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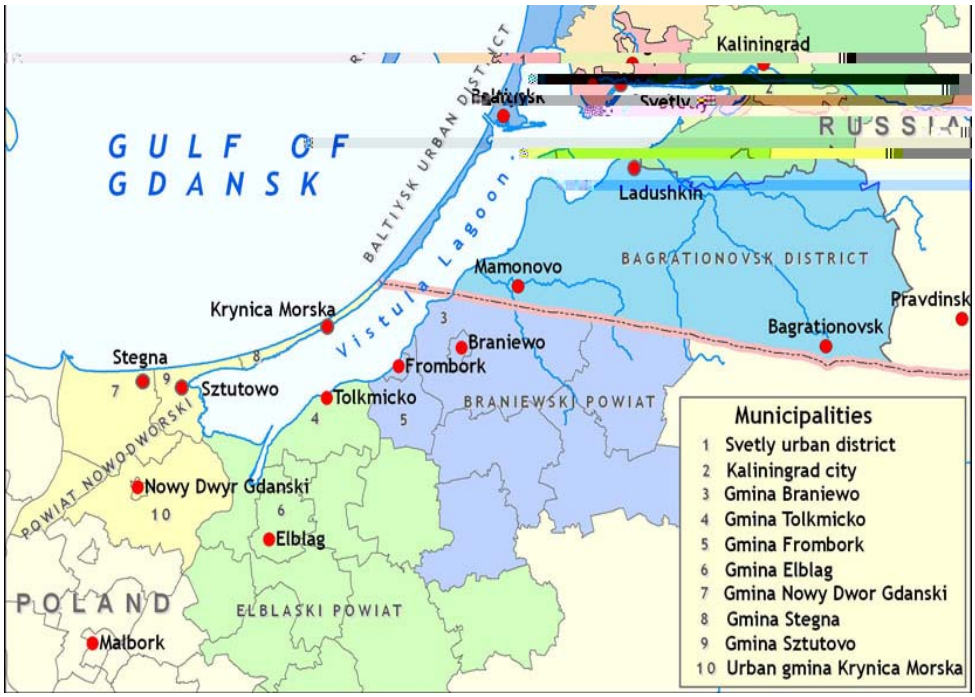

Discussion on the Vistula Lagoon regional development considering local consequences of climate changes

Interim report on the ECOSUPPORT BONUS+ project "Advanced modelling tool for scenarios of the Baltic Sea ECOsystem to SUPPORT decision making" and RFBR project No. 08-05-92421

Anastasia Domnina, Boris Chubarenko

Atlantic Branch of P.P Shirhov Institute of Oceanology of Russian Academy of Sciences, Kaliningrad, Russia

Front:
Map of the municipalities around the Vistula Lagoon

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Atlantic Branch of P.P Shirhov Institute of Oceanology of Russian Academy of Sciences, Kaliningrad, Russia, annasta_sea@mail.ru, chuboris@mail.ru

Summary

Information about natural and economic conditions in the Vistula lagoon together with directions of development of municipalities around the lagoon is presented in the report. The review of directions of development show that all municipalities aim to develop tourism, harbours and land transport. Moreover, Polish municipalities give large attention to environmental protection. In the future the development towards these strategic directions will continue together with an increased role of environmental protection and consequences of climate changes. Assessment of tolerance of Vistula Lagoon municipalities' development strategies to climate changes have shown that directions of Polish municipalities' development is less tolerant to consequences of climate change because of a large area disposed to possible flooding, and therefore possibly high expenses for prevention of territory flooding. The Vistula Lagoon is a subject of high anthropogenic pressure and some consequences due to climate changes were discussed. Obviously, due to different economic experience, economic systems and future plans the pressure will not be equal in Polish and Russian parts of the lagoon. Complex measures on modernization of monitoring climate changes and adaptation as well as strong cooperation between all municipalities around the Vistula Lagoon are essential.

Sammanfattning

I denna rapport presenteras information om miljömässiga och ekonomiska förutsättningar i området kring Frisches Haff, tillsammans med tänkbar framtida utveckling för de kommuner som finns i området. Översikten över tänkbara utvecklingar visar att alla kommuner avser att utveckla turism, hamnaktiviteter samt landtransporter. Polska kommuner avser att lägga stor vikt vid naturskydd. I framtiden kommer utveckling inom dessa strategiska områden att fortsätta, men ökad vikt kommer att bli nödvändig då det gäller naturskydd och konsekvenser på grund av den pågående klimatförändringen. En utvärdering av utvecklingsstrategierna i Frisches Haffs kommuner, med avseende på känslighet för klimatförändringar, har visat att Polska kommuners strategier för utveckling är känsligare för klimatförändringar eftersom stora områden har en ökad framtida översvämningsrisk, och därmed ökade framtida kostnader i samband med ökat behov av översvämningsskydd. Frisches Haff är utsatt för stor påverkan från mänskliga aktiviteter och ytterligare konsekvenser i samband med detta och klimatförändringen diskuteras i rapporten. Eftersom ekonomiska system, ekonomiska konsekvenser och framtida planer skiljer sig åt mellan länderna så kommer även framtida miljöpåverkan och konsekvenser av denna bli olika i den ryska och den polska delen av området. Det är av stor vikt att modernisera övervakningen av klimatförändringar, klimatanpassning samt att stärka samarbetet mellan alla kommuner i området.

Абстракт

В данном отчете представлена информация о природных условиях Вислинского залива, направлениях развития российских и польских муниципалитетов, расположенных вокруг него. Выяснилось, что польские и российские муниципалитеты вокруг Вислинского залива стремятся развивать туризм и портовый и наземный транспорт, в польских муниципалитетах уделяется значительное внимание охране окружающей среды. В перспективе развитие этих направлений продолжится с учетом возможных последствий климатических изменений, произойдет увеличение роли охраны окружающей среды. Оценка толерантности направлений развития муниципалитетов по отношению к климатическим изменениям показала, что направления развития польских муниципалитетов более чувствительны к последствиям изменения климата вследствие большой возможной площади затопления и больших экономических затрат на

предотвращение затопления. Обсуждаются изменения антропогенного влияния на Вислинский залив в результате изменения климата. В настоящее время Вислинский залив испытывает высокую нагрузку, и в дальнейшем, с развитием экономики, ожидается увеличение нагрузки, что потребует принятия комплекса мер по мониторингу климатических изменений и адаптации к ним, объединения усилий всех муниципалитетов вокруг Вислинского залива.

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1 Introduction

Most part of the Vistula Lagoon coastal area is a low-lying ground, so it is highly vulnerable to sea level rise and to other potential impacts of climatic change. Vistula Lagoon is a trans-border water area (Domnin and Chubarenko, 2008). Part of the lagoon belongs to the Republic of Poland, and other part belongs to the Russian Federation. Environmental conditions in the lagoon vicinity, and especially their dynamics due to climatic changes, may have an impact on the economic activities of territorial administrative entities which have a direct access to the lagoon.

This paper provides (a) information on the Russian Federation and the Republic of Poland territorial-administrative entities, which border the lagoon, (b) gives both a review of strategies for their development and an analysis of the stated strategic objectives stability in relation to expected climatic changes and (c) discusses the issue of changing of the human pressure to the lagoon in connection with the economic development strategies implementation at the background of climatic changes.

2 General characteristics of the Vistula Lagoon

The lagoon has an elongated shape; it is stretched along the coast (Fig. 1) and is connected to the sea by Baltiysk Strait, where the navigational fairway passes (with 12-14 m depth). The total water surface area of the lagoon is 815 km^2 (Chubarenko, 2008). Most part of the lagoon (north-eastern part, 495 km^2) is located within the Kaliningrad Oblast and the rest part (south-western part, 320 km^2) is situated in Poland. The length of the lagoon from north to south is 88 km; from west to east the length is 10 km. The average depth is 2.6 m and the maximum depth is 5.5 m (excluding ship channel). The lagoon shores form slightly concaves. The water area of the largest bay, Primorsk Bay, is bordered by a ship channel dam islands. The region climate is mild, wet with warm winter and cold summer (Tersiev, 1985).

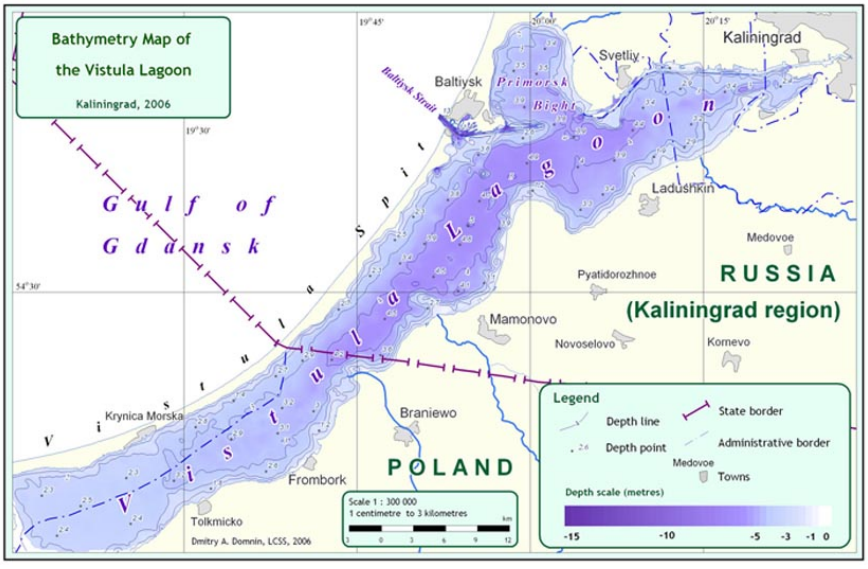

Fig. 1. Map of the Vistula Lagoon (Chubarenko, 2008).

2.1 Hydrological and hydrochemical regimes

Fluctuation of the Baltic Sea level and river runoff influence the formation of the Vistula Lagoon hydrological regime. The main inflow of fresh water is from the Pregolia River (41%) together with small rivers along the perimeter of the lagoon (Tersiev, 1985, Chubarenko, 2008). Mean annual water surface level is just on 5-8 cm higher than mean water level in the Baltic Sea. Sea water actively penetrates into the lagoon, providing an average salinity fluctuation in the range of 3-4.5 psu depending on season (Grinkov, 1975). The lagoon form promotes the development of significant local level fluctuations due to wind surge.

The Vistula Lagoon can be divided into three compartments in accordance with the salinity level: olyhaline (desalinated) area is the south-western Polish part of the lagoon (salinity is up to 2.2 psu), mesohaline area (2-4 psu) covers the most part of Russian territory, and polyhaline (relatively saline) area is the territory siding to the Baltiysk Strait (salinity up to 5.5 psu). The existence of such compartments under different conditions determines the diversity of the forage organisms' species composition and biological productivity of the lagoon.

Hydrological spring in the lagoon starts in April, when water temperature begins to rise rapidly (Tersiev, 1985). The most rapid warming is in the coastal and wellhead areas of rivers. The difference in water temperature between coastal and open areas of the lagoon may reach 4-5 °C. Hydrological summer usually comes in July, with maximum temperatures of 20-26 °C. At the end of September and in October water is cooled down to 8-9 °C.

Oxygenating regime of the lagoon varies depending on water temperature, and on intensity of photosynthesis and wave disturbance (Tersiev, 1985, Chubarenko, 2008). Dissolved oxygen concentration increases in the direction from the Kaliningrad to the Baltiysk Strait. The oxygen concentration in the surface water layers is higher than in the bottom waters. The maximum oxygen concentration is in spring. In summer, especially at night, oxygen deficiency may be observed in the bottom layers and in strongly overgrown shallow waters. It is especially specific in calm weather for the Primorsk Bay and for the north-eastern part of the lagoon.

2.2 Biological characteristics

One of the Vistula Lagoon biological characteristics is that it is not rich in quantitative and species composition of phyto- and zooplankton (Grinkov, 1975). Bream, pike perch and eel are the main commercial fishes. The other species, which take significant place in fishery, are roach, perch, burbot, pike and white bream. At certain times Baltic herring, smelt, lamprey, river flounder, salmon and trout come to the lagoon. Chub, European smelt, tench and crucian carp are in small amounts in the lagoon, so they don't have commercial value. The location of the main fish spawning areas is shown in Fig. 2.

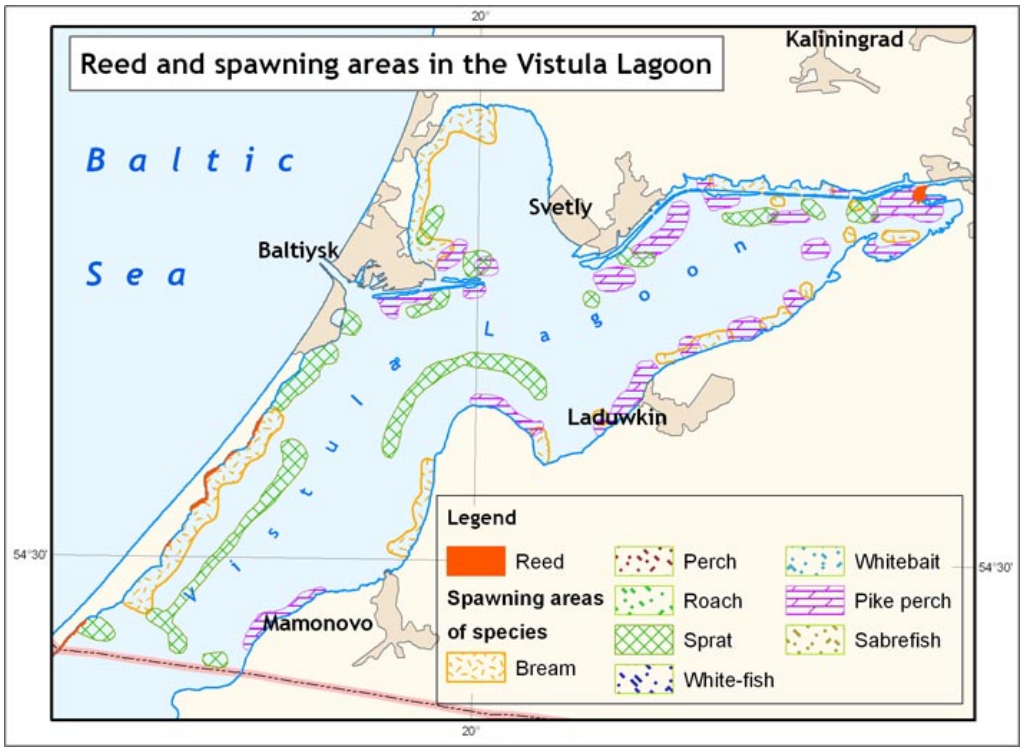

Fig. 2. Reed and spawning areas in the Vistula Lagoon (Russian part of the Lagoon (Osadchiy, 2000).

Water vegetation in the Vistula Lagoon mainly consists of algae and reeds (Grinkov, 1975, Chubarenko and Margonski, 2008). They grow along the Vistula Spit, forming a protective zone 50-150 m wide, and their quantity increases from the Baltiysk Strait to the central and southern areas of the Polish part. Also, their habitats are in the area of the Prohladnaya River mouth, the Primorsk Bay coast and forming a solid band along the Kaliningrad Sea Navigable Canal (from the Pribrezhny village to the Kaliningrad city) (The Scheme of ..., 2004).

Eutrophication is a major problem for the Vistula Lagoon. It is characterized as a highly eutrophic lagoon (The Scheme of ..., 2004; Chubarenko and Margonski, 2008).

2.3 Social and economic characteristics

Population in the Vistula Lagoon coastal areas is uneven (Fig. 3 and 4). 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 the south and west of the Vistula Lagoon are relatively poorly populated. In all these regions the average population density rarely exceeds 20 people per km^2 (State of the Coast ..., 2008).

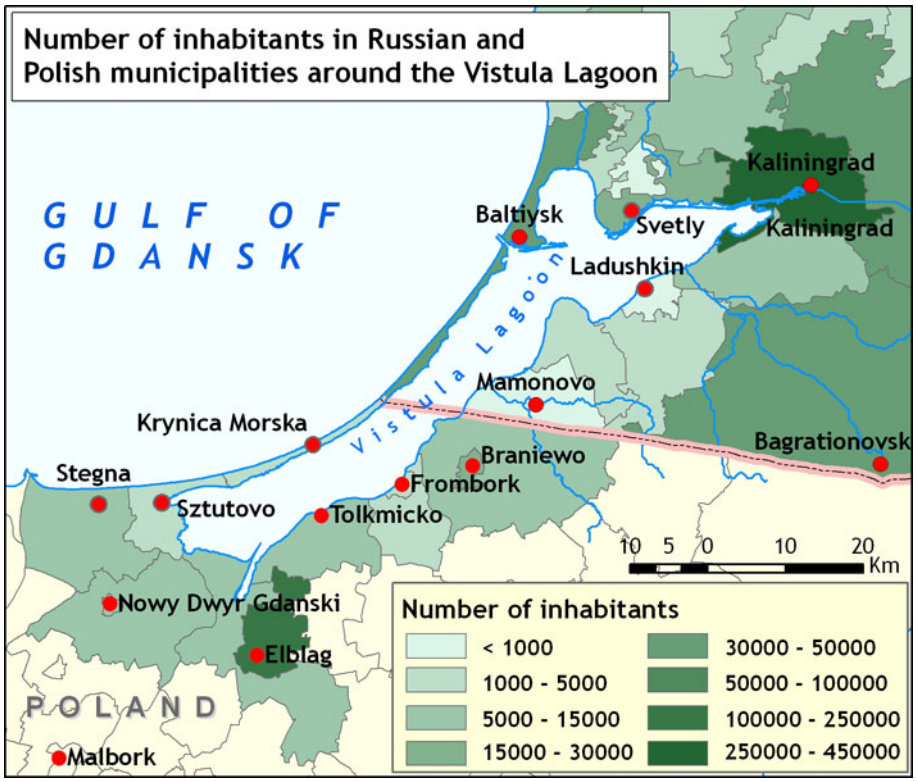

Fig. 3. Number of inhabitants around the Vistula Lagoon. Data taken from "State of the Coast …" (2008). The Polish Varmia-Mazurian Voivodship data was not available in analysis.

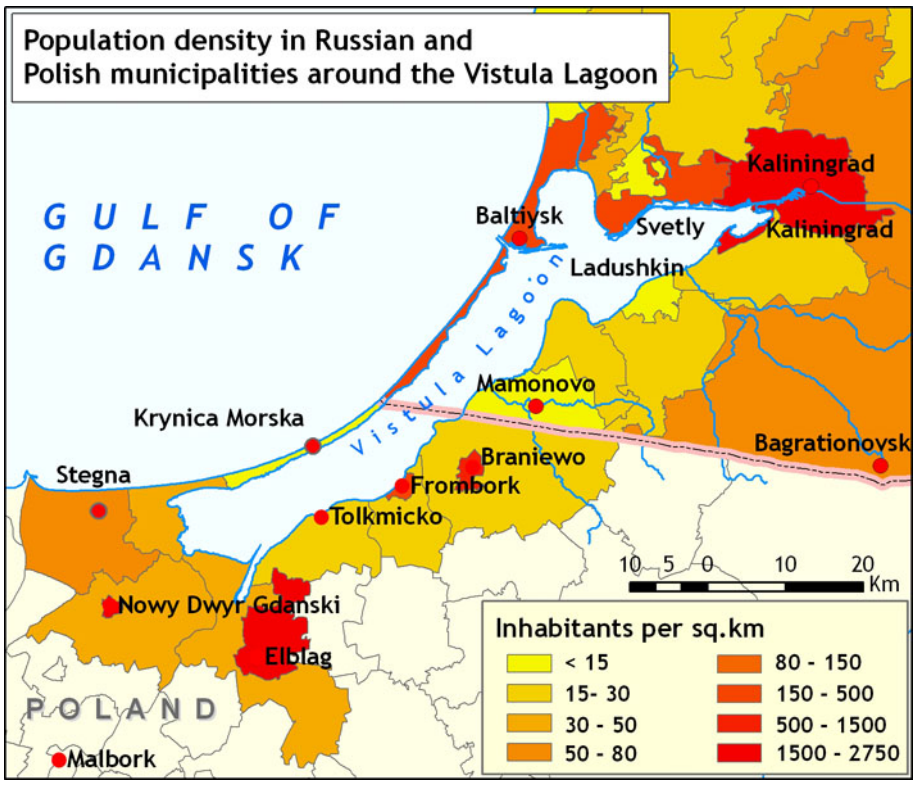

Fig. 5. Population density around the Vistula Lagoon. Data taken from "State of the Coast …" (2008). The Polish Varmia-Mazurian Voivodship data was not available in analysis.

The largest number of employed population is observed in the Kaliningrad and Svetly (up to 70%), whereas in other territory population employment is low, about 20% (Fig. 5)[1].

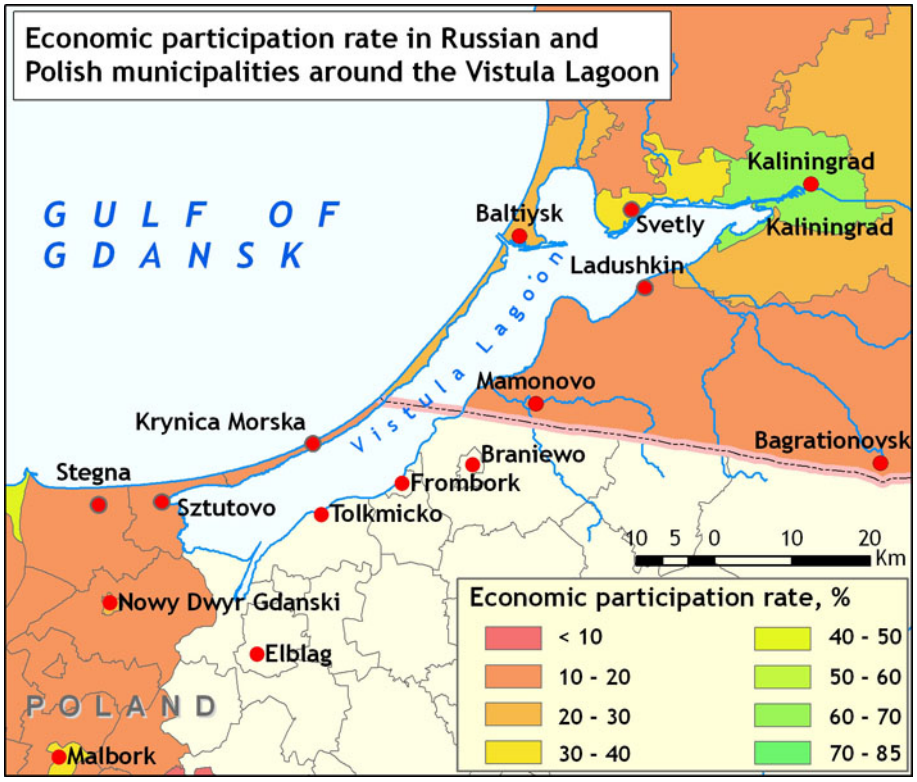

Fig. 5. Economic participation rate around the Vistula Lagoon. Data taken from "State of the Coast …" (2008). The Polish Varmia-Mazurian Voivodship data was not available in analysis.

3 Directions of development for municipalities of the Vistula Lagoon

Baseline information from public sources (www.gov39.ru for the Kaliningrad Oblast, and www.zalew.org.pl for the Polish part of Vistula Lagoon area) was used for municipalities' development strategies analysis.

The administrative-territorial division of Polish and Russian parts of the Vistula Lagoon is different. Polish administrative units bordered to the Vistula Lagoon are finer than Russian ones (Tab. 1, Fig. 6).

Coastal municipalities in their development rely primarily on development of tourism and recreation and port infrastructure while the inner municipalities, which do not have an access to the lagoon area, focus on agriculture and industry development. Mostly, such economic orientation is due to the historical reasons.

[1] The Polish Varmia-Mazurian Voivodship data were not available in analysis.

Tab. 1. Municipalities around the Vistula Lagoon grouped for Russian and Polish parts of the lagoon.

Minicipality	Country	Area, km^2	Number of inhabitants, thousands	Population density, persons/km^2
Kaliningrad city	Russia	223	427	1914,8
Zelenogradsk district	Russia	2016,49	32,5	16,1
Svetly urban district	Russia	80,23	28,7	357,7
Baltiysk urban district	Russia	101,3	36,2	357,4
Gurievsk district	Russia	1363	50,5	37,1
Bagrationovsk district	Russia	1146	33,3	29,1
Mamonovo urban district	Russia	100	7,5	75,0
Ladushkin urban district	Russia	28,2	3,8	134,8
Average in Russian part	Russia	5058,22	619,5	77,44
Elblag	Poland	80	127,055	1588,2
Elblag Gmina	Poland	192,1	6,462	33,6
Tolkmicko Gmina and city	Poland	225,3	6,67	29,6
Braniewo city	Poland	12,4	17,87	1446,2
Frombork gmina and city	Poland	125,8	3,79	30,1
Nowy Dwor Gdanski gmina and city	Poland	213	17,887	84
Krynica Morska	Poland	102	1,371	13,4
Stegna gmina	Poland	169,6	9,52	56,1
Sztutowo gmina	Poland	107,5	3,52	32,7
Average in Polish part	Poland	1227,7	368,21	21,5

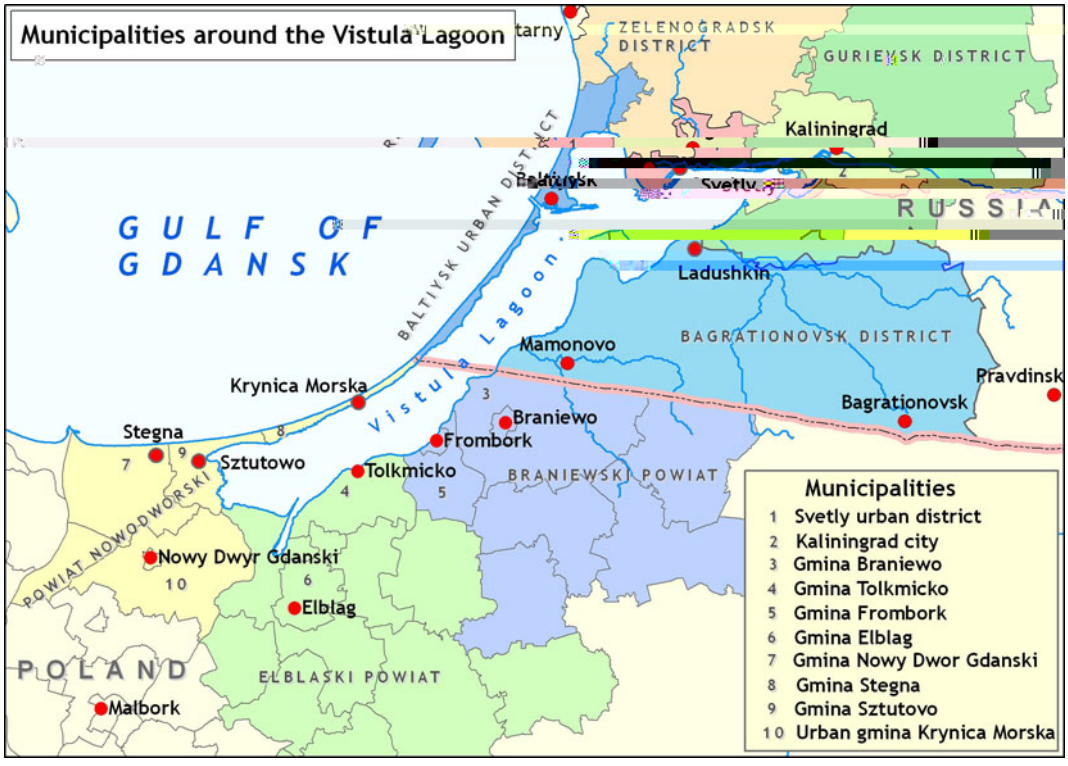

Fig. 6. Municipalities around the Vistula Lagoon.

3.1 Polish part of the Vistula Lagoon

Polish municipalities, located on the Vistula Lagoon coast, are united to Municipal Union of Communes Located at the Vistula Lagoon (www.zalew.org.pl). The Union's main aims are carrying out various public tasks in the field of environmental protection and activating the whole region as far as economics and tourism are concerned. The Union was founded in 1996 and it consists of the following members: towns of Elbląg, Braniewo, Krynica Morska, the join town and gmina[2] administration of Frombork, the join town and gmina administration of Tolkmicko, the join town and gmina administration of Nowy Dwor Gdanski, and, separate from towns, the gmina Elbląg, gmina Sztutowo and gmina Stegna.

Towns and gminas included in the Union developed their economic proposals in priority areas. Basically, all municipalities are keen to develop tourism and recreation and environmental protection, as well as agriculture and food production (Fig.7, Tab. 2).

Fig. 7. Municipalities around the Vistula Lagoon and their strategic priorities (materials from: www.gov39.ru, www.zalew.org.pl)

Braniewo, the town. Braniewo is located not far from the border (6 km) and close to the Vistula Lagoon (10 km). Road and railway are passed through the town connecting

[2] Gmina – Polish official name for small commune

Kaliningrad with Poland. One of the main priority directions is environmental protection and tourism and recreation. There are investment proposals for construction of flats and service objects, sports centers, yacht marina, Integrated Cultural Centre East-West, production plants and objects for trade and services.

Elbląg, gmina. It is located partially on Vistula Zulawy (the lowest point is located 1.8 m below sea level) and Elbląg Upland. Several main roads and railways cross the region of the gmina. The main priority directions are agrotouristic, agriculture and food production, tourism and recreation, as well as environmental protection.

Elbląg, the city. Elbląg is located at the meeting point of Vistula Zulawy and Elbląg Upland, on the river Elbląg. It is an important industrial, administrative and cultural centre. It has a port. Machine industry, brewery, food industry, furniture and textile and leather industry are predominant in the city. It is planned to develop a tourist direction and flat construction. One of the priority directions is environmental protection. There are plans to turn Elblag in port city by building a canal across the Vistula Lagoon and the Vistula Spit to connect Elblag port to the sea waters.

Frombork, gmina and city. Frombork is located at the Vistula Lagoon coast. The climate is agreeable; nature and localization are fairly attractive. It is the place of Nicholas Copernicus work and death (1510 - 1543). The main priority direction is tourism and recreation. Authorities of the town and gmina administration provides for accomplishment: terrain and objects in the closest vicinity of the harbor suitable for yacht marina, areas around salt spring and localizations for hotels with a view to the Vistula Lagoon.

Sztutowo, gmina. Sztutowo is situated in the Scenery Park "Mierzeja Wislana" (Vistula Spit). The main priority direction is tourism and recreation. To improve the direction development it is necessary to build facilities related to shipping, for provision of tourist services (complex of trade services and catering, leisure and recreation complex), to construct board or recreation, to create a center of equestrian sport, to construct an inn, and camping trailers base for motorized tourists. It is also planned to develop craft and port activities.

Stegna, gmina. Stegna is an important communicational junction of the Vistula Spit connecting roads from Gdansk and Nowy Dwor Gdanski to Krynica Morska and Pyaski. Fertile soil and close waterfront create good chances for agriculture business, fishing, tourism and recreation.

Krynica Morska, the town. Krynica Morska is located on the Vistula Spit, which border the Vistula Lagoon from the Gulf of Gdansk. It is characterized by a unique type of climate with clean air and full of iodine. There are a lot of sandy beaches and sources of warm salt water. Krynica is mainly regarded as famous holiday resort offering 9500 lodgings. Town plans for further development of tourism and recreation.

Nowy Dwor Gdanski gmina and city. Nowy Dwor Gdanski is the city on Vistula Zulawy located on the river Swieta, 23 km away from Elbląg and 40 from Gdansk. It is the centre of big agricultural region Vistula Zulawy. The road to Warsaw passes near the city. Nowy Dwor Gdanski gmina and city aspire to develop agriculture, food

processing and fodder production. The idea of «Small Holland» also seems very attractive. This project is construction of copies of Netherlands cities with reserve and various holdings (livestock, fish, flowers).

Tolkmicko gmina and city. Gmina Tolkmitsko is an attractive touristic area. There are 3 forest reserves: Kadynsky forest, beeches of Elblag Upland and Pyuropushnikovy Yar. The main economic sectors of all gminas are fishing, fruit and vegetable processing industry, production of construction ceramics and tourism and recreation. Increased economic activity and tourism of Polish gminas are consequences of the existing relations with the Kaliningrad Oblast, as well as the possibility of using the Vistula Lagoon water for commercial and passenger shipping. Apart the passenger connection, there is a possibility of rapidly putting into operation a ferry line across the lagoon to Vistula Spit. Attractive areas situated on the lagoon coast favor the development of recreation facilities.

Tab. 2. Direction of municipalities' development of the Polish part of Vistula Lagoon. The selected directions are marked with painted cells.

Administrative unit	Strategic directions of development						
	Food production	Industrial production	Agriculture	Port and ground transport	Fishing industry	Tourism and recreation	Environmental protection
Braniewo town							
Elbląg Gmina							
Elbląg							
Frombork gmina and city							
Sztutowo gmina							
Stegna gmina							
Krynica Morska							
Nowy Dwor Gdanski gmina and city							
Tolkmicko Gmina and city							
Total number of directions (popularity)	4	1	4	2	2	9	7

3.2 Russian part of the Vistula Lagoon

The Vistula Lagoon municipalities in the Kaliningrad Oblast are Baltiysk, Zelenogradsk, Gurievsk, Bagrationovsk metropolitan regions (or municipal districts), the urban district "the City of Kaliningrad," as well as Mamonovo, Ladushkin and Svetly urban districts. (Tab.1, above).

Analysis of social and economic development strategies for municipalities around the Vistula Lagoon in the Kaliningrad Oblast for the period to 2016 (Karmanov et al., 2010) showed that strategic directions of varying degrees of priority are:

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

Each municipality selects the strategic development direction depending on its economic and geographical situation and social conditions (Fig. 7, above). Recreation and tourism are the most popular directions for strategic developments of the Vistula Lagoon municipalities (7 municipalities). The next most popular directions are industry (6 municipalities) and transport (5 municipalities) (Tab. 3).

Tab. 3 (Karmanov et al., 2010) illustrates directions of development of the Vistula Lagoon municipalities of the Kaliningrad Oblast and the order of its priority: highest priority are marked with symbol «A», the second priority with symbol «B», and similar for «C», «D» and «E». The line "Popularity" indicates the occurrence frequency of the development direction regardless of its priority.

Urban districts «the City of Kaliningrad», Mamonovo and Svetly. They have similar priorities for the development direction and its distributions. The main priority direction is the ‘port and ground transport’, which is reasonable, because Kaliningrad and Svetly are the main port stations in Kaliningrad Oblast, and Mamonovo is a big terminal at the border with Poland. The second priority direction for these cities is ‘industrial production’, and the third direction, with the exception of Svetly urban district, is ‘tourism and recreation’.

Baltiysk metropolitan region. It has the greatest number of development directions – 5. Mainly, since it has a big port, the main priority direction is ‘transport’. The second development direction is ‘tourism and recreation’. This is facilitated by a favorable geographical position, the presence of wide beaches on the sea, by nature and area climate. The third priority development direction of the region is ‘industrial production. The last directions are ‘agriculture’ and ‘environmental protection’.

Ladushkin urban district. It is going to develop as a major tourist and recreational complex and chose this area as its only priority direction. It has (Plan of terrestrial development..., 2008):

- a favorable geographical position (center of local area, proximity to the city of Kaliningrad, the location on transportation routes - railway and road);

- climatic conditions, landscape (the shore of the Vistula Lagoon, forest areas, free territories for flat, civic, and of industrial construction).

Tab. 3. Development directions of municipalities of the Russian part of the Vistula Lagoon according to their priorities (Karmanov et al., 2010).

Administrative unit	Strategic directions of development				
	Industrial production	Agriculture	Port and ground transport	Recreation and tourism	Environmental protection
Kaliningrad urban district	**B**		**A**	**C**	
Ladushkin urban district				**A**	
Mamonovo urban district	**B**		**A**	**C**	
Svetly urban district	**B**		**A**		
Bagrationovsk metropolitan region		**A**		**B**	
Baltiysk metropolitan region	**C**	**D**	**A**	**B**	**E**
Gurievsk metropolitan region	**A**	**C**		**B**	**D**
Zelenogradsk metropolitan region	**C**	**B**	**D**	**A**	
All Russian municipalities of the Vistula Lagoon	**III(1)**	**IV(1)**	**I(4)**	**II(2)**	
Popularity	**6**	**4**	**5**	**7**	**2**

Conventions

A	The first strategic direction
B	The second strategic direction
C	The third strategic direction
D	The fourth strategic direction
E	The fifth strategic direction

I(5)	The main priority development direction.
II(4)	The 2nd priority strategic development direction
III(3)	The 3d priority strategic development direction
IV(1)	The 4th priority strategic development direction
	In brackets – the number of municipalities that consider this direction as the 1st priority strategic development direction.

Bagrationovsk metropolitan region. It has a quite extensive area and more stretched inland, there are no big industrial enterprises, so the main priority direction is 'agriculture' (i.e. a restoration of previous volume, and enlargement). The second priority direction is 'tourism and recreation', it is planned to create a border recreational area.

Gurievsk metropolitan region. It also has an extensive area and is located almost on the ring of Kaliningrad. The area has a small length of coastline. The priority direction here is the 'industrial production'; the second priority direction is 'tourism and recreation', and then 'agriculture' and 'environmental protection'.

Zelenogradsk metropolitan region. It is located on the north of the Vistula Lagoon and has a small wetland way-out to its waters. The main development direction of the area is 'tourism and recreation', as Zelenograd region in the north has a wide way-out to the Baltic Sea (there is not any business activity near the lagoon). The second direction is 'agriculture', the next are 'industrial production' and 'transport'.

Thus, it is clear that absolutely all municipalities, except for the Svetly urban district, have tourism and recreation in their priority development directions. Zelenogradsk and Ladushkin regions have recreation as the main development direction. 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). However, the most popular priority development is 'port and land transport' (Kaliningrad, Mamonovo, Baltiysk region). 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).

4 Assessment of tolerance of Vistula Lagoon municipalities' development strategies to climate changes

4.1 Possible climate changes

Increased risk of flooding and changes in climatic characteristics (temperature, temperature resistance in different seasons, precipitation) will be tangible effects of climate changes for coastal municipalities of the Vistula Lagoon. The air temperature will increase by 1.4 - 5.8°C due to an increase of carbon dioxide concentrations in the atmosphere (Cubasch et al., 2001). According to an overview of climate change simulations (Storch and Omstedt, 2008) for the period of 1990 to 2100, in general, the temperature in the Baltic Sea region will increase, and it will have greater impact on the northern part of the region. According to Meier et al. (2011a) the mean 2 m air temperature changes between 2061-2090 and 1970-1999 for A1B scenario of global emission will be of 2-4°C in winter and 1-3°C in summer.

Combined results from global circulation model (GCM) simulations, the temperature in the Baltic Sea region by the end of the 21st century will increase in winter by 4 - 6 °C, and in summer by 3 - 5 °C (Storch and Omstedt, 2008). A recent study (Meier et al., 2011a) showed that seasonal mean sea surface temperature rise between two thirty years periods (2061-2090 and 1970-1999) for the A1B scenario may be 2.0-2.2 or 2.8-3°C

(December-February), 1.6-2.0 or 2.4-2.8 °C (March-May), 1.4-1.6 or 2.2.-2.4°C (June-August), 1.8-2.0 or 2.4-2.6°C depending on numerical model used. Also the length of the growing season will increase. According to the regional models the growing season in the southern Baltic Sea region will increase by 30 - 90 days to the end of the 21st century (Storch and Omstedt, 2008).

The data on the rainfall increase vary depending on the model, but in general it is expected that in the whole region winters will become wetter and summers will be dryer, especially in the southern Baltic Sea region. River runoff for the whole Baltic region will increase, but for the Baltic Proper it will decrease (Graham, 2004, Meier et al., 2011b). If the calculated sea surface height (SSH) is used as forcing for the Baltic Sea model, the salinity of the Baltic Sea is projected to decrease between 8 to 50% (Storch and Omstedt, 2008).

The area of main possible flooding (at sea level rise by 2 meters) in the Kaliningrad Oblast is occupied a narrow coastal strip from the Primorsk Bay to the village of Pribrezgny, as well as downstream part of the river Primorskaya (Fig. 8). Potentially flooded area on Poland part of the Vistula Lagoon is much greater; almost the whole region of Vistula Zulawy and Nogat River may be flooded.

Fig. 8. Possible area flooding according to the portal Flood maps (http://flood.firetree.net/?ll=54.4652,19.6848&z=8&m=2&t=3)

4.2 Climate change impacts on individual sectors of the economy

4.2.1 Agriculture and food industry

One of the most sensitive sectors to climate change is agriculture and agricultural products processing. The development of agriculture depends on the temperature and moisture. For the Vistula Lagoon warmer summers and longer growing seasons are projected, and therefore the possibility of obtaining higher yields will increase (Bates, et al, 2008).

Vegetation period is the period when average daily temperature exceeds 10 ^{0}C (www.prostoflora.ru). Making an estimation of temperature regime shift based on data obtained from modeling of air temperature field for the Baltic Sea area within the ECOSUPPORT project (2009-2011, http://www.baltex-research.eu/ecosupport), it can be concluded, that the increase of temperature by 4^{0}C to the end of XXI century might lead to prolongation of vegetation period for approximately 1 month – 2 weeks in the spring time and 2 weeks during autumn for the Vistula Lagoon area.

On the other hand, warming and increase of extreme weather events (e.g., the duration of high temperature and drought) may increase the variability of crop yield, and even lower average yield. In particular, increasing the frequency of extreme climatic events in the region during certain stages of culture growth (e.g., heat stress during the flowering period, rainy days on the dates of sowing) with higher intensity rainfall and more prolonged dry periods will likely reduce the yield of summer crops. Also, heavy rainfall, intensive soil moisture and flooding can hinder to receive a large yield (Bates, et al, 2008).

Negative aspects of climate change may interfere with the active development of agriculture in Bagrationovsk, Gurievsk, Zelenogradsk and the Baltiysk regions in the Kaliningrad Oblast, as well as in gminas of Elblag, Stegna, Nowy Dwor Gdanski and Tolkmitsko in Poland. In the case of water level increase municipalities on Polish territory may suffer stronger because total possible flooding of deltas Nogat and Vistula is predicted at an increase of the water level by 2 meters.

One of the ways to overcome the climate-change effects is a selection of more resistant crops for food production, repair, construction and maintenance of drainage canals and dikes.

4.2.2 Port and land transport

Flooding caused by rising water levels and increase of extreme weather events (such as storms and hurricanes) pose a threat to transport networks in some areas. This includes localized streets flooding, flooding of subway systems and damages associated with flooding and landslides for bridges, roads and railways (Bates, et al, 2008). There is a need to recover, to increase the capacity and to observe the storm drain system, which is especially important for the municipalities of the Vistula Lagoon area.

Municipalities that chose port activities as a priority direction should take into account the adverse effects of climate changes, because beach erosion and sediment movement are defining factors in the development of port structures. Rising sea levels and increasing salinity can also influence to the port structures by making the exploitation conditions harder.

4.2.3 Tourism and recreation

Climate change impacts on tourism include on one hand a prolongation of the tourist season in the Vistula Lagoon area but will on the other hand change the water quality conditions.

Evaluation of tourist season prolongation, based on data obtained from modeling of air temperature field for the Baltic Sea area within the ECOSUPPORT project (2009-2011, http://www.baltex-research.eu/ecosupport), showed that in case of increased air temperatures in Vistula Lagoon area by 4 ^{0}C (to the end of XXI century), the period of comfort perception of air and water temperature will become longer – duration of tourist season could b enlarged by approximately 1 month in the spring time and 2 weeks in the autumn. Duration of swimming season related to increased water temperature in the lagoon will become longer for about 1 month as well.

Rising temperatures will cause an increase in eutrophication of the Vistula Lagoon, leading to expansion of algal and reed beds areas along the coast (The scheme of…, 2005). In general, the negative impact on tourism and recreation activities due to change of water quality may not be very large, because this economic sector is very flexible and well-organized. An account of both a municipalities existing capacities and market interest will help to mitigate the negative impact of climate change.

Infrastructure in low-lying coastal areas is vulnerable to sea level rise, floods, hurricanes and other extreme atmospheric events. The number of coastal infrastructure objects at risk is growing rapidly as a result of the growth of coastal cities and the expansion of tourism (Bates, et al, 2008). For example, in Poland, the estimated cost of damage from a possible rise of sea level by 1 m up to 2100 is 30 billion dollars due to the impacts on urban areas, sewerage systems, ports and other infrastructure (Bates, et al, 2008). A number of municipalities around the territory of the Polish part of the Vistula Lagoon are under greater threat of flooding (gminas Stegna, Shtutovo, Nowy Dwor Gdansk, Elblag); it is necessary to observe the state of dams and canals, to build new defenses according the needs.

4.2.4 Fishery

Taking into account total analysis of climate change effects for freshwater aquaculture and fishery made in Bates et al (2008), we may formulate the following issues for the Vistula Lagoon:

- rise of temperature, drop of oxygen content and, possibly, pH drop;

- worsening of quality and further increasing, to a certain extent, of the water volume;

- extreme meteorological elements ;

- water level raising and conflict of interest between fishing and transport functions of the lagoon due to expansion of shipping;

- potential change of biodiversity of the lagoon.

Positive effects include increasing of growth rate and efficacy of food resources use; increasing of growing period duration; range expansion.

The mentioned consequences shall be taken into account by municipal governments aiming to develop fishery (Stegna and Tolkmitsko municipalities).

4.2.5 Industrial production

Climate changes do not directly affect the industrial production apart from danger of under-flooding of working areas (situated on the floodplain) and extreme meteorological events. The exception are an industrial facilities for products susceptible to climate (for example: food industry enterprises) (Bates et al, 2008). Danger of under flooding is not an actual problem for municipalities round the Russian part of the Vistula Lagoon as the facilities are situated on the territory of more than 2 m above sea level. Among municipalities of the Polish part only Elblag (city) has industrial production as a priority. In the case of water level rising by more than 2 m, the danger of flooding of the wide space and part of Elblag city is possible.

4.2.6 Environment protection

Protection of the environment is one of the priority directions for the development in some municipal governments. Strictly speaking, the environment protection itself couldn't be a direction of economic development, and rather should be considered as essential condition for any economic development. Anyhow, this is an important activity, which could be also affected by local climate changes.

Abrasion of the coastlines is the instability factor for existing and long-term development of protected natural territories. In particular it is true for the Russian part of the Vistula Spit that has no conservation status but has the problem of stream-bank erosion especially strong on some segments, and there is a danger for the motor road. Climate change may also cause a gradual change of plant formation that actually is a natural phenomenon but regardless of that natural system conservation measures shall necessarily be taken.

4.3 Discussion on tolerance of the development strategies for the municipalities of the Vistula Lagoon to possible climate changes (qualitative assessment)

Stability analysis of the directions of municipalities development was made by a 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 objects of touristic infrastructure etc.), so it is impossible to make quantitative estimations of possible changes due to climate changes in monetary or % expression.

We made an analysis where each direction for the development was characterized by one of three quality characteristics:

- 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 flooded territories are negligible. Here are Ladushkin, Mamonovo, Bagrationovsk, Gurievsk, Zelenogradsk municipalities (Kaliningrad Oblast) as well as Krynica Morska (Poland).

- 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 area of municipality. This group includes Kaliningrad, Svetlyi, Baltiysk municipalities in Kaliningrad Oblast and Frombork municipality in Poland.

- 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 square of the flooded territories (in case of absence of protection constructions) is very high (50 to 90% of total area). Construction of embankments, bypass canals net, bank strengthening, continuous monitoring and other measures for prevention of the negative effects may obviously increase stability of the directions for the development. This group includes almost all cities and municipalities of the Polish part of the Vistula Lagoon.

Results of stability evaluation of different priority directions for the development with reference to possible climate changes are presented in the Tab. 4. In general, the situation in the Polish part of the Lagoon is more complicated which is mainly caused by bigger danger of under flooding of the southern, Polish part of the lagoon, than northern, Russian part.

Altogether effects of changes of flood or droughts frequency or quantity, 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).

Inclusion of factor of variability of the present-day climate in the structure of water resources management will ease the adaptation to the future climate change. Nevertheless any adaptive measures for the climate changes involve expenditures not only in monetary expression but from the point of view of necessity of potential conflicts between groups with different interests' settlement (Bates, et. al, 2008).

Generally speaking, development strategies of Russian municipalities are tolerant to consequences of climate change – only 3 of 8 strategies are characterized by mean tolerance. Development ideas of Polish municipalities mainly have low tolerance due to big areas of possible flooding and possibly high expenses for prevention of territory

flooding. Only the development trend of Krynica Morska is characterized by high tolerance because possible flooding area is small.

Tab. 4. Tolerance of development directions for the Vistula Lagoon municipalities to climate changes.

Administrative division	Development strategies							
	Industrial production	**Agriculture**	**Food production**	**Seaport and surface transport**	**Fishery**	**Recreation and tourist industry**	**Environmental protection**	**Development strategies in general**
Kaliningrad GO								
Ladushkin GO								
Mamonovo GO								
Svetlyi GO								
Bagrationovsk MR								
Baltiysk MR								
Gurievsk MR								
Zelenogradsk MR								
Branevo, city								
Elblag, municipality								
Elblag, city								
Frombork, municipality and city								
Shtutovo, municipality								
Stegna, municipality								
Krynica Morska, city								
Nowy Dwor Gdanski, city and municipality								
Tolkmicko, city and municipality								

Gradation of tolerance of the municipalities' strategies[3]

[3] evaluations were made for extreme values of water level raising – up to 2 m

5 Evaluation of the pressure on the Vistula Lagoon in the event of climate change

The Vistula Lagoon is a small inland aquatory and any changes of climate and economic activities reflect in the water body ecosystem in a short time. The territories of all municipalities around the Vistula Lagoon are located in a zone where runoff time[4] for all small rivers flowing into the Vistula Lagoon equals approximately 1 day in yearly average conditions (Chubarenko and Domnin, 2011).

Eutrophication is one of the main problems of the Vistula Lagoon. It is defined as high eutrophic water body in "The scheme of…" (2004) and as polytrophic/eutrophic in Chubarenko and Margonski (2008). Once an increase of mean temperature and development of the agricultural activities are expected, further intensification of lagoon eutrophication may take place.

Nowadays, the share of the coastal regions territories intensively used for agricultural industry varies from 0.4 to 5%. In the future, agriculture is planned to be developed in Gyrievsk, Bagrationovsk, Zelenogradsk Baltiysk municipalities in Kaliningrad Oblast (Russia), in Elblag, Stegna, Tolkmicko, Nowy Dwor Gdanski municipalities in Poland. All of them are situated on the lagoon coast. Runoff time is approximately a few hours in spring (Chubarenko and Domnin, 2011), and it favors quick ingress of nutrients in the lagoon water.

The evaluation of the pressure on the Vistula Lagoon directly was not conducted because of absence of reliable figures about the pressure in the hydrographic water basin for the present day and in prospective.

We can refer to the analysis made by HELCOM according to the data of 2006. The charts of nitrogen and phosphor concentrations in the water of the South-East Baltic Sea are shown in Fig. 9. The main source of these substances in the south-east part of the Baltic Sea is the Visla River. Visual representation of pressure of any aspect of human activity on the increase of eutrophication, contamination by hazardous substances and pauperization of biodiversity is shown in the aquatory pressures and effects charts (Fig. 10a). The pressure index represents a sum of all potential effects on the Baltic Sea and integrates all available data relating to the human activity and a sum of all pressures on the ecosystem of the Baltic Sea as well. Potential result of the human intervention is presented in Figure 10b (HELCOM, 2010).

[4] Runoff time is a time needed for water to flow from upper to lower part of the river stream

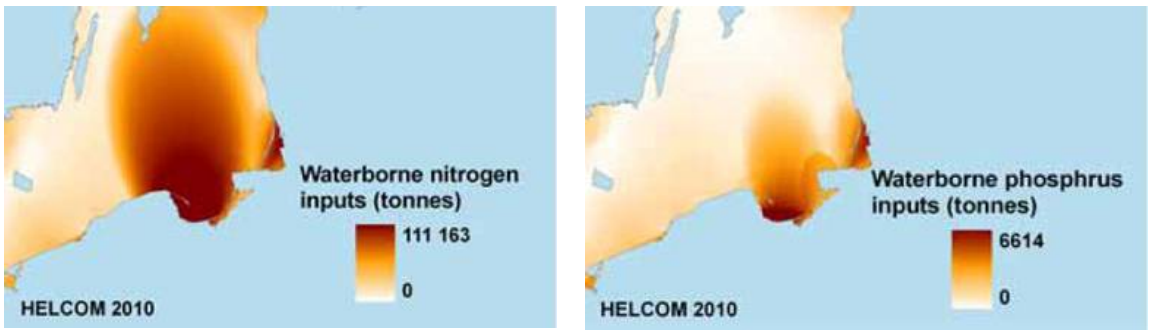

Fig. 9. Average annual waterborne inputs of nitrogen (a) and phosphorus phosphorus (b) from rivers and coastal point sources in 2006. (HELCOM, 2010).

Generally taking into account the HELCOM report (HELCOM, 2010), we may conclude for the Vistula lagoon that rise of temperature, amount of precipitations and development of agricultural industry along with the existing technologies will inevitably lead to the increase of the nutrient pressure to the lagoon.

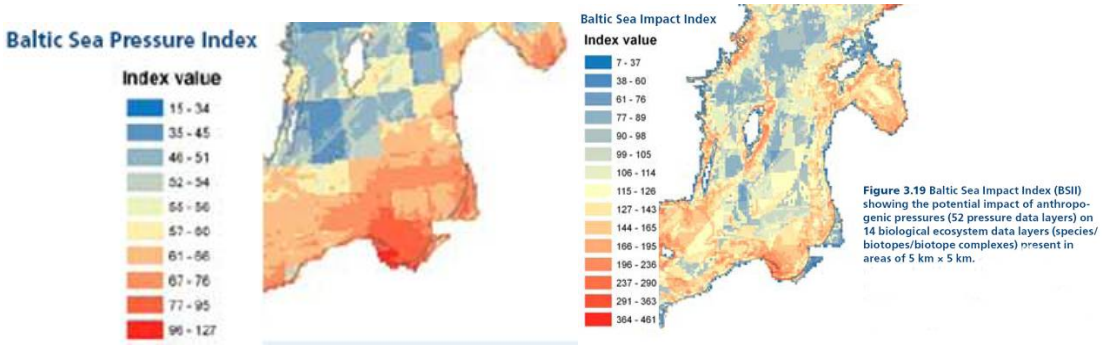

Figure 10. The Baltic Sea pressure index (a) and pressure (impact) index (b). From HELCOM (2010).

The Vistula Lagoon is an aquatory subjected to high pressure so development of any sector not only agricultural industry will increase the pressure on it: shipping, tourist industry, and industrial production. Obviously, due to different economic experience, economic systems and future plans, the pressure will not be equal in Polish and Russian parts of the lagoon. Therefore, trans-boundary issues should be taken into account, as the negative consequences of activity strengthened by the climate changes in one part of the lagoon will inevitably affect the whole water body.

Complex measures on modernization of the coastal infrastructure monitoring of various impacts of extreme meteorological elements, training people, introduction of ecological consciousness in the society and probably complex of economic motivations or directly functioned punitive penalties, as well as strong cooperation between the Polish and Russian municipalities around the Vistula Lagoon are essential. All these measures need big financial expenditures but help both to decrease the potential pressure to the Vistula Lagoon and surrounding area and to avoid the economic losses relating on the climate change and the municipalities development in future.

6 Economical use of the Vistula Lagoon today and in prospect

6.1 Present-day condition

The Polish part of the Vistula Lagoon and surrounding coast are used rather intensively. A lot of ports and small harbors are in operation in the Polish side of the Vistula Lagoon. There are 10 ports and 5 landing stages on the territory, including: seaport in Elblag, port and landing stages in Krynica Morska, Tolkmicko, Frombork and in the townships Piaski, Katy Rybackie as well as and in other territories. Sea border terminals are situated in Elblag and Frombork.

Passenger shipping is executed on routes Elblag- Krynica Morska, Elblag-Ostruda, Frombork- Krynica Morska. Besides the mentioned routes, touristic routes are executed in Katy Rybackie, Piaski and Tolkmico. The passenger traffic of Polish ports and landing stages reaches 71.9-121.1 thousand passengers per year including 14.3-21.2 thousand in Elblag.

The Vistula Lagoon is intensively used for fishery. 380 fishermen united in cooperatives are working on the Polish part.

The lagoon aquatory is open for sailing during 7-8 months. Bases for yachting sport are located in Krynica Morska and Elblag. On winter the frozen lagoon could be used for ice sailing. The polish territory of the Vistula Lagoon basin is very attractive from the touristic point of view, for example 328 hotels, guest homes, camping sites and other hotel facilities are open for the tourists. Many of these facilities have swimming pools, inventory for sailing and bicycling. There is a possibility for horseracing, fishery and hunting in the surrounding forests. It is comfortable to get to Gdansk, Malbork, Ostruda, Kaliningrad from here.

Regarding natural protected territories, there are 2 landscape parks and 9 natural reserves in the Polish part of the Vistula Lagoon:

- “Elblag Highland” Scenery Park,
- “Kadyny Forest” Sanctuary
- "Beech Tree of the Elblag Highlands" Sanctuary
- "Pioropusznikowy Jar" Sanctuary
- " Druzno Lake " Sanctuary
- "Zatoka Elblagka" Sanctuary
- Mierzeja Wislana Scenery Park
- Sanctuary of cormorant
- "Beech Tree of the Mierzei Wislanej" Sanctuary
- "Mewia Lacha" Sanctuary

Thanks to last year’s improvements of waste treatment it has become possible to open many beaches that has been closed for several years (for example Tolkmicka and Kadyny).

The Russian part of the Vistula Lagoon is intensively used as well (Fig. 11) and shipping and fishery are the main types of maritime activities.

The Vistula Lagoon is an important fishery aquatory for the Kaliningrad Region, catching is executed mainly by means of net laying (Osadchy, 2000). Fish catching in the aquatory of the Kaliningrad Region does not exceed allocated quotas and is in general lower than the set level (State of the Coast…, 2008). The commercial species of Vistula Lagoon are the following: Baltic herring, pike perch, bream, roach, eel, perch, sabrefish. Baltic herring is the most productive specie (State of the Coast…, 2008).

The aquaculture is underdeveloped in the lagoon. There is only one trout fishpond in Pribrezhniy settlement near Kaliningrad, "Kaliningrad Center Aquaculture" (Andriashkina et al., 2009).

The Kaliningrad Oblast has one seaport on the Vistula Lagoon named Kaliningrad and including port stations Svetliy, Baltiisk and Vostochniy (State of the Coast…, 2008). The seaport is steadily developing although its capacity is much less than the capacity of the seaports of neighbor states (Kaliningrad, Russia – 15.2 mln.tonns in 2006, Klaipeda, Lithuaia – 23.6 mln.tonns). The passenger transportation in the Kaliningrad seaport is at the stage of formation for the present day. In 2006 the passenger traffic was 12 thousands of passengers that is hundred times less than in the neighbor states (680 thousands of passengers were transported in the Gdansk and Gdynia seaports) (State of the Coast…, 2008). Up until recently the passenger rout Kaliningrad-Frombork has been working, but for the present moment it is still recovering after 3-year break caused by the switch to the new agreement on shipping in the Vistula Lagoon.

Dredging work is conducted in the Kaliningrad Maritime Canal on the Vistula Lagoon that is connected with maintaining and improvement of the transit capacity of the Canal. The discharge of the clean medium sand is executed in the Baltic Sea aquatory, while fine-grained soil with different pollution intensity is used for strengthening of water breaker and inner sites of the protection embankment islands of the Kaliningrad Maritime Canal (Andriashkina et al., 2009).

The point sources located on the coast (Kaliningrad, Svetliy, Baltiisk, Ladushkin, Mamonovo, fish-processing facilities) are discharging the waste waters into Vistula Lagoon. Mechanically cleaned waste waters from Kaliningrad go by bypass open collector to the Primorskaya Bay at the north of the Vistula Lagoon. Furthermore, the waste effluents of cities and facilities are discharged into the Pregolya River also entering the Vistula Lagoon (Andriashkina et al., 2009).

Biogenous effluents from the agricultural sector flow into the lagoon aquatory everywhere through the network of smaller rivers, streams and channels.

The touristic sector in the Russian part of the Vistula Lagoon is undeveloped. For the present day touristic infrastructure has no possibilities to admit small crafts.

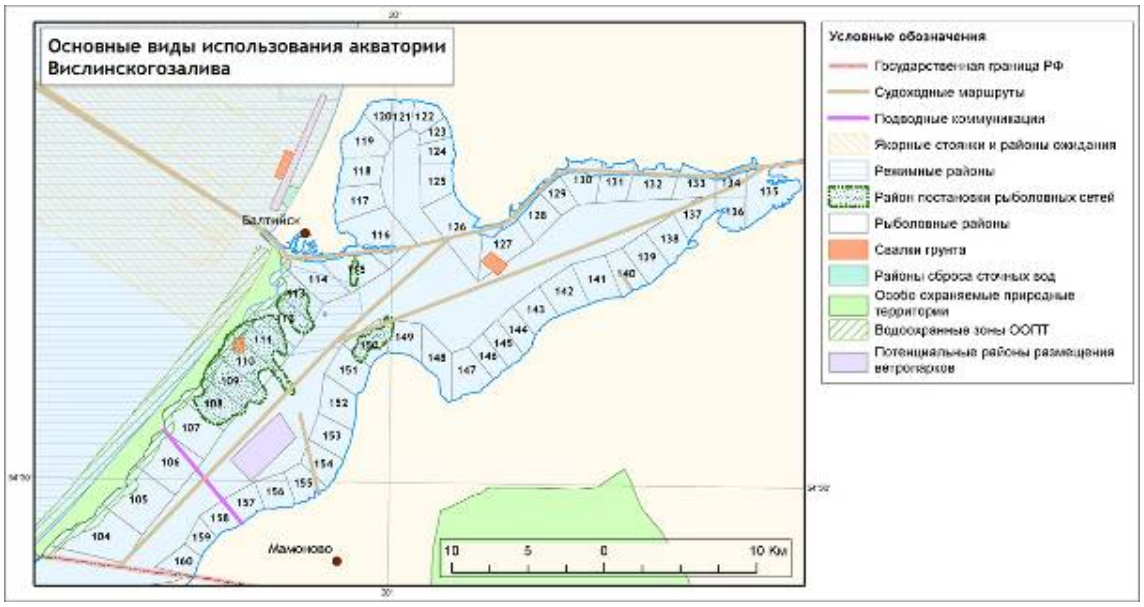

Fig. 11. The main users and environmental conditions of the Vistula Lagoon (Gogoberidze and Domnina, 2010)

6.2 Perspectives of economical use of the lagoon in 10 years

The investment proposals of the Polish municipalities show that active development of the touristic sector, small crafts shipping, ferry traffic between the cities of the Polish part of the Vistula Lagoon will take place. Some municipalities are planning to develop the agricultural and food industry.

The municipalities pay much attention to the environmental protection and propose to extend the list of especially protected natural territories in future.

Strategies of the Russian municipalities are mainly designed for a period until 2016. Most of the Russian municipalities are planning to develop the touristic and recreation sector and small crafts shipping just as their Polish colleagues. The anchorages for small pleasure boats are situated predominantly in the settlements of the lagoon so their modernization and rearrangement are possible (State of the Coast…, 2008). In perspective (on the base of rearranged infrastructure) development of the yacht tourism, kite surfing, ice sailing and sport fishery is possible as well as development of the inland waterways in order to improve communication with Poland. Furthermore there are plans for recovery of shipping inner routs from Poland to Lithuania through the Kaliningrad Region through the aquatory of the Vistula Lagoon and Curonian Lagoon.

Over the last years an increased interest in the fishery sector is observed. Within the context of the national project “Development of Agriculture Complex” construction of a fishery plant is conducted near the Svetlyi city.

Construction of the deepwater port complex admitting crafts with draft rate 15-17 m, including construction of the big transfer container terminal are planned.

7 Conclusion

Changes of climate characteristics and threat of flooding will cause gradually increasing impact on all kinds of economic activities in Vistula lagoon and coastal zone.

Information from open sources (www.gov39.ru and www.zalew.org.pl, respectively) was used for analysis of strategies and development trends of municipalities of Russian and Poland parts of Vistula Lagoon (administrative-territorial division on the Polish side is smaller than on the Russian side).

Coastal municipalities in their development mostly rely on development of tourism, recreation and port infrastructure, but the municipalities, which have no direct access to the water area, opt to development of agriculture and industry.

Analysis of possible stability of strategies of municipal development was performed by a qualitative method of expert evaluation. One of three qualitative characteristics was assigned for each municipality development strategy according to the stability level: high, average and low stability. Stability level was primarily determined on the basis of interconnection of one or another strategy implementation and consequences of climate change (temperature increasing, changing amount of precipitations, increasing of number of extreme weather conditions, growing of groundwater level) and area of possible flooding, or economical expenses for prevention of negative consequences.
Consequences of climate changing will probably show for the municipalities of Vistula Lagoon as increasing of flooding threat, changing of climate characteristics and increasing number of extreme weather conditions.

General circulation models show that the South-East part of Baltic sea will experience the following effects to the end of XXI century: increasing of air temperature, vegetation period will become longer, winter will be more humid and summer dryer (Storch, and Omstedt, 2008). River discharge will be reduced in this area and sea salinity will increase (Meier, 2004). Models of territory flooding (http://flood.firetree.net/) also show, that flooded municipality areas of Polish part of Vistula Lagoon are much more significant, than Russian ones.

The most severe consequences due to climate change are expected for agriculture and tourism and recreation industry, such consequences will be both positive and negative. On one hand., a prolongation of the vegetation period, the tourist and swimming seasons will occur, but on the other hand the following effects are expected: growth of extreme weather conditions, changing of Vistula lagoon water quality due to http://www.multitran.ru/c/m.exe?a=110&t=3915437_2_1&sc=30eutrophication, increased groundwater level and sea level in general which is especially critical for low-lying coastal territories of Vistula Lagoon.

Strategies and development trends of 17 municipalities of Russia (Kaliningrad Oblast) and Poland (Warmińsko-Masurian and Pomeranian Voivodeship) were analyzed in this report. Generally, development strategies of Russian municipalities are more tolerant to consequences of climate change. Strategic directions of economic activities in Poland municipalities are less tolerant in comparison with Russian ones due to large possible flooding areas or high economic expenses for prevention of flooding. Only development strategy of Krynica Morska is characterized by high tolerance because possible flooding area is small.

Inclusion of climate changes in the management structure related to water resources will simplify adaptation to the further climate change. Herein it is necessary to consider that any measures for adaptation to climate changes require economic expenses and settlement of potential conflicts among different economic activities.

8 Acknowledgement

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SMHI

Swedish Meteorological and Hydrological Institute
SE 601 76 NORRKÖPING
Phone +46 11-495 80 00 Telefax +46 11-495 80 01

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