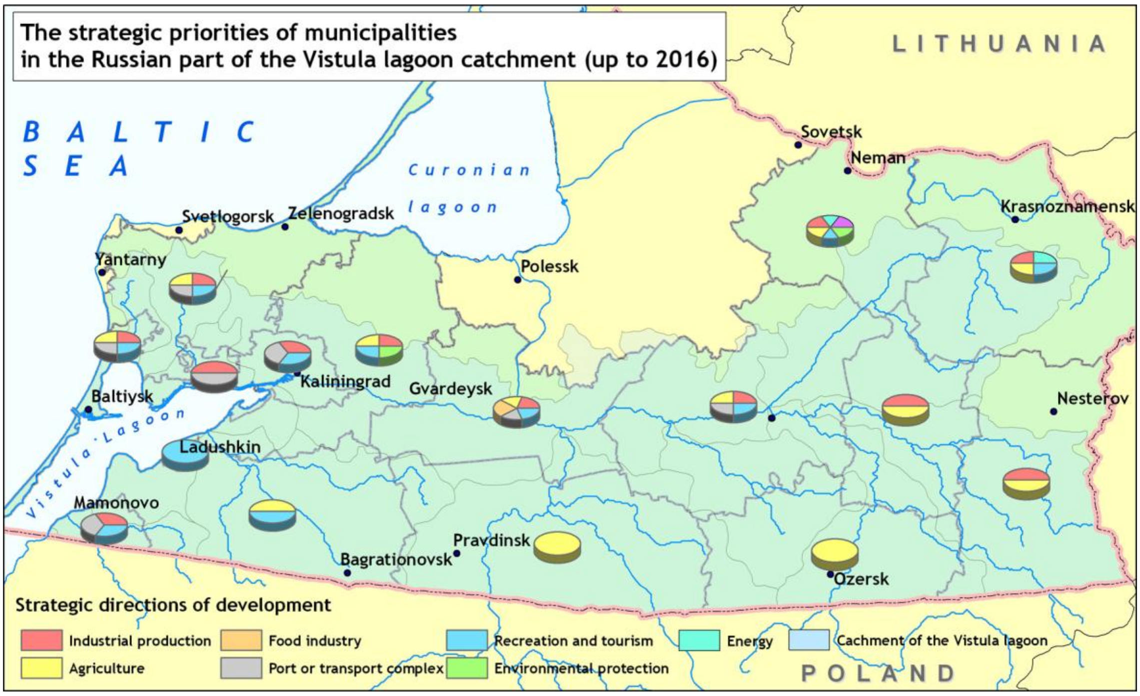


Figure 3.5. Future economic development of municipalities of the Russian part of the Vistula lagoon catchment. (Karmanov, Chubarenko, Domnin, Hansson, 2010)

Almost all coastal municipalities (Baltiysk, Kaliningrad, Ladushkin, Mamonovo, Bagrationovsk, Gurievsk and Zelenogradsk) have tourism and recreation included in their priority development directions (Domnina, Chubarenko, 2011). Some coastal municipalities plan to develop the port and transport complexes (Kaliningrad, Svetly, Mamonovo, Baltiysk). Municipalities, which don’t have connection with the lagoon, or have little connection with it, consider ‘industry production’ and ‘agriculture’ as the main priority development directions (Gurievsk, Bagrationovsk, Pravdinsk, Ozersk, Nesterov, Krasnoznamensk municipal districts). Municipalities around Kaliningrad plan to develop industrial production. Thus, industrial production, agriculture and tourism are the most popular directions of the development of municipalities. However, the disadvantage of all strategies is little attention to environmental protection and climate changes. In addition, the scenarios of climate change are not mentioned in any document of strategic development. Meanwhile, climate changes will affect virtually all economic sectors of the region (Karmanov et al., 2010).

Existing and planned harbour infrastructure. Currently, about ten large and small harbours and moorings have access to the water area of the Vistula Lagoon (Figure 3.6). Kaliningrad, Svetlyy and Baltiysk port are designed primarily for serving large commercial vessels. All other moorings have local significance and serve small fishing and pleasure boats.

At present, the Lagoon has navigational corridors from the Baltiysk Strait to Kaliningrad Port by Kaliningrad Marine Channel with a depth of more than 10 meters. In addition, the fairway is located in centre of the Lagoon and connects the Russian ports with the Polish Republic.

There is a project to build a Deep-sea Terminal at Severny Cape. This port will be able to receive modern large vessels with deep draft and large carrying capacity; it will provide further implementation of container traffic to the transport and technology systems of cargo handling by modern terminals. This will considerably increase the cargo turnover of shipping of the port, as well as expand the range of transported goods[3].

Deepwater channel from the Baltiysk Strait to the port is required for the construction of the port facility (Figure 3.6, red line). The planned length of the Channel is of more than 10 km, the depth is 18 meters and the width is 260 m.

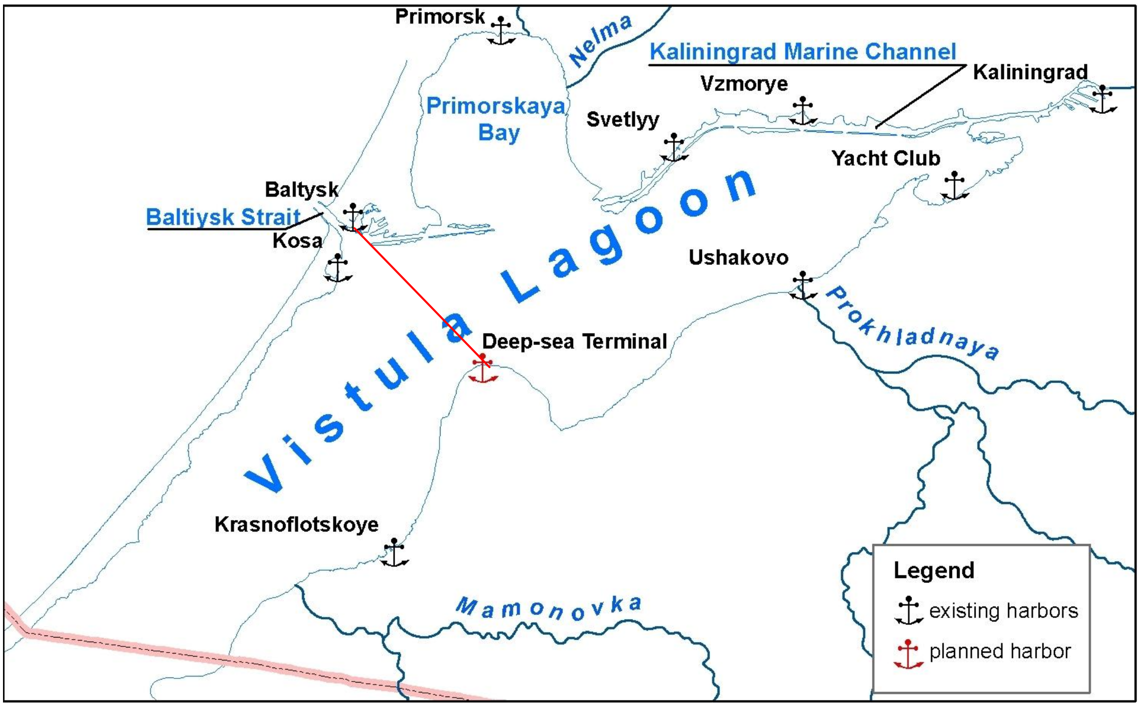


Figure 3.6 Present and planned port infrastructure of the Vistula Lagoon (State of the Coast ..., 2008, developed by D.Domnin)

3.2 Institutions, laws, rights and conflicts

3.2.1 Spatial planning legal system in Poland

As there is no official spatial planning legal system in Russia, only the situation in Poland will be described here.

Spatial planning of marine areas (without coastal land) is under jurisdiction of the relevant Maritime Office. It means that any ventures in the territorial sea, marine inland waters (e.g. lagoons) and exclusive economic zone must have an approval of the Maritime Office in charge. Maritime Offices are governmental agencies within the Ministry of Transport, Construction and Maritime Economy. Implementation of marine spatial plans is also executed by Maritime Offices – for Vistula Lagoon it is the Maritime Office in Gdynia.

Maritime Offices also enjoy various degrees of jurisdiction in some specific areas of coastal land. One of them is the technical belt. This belt comprises the area stretching from shoreline to: (a) 20 – 200 m landward of the first landward dune foot, (b) foot of landward dike slope, (3) 10 – 100 m landward of cliff top; Maritime Offices have full decisional power in this zone, and all plans in this belt must be approved by them. The second belt, 1000 - 2500 m wide, is situated landward of the technical belt and

[3] Sergeeva L.G. Assessment of possible impact of Deep-sea Terminal building to hydrological conditions of the Vistula Lagoon. // Baltic Region, - vol. 1(7), - 2011 C. 54-61. Original source: Сергеева Л.Г. Оценка возможного влияния строительства глубоководного морского порта на гидрологический режим Вислинской лагуны // Балтийский регион,- вып. 1(7),- 2011,- С. 54-61.

is called the protection belt. The Maritime Offices enjoy some degree of jurisdiction in this belt, so all decisions on investments, land uses, etc. must be consulted with them respecting their recommendations. Fig. 3.7 outlines this system of legal responsibility; the concept of technical and protection belt originates from the Ordinance of the Government, which is available in the relevant book of law.

The coastal belts, introduced as governmental regulatory instruments, are intended to enforce rudimentary order in coastal areas, preventing ‘coastal squeeze’ in the wake of sea level rise and other climate change impacts. Since Maritime Offices are also in charge of adaptation to the effects of climate change in coastal zones, they have power to set recommendations regarding this adaptation. The most important recommendation defines areas below +2.5 m above the current mean sea level as regions endangered by sea level rise and marine floods. In some communes lying on Vistula Lagoon the less severe restriction of + 2.2 m was adopted after consultations between the Maritime Office in Gdynia and local authorities. Supplementary recommendations in areas below +2.5 m datum include e.g.: (i) minimum ground floor level (datum) – usually + 2.5 m, (ii) requirements regarding the construction of basements – watertight systems in case of high groundwater table or restrictions (ban) on basement construction, (iii) minimum dike crest level (datum) – this can be found in the relevant book of law, where a classification of hydraulic structures and facilities is provided, (iv) requirements regarding sewage systems – stop valves preventing backwater of mixed sewage and flood water during inundation periods, (v) prevention of rainwater drainage from flooding during storm surges.

The responsibility for spatial planning in coastal municipalities and communes outside the coastal zone is divided among the self-governmental authorities of the municipality and the province. There are two legal instruments that provide regulations: (i) the ‘study on conditions and directions of spatial management of municipality’; it covers the whole municipality and is indicative; spatial plans on municipality level are drafted by the mayor of the municipality and are approved by the Municipality Council, (ii) the ‘local spatial management plan’ that covers a selected area; it is the act of local law, which must be consistent with the relevant ‘study on conditions and directions of spatial management...’; the plan is binding for potential investors, so if the area is situated below +2.5 m above the current msl, the recommendations of the Maritime Offices on ground floor datum, basement restrictions, etc. usually apply. Therefore, local spatial management plans provide a space where the government policies (through Maritime Offices) and local authorities intersect and must be formalised. For this reason, they are the most important elements of successful management in coastal communes and municipalities. Municipal and communal authorities are inclined by governmental agencies (e.g. Maritime Offices) to draw local spatial management plans, because they facilitate business activities and generate transparency (potential investors read them before considering an investment and compare locations).

On the provincial level, all studies on conditions and directions of spatial management of municipalities are integrated by the Province Marshal, who drafts the Spatial Management Plan for the province; it must then be accepted by the Provincial Assembly. It has an indicative character.

At the national level a strategic, however, not binding document is the ‘Concept of Spatial Development of the Country’ which is elaborated and approved by the government and presented to the parliament. Main conclusions from this document should be taken into account, while drafting plans at provincial and municipal levels.

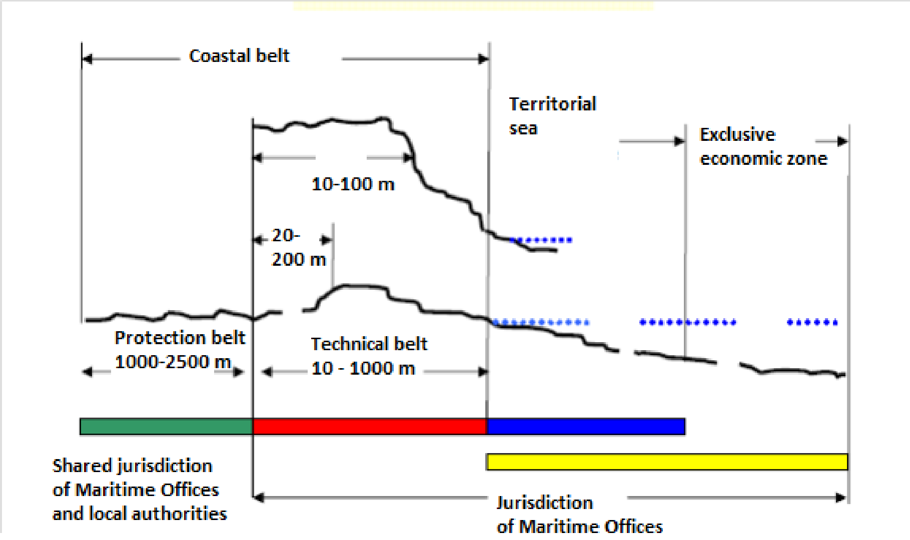


Figure 3.7 Jurisdiction in Polish coastal areas

3.2.2 Other legal instruments and institutions

The legal concepts of governance in Polish coastal areas follow the hierarchical order, where EU legal instruments (WFD, Habitat Directive, Natura 2000 and other instruments apply to a given environment – e.g. Vistula Lagoon) are incorporated into the national legislation and then transmitted for implementation by national, regional (provincial) and local authorities. On the other hand, provincial and local authorities voice interests and needs of local communities. In this way, top-down and bottom-up approaches to spatial planning and management can be harmonised.

The most important piece of national legislation that influences the functioning of coastal zones (incl. Vistula Lagoon) is the Coastal Protection Act of Parliament of 2003, which stipulates the maintenance of the shoreline position from year 2000 by 2023. It is executed by Maritime Offices. Also, as described above, the offices set out recommendations for spatial development in areas endangered by sea level rise.

River catchments are administered by the Regional Water Management Boards. They are responsible for the implementation of comprehensive water management (maintenance of navigation, flood control, implementation of WFD, rehabilitation of degraded sub-catchments, early spring ice flow control) in each basin. The success of integrated spatial management requires good cooperation between the Water Management Boards and Maritime Offices in estuaries where areas of competence may intersect.

The third-most important actors in charge of good governance of the Vistula Lagoon are the Provincial Inspectorates of Environmental Protection, which are in charge of monitoring environmental parameters; they provide information on water quality in the lagoon to all actors involved in its management and to the public via the Internet.

The Russian Water Code is the main law which regulates an activity around the Vistula Lagoon. Some international conventions, which are also ratified by Russian Government and comprise a legislative basis for environmental management in the Russian part of the Vistula Lagoon (see ANNEX 2).

3.2.3 The tools of cooperation between the Kaliningrad region of the Russian Federation and the Republic of Poland in the field of ecology

Basic documents

The cooperation of the Kaliningrad region of the Russian Federation with regions of the Republic of Poland in the field of environment protection and management is based on the two fundamental intergovernmental agreements.

This, first of all, is the Agreement on cooperation of the Kaliningrad region of the Russian Federation and the north-eastern voivodeships of the Republic of Poland dated 22 May 1992 (the text of the Agreement can be found on the website of the Ministry of International Affairs: http://www.mid.ru/bdomp/sbor.nsf/fe3845c0f6d9b35443256c8a004e8835/0a4c40d159dc96b043256c8a0047bc59!OpenDocument), the article 13 of which determines the issues of cooperation in the field of environment protection in the border areas, and the economic use of the border surface and groundwater including the Kaliningrad (Vistula) Lagoon.

The second is the Agreement between the Government of the Russian Federation and the Government of the Republic of Poland on cooperation in the field of environment protection dated August 25 1993, and aimed at an improvement of the environmental conditions, ecological security improving and pollution prevention in both countries and the Baltic Sea. At that this Agreement lays emphasis on the implementation of these objectives in the border areas by promoting cooperation between local administrations and self-governments, institutions, enterprises and non-governmental organizations in the field of environment protection.

Besides, the Russian Federation and the Republic of Poland have ratified a number of international conventions covering various issues in the field of environment protection and natural resource management (Table 3.1).

Table 3.1. International conventions in the field of environment protection ratified by the Republic of Poland and the Russian Federation and used by the Russian-Polish Council on cooperation between the Kaliningrad region of the Russian Federation and the regions of the Republic of Poland

Title of the document	Date of adoption
Convention on Protection of Marine Environment of the Baltic Sea Region (HELCOM)	Helsinki 1974-1992
UN-ECE Convention on the Protection and Use of Transboundary Watercourses and International Lakes	Helsinki 1992
UN Convention on Biological Diversity	Rio-De-Janeiro 1992
UN Convention on Wetlands of International Importance Especially as Waterfowl Habitats (Ramsar Convention)	Ramsar 1971

The Agreement between the Government of the Russian Federation and the Government of the Republic of Poland on cooperation of the Kaliningrad region of the Russian Federation and the north-eastern voivodeships of the Republic of Poland of 22 May 1992 has established a framework for cooperation of the Kaliningrad region and the north-eastern voivodeships of Poland including in the field of environment protection and natural resource management.

The Russian-Polish Council.

According to the Article 15 of the Agreement on cooperation of the Kaliningrad region of the Russian Federation and the north-east voivodeships of the Republic of Poland of 22 May 1992 both sides appoint their Commissioners responsible for coordination of programs and activities aimed at development of cooperation between the Kaliningrad region and the Polish north-eastern voivodeships.

The structure providing execution of the Agreement is the Russian-Polish Council on cooperation of the Kaliningrad region of the Russian Federation and the regions of the Republic of Poland (hereinafter - the Council) that was established in 1994 and nowadays acts in accordance with the Statute. The Council acts as a working member of the Commissioners.

The Council consists of two national parties – Russian and Polish formed on a parity basis. The Chairmen of the national parties of the Council are Commissioners.

In order to solve any issues in coordinated areas of cooperation the Council forms commissions or working groups. At this time the Council includes 12 commissions in various areas of cooperation including the Commission on environment protection and integrated use of the Kaliningrad (Vistula) Lagoon.

The Russian-Polish Council meets annually on the Polish and Russian side alternately. At the Council meetings they consider the issues previously discussed by the Commissioners, hear reports of the committees that are within the Council on the work done during the year, execution of the decision of the protocol of the previous meeting and planned activities for the next year. The parties sign the protocol according to the results of the Council meeting. All documents of the Council and its Commissions are prepared in Polish and Russian languages, which are working languages of the work of the Council and its Commissions.

The first meeting of the Council was held in October 1994 in Svetlogorsk (II meeting: Goldap – 1995; III: Kaliningrad – 1996; IV: Gdansk – 27-28 October 1999; V: Kaliningrad – 18-19 July 2001; VI: Gozuw Wielkopolski – 22-23 March 2003; VII: Svetlogorsk – 21-22 March 2005; VIII: Warsaw – 2007; IX: Kaliningrad – 03-03 December 2008; X: Olsztyn – 25-26 February 2010; XI: Zelenogradsk – 02-03 June 2011; XII: Warsaw – 15-16 May 2012).

Official information about meetings of the Council is published on the website of the Government of the Kaliningrad region (www.gov39.ru) according to conduction.

Currently, Nikolay N. Tsukanov, the Governor of the Kaliningrad region is the Commissioner of the Government of the Russian Federation on implementation of the intergovernmental Agreement on cooperation of the Kaliningrad region and the north-eastern voivodeships of Poland according to the Decree of the Government of the Russian Federation of 22.12.2011.

The Governor of the Kaliningrad region is also the chairman of the Russian part of the Council.

The Chairman of the Polish part of the Council is Petr Stakhanchik, the Deputy Minister of Internal Affairs of the Republic of Poland (information is from the website of the Government of the Kaliningrad region: http://www.gov39.ru/novosti-2/otkrytie-dnej-kaliningradskoj-oblasti-sostoitsya-v-korolevskom-zamke-varshavy-2528973493/)

The Russian part of the Council is approved by the Decree of the Governor of the Kaliningrad region as needed due to changes in personnel.

The current structure of the Russian part of the Council is approved by the Decree of the Governor of the Kaliningrad region from 19.10.2011 № 239 (the text of the Decree is available on the website of the Governor of the Kaliningrad region: http://gubernator.gov39.ru/dokumenty/?catid=40&search_nr=239&search_title =)

The Commission on environment protection and integrated use of the Kaliningrad (Vistula) Lagoon

The article 13 of the Agreement on cooperation of the Kaliningrad region of the Russian Federation and the north-eastern voivodeships of the Republic of Poland of 22 May 1992 determines the issues of cooperation in the field of protection of the environment in the border areas, and economic use of the border surface and groundwater including the Kaliningrad (Vistula) Lagoon.

In order to implement this article they formed the Commission on environment protection and integrated use of the Kaliningrad (Vistula) lagoon within the Russian-Polish Council on cooperation between the Kaliningrad region of the Russian Federation and the regions of the Republic of Poland (hereinafter – Russian-Polish Commission). The Commission has been working for 17 years. The name of the Russian-Polish Commission in Polish is Komisja ds. Ochrony Środowiska i Kompleksowego Zagospodarowania Zalewu Wiślanego.

Members of the Russian part of the Russian-Polish Council are approved by the Governor of the Kaliningrad region as needed due to changes in personnel. It consists of a chairman and secretary as well as chairmen and experts of working groups on directions of the Commission activity, including representatives of the executive power of the Kaliningrad region, the regional bodies of the federal executive power in the Kaliningrad region, and scientific community in the field of environment protection and natural resource management. The list of agencies and organizations representatives, of which are part of the Russian-Polish Commission in 2012 is presented in Table 3.2.

The Polish part of the Commission also includes a chairman and secretary as well as the chairmen and experts of the sub-committees on directions of the Commission activities, including representatives of the Polish environmental institutions.

Table 3.2. The list of agencies and organizations representatives, of which are part of the Russian-Polish Commission on environment protection and integrated use of the Kaliningrad (Vistula) lagoon.

№	– Name of institution, organization
1.	Federal Service for Supervision of Natural Resources for the Kaliningrad region
2.	Ministry of Infrastructure Development of the Kaliningrad region (Department of Regulation in the Field of Energy Conservation, Fuel and Energy Complex, Subsoil Management and Water Resources)
3.	Kaliningrad Centre for Hydrometeorology and Environmental Monitoring of the Federal Service for Hydrometeorology and Environmental Monitoring
4.	Water Resources Department of Neva-Ladoga Basin Water Department of the Federal Agency for Water Resources
5.	Agency for Protection, Reproduction and Use of Wildlife and Forests of the Kaliningrad region
6.	Agency for Fishing and Fishing Industry Development of the Kaliningrad region
7.	West-Baltic Territorial Department of the Federal Agency for Fishing
8.	State public institution of the Kaliningrad region «Nature Park Vishtynetsky»
9.	Immanuel Kant Baltic Federal University
10.	Kaliningrad State Technical University

The meetings of the Commission are held as needed before the meeting of the Russian-Polish Council in order to summarize the work of the Commission for the previous year, and agree upon the directions and specific activities for the next year.

According to the results of the meeting, the chairmen of the Polish and Russian parts agree upon the plan of work for the Commission for the next year.

The chairmen of the Russian and Polish parts of the Commission prepare agreed proposals to be included in a protocol decision on the results of the Russian-Polish Council. A protocol decision is valid and signed by its co-chairmen.

The first meeting of the Commission took place on the 11th of April, 1995 in Elbląg. At the meeting the sides exchanged the results of the investigation of water quality in the rivers of Lava (Lyna) and Angrapa (Vengrapa) and the Kaliningrad (Vistula) Lagoon. It was proposed to exchange information on water quality of these water objects in the future; the priority issues for further cooperation were identified as following:

- protection of waters of the Kaliningrad Lagoon in view of its tourism and economic attractiveness;
- monitoring of cross-border waters of the rivers of Lava (Lyna) and Angrapa (Vengrapa) as well as the Kaliningrad (Vistula) Lagoon.

Henceforth, the priority directions of cooperation within the Russian-Polish Commission were the following:

- monitoring of transboundary waters of the rivers of Lava (Lyna) and Angrapa (Vengrapa) as well as the Kaliningrad (Vistula) lagoon and integrated use of these waters;
- transboundary movement of hazard waste;
- the program «Green Lungs of Europe»;
- assessment of the environmental conditions, and planning for the Polish and Russian part of the Vistula lagoon;
- assessment of the impact on the environment.

Recently the main directions of the work of the Commission have been the following:

- cooperation on monitoring of surface waters in the border areas of the Kaliningrad region of the Russian Federation and the Republic of Poland;
- cooperation in the field of natural resources and environment protection in the border areas of the Kaliningrad region of the Russian Federation and the Republic of Poland;
- cooperation in the field of biodiversity conservation, development and management of protected areas, sustainable forest management in the border areas of the Kaliningrad region of the Russian Federation and the Republic of Poland;
- cooperation in the field of attracting foreign investments, implementation of international projects and programs on nature resources management and environment protection.

3.2.4 Problems and conflicts in the Polish part of the lagoon

The most complex problem in the Vistula Lagoon features a general issue of cooperation between an EU and a non-EU country. A platform alleviating possible conflicts of interest may be the HELCOM convention and the resulting Baltic Sea Action Plan that aims at reducing the inputs of nutrients by all Baltic countries to achieve adequate water quality in the whole Baltic Sea until 2020. For each country a threshold of nitrogen and phosphorus emissions was determined based on their catchment and population. Although timely, this measure will not be able to solve other problems associated with the functioning of Vistula Lagoon.

In the Polish part of the lagoon, the greatest problem is related to the future of harbour in Elbląg. As shown in Fig. 3.8, its traffic potential is not fully used. The main reason for this is the virtual isolation of the harbour (and the rest of the Polish part of the lagoon) from the Baltic Sea, and volatile relations between Poland and Russia. Currently, a local visa waiver scheme between the Kaliningrad region and the environs of the lagoon, including the tri-city agglomeration (Gdańsk, Sopot, Gdynia) has come into force, but it is only applicable for road traffic. Access through the Baltiysk Strait requires a long notice (1 month), which is a serious impediment. Alternative solutions include the construction of a cross-cut through the Spit in order to create an access route that is situated entirely on EU territory. This is one of the hottest present issues in the area. Four different locations - Skowronki, Nowy Świat, Przebrno, and Piaski have been taken into account. Based on environmental impact studies and economical analyses, the most appropriate location has been determined (Skowronki), but decisions are a long time coming (Fig. 3.9).

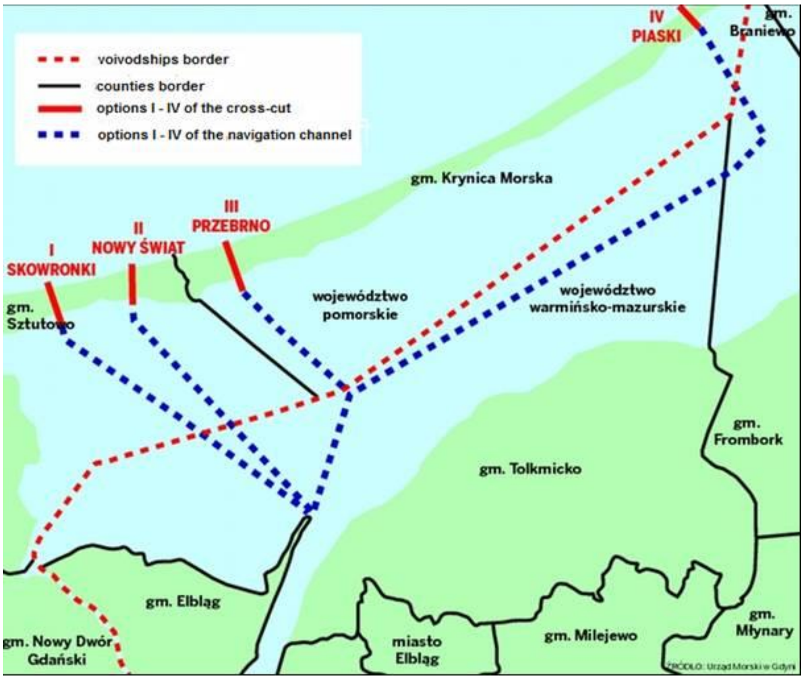


Figure 3.9 Possible locations of the Vistula Spit cross-cut. Source: Maritime Office in Gdynia

Many questions regarding this investment have to be answered: how will this improve economy of the Vistula Lagoon area with special focus on the Elbląg city? Will it be an economically profitable investment? Will it have any significant impact on the lagoons environment? Will the cut-off part of the Spit suffer from impaired communication with the mainland and lesser tourists inflow? Will this create any political problems? Those and many more questions, as well as high costs of investment and some uncertainty of its future impacts prevent final decision on the cross-cut construction. Another option is the revitalisation and extension of the passage from the Vistula River to the lagoon through the Szkarpawa River branch (Fig. 3.10); both options are costly and the resulting economic gains uncertain.

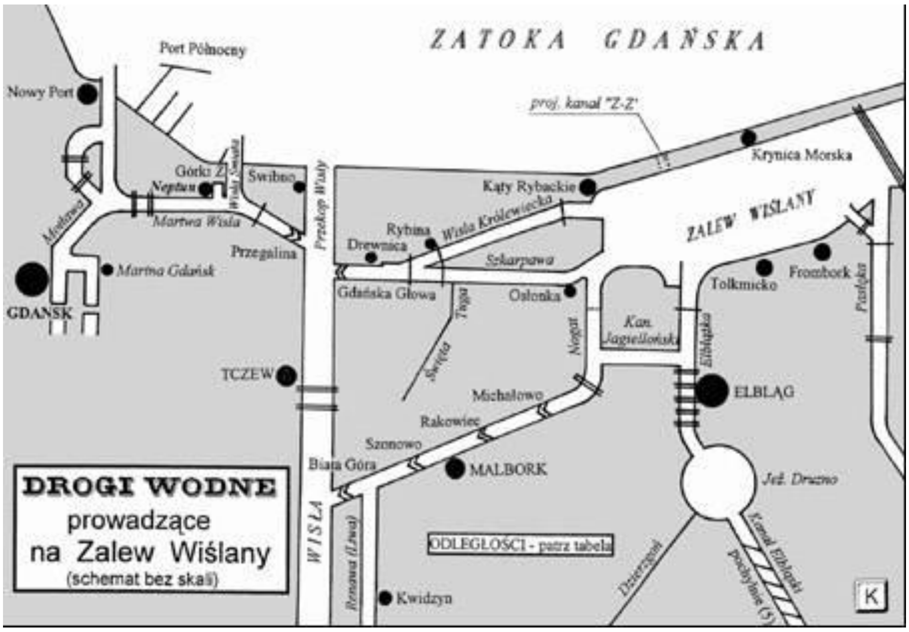


Figure 3.10 Water ways leading to the Vistula Lagoon. Source:
http://www.kulinski.zagle.pl/zw/02_zalew_wislany_charakterystyka_akwenu.htm

Fishermen highlight the necessity of the Polish-Russian cooperation related to the maintenance of fish stocks. They view (joint) stocking of the lagoon with juvenile eel as a means of sustainable fishing. However, different fishing regulations in Poland and Russia, such as not fully consistent protection periods, different regulations on net types and sizes plus difficulties associated with the financing of stocking by both partners are serious impediments to reaching satisfactory progress in this regard.

The three counties in Poland share the same problems: (i) lack of large companies securing jobs and attracting high qualified personnel; as a result there are no economic engines to boost economic recovery of the lagoon's environs; the only exception is the seasonal influx of tourists to Baltic Sea beaches, which is reflected by the large number of beds along the Vistula Lagoon Spit in Nowy Dwór Gdański county; this happens irrespective of the lagoon's presence, therefore tourism within the lagoon cannot be considered as important constituent of local economy, (ii) very high unemployment of mostly low-trained and aging farm workers after the bankruptcy of state controlled farms and the resulting very low incomes of vast majority of them; this is the major source of economic stagnation. Stagnant economy leads to escape of young people to tri-city agglomeration of Gdańsk, Sopot and Gdynia, Warsaw, Olsztyn (capital of Warmia-Masuria Province) or abroad. As a result further rapid depopulation of already scarcely populated areas is a serious perspective.

The Spit (situated in Pomerania Province) appears virtually isolated from the hinterland in Warmia-Masuria Province. At the Spit tourism is boosted by nice Baltic Sea beaches and no incentives exist to expand the movement of tourists to the southern side of the lagoon. More frequent and less expensive boat traffic is viewed as a means of partly overcoming this problem; tourists living in the hinterland might take daily trips to the beaches at the Spit and return for the night – lower accommodation prices there could compensate expenses related to such shuttle commuting. Currently, the major tourist attraction in the lagoon's south is the town of Frombork with the cathedral housing the grave of Copernicus; the lack of a good connection with the Spit largely reduces the time tourists spend on its southern coast; most of them are defined by local tourist businesses as 'one day sandwich eaters'.

The character of the lagoon's bottom may be a large impediment for the expansion of tourism; even though the water quality of rivers discharging to the lagoon has improved substantially, the bottom is made of sediment with large admixtures of mud and nutrients, therefore bathing conditions cannot be recommended as attraction to tourists with children.

3.2.5 Discussion on "conflicts of interests" between economic plans for the Russian side and possible changes of environmental conditions due to the climate change

Economic activity is well developed in the Vistula Lagoon; and there are good prospects for further growth (plans for a deepwater port "Balga", an opening of navigation between Poland and Russia, the construction of a wind farm, the development of aquaculture in the lagoon water area).

Initial analysis of the conflicts «use – use», «use – nature« and «potential danger« had been undertaken earlier (Andriashkina, Domnin, Chubarenko B, 2008). Expert estimation was conducted on three quality characteristics: high, mean and weak tolerant. As a result, it was found that the selected potential conflicts, both between users and between users and the natural environment, were not real conflicts.

However, this method is imperfect and does not consider the effects of the climate change, as well as several other factors. In addition, it was only applied to the lagoon water area. Although at present a comprehensive approach to the assessment of conflict, taking into account not only the waters, but also the coastal strip is needed.

Stability analysis of the directions of municipalities’ development was made by qualitative method of expert estimation. There were no possibilities to make quantitative estimations as the directions for the development were in fact just declared. The development strategies stated by the municipal governments contain no quantitative figures (agriculture acreage; types and intensity of the recreational activity; location, capacity and cost of the elements of touristic infrastructure etc.), so that it is impossible to make quantitative estimations of possible changes due to the climate changes in monetary or % expression (Domnina, Chubarenko, 2011).

We made an analysis where each direction for the development was characterized by one of three quality characteristics (Domnina, Chubarenko, 2011):

- high tolerant. Plans of the municipal governments for implementation of this particular direction of development virtually do not depend on consequences of climate changes or these changes are negligible and well smoothed by management decisions. The areas of flood-endangered territories are negligible. This concerns Ladushkin, Mamonovo, Bagrationovsk, Gurievsk, Zelenogradsk municipalities (Kaliningrad Oblast).

- mean tolerant. Implementation of this particular direction of development depends on the areas of flooded territories and extreme meteorological elements. Possibly flooded territories are not so large and they don’t exceed 50% of an area of a municipality. This group includes Kaliningrad, Svetly, and Baltiysk municipalities in the Kaliningrad Oblast.

- weak tolerant. Plans of the municipal governments much depend on consequences of climate changes. Prevention of the negative effect predominantly connected with flooding of the territory needs huge economic expenditures. For this group the area of the flooded territories (in case of absence of protection constructions) is very high (50 to 90% of the total area). Construction of embankments, bypass canals net, bank strengthening, continuous monitoring and other measures for prevention of the negative effects may obviously increase the stability of the directions for the development. This group includes almost all cities and municipalities of the Polish part of the Vistula Lagoon.

The basis of the evaluation was to assess whether a particular activity contributes to the possibility of flooding and extreme weather events. In general, the territory of the Russian part of the Vistula Lagoon catchment is fairly stable in terms of these effects of climate change. Effects of changes in the flood or droughts frequency or quantity, and quality or seasonal terms of water supply, may be controlled by the relevant infrastructure investments and changes of water resources and land use management (Bates, et al., 2008).

The inclusion of the factor of variability of the present-day climate in the structure of water resources management will facilitate the adaptation to the future climate change. Nevertheless, any adaptive measures for the climate changes involve expenditures not only - of money, but also associated with the necessity of solving potential conflicts between groups within different settlements (Bates, et al., 2008).

3.3 Knowledge gaps

1. The Vistula Lagoon remains economically stagnant. Thus, the city of Elbląg intends to base its economic future on harbour services using the already available infrastructure. Therefore, Elbląg authorities lobby for the construction of the passage across the Spit and the navigational channel running in the lagoon entirely on the EU territory from this passage to the harbour. This venture is very uncertain from many perspectives, featured by several key knowledge gaps. Among them the greatest one is related to economic feasibility of construction of the cross-cut, that means if and when the construction costs will be outweighed by benefits to Elbląg and its environs and whether Elbląg will be the sole beneficiary or also other communities will have their shares directly or indirectly. The second gap is linked to ecological consequences of the construction and maintenance of 5 m deep navigational channel, situated entirely in the Natura 2000 area. The third gap is associated with the impacts of cross-cut construction and the resulting economic change on land use changes and demographic trends. Finally, it is not known whether the harbour is intended to function only as a traffic centre or also as a (local) processing hub, where shipped-in materials are processed and re-shipped further inland or back to through the sea.
2. The second set of issues is associated with information blocks and the ensuing insufficient flow of information on economic plans and intentions in the Polish and Russian parts of the lagoon. Thus, the integration of information regarding current and future socio-economic conditions of the Polish and the Russian part of the lagoon to facilitate a more sustainable transboundary management of the lagoon would be welcome. For example, an issue that does not generate large coasts but is difficult from the legal standpoint is the elaboration of a pathway towards visa free travel schemes for boat and yacht traffic in the lagoon.
3. The third gap is connected with the unknown consequences of climate change for the functioning of the lagoon. The anticipated change of physical processes will concern primarily the risk of more frequent and more extreme storm surges, producing augmented threats of inundation to depression areas in south west corner of the lagoon. The ecological impacts will be dominated by the growth of temperature in the lagoon’s water column and larger inflows of fresh water due to anticipated increase in precipitation. This will have serious consequences on biodiversity of the lagoon and possible negative habitat change. Also, another unknown element are future interactions (and possible feedbacks) between the climatic and socio-economic evolution to evaluate the lagoon’s future carrying capacity in terms of discharge of pollutants, predominantly nutrients.
4. The next gap is related to the overcoming of virtual separation of the Spit from the south coast of the lagoon. Since clean Baltic sandy beaches are the main attractor for visitors, solutions to also incorporate the lagoon’s hinterland into the tourist business should be identified.
5. The final gap is linked to harmonization of legislation concerning coastal zone management and nature preservation (NATURA 2000) in order to promote sustainable development in the area. Legislation regarding the use of the waters and coastal zone and that related to the protection of

natural resources are not consistent. Such situation prevents necessary actions aiming to improve the area’s economy, such as investment in harbour infrastructure, restoration of beaches, construction of resorts, hotels in the coastal areas, building pathways to the seaside beaches (Piaski village case), and prevention from overuse of fish resources by the cormorants.

References

Abramov R., Stont Ja. “Vityaz” and “Baltiyskaya kosa”. Weather and environment conditions 1997 – 2002. Data of Marine meteorology Lab. of AB IO RAS. Editor E.Krasnov. Kaliningrad, 2004. P. 22. Original source: Абрамов Р.В., Стонт Ж.И. «Витязь» и «Балтийская коса». Погода и экологическая обстановка 1997-2002 гг. Данные лаборатории морской метеорологии АО ИО РАН. Отв. ред. Е.В. Краснов. – Калининград: Изд-во КГУ, 2004. – С. 22.

Adamkiewicz-Chojnacka B, Lesniak D (1985) Evaluation of biomass of the rotifers (*Rotatoria*) in salty water of the Vistula Bay in 1975, 1977 and 1978 (in Polish). Studia i Materiały Oceanologiczne PAN, Biologia Morza 46:273–308

Adamkiewicz-Chojnacka B, Majerski J (1980) Zooplankton of the Vistula Bay during summer season (in Polish). Zesz Nauk ART Olsztynie 10:85–94

Adamkiewicz-Chojnacka B, Radwan S (1989) Vertical distribution of *Rotatoria* biomass in brackish waters of the Vistula Lagoon (in Polish). Pol Arch Hydrobiol 36:105–111

Adamkiewicz-Chojnacka B, Rozanska Z (1990) Seasonal variations of the biomass of *Copepoda* and *Rotatoria*: permanent components of the zooplankton in the Vistula Lagoon. Limnologica (Berlin) 20:71–73

Andriashkina A., Domnin D., Chubarenko B. Potential and conflicts of marine water area use in Russian part of the South East Baltic // North East of Russia in the Baltic Sea Region: problems and perspectives of economic cooperation and collaboration: Monograph / Zaucha J., Fedorov G., Limonov L., Oding N. (Eds.) – Kaliningrad: Kant’s RSU, 2008. – pp. 230-257

Andrulewicz E., Chubarenko B.V., Zmudinski L. Vistula Lagoon - Troubled Region with Great Potential. // WWF Bultic Bulletin.-1994. – No 1.- Pp. 16-21.

Aristova GI (1965) Benthos of Curonian and Vistula lagoons (in Russian). Atlantic Institute for Fishery and Oceanography, Kaliningrad, pp 40–49

Aristova GI (1973) Benthos of Curonian and Vistula lagoons of the Baltic Sea and its significance in fish food (in Russian). PhD Thesis. Kaliningrad Technical Institute for Fishery and Fish Industry

Assessment of climate change for the Baltic Sea basin. Springer Verlag, Berlin, Heidelberg, 2008. 264 p.

Barinova G.M. 2002. Kaliningrad region. Climate. Kaliningrad. 194 p. Original source: Баринова Г.М. 2002. Калининградская область. Климат. Калининград. 194 с.

Bartel R, Wilkonska H, Borowski W (1996) Changes of the ichthyofauna in the Vistula Lagoon. In: Volskis R (ed) Proceedings of the International Meeting on Baltic Network of Biodiversity and Productivity of Selected Species in Coastal Ecosystems, Nida, (Lithuania), 4–8 October 1995, pp 12–24

Bates, B.C., Z.W. Kundzewicz, S.Wu and J.P. Palutikof, Eds., 2008: Climate Change and Water. Technical Paper of the international Panel on Climate Change, IPCC Secretariat, Geneva, 210 pp.

BERNET (2000) Wetland management. Bernet Theme Report, Attachment. Fyn Country, Odense, Denmark

Biernacka I (1956) Przyczynek do znajomosci pierwotniaków Zalewu Wislanego. Pol Arch Hydrobiol 3:43–68

Bobykina V.P. Coasal morphodynamics of the Vistula Spit. / Dynamics of the Coastal Zone of Non-tidal Seas: Materials of the International Conference (school-seminar). - Kaliningrad: Terra Baltica, 2008. Pp. 37-38. Original source: Бобыкина В.П. Морфодинамика берегов Балтийской косы. / Динамика прибрежной зоны бесприливных морей: Материалы международной конференции. =Dynamics of the Coastal Zone of Non-tidal Seas: Materials of the International Conference (school-seminar). – Калининград: Терра Балтика, 2008. С. 37-38.

Bobykina V.P. Coastal reeds of the Vistula Spit and Geoecology lagoon shore / Ecological problems of the Kaliningrad region and the Baltic region. Publ KSU, 2002. Pp. 151-155. Original source: Бобыкина В. П. Прибрежные тростники Вислинской косы и геоэкология лагунного берега /

Экологические проблемы Калининградской области и Балтийского региона. Изд-во КГУ, 2002. С. 151-155.

Bobykina V.P., Boldyrev V.L. Present state of the Vistula lagoon coast as the coastal ecosystem's component / Estuarine ecosystems: structure, function and management (Abstracts), Kaliningrad-Svetlogorsk, 16-22 September 2007. P. 15-16.

Bogdanov NA, Vorontsov AA, Morozova LN (2004) Tendencies of chemical pollution and dynamics of the Kaliningrad bay (in Russian). Russ Water Resour 31:576–590

Boldyrev V. L., Bobykina V. P. Current Condition of the Curonian and Vistular Spits Lagoon Coasts and Their Interaction with the Lagoon Waters / Vol. of Abstracts. Int. Conf. “European Lagoons and their watersheds: function and biodiversity. Klaipeda, Lithuania, October 4-9, 2005.” P. 30.

Brzeska A (1995) Zoobentos of the Vistula Lagoon (in Polish). MSc Thesis. Wyzsza Szkoła Pedagogiczna w Słupsku. Zakład Ekologii i Ochrony Srodowiska. Słupsk

Chechko, V.A. Spatial structure and evolution of bottom sediments in the Vistula Lagoon. [In] Transboundary waters and basins in the South-East Baltic, ed. by B.Chubarenko, – Kaliningrad: Terra Baltica, 2008.- ISBN 978-5-98777-031-3.- 244-249 pp.

Chechko, V.A., Blazhchishin, A.I, 2002. Bottom deposits of the Vistula Lagoon of the Baltic Sea. // Baltica, vol. 15., pp. 13 – 22.

Chubarenko B. and P. Margoński. 2008. The Vistula Lagoon. In: Schiewer (ed.): Ecology of Baltic Coastal waters; Ecological Studies, Vol. 197, 167-195. Springer-Verlag Berlin Heidelberg

Chubarenko B. Shared watersheds in the South-Eastern Baltic / Transboundary waters and basins in the South-East Baltic, ed. by B.Chubarenko, – Kaliningrad: Terra Baltica, 2008.- ISBN 978-5-98777-031-3.- 7-21 pp.

Chubarenko B. The Vistula Lagoon. [In] Transboundary waters and basins in the South-East Baltic, ed. by B.Chubarenko, – Kaliningrad: Terra Baltica, 2008- ISBN 978-5-98777-031-3.- 37-57 pp.

Chubarenko B., Navrotskaya S., Stont Zh. (2012) Long-term trends of meteorological andhydrological characteristics for coastal zone of the Kaliningrad Oblast (Russia): Report of subcontract work within the BaltAdapt Project between the Permanent International Secretariat of the Council of the Baltic Sea States (CBSS), the Client, and the Baltic Institute of Ecology of Hydrosphere (BIEH), the Contractor. - Kaliningrad, 2012. - 54 p.

Chubarenko B.V. and Chubarenko I.P. 1998. The field study of the frontal area between the coastal zone and the Vistula Lagoon (South-Eastern Baltic). Oceanic Fronts and Related Phenomena (Konstantin Fedorov Memorial Symposium), Pushkin.

Chubarenko B.V. Zoning of Kaliningrad Bay and estuarine part of the Pregolia River on indicators of hydrological and ecological conditions aimed to optimize the monitoring / Complex study processes, characteristics and resources of the Russian seas of the North European Basin (project of the program of "Study of the nature of the World Ocean" Federal Program "World Ocean"). – Vol.2 – Apatity: Kolsk scientific centre RAS, 2007. – 591-602p. Original source: Чубаренко Б.В. Зонирование Калининградского залива и устьевого участка реки Преголи по показателям гидролого-экологического состояния и в целях оптимизации мониторинга / Комплексное исследование процессов, характеристик и ресурсов российских морей Северо-Европейского бассейна (проект программы «Исследование природы Мирового океана» федеральной целевой программы «Мировой океан»). - Вып. 2 - Апатиты: Изд. Кольского научного центра РАН, 2007. - С. 591-602.

Chubarenko B.V., Shkurenko V.I. Features of the hydrological structure of water in the estuary of the Pregolia River and at berthing “Vityaz” // Ecological problems of the Kaliningrad region and the South-East Baltic. – Kaliningrad. KSU.- 1999/- p.41-47. Original source: Чубаренко Б.В., Шкуренко В.И. Особенности гидрологической структуры вод в эстуарии реки Преголи и в точке стоянки НИС “Витязь” // Экологические проблемы Калининградской области и юго-восточной Балтики.- Калининград. КГУ.- 1999.- с.41-47.

Chubarenko B.V., Shkurenko V.I. The physical mechanisms of penetration of salt water up the Pregolia River, taking into account the influence of the bottom topography // Physical problems of ecology, vol. 7. – M.; Moscow State University Press, 2001, - p.80-88. Original source: Чубаренко Б.В., Шкуренко В.И. Физические механизмы проникновения солёных вод вверх по реке Преголе с учётом влияния рельефа дна. // Физические проблемы экологии (экологическая физика), вып. 7. - М.; Изд-во МГУ, 2001. - с. 80-88.

Chubarenko B.V., Umgiesser, G., Chubarenko, I., Davulienė, L., Razinkovas, A., Feike, M. Numerical modeling of the Curonian and Vistula lagoons revisited. / Transboundary waters and basins in the South-Eastern Baltic. Chubarenko B.V. (Ed.). – Kaliningrad: Terra Baltica, 2008..- Pp. 177-192.

Chubarenko I.P., Chubarenko B.V., 2002, General water dynamics of the Vistula Lagoon. Environmental and Chemical Physics. 24, No4: 213 – 217.

Chubarenko, B. Monitoring Physical Processes. [In] Gonenc I.E., Koutitonsky, V.G., Rashleigh, B., Ambrose, R.B., Wolflin, J. (eds.) Assessment of the Fate and Effects of Toxic Agents on Water Resources. Security through Science Series C: Environmental Security, Springer, 2007. Pp. 109-126.

Chubarenko, B., Chechko, V., Kurchenko,V., 2005. Suspended sediment studies in the Vistula Lagoon and its navigational canal. – In: Sediment Transport in Rivers and Transitional Waters, Gdansk, p. 40-45.

Chubarenko, B.V., 1994. Analysis of secondary pollution of the Kaliningrad and Curonian lagoon areas. – Geography and natural resources, №3, p.33-40, (in Russian).

Chubarenko, B.V., Chubarenko, I.P. Regionalisation of the Pregolia River estuary and Russian part of the Vistula Lagoon on hydrophysical parameters // Extended Abstracts of Int. Conf. on Regionalization in Hydrology, Braunschweig, Federal Republic of Germany, 10-14 March, 1997.-pp.41-44.

Chubarenko, B.V., Chubarenko, I.P., Baudler, H. (2005) Comparison of Darss-Zingst Bodden Chain and Vistula Lagoon (Baltic Sea) in a View of Hydrodynamic Numerical Modelling. The Baltica, vol. 18-2, 56–67.

Chubarenko, I.P., Esiukova, E.E., Hutter, K. (2004) Impact of the Ice Formation on Seasonal Salinity Increasing the Vistula Lagoon. In: Pro-ceedings of the VI scientific Workshop on High Resolution Operational Model of the Baltic Sea, 8–10 September, 2003, Saint Petersburg, Russia, pp. 58–68. St. Petersburg: Russian State Hydrometeorological University and MOR-ZASCHITA.

Climate Change 2007: Synthesis Report. (2007) Contribution of Working Groups I, II and III to the Fourth Assessment Report. Valencia. 2007. 52 p.

Cywinska A, Rozanska Z (1978) Zoobenthos of the Vistula Lagoon (in Polish). Studia i Materiały Oceanologiczne, Biologia Morza 21:145–160

Domnin D.A. Geoecological assessment of the state of watersheds of Kaliningrad Oblast. PhD Thesis. 2012. 170 p.

Domnin D.A. Geographical description of study area. [In] Report of Grant 08-05-92421-BONUS_a of Russian Fund for Basic Research. Theme "Advanced modeling tool for scenarios of the Baltic Sea ecosystem to support decision making – ECOSUPPORT", Kaliningrad, 2011.

Domnin D.A., Chubarenko B.V. Atlas of river transboundary catchments of Kaliningrad Oblast. – Kaliningrad: Terra Baltica, 2007. – 38 p. Original source: Домнин Д.А., Чубаренко Б.В. Атлас речных трансграничных бассейнов Калининградской области. – Калининград: Терра Балтика, 2007. – 38 с.

Domnina A., Chubarenko B. Discussion on the Vistula Lagoon regional development considering local consequences of climate changes. [In] SMHI Oceanography Series.- 2011.- № 112.- Norrkoping: SMHI.-ISSN 0283-7714. 44 p.

Ezhova EE, Chubarenko BV, Blazhchishin AI, Chubarenko IP (1999) Sediment–water interactions in the Vistula Lagoon – some preliminary results. In: Heiskanen AS, Lundsgaard C, Registadt M, Olli K, Floderus S (eds) Sedimentation and recycling in aquatic ecosystems. Finn Environ 263:78–83

Ezhova EE, Rudinskaya LV, Pavlenko-Lyatun MV (2004) Macrozoobenthos of the Vistula Lagoon (in Russian). In: Alimov AF, Ivanova MB (eds) Regularities of hydrobiological regime in water bodies of different types. Moscow: “Scientific World”, pp 146–164

Fall A (1993) Macrozoobenthos of the Vistula Lagoon (in Polish). M.Sc. Thesis. Uniwersytet Gdanski, Zakład Genetyki, Gdansk

Goc, M. (2006): Kormoran w Europie i Polsce: stan populacji, status prawny, regulacja liczebności. In: Wołos A., Niedoszytko B. (eds.) Jeziora Raduńskie: Przemiany i kierunki ochrony. Olszyn. Pages 73-85.
Goc, M.; L. Iliszko & L. Stempniewicz (2005): The largest European colony of the Great Cormorant on the Vistula Spit (N Poland) - an impact on the forest ecosystem. Ecol. Questions 6: 111-122.
Handbook on climate of the USSR. 1966. No. 6. Lithuanian SSR and the Kaliningrad region of the RSFSR. Part 3. Wind. - Leningrad, 92 p. Original source: Справочник по климату СССР. Вып. 6: Литовская ССР и Калининградская обл. РСФСР. Часть III. Ветер. Л.: Гидрометеоиздат, 1966. 90 с.
Handbook on climate of the USSR. 1968. No. 6: Lithuanian SSR and Kaliningrad Region of RSFSR. Part 4. Humidity of air, precipitation, snow cover. L., 186 p. Original source: Справочник по климату СССР. Вып. 6: Литовская ССР и Калининградская обл. РСФСР. Часть IV. Влажность воздуха, атмосферные осадки, снежный покров. Л., 1968. 186 с.
Handbook on climate of the USSR. 1969. No. 6: Lithuanian SSR and Kaliningrad Region of RSFSR. Part 5. Cloudiness and atmospheric effects. - Leningrad, 130 p. Original source: Справочник по климату СССР. Вып. 6: Литовская ССР и Калининградская обл. РСФСР. Ч. V. Облачность и атмосферные явления. Л.,1969.130 с.
http://arko39.ru/tekuwaya_deyatelnost_agentstva/ - Агентство по рыболовству и развитию рыбохозяйственного комплекса
http://newkenigsberg.ru/index.php?type=501&newsid=225 – Инкер К. Выгодный развод. // Новый Кенигсберг. 03.2008 г
Hydro-meteorological regime of the Vistula Lagoon. Under N. N. Lazarenko and A.Maevsky's edition. L., 1971. Pp.57-69. Original source: Гидрометеорологический режим Вислинского залива. Под редакцией Н.Н. Лазаренко и А. Маевского. Л., 1971. С. 57-69.
Jazdzewski K, Konopacka A, Grabowski M (2002) Four Ponto-Caspian and one American gammarid species (*Crustacea*, *Amphipoda*) invading Polish waters. Contrib Zool 71:115–122
Jurgelėnaitė A., Kriaučiūnienė J., Šarauskienė D., 2012, Spatial and temporal variation in the water temperature of Lithuanian rivers. Baltica 25(1), 65-76. Vilnius. ISSN 0067–3064.
Karmanov K., Chubarenko B., Domnin D., Hansson A. Attitude to climate changes in everyday management practice at the level of Kaliningrad Region municipalities // Oceanography, No.4, 2010, SMHI Publishing, pp. 1-12.
Kopiec J. 2008. Sprawozdanie z badań wód Zalewu Wiślanego prowadzonych przez Wojewódzki Inspektorat Ochrony Środowiska w Olsztynie w latach 2007-2008, WIOŚ Olsztyn, Delegatura w Elblągu
Kopiec J. 2011. Monitoring wód Zalewu Wiślanego. In: Budzyńska D. (ed) Raport o stanie środowiska województwa warmińsko – mazurskiego w 2010 roku, Biblioteka Monitoringu Środowiska, Olsztyn: 45-49
Kruk M. (2011) Zalew Wiślany pomiędzy lądem a morzem. Kłopotliwe konsekwencje. In: Kruk M, Rychter A., Mróz M. (eds) Zalew Wiślany. Środowisko przyrodnicze oraz nowoczesne metody jego badania na przykładzie projektu VISLA, Elbląg: 21-50
Krylova OI (1985) Functioning of plankton and benthos of the Curonian and the Vistula Lagoons of the Baltic Sea in relation to their ecological differences (in Russian). Atlant NIRO, Kaliningrad, Dep. in CNIREIRH, N 714-RX-D-85, 21.10.1985
Krylova OI, Naumenko EN (1992) Phytoplankton and primary production of the Vistula Bay (in Russian). Ecological fisheries research in the Vistula Bay of the Baltic Sea. Trudy AtlantNIRO, pp 14–33
Kwiatkowski J (1996) Evaluation of possibilities of ecological quality improvement in the Vistula Lagoon (in Polish). GEOMOR, Sopot
Kwiatkowski J, Chubarenko B, Rasmussen EK (1996) The Vistula Lagoon as a trap of nutrient pollution of the Baltic Sea. In: Proceedings of the Conference: Functioning of Coastal Ecosystem in Various Geographical Regions, 5–7 September 1996, Gdansk
Kwiatkowski J, Rasmussen EK, Ezhova EE, Chubarenko BV (1997) The eutrophication model of the Vistula Lagoon. Oceanological Stud 26:5–33

Lazarenko, N. N., Majewski, A. 1971. Hydrometeorological regime of the Vistula Lagoon. Лазаренко Н.Н., Маевский А. Гидрометеорологическй режим Вислсинского залива.- Л.:Гидрометеоиздат, 1971.

Lazarenko, N. N., Majewski, A. 1975. The hydrometeorological system of the Vistula Lagoon. [Hydrometeorologiczny ustrój Zalewu Wiślanego]. IMGW. Wydawnictwo Komunikacji i Łączności, Warszawa, 1975. 518 pp.

Lazarenko, N.N., Maevskiy, A., eds., (1971) Gidrometeorologicheskiy Rezhim Vislinskogo Zaliva [Hydrometeorological Regime of the Vistula Lagoon]. Lenin-grad: Gidrometeoizdat (in Polish and Russian)

Malinin V., Gordeeva S., Shevchuk O. (2010) Modern sea level variability and its causes / Congress of Russian Geographic Society. Proceedings. SPb. 2010. Vol. III. Part 1. P. 83-87. Original source: Малинин В.И., Гордеева С.М., Шевчук О.И. Современная изменчивость уровня Мирового океана и ее причины / Съезд РГО. Сборник научных работ. СПб. 2010. Т. III. Ч. 1. С. 83-87.

Markova L.L. Rivers // Kaliningrad Oblast: Nature sketch / compiler D.Ya. Berenbeym, ed. V.M. Litvin. – 2nd publication with add. and wid. – Kaliningrad: Yantarny Skaz, 1999. – 69-83. Original source: Маркова Л.Л. Реки // Калининградская область: Очерки природы / Сост. Д.Я. Беренбейм; Науч. ред. В.М. Литвин. – 2-е изд., доп. и расш. Калининград: Янтарный сказ, 1999. – С. 69-83.

Marut S (1990) Macrozoobenthos of the Vistula Lagoon (in Polish). MScThesis. Wyzsza Szkoła Pedagogiczna w Słupsku, Instytut Biologii, Słupsk

Meier H.E.M., 2006. Baltic Sea climate in the late twenty-first century: a dynamical downscaling approach using two global models and two emission scenarios, Clim. Dynam., 27 (1), 39–68.

Mellin, M.; I. Mirowska-Ibron; J. Gromadzka & R. Krupa (1997): Recent development of the Cormorant breeding population in north-eastern Poland. Suppl. Ric. Biol. Selvaggina 26: 89-95.

Naumenko EN (1999) Species composition, seasonal and long-term dynamics of zooplankton abundance and biomass in the Vistula Lagoon of the Baltic Sea. In: Proceedings of the Symposium on freshwater fish and the herring populations in the coastal lagoons – environment and fisheries. 6–7 May 1998, Gdynia, Poland, pp 161–173

Naumenko EN (2004) Zooplankton of the Vistula Lagoon (in Russian). In: Alimov AF, Ivanova MB (eds) Regularities of hydrobiological regime in water bodies of different types. Moscow “Scientific World”, pp 141–146

Naumenko EN, Polunina YuYu (2000a) *Cercopagis pengoi* (Ostroumov, 1891) (*Cladocera*, *Podonidae*) a new species introduced to the Vistula Lagoon (Baltic Sea) (in Russian). In: Introduced species in the European Seas of Russia. Kolskij Nauchnyj Tsentr RAN, Apatity, pp 121–129

Naumenko EN, Polunina YuYu (2000b) New *Cladocera* species *Cercopagis pengoi* (Ostroumov, 1891) (*Crustacea*) in the Vistula Lagoon on the Baltic sea. ICES CM 2000/U 14:8

Navrotskaya S., Chubarenko B. (2011) Comparison of average and extreme levels in the Baltic Strait and the mouth of the river Pregola (Vistula Lagoon) for the period 1901-2006 years. Transactions of Russian Geographic Society. 2011. Vol. 143. No. 4. P. 75-80. Original source: Навроцкая С.Е., Чубаренко Б.В. Сравнение средних и экстремальных уровней в Балтийском проливе и устье реки Преголи (Калининградский залив) за период 1901-2006 гг. Известия РГО. 2011. Т.143. Вып. 4. С. 75-80.

Navrotskaya S., Chubarenko B. (2012a). On raising the sea level in the Russian part of the Vistula Lagoon // Journal of Meteorology and Hydrology. No. 1. P. 57-67. Original source: Навроцкая С.Е., Чубаренко Б.В. О повышении уровня моря в российской части Вислинского залива // Метеорология и гидрология. 2012. № 1. С. 57-67.

Navrotskaya S., Chubarenko B. (2012b). On trends in water levels in the Russian part of the Vistula Lagoon and the adjacent waters of the Baltic Sea // The regional effects of global climate change (causes, effects, projections): Proceedings of the International Conference (Voronezh, June 26-27, 2012). - Voronezh: Publishing House "Science Book", 2012. P. 248-251. Original source: Навроцкая С.Е., Чубаренко Б.В. 2012 б. О тенденциях изменения уровня воды в российской части Вислинского залива и прилегающей акватории Балтийского моря // Региональные

эффекты глобальных изменений климата (причины, последствия, прогнозы): Материалы международной научной конференции (г. Воронеж, 26-27 июня 2012 г.). – Воронеж: Изд-во «Научная книга». 2012. С.248-251.
OECD (1982) Eutrophication of waters. Monitoring, assessment and control. OECD, Paris
Pilipchuk V., Chubarenko B. Results of monitoring in the Vistula Lagoon and River Pregolia estuary zone in 2012. Technical Teport. Atlantic Branch of P..P.Shirshov Institute of Oceanology of Russian Academy of Sciences. 2012.
Plinski M (1995) Vascular plants of the northern part of the Vistula Lagoon. Bull Mar Inst 22:81–87
Plinski M, Krenska B, Wnorowski T (1978) Floristic relationships and biomass of vascular plants of the Vistula Lagoon (in Polish). Studia i Materiały Oceanologiczne, Biologia Morza 21:161–196
Plinski M, Simm A (1978) Seasonal fluctuations in the composition, distribution and quantity of phytoplankton in the Vistula Lagoon in 1974 and 1975 (in Polish). Studia i Materiały Oceanologiczne, Biologia Morza 21:53–80
Polunina YuYu (2001) Population biology of the Ponto-Caspian invader *Cercopagis pengoi* (*Cladocera*) in the Vistula Lagoon of the Baltic Sea. Baltic Sea Science Congress 2001. Past, present and future – a joint venture. Stockholm University, Sweden, 25–29 November, Abstract, Poster No. 125:276
Przybysz, J. (1997): Kormoran [Cormorant]. Lubuski Klub Przyrodników. Świebodzin. 108 pp.
Psuty I (2012) The current state of Vistula Lagoon Polish fisheries. Perspectives for development. ARTWEI Project Report, 63pp. http://www.balticlagoons.net/artwei/wp-content/uploads/2012/05/PSUTY-Vistula-Lagoon-Fishery_final-m1.pdf
Rasmussen EK (1997) Summary report on International project “Prioritising hot spot remediation in the Vistula Lagoon catchment: environmental assessment and planning for the Polish and Kaliningrad parts of the Lagoon”, Water Quality Institute (DK); Danish Hydraulic Institute (DK); GEOMOR (Poland); P.P. Shirshov Institute of Oceanology, Atlantic Branch (Russia), 2nd edn
Renk H, Ochocki S, Zalewski M, Chmielowski H (2001) Environmental factors controlling primary production in the Polish part of the Vistula Lagoon. Bull Sea Fisheries Inst 1:77–95
Riech F (1928) Beiträge zur Kenntnis der litoralen Lebensgemeinschaften in der poly- und mesohalinen Region des Frischen Haffes. Schr Phys Ökonom Ges 65:32–47
Rozanska Z (1963) The Vistula Firth zooplankton (in Polish). Zesz Nauk WSR w Olsztynie 16:41–57
Rozanska Z (1967) Zooplankton i krótka charakterystyka hydrologiczna Zalewu Wiślanego i Zalewu Szczeciskiego w świetle badan XX- lecia. Stud Mater Mor Inst Ryb Gdynia Series A 4:27–37
Rozanska Z (1972) Zooplankton zalewów przybałtyckich. Studia i Materiały Oceanologiczne 3:141–148
Rudinskaya LV (1999) Water salinity impact upon bottom invertebrates structure in the Vistula Lagoon. In: Proceedings of symposium on freshwater fish and the herring populations in the coastal lagoons – environment and fisheries. 6–7 May 1998, Gdynia, Poland, pp 202–219
Rudinskaya LV (2000a) The influence of water salinity on the structure of benthic invertebrates in the Vistula Lagoon of the Baltic Sea (in Russian). Hydrobiological Studies in the basin of the Atlantic Ocean. V.1.: Freshwater hydrobiology. Atlantic Institute for Fishery and Oceanography, Kaliningrad, pp 50–58
Rudinskaya LV (2000b) Dynamics of biomass and abundance of the *Marenzelleria viridis* and its influence upon the structure of benthic community in the Vistula Lagoon. In: Invading species in the European Seas of Russia. Apatity: KNC RAN, pp 193–202
Senin YuM, Smyslov VA, Khlopnikov MM (2004) General characteristics of the Vistula Bay. In: Alimov AF, Ivanova MB (eds) Regularities of hydrobiological regime in water bodies of different types. Moscow: “Scientific World”: pp 17–18
Shalaginova E.E., Shmutinsky M.A., Tsvetkov V.A., Borisova N.S. Baltic Spit: nature, history, modernity. – Kaliningrad: Amber Tale, 2009. – 288 p. Original source: Шалагинова Е.Е., Шмутинский М.А., Цветков В.А., Борисова Н.С. Балтийская коса: природа, история, современность. – Калининград: Янтарный сказ, 2009. – 288с.
Siegel H., Gerth M., Tschersich G., 2006, Sea surface temperature development of the Baltic Sea in the period 1990–2004. Oceanologia, 48 (S), 119–131.

Silich M.V. (a) Water balance of Lagoon // Hydrometeorological regime of Vistula Lagoon, ed. Lazarenko N, Maevski A., Leningrad: Hydrometeoizdat, 1971, - P. 143-172. Original source: Силич М.В. Водный баланс залива. // Гидрометеорологический режим Вислинского залива, под ред. Лазаренко Н., Маевского А, Л.: Гидрометеоиздат, 1971, - С. 143-172

Silicz M.W. 1975. Water balance. In: Hydrometeorological regime of Vistula Lagoon, Lazarienko N., Majewski A. (Eds), Warsaw, pp. 267-270 (in Polish)

State of the Coast of the South East Baltic: an indicators-based approach to evaluating sustainable development in the coastal zone of the South East Baltic Sea. Gilbert C. (Ed.). (co-authors: I. Bagdanaviciute, N. Blazauskas, A. Brzezinska, B. Chubarenko, A. Cieslak, I. Dailidiene, D. Domnin, J. Gajewski, Gilbert C., S. Gulbinskas, M. Kalas, M. Matczak, J. Mikelenaite, R. Mileriene, K. Rybka, A. Staskiewicz, I. Stawicka, K. Szefler, E. Visakavicius). Drukamia WL, Gdansk, 2008. 164 p.

Stigebrandt A., Gustafsson B.G., 2003, Response of the Baltic Sea to climate change – theory and observations, J. Sea Res., 49 (4), 243–256.

Stont Zh., Chubarenko B., Goushchin O., 2010, Changes in hydro-meteorological characteristics for marine coast of the South-East Baltic. News of RGS. Vol. 142. No. 4. P. 48-56.

Szarejko-Łukaszewicz D (1957) Qualitative investigations of phytoplankton of Firth of Vistula in 1953 (in Polish). Prace MIR, Gdynia 9:439–451

The scheme of nature conservation of the Kaliningrad Region. TENAX MEDIA PUBLISHING HOUSE, Kaliningrad, 2004. – 136 p.

Trzosinska A (1975) Suspended particulate matter (in Polish). In: Lazarenko NN, Majewski A (eds) The hydrometeorological system of the Vistula Lagoon. IMGW, Wydawnictwo Komunikacji i Łączności, Warsaw

Tsybaleva GA, Andronov VN, Polunina YuYu (2000) Structural characteristics of zooplankton from the Pregola River–Kaliningrad Sea Channel system. Proceedings of the International Conference KGTU. Kaliningrad, Part 1, pp 94–96

Wiktor J, Wiktor K (1959) Study on biology of the Baltic Sea coastal lagoons in Poland (in Polish). Przyroda Polski Zachodniej 3:7–28

Witek B, Plinski M (2000) The first recorded bloom of *Prorocentrum minimum* (Pavillard) in the coastal zone of the Gulf of Gdansk. Oceanologia 42:29–36

Witek Z, Zalewski M, Wielgat-Rychert M (2010) Nutrient stocks and fluxes in the Vistula Lagoon at the end of the twentieth century, Pomeranian Academy in Słupsk, Sea Fisheries Institute in Gdynia, Słupsk-Gdynia, 186pp.

www.meteo.lt

Wypych, K., Nieczaj, J., 1975. Osady denne. – In: Hydrometeorologicny ustroj Zalewu Wislanego, Warszawa, p. 41-46, (In Polish).

Zachowicz, J., Uscinowicz, S., 1996. Geochemical atlas of the Vistula Lagoon. Warszawa, 94 p.

Zmudzinski L (1957) The Firth of Vistula zoobenthos. Reports of the Sea Fisheries Institute in Gdynia 9:453–500

Zmudzinski L (2000) Long-term changes in macrozoobenthos of the Vistula Lagoon. Sea and Environment (Jura ir Aplinka), Klaipeda University, 1:46–50

ANNEX 1. Detailed information on infrastructure in the Polish part of the Vistula Lagoon

City of Elbląg

The social and economic infrastructure of Elbląg, based on 2010 data, is summarized in the following points:

1. Water supply by municipal system in 2010: 8,422,500 m^3, covering 100% of demand.
2. 98% of population is connected to waste water management system of separate rainwater/sewage collection. Elbląg River connected to Vistula Lagoon, performance of wastewater treatment facilities is adequate as to national and European norms. The remainder 2% drain to septic tanks, from which wastewater is transported to the sewage system by wastewater trucks and discharged to the sewage system.
3. 70% of water consumers are households, 19% business and 11% unspecified users. The rainwater drainage system (277 km of pipelines) is a system, whose core originates from before WWII. Since its development failed to keep pace with city extension after that war, the rainwater drainage network does not cover some city districts.
4. 88% of heat production originates from the local combined, coal fired heat and power plant, more than 11% from a dedicated local heat production plant and only 0.25% from individual installations; this is good from the environmental point of view, as noxious gases and dust are treated on-site.
5. General solid wastes produced in the city in 2010 amounted to 53,500 tons; selective collection of waste for recycling (glass, paper, plastic) is also effective. The collection of dangerous wastes and processing of waste from construction sites (rubble) are operational as well. Also, an integrated waste management system including (most) communes in Elbląg County and the town of Braniewo and Pasłęk, was introduced in 2010 using, *inter alia*, EU funds.
6. The number of private businesses in 2010 was 11,801 compared to 992 in the public sector. Among them 12,111 were micro-businesses (up to nine employees), 539 small enterprises employing 10 – 49 people, 120 medium enterprises with 50 – 249 employees and 17 big companies with more than 250 staff, one of which had a staff larger than 1,000.
7. The turnover of Elbląg harbour, the largest harbour in the Polish part of Vistula Lagoon, is illustrated in Fig. 3.7, which shows that after almost complete freeze between 2006 – 2009 the activities of the harbour were restarted in 2010, but the volume of traffic is still only a small fraction of that from 1990's. Fig. 3.7 is a graphical depiction of the total dependence of harbour performance on global relations between the governments of Poland and the Russian Federation.
8. 76% of children aged 3 - 6 attended kindergartens (3,345 children in 2010/2011). Primary education was provided by 16 schools, secondary education is available at 17 public and 11 non-public schools. There are also nine trade schools offering courses for 49 professions. There are two dominant higher education units: State Higher Trade School and Elbląg Higher Art and Economic School: in all the number of students exceeds 6,000.
9. Tourist sector: 1 four star hotel with 85 rooms, swimming pool and conference rooms, 9 three star hotels with 570 beds, 2 two star hotels with 107 beds, 1 two star camping for 100 guests and plus 13 non-categorized units with 957 beds.
10. Housing sector: The number of apartments inhabited in 2010 was 45272, which is equivalent to 359 flats per 1,000 inhabitants. The average flat measured 57.8 m^2 and was inhabited by 2.78 residents.
11. 99.9% per cent of apartments had access to running water, 97.6% to a flushed toilet, 93% to a bathroom, 91.1% were connected to the gas network and 84.5 % were equipped with central heating.

12. Flood safety issues: In general, flood defences due to storm surges in Vistula Lagoon are drastically inadequate. The greatest flood risk source emerges from Elbląg River, which is directly connected to the lagoon, and whose levees are insufficiently high to prevent inundations; minor exceedance of the warning level at 590 cm triggers inundations. The second hot spot is the flood embankment with Radomska Street on its top: when overtopped inundations spread further. Insufficient height of flood defences of the canal surrounding Granary Island triggers additional losses. Finally, high water levels in Fiszewka, a branch of the Elbląg River, may damage of one of the exit roads to Malbork town; hydraulic infrastructure preventing surges in Fiszewka (a lock) is missing. In summary, the lack of appropriate anti-flood infrastructure is one of major problems the city has been facing for decades.

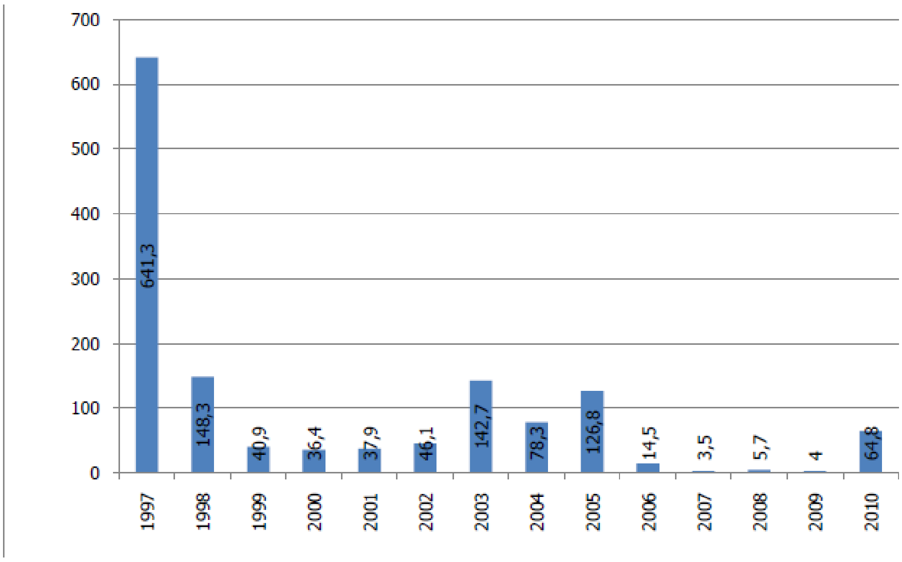


Figure 3.7 Elbląg harbour traffic (thousands of tons)

Elbląg County

The infrastructure of this county, based on 2005 data, is presented in the following points:

1. Roads: 72 km of major (national) roads, administered by the government, 175 km of provincial roads (administered by the province authorities), 540 km of county roads (administered by the county), of which 522.9 km are paved roads, and 1,083 km of local roads administered by communes, of which 234.4 km are paved.
2. Railway lines: (i) electrified, dual track lines Elbląg – Malbork and Elbląg –Bogaczewo, (ii) electrified, single track line Bogaczewo-Pasłęk-Morąg-Olsztyn, (iii) single track line Bogaczewo-Braniewo-Kaliningrad, (iv) single track line Elbląg-Braniewo running close to Vistula Lagoon; good technical conditions of 80% of the major lines and 50% of the local lines, but their common problem is lack of profitability.
3. Waterways: Elbląg River – Jagielloński Canal, Szkarpawa (northernmost connection of the Vistula River to Vistula Lagoon) and Elbląg Canal are navigable for tourist purposes (small vessels), major waterway along the lagoon should regain its importance when a visa-waiver scheme comes into force between Poland and the Kaliningrad region.
4. Public transport: 13 bus lines with a total length of 329 km and 162 daily courses; daily mileage 3,670 km.
5. Water supply (as of 1998): 701.8 km of pipelines and 8,404 connections to residential buildings; in towns, 98.4% of inhabitants have running water compared to 80.2% in smaller villages (85.6% on average).

6. Sewage system: (as of 1998) 74.1 km of sewers with 2,335 connections to buildings; 73% of the inhabitants are connected to sewers in towns compared to 7% in villages (22% on average). Waste water treatment plants serve ca. 95% of town residents and only 14% of villagers.
7. Connection to the gas network: 28.8 km of pipelines and only 251 (collective?) users.
8. Waste management: industrial wastes: 4,500 tons stored at two landfills, 1,100 tons (?) of municipal wastes were stored at five landfills. Systems of selective collection of wastes are operational in the following communes: Elbląg, Gronowo Elbląskie, Milejewo, Pasłęk and Tolkmicko.
9. Housing: the majority of houses and buildings originates from the beginning of the 20th century, although they are mainly made of brick; overall, there are 16,474 flats with 61,992 rooms in the county; on average 3.43 people live in one flat.
10. The business sector counts 3,349 enterprises of which 20 – 25% are inoperative. It is estimated that ca. 95% of the active remainder consists of small ventures employing up to five people.
11. Protected areas: (i) NATURA 2000 areas; habitat protection: PLC 280001 (Lake Drużno), PLH280006 (Pasłęka river), PLH 280007 (Vistula Lagoon and Vistula Lagoon Spit); bird protection: PLB280002 (Pasłęka river valley), PLC280001 (Lake Drużno), PLB280010 (Vistula Lagoon), (ii) 8 natural reservations – 4,014.5 ha, (iii) Landscape Park "Wysoczyzna Elbląska" (Elbląg Highlands) 11,554 ha, (iv) 10 protected landscape areas 58,842.5 ha, 601 registered monuments of nature,
12. Education: 27 primary schools, 11 gymnasiums, four groups of secondary schools of various types, nine kindergartens,
13. Health services: hospital at Pasłęk town with 95 beds plus hospitals in Elbląg city, number of beds per 10,000 inhabitants: 16.5 vs. 21 national average,
14. Tourist sector: seven hotels and motels with 416 beds,
15. Agriculture: arable land – 60,203 ha, orchards – 668 ha, meadows – 11,066 ha, pastures – 15,270 ha, forests – 26,191 ha, other 29,657 ha; 65% of agricultural soils has adequate moisture, 10% is periodically too wet; the condition of the primary irrigation infrastructure in areas belonging to the Vistula river delta (major canals and pump stations) is adequate, the conditions of secondary infrastructure is deficient (poor maintenance of ditches and smaller levees).

Braniewo County

The infrastructure of Braniewo County is described in the following points:

1. Roads: 42.6 km of major (national) roads administered by the government; they connect Poland with the Kaliningrad region, 114.3 km of provincial roads, administered by Warmia-Masuria Province, 417.5 km of county roads (352.7 km paved) and 323.9 km of communal roads (only 35.5 km paved).
2. Railway lines: extension of the (single track) line from Bogaczewo to Braniewo (see description of railways in Elbląg county) and then to the Kaliningrad region, there is a railway frontier crossing at Braniewo; there is another single track connection Elbląg-Braniewo (see description of Elbląg county railways) that runs very close to Vistula Lagoon – it is used very rarely only in the summer season.
3. Waterways: a (seasonal) connection from Frombork to Krynica Morska across Vistula Lagoon, connections with the Kaliningrad region will be possible when a visa-waiver scheme comes into force between Poland and the Kaliningrad region. A small wharf is also available at Nowa Pasłęka village; it is situated very close to the frontier with Kaliningrad region.
4. Public transport: Nine local bus lines and three lines running across and beyond the county.
5. Frontier crossings: road at Gronowo and Grzechotki, railway at Braniewo and waterway at Frombork
6. Water supply: 457.4 km of pipelines, 4,463 buildings and 8,171 households are connected to the water supply system. There is a 100% access to running water at Braniewo and Frombork towns, other communes have a rate of about 80% with the exception of Pieniężno commune, where only 40% are connected to the system. On average, 97% of inhabitants have access to running water.

7. Sewage system: 100.7 km of sewers with connections to 1,532 buildings and 4,184 apartments. Wastewater is treated by 14 treatment plants (mechanical and biological treatment).
8. Connection to gas network: no such facilities.
9. Waste management: four landfills serve the whole county storing municipal wastes; waste segregation is executed at Braniewo town.
10. Housing: 12,975 flats with 5,433 in Braniewo. An average flat has 60 m^2 and is inhabited by 3.6 persons. There are six collective heating plants operating in major settlement areas (Braniewo, Frombork, Pieniężno), villages with dispersed houses must rely on individual heating facilities.
11. Protected areas: four natural reservations; (i) beaver reservation on Pasłęka River – protected species: beavers, (ii) peat bog reservation in Braniewo commune – protected species: shrub birch, (iii) landscape reservation in Wałsza river valley in Pieniężno commune, (iv) peat bog reservation in Wilczęta commune – protected species – cloudberry; nine areas with protected landscape; 188 registered monuments of nature.
12. Education: 20 primary schools, 14 secondary schools and 16 kindergartens. One branch of the University of Warmia and Mazury, Olsztyn city (capital of Warmia-Masuria Province) is based at Braniewo and educates ca. 300 students.
13. Health services: hospital at Braniewo with 87 beds, hospital for mentally ill patients in Frombork with 210 beds serving the counties of Braniewo and Elbląg as well as the city of Elbląg.
14. Business sector: There are ca. 2,900 businesses of which 92% are private enterprises. About 94% of all enterprises are small firms employing up to nine people, about 4 – 5% are medium firms with 10 – 49 employees, and slightly more than 30 firms employ more than 50 people. More than 55% of the businesses are based in Braniewo, 14% in Pieniężno and 10% in Frombork.
15. Tourist sector: Braniewo - five hotels with 191 beds, Frombork – nine hotels with 455 beds, Pieniężno - five hotels with 98 beds plus other smaller enterprises that together offer 807 all-year beds. Also, 50 beds are available at eight agro-tourist households plus three camping sites, which are active in the summer season.
16. Agriculture: the land use structure comprises 61.44% (73,775 ha) of cultivated areas of which 50,892 ha are arable areas, 7,733 ha meadows, 15,007 ha pastures, and 143 ha orchards.

Nowy Dwór Gdański County

The infrastructure of Nowy Dwór Gdański County is summarized in the following:

1. Roads: major (national) roads 32.2 km, provincial roads (under administration of Pomerania Province authorities) 61.7 km, county roads (298.1 km) – all these roads are paved, commune roads (279.4 km of which 242.1 paved).
2. Railway lines: no passenger lines, cargo station at Nowy Dwór town.
3. Waterways: cargo transport along Vistula, Dead Vistula branch (1,000 ton barge limit), Szkarpawa and Nogat branches (500 ton barge limit), navigational waterways along Vistula Lagoon.
4. Public transport: about 20 permanent and seasonal bus routes.
5. Water supply: 474.9 km of pipelines and 4,257 connections to buildings.
6. Sewage system: 160.9 km of sewers, 2,303 connections to buildings and four wastewater treatment plants (mechanical and biological purification).
7. Waste management: municipal wastes from the county are stored at a landfill in another county (Tczew), situated outside Vistula Lagoon catchment. Segregation of wastes is insufficient.
8. Connection to gas network: ca. 40% of residents of Nowy Dwór Gdański town is connected; other communes have no network gas access.
9. Housing: data not found,
10. Protected areas: 16,962 ha (26% of county's area) is occupied by protected areas. There are 3 natural reservations (241 ha): (i) beech tree reservation at Stegna commune (near Vistula Lagoon Spit root) – 7 ha, (ii) faunistic reservation at Kąty Rybackie village (Spit root) – protected species cormorant and grey heron – 102.54 ha, (iii) Mewia Łacha faunistic reservation at Vistula river mouth alluvial fan – 131.5 ha designed as nesting area and a hub of bird migration routes: this reservation is not related to the functioning of the lagoon; landscape park Mierzeja Wiślana

(Vistula Lagoon Spit) – 4,410 ha of which 3,310 are forests; 12,301 ha – areas of protected landscape,

11. Education: eight primary schools, 10 secondary schools,
12. Health services: hospital in Nowy Dwór Gdański just became (Jan. 2012) part of a healthcare complex at Malbork (neighbouring county south of Nowy Dwór); health services have thus been transferred to another county,
13. Business sector: 3,375 firms of which 163 are public and 3,112 are private companies; 2,759 firms are small family businesses,
14. Tourist sector: 9,604 mostly seasonal beds, the majority of which lies on the Vistula Lagoon Spit and near its root in the proximity of the Baltic Sea; this illustrates the business potential generated by Baltic Sea beaches irrespective of the presence of Vistula Lagoon,
15. Agriculture: arable land 34,531 ha (87.35%) of agricultural land uses, orchards 62 ha (0.16%), meadows 2975 ha (7.53%), pastures 1964 ha (4.97%), forests 5242 ha (8.03%). The strong point of the county's agriculture is the large number of large, market oriented farms; the major problem is the malfunctioning of irrigation infrastructure, often situated in depression areas.

ANNEX 2. International conventions applied to the Vistula Lagoon

Title, website	place and date	level	Russia
Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention) http://www.ramsar.org/cda/en/ramsar-documents-texts-convention-on/main/ramsar/1-31-38%5E20671_4000_0__ http://www.ramsar.org/pdf/key_cps_ratifs.pdf	Ramsar, 02.02.1971	world	Participant 11.10.1976
Convention on International Trade in Endangered Species of Wild Fauna and Flora (Washington Convention, CITES) http://www.cites.org/eng/disc/text.php#texttop	Washington 03.03.1973	world	Participant 1976
Convention on Fishing and Conservation of the Living Resources in the Baltic Sea and Belts http://eelink.net/~asilwildlife/CFCLRBS.html	Gdansk 13.09.1973	regional	participant 28.07.1974
Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal http://archive.basel.int/text/con-e-rev.pdf	Basle 22.03.1989		participant 01.05.1995
International Convention on Oil Pollution Preparedness, Response and Co-operation (OPRC) http://www.imo.org/About/Conventions/ListOfConventions/Pages/International-Convention-on-Oil-Pollution-Preparedness,-Response-and-Co-operation-(OPRC).aspx	London 30.11.1990	world	participant
Convention on Environmental Impact Assessment in a Transboundary Context http://www.unece.org/fileadmin/DAM/env/eia/documents/legaltexts/conventiontextenglish.pdf	Espoo 25.02.1991	world	No information
Convention on the Transboundary Effects of Industrial Accidents http://ec.europa.eu/environment/seveso/pdf/98685ec_conv.pdf	Helsinki 17.03.1992	world	Participant 04.11.1993
Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention) http://www.unece.org/fileadmin/DAM/env/water/pdf/watercon.pdf	Helsinki 17.03.1992	world	No information
Convention on the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Convention) http://www.helcom.fi/Convention/en_GB/text/	Helsinki 09.04.1992	regional	participant
United Nations Framework Convention on Climate Change http://unfccc.int/resource/docs/convkp/conveng.pdf	New York 09.05.1992	world	Participant 04.11.1994
Convention on Biological Diversity http://www.eoearth.org/article/Convention_on_Biological_Diversity http://www.cbd.int/doc/legal/cbd-en.pdf	Rio de Janeiro, 05.06.1992	world	Participant 17.02.1995

Convention on the Law of Non-Navigational Uses of International Watercourses http://untreaty.un.org/ilc/texts/instruments/english/conventions/8_3_1997.pdf	New York 21.05.1997	world	Participant 15.11.1997
Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters (Aarhus Convention) http://www.unece.org/fileadmin/DAM/env/pp/documents/cep43e.pdf	Aarhus, 25.06.1998	European	–
– European Landscape Convention http://conventions.coe.int/Treaty/en/Treaties/Html/176.htm	Florence, 20.10.2000	European	–
UNESCO Convention on the Protection of the Underwater Cultural Heritage http://www.icomos.org/risk/2006/unesco-convention.pdf	Paris, 02.11.2001	world	–

ANNEX 3. Legal framework of natural resources use management and their preservation in the Russian Federation

№	Document name, reference	Adoption date	Contents
	RF Law dated February 24, 1992 № 2395-1 "On mineral resources " http://base.consultant.ru/cons/cgi/online.cgi?req=doc;base=LAW;n=118195	dated 21.02.1992 (edited 06.12.2011)	Legal relationship regulation in the field of ground water use as mineral resources, as well as water objects necessary for works execution associated with mineral resources use.
	"Civil Code of the Russian Federation (part one)" dated October 21, 1994 № 51-FL http://www.consultant.ru/popular/gkrf1/	dated 21.10.1994 (edited 28.11.2011)	Civil and legal relationship regulation in the field of water objects use: specification of the legal state of participants of the present relations, grounds for origin and exercise procedure of proprietary rights and other corporeal rights on water objects, regulation of agreement obligations, as well as other contractual relations between participants of the present relations.
	Federal Law of March 14, 1995 N 33-FL "On nature reserves" http://base.consultant.ru/cons/cgi/online.cgi?req=doc;base=LAW;n=131663	dated 14.03.1995 (edited 25.06.2012)	Relations regulation in the field of arrangement, preservation and use of nature reserves: specified categories and kinds of NR, description of their purpose and legal state
	Federal Law of April 24, 1995 N 52-FL "On animal life" http://base.consultant.ru/cons/cgi/online.cgi?req=doc;base=LAW;n=121955	dated 24.04.1995 (edited 21.11.2011)	Relations regulation in the scope of animal life and environment preservation and use: powers differentiation of RF state bodies, RF subjects and local authorities in the field of AL objects protection and use; determination of the procedure of development and implementation of specific public programmes stipulation for certain activities aimed at AL objects and their EC protection, as well as the procedure of AL objects use, responsibility specification of the

			persons guilty of the RF legislation violation in the field of AL and their EC preservation and use.
	Federal Law of November 23, 1995 N 174-FL "On Environmental Impact Assessment " http://base.garant.ru/10108595/1/#100	dated 23.11.1995 (edited 28.07.2012)	Legal relationship regulation related to favourable E preservation by means of prevention of the negative impact caused by economic or other types of activity: specification of powers of the RF President, RF public authorities and local authorities in the scope of EIA. Two types of EIA are specified: state and public; the notion of EIA procedure and responsibility for EIA legislation violation are described.
	Federal Law of November 30, 1995 N 187-FL "On continental shelf of the Russian Federation" http://base.consultant.ru/cons/cgi/online.cgi?req=doc;base=LAW;n=121953	dated 30.11.1995 (edited 21.11.2011)	Specification of the status the RF continental shelf, sovereign rights and jurisdiction of the RF: CS borders, RF rights and obligations on CS, particular CS exploration and its mineral resources development, peculiarities of CS fishing, the procedure of establishment, exploitation and use of artificial islands, instalments and erections on CS, principles of marine research carrying out, public EIA, public environmental supervision and monitoring of CS, rules of waste burial at CS
	"Criminal Code of the Russian Federation" (utilized part) of June 13, 1996 N 63-FL http://base.garant.ru/10108000/	dated 13.06.1996 (edited 28.07.2012)	Chapter IX (Crimes against public security and peace), Chapter 26 (Environmental crimes) specifies the amount of criminal liability for RF laws violation in the field of environmental protection
	Federal Law of June 24, 1998 N 89-FL "On production and consumption wastes" http://base.garant.ru/12112084/	dated 24.06.1998 (edited 28.07.2012)	Legal basis specification for production and consumption waste handling, as well as involving such waste in the economic turnover as additional sources of raw materials; powers differentiation of RF state bodies, RF subjects

			and local authorities in the field of waste handling; description of principal requirements applied to waste handling, as well as standards, state recording and accounting in the scope of waste handling; specification of types of liability for violations of the RF legislation herein.
	Federal Law of July 19, 1998 N 113-FL "On hydrometeorological service" http://base.consultant.ru/cons/cgi/online.cgi?req=doc;base=LAW;n=121978	dated 19.07.1998 (edited 21.11.2011)	Establishment of legal activity ground in the field of hydrometeorology and related fields (hydrometeorological service activity) intended for needs satisfaction of the state, natural persons and legal entities in hydrometeorological, helio-geophysical information, as well as data of the environment state and pollution).
	"Budget Code of the Russian Federation" of July 31, 1998 N 145-FL http://www.consultant.ru/popular/budget/	dated 31.07.1998 (edited 01.09.2012)	Specification of the list and amount of allocations of water object users to budgets of different levels in the RF
	Federal Law of July 31, 1998 N 155-FL "On inland sea waters, territorial sea and adjacent area of the Russian Federation" http://base.consultant.ru/cons/cgi/online.cgi?req=doc;base=LAW;n=121959	dated 31.07.1998 (edited 21.11.2011)	Regulation of natural resources use, environment protection, protection and conservation of marine environment and natural resources of inland sea waters and territorial sea of the RF
	Federal Law of December 17, 1998 N 191-FL "On the special economic zone of the Russian Federation" http://base.consultant.ru/cons/cgi/online.cgi?req=doc;base=LAW;n=121958	dated 17.12.1998 (edited 21.11.2011)	Status determination of the special economic zone in the RF, sovereign rights and jurisdiction of the Russian Federation in its SEZ: definition, basic notions and borders of SEZ; specification of rights and obligations of the RF and other states in the SEZ; peculiarities of fishing arrangement, exploration and development of nonliving resources, marine resource research of water bio-resources, public EIA and environmental supervision carrying out in the SEZ.

	"Tax Code of the Russian Federation (part two) " of August 5, 2000 N 117-FL http://base.consultant.ru/cons/cgi/online.cgi?req=doc;base=LAW;n=133353	dated 05.08.2000 (edited 28.07.2012)	Specification of the scope of tax-payers and tax rates for water objects use
	"Code of inland water transport of the Russian Federation” of March 7, 2001 N 24-FL http://www.consultant.ru/popular/wattrans/	dated 07.03.2001 (edited 28.07.2012)	Regulation of the activity related to shipment by inland water transport: legal grounds for this activity category (license), legislation observance control, rules of the use of water objects and offshore coastal strip in the course of shipment by IWT.
	Federal Law of July 10, 2001 N 92-FL "On special environmental restoration programmes for radiative areas" http://base.consultant.ru/cons/cgi/online.cgi?req=doc;base=LAW;n=131659	dated 10.07.2001 (edited 25.06.2012)	Determination of the procedure of adoption and implementation of special environmental programmes aimed at radiation security of population, general reduction of the risk of radiation impact and ecological situation improvement in radiative areas by means of specific rehabilitation activities, utilization or elimination of radioactive facilities taken out of service; specification of the role of the RF governmental bodies.
	"Land Code of the Russian Federation” of October 25, 2001N 136-FL http://www.consultant.ru/ popular/earth/	dated 25.10.2001 (edited 28.07.2012)	Specification of the legal state of water fund lands, their use and protection procedure
	"Code of administrative violation in the Russian Federation " of December 30, 2001 N 195-FL http://base.consultant.ru/cons/cgi/online.cgi?req=doc;base=LAW;n=131969	dated 30.12.2001 (edited 28.07.2012)	Establishment of administrative responsibility of individual persons, legal entities and officials for law violation in the field of natural resources management and environmental protection
	Federal Law of December 20, 2004 N 166-FL"On fishing and water biological resources preservation” http://base.consultant.ru/cons/cgi/online.cgi?req=doc;base=LAW;n=122801	dated 20.12.2004 (edited 06.12.2011)	Relationship regulation in the scope of fishing and aquatic bioresources conservation: provision of basic notions and principles in the field of fishing and aquatic bioresources conservation, public monitoring carrying out and government

			control in the field of fishing and aquatic bioresources conservation, description of the scope of law, working rules and admissible fishery volumes
	" Urban Development Code of the Russian Federation" of December 29, 2004 N 190-FL http://www.consultant.ru/popular/gskrf/	dated 29.12.2004 (edited 28.07.2012)	Definition of terms and conditions of the urban development works that may have a negative impact on the environment and water bodies including mandatory EIA of urban development project documentation planned in the special economic zone of the Russian Federation, on the continental shelf of the Russian Federation, in the inland waters, territorial sea of Russia, in nature reserves.
	"Water Code of the Russian Federation" of June 3, 2006 N 74-FL http://www.consultant.ru/popular/waternew/	dated 03.06.2006 (edited 25.06.2012)	Regulation of legal relationship of water bodies use and protection: water bodies classification, definition of water relations participants and rules of their use depending on their designation, assignment of water bodies for use (water use agreement, decision of government bodies concerning object assignment for use), specification of terms of reference of government bodies in the field of water bodies use and protection

ANNEX 4. Other statutory acts of the Russian Federation

№	Document name, reference	Adoption date	Contents
	Order of Ministry of Natural Resources dated December 12, 2007 N 328 "On approval of guidelines for development of admissible impact standards for water bodies" (Registered in the RF Ministry of Justice 23.01.2008 N 10974) Annex A. Water bodies use in accordance with the Water Code of the Russian Federation of June 3, 2006 г. N 74-FL and the associated types of regulated impact allowed for water bodies http://www.garant.ru/products/ipo/prime/doc/2063965/	dated 12.12.2007	Methods for development of the allowable impact on water objects for setting of secure levels of pollutant content considering natural and climate conditions and economic zonation
	Regulation of the RF Government of March 10, 2009 N 223 "On limits (admissible volumes) and sampling (withdrawal) quotas for water facility and sewage" http://base.consultant.ru/cons/cgi/online.cgi?req=doc;base=LAW;n=85729	dated 10.03.2009	Setting limits on the amount and quotas for removal of water from water bodies and sewage for the period up to 2014, by year
	Order of the Russian Fishery Agency dated August 4, 2009 № 695 "On approval of guidelines for development of water quality standards for fishery water bodies, including the standards of maximum permissible concentrations of harmful substances in water fishery bodies" (registered in the Ministry of Justice on 03.09.2009 N 14702) http://base.consultant.ru/cons/cgi/online.cgi?req=doc;base=LAW;n=91976;fld=134;dst=100011;rnd=0.8301124311983585	dated 04.08.2009	Guidelines for determination of water quality and the content of harmful substances contained in water
	Regulation of the RF Government of August 12, 2010 N 623 "On approval of technical rules on safety of inland waterway transport"	dated 12.08.2010	Establishment of mandatory baseline minimum requirements for safety, marking and identification of inland water transport

	http://base.garant.ru/199131/		objects
	Order of the RF President "On approval of the implementation plan for the Climate Doctrine of the Russian Federation for the period up to 2020) of 25 April 2011 № 730-p http://www.garant.ru/products/ipo/prime/doc/2074495/	dated 25.04.2011	Provision of a comprehensive plan for implementation of the RF Climate Doctrine with step by step guidelines for of regional socio-economic development programmes formation: event name, a list of responsible federal executive authorities, implementation term
	Government policy principles in the field of environmental development of Russia till 2030 (approved by the President of the Russian Federation on April 30, 2012) http://www.garant.ru/products/ipo/prime/doc/70069264/	dated 30.04.2012	Specification of purpose, principles, main objectives and mechanisms of the government environmental policy for the period up to 2030

ANNEX 5. Declarations of the Russian Federation.

№	Document name, reference	Adoption date	Contents
	The Marine Doctrine of the Russian Federation for the period up to 2020 (approved by the President of the Russian Federation on 27 July 2001) http://flot.com/nowadays/concept/27-07-2001.htm	dated 27.07.2001	Determines the direction of the state policy of the Russian Federation in maritime activities on research, development and use of World ocean in the interests of safety, sustainable economic and social development of the state; sets the sphere of national interests of the Ministry of Defence of the Russian Federation, objectives and principles of the national maritime policy, functional and regional directions of maritime policy.
	The Ecological Doctrine of the Russian Federation (approved by the Government order № 1225-р dated 31 August 2002) http://www-sbras.nsc.ru/win/anonses/1001.html	dated 31.08.2002	Defines the goals, directions, objectives and principles of conduction of the single state policy in the field of ecology in the Russian Federation; defines the priority directions of activity on guarantee of environmental safety of the Russian Federation, the ways and means of implementation of the state policy in ecology, including regional policy.

	The Climate Doctrine of the Russian Federation (approved by the President of the Russian Federation on 17 December 2009) http://meteoinfo.ru/climatedoctrine	dated 17.12.2009	Defines the main directions of conduction of both internal and external state policy on the issues related to possible global and regional climate change and its consequences influencing over environmental, economic and social aspects of sustainable development of the Russian Federation.