TRANSBOUNDARY WATERS AND BASINS IN THE SOUTH-EAST BALTIC

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This book is a collection of articles, presented information on coastal waters, lagoons and main river basins in the south-east part of the Baltic Sea, related to the Kaliningrad Oblast of the Russian Federation. The book is devoted to wide audience of environmental experts, students and readers interested in water issues.

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Contents

Preface

This book is a collection of articles, which comprehensively presents an information on coastal waters, lagoons, and main river basins of the Kaliningrad Oblast of the Russian Federation. The book is a reflection on rising interest of international water expert community to the Kaliningrad Oblast and to results of international projects implemented by Kaliningrad organizations and their foreign partners in the field of water management.

Water quality in the Baltic Sea and especially in its coastal zone is mostly determined by quality of water in the catchment basin. Waters entering the Baltic from the territory of the Kaliningrad Oblast drain areas of Poland and Lithuania as well. Northern part of the Oblast belongs to watershed of the Neman River, which enters the Baltic in Lithuania. Thus, water resources of the Oblast are fully transboundary, and responsibility on quality of inner and coastal waters is shared between the Kaliningrad Oblast, Lithuania and Poland. Analysis made by (Chubarenko, Alexeev, 2005)* revealed the need in systematic collection of information about transboundary waters of the Kaliningrad Oblast (marine, coastal, inland). It was a starting point for the decision to work on the book, which aim is to show the main characteristics of transboundary river basins and shared inner coastal waters (lagoons) in the south-east part of the Baltic Sea.

An important step in "opening" the information, which before was only accessible in Russian, to international audience was done by short brochure "Kaliningrad Oblast Water Bodies: Environmental Assessment" issued by Kaliningrad experts during the Tacis project ENVRUS 9803 "Water Environmental Monitoring and Management in the Kaliningrad Oblast". The present book continues this tradition and presents an information on waters of the Kaliningrad Oblast more widely and deeply.

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* Chubarenko, B.V., Alexeev, F.E. (2005) Trans-boundary Character of Water Resources in the South-eastern Baltic as the Basis of the Strategy for Sustainable Development of Water Resources. In: *Perspectives of Interregional Cooperation Development: Kaliningrad Oblast within the Euro-region "Baltic"*, pp. 202–223. Kaliningrad.

Chapter 1 of the book presents oceanographic, hydrological and geographic overviews of ecological conditions in the main transboundary water basins and water bodies of the Kaliningrad Oblast of the Russian Federation as well as in the coastal waters of the Baltic Sea. Chapter 2 gives examples of legal and organizational prerequisites for transboundary cooperation. Case studies presented in Chapter 3 introduce some specific important problems for transboundary waters and land territories of the South-East Baltic. Collection of papers for this book started in 2005 from (Kessler P., Kondratenko S., Durkin M.), other papers were submitted during 2005–2007.

Preparation of the book was started within the frame of the Tacis Project "Seagull RC—Russian component of the development strategy for Euroregion Baltic", No. 61.131/90 (2005–2006) and Seagull DevERB INTERREG project (2005–2006, working package 2 "Water resources"). The work was finished with support of the Tacis Project "Sustainable Development Indicators for ICZM in the South-Eastern Baltic (SDI-4-SEB)", 2006/131-758 (2007–2008), and the grant No. 08-05-01023 of the Russian Foundation for Basic Research.

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Chapter 1. General description of transboundary waters and basins shared between the Kaliningrad Oblast (Russian Federation), Lithuania and Poland

Shared watersheds in the South-East Baltic

Boris V. Chubarenko

Introduction

Most of the river basins in the South-East Baltic are transboundary. State borders as well as internal borders between municipalities don't coincide with the boundary lines of the main watersheds. This non-coincidence of natural and administrative spatial division makes a task of water management in the region rather complicated. Moreover, the countries shared catchments have different management experience and legal basis. Lithuania and Poland as members of the European Union are obliged to follow the EU Water Framework Directive, while the Kaliningrad Oblast as a part of the Russian Federation uses the Russian Water Code as a principal law of water usage and protection. In order to approach sustainable water resources management in the region the joint goals are to be set up. The same standards in water usage and the equal procedures of water quality control, water monitoring and management have to be implemented within all shared basins.

The main purpose of this paper it to give an overview of the transboundary basins in the South-East Baltic, with the specific emphasis on the Vistula Lagoon catchment as a main shared basin between the Kaliningrad Oblast (the Russian Federation) and Poland.

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The shared watersheds

The main rivers inflowing the South-East part of the Baltic Sea are transboundary. The Vistula and Neman (or Nemunas) rivers are the second and forth largest rivers in the Baltic catchment, the Pregolya River may be considered as middle or small scale Baltic river. Their average runoffs are of 33.6, 19.9 (Bergstrom & Carlsson, 1994) and 1.53 (Silich, 1971) km^3 a year respectively. The drainage area of the Vistula River is of 193 910 km^2 (Voipio, 1981), and it covers practically the whole territory of Poland, but includes also relatively small parts of Ukraine (6 percent of the Vistula catchment) and Belarus (6.5%) (Evaliuation…, 2005). The upper part or 46 percent of the Neman watershed (the total Neman catchment is of 98 200 km^2 (Voipio, 1981) is in Belarus (Evaliuation…, 2005), the rest is in Lithuania, but lower stream includes Russian territory also, namely, the northern part of the Kaliningrad Oblast. The catchment of the Pregolya River starts in Poland, and, then, covers the main part of the Kaliningrad Oblast, the Russian Federation (Fig. 1).

According to the definition given in the (Convention…, 1992) a term "transboundary waters" means any surface or ground waters, which mark, cross or are located on boundaries between two or more States…" The term "shared river basin" refers to a basin which watershed comprises from several segments, and each of these segments belongs to the different administrative units. In case these segments are parts of different countries, the shared river basin is called an in-

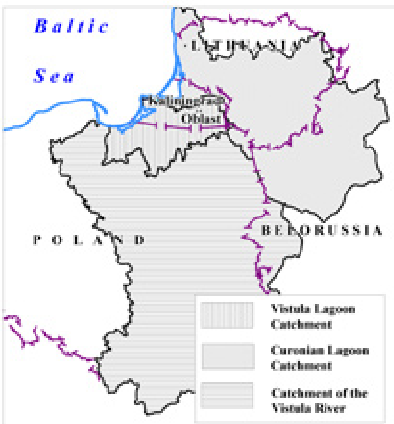

Fig. 1 Main transboundary watersheds in the South-East Baltic (from South to North): the Vistula River catchment, the Vistula Lagoon catchment including the Pregolia River and small rivers, the Curonian Lagoon catchment including the Neman River and small rivers.

ternational or transboundary river basin. As a watershed boundary doesn't coincide with the administrative boundaries very often (within the limits of one country), a river basin might be shared also by different counties, municipalities or communities.

One may introduce two principal types of shared river basins. A ***shared basin of consecutive type*** is that, which upper part is located within the limits of one administrative unite, while a lower part belongs to another one. If a river passes along the boundary between two administrative units, its basin is considered as a ***shared river basin of parallel type***, because each side of the basin (left and right) belongs to different administrative units. Very often a river basin is considered of a mixed type, as it has parts of consecutive and parallel types (Fig. 2).

A river stream segment refers to a *shared watershed of consecutive type* if a river stream directly crosses an administrative boundary (international or internal). In this case, two parts of the river stream segment (situated upstream and downstream of this boundary) have their own sub-catchments and each of these sub-catchemnts belongs to different administrative units divided by this boundary. For the watershed of a consecutive type one may easily define the water flux from upstream catchment to downstream catchment.

A river stream segment is of a *shared watershed of a parallel type* if an administrative boundary (international or internal) passes along the

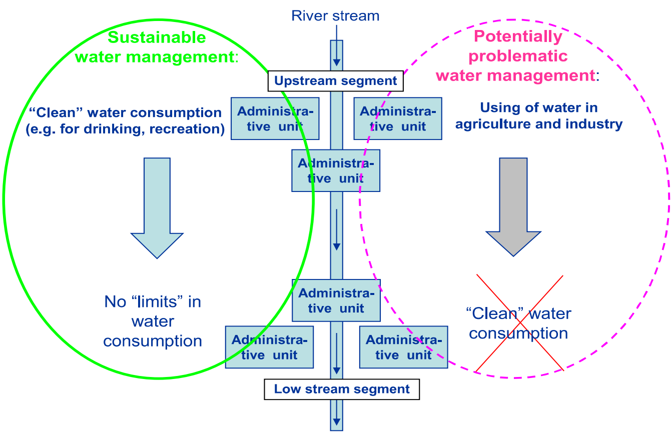

Fig. 2. Two principle schemes of water consumption in a basin. Administrative units form parallel and consecutive structures depending on their position against the main river stream.

stream. In this case, sub-catchments divided by the administrative border are on different sides of a river stream, and there is no flux from one sub-catchment to another. Both of them contribute their runoffs towards one section of the river stream from left and right side respectively.

The above-mentioned water basins of the Vistula River and Pregolya River may be considered of the consecutive type in general. Even in case, these rivers have tributaries of the same order (in a river's structure) which head in different countries, the basins of these tributaries are of the consecutive type, and, respectively, the whole river basin is of the consecutive type. In opposite, the lower part of the Neman River catchment, where Neman passes along the border between Lithuania and the Kaliningrad Oblast (the Russian Federation), could be considered as a typical example of a shared transboundary watershed of a parallel type.

Water management issues concerning shared watersheds

Water quality in the Baltic Sea, especially in its coastal waters, directly depends on economic activity and water usage in its drainage basin. The major part of total nutrient load entering the Baltic today comes from diffusive sources (Veivo, 2004) and especially from agricultural soils, where nutrients were deposited in past (Raateoja & Pitkanen, 2004) and are still accumulating nowadays.

The necessity to coordinate different national approaches complicates a sustainable water management within a transboundary or shared river basin. It becomes more complicated in case countries with different legal systems and economic principles are included within one basin. The Kaliningrad Oblast is in the neighbourhood of the EU countries—Poland and Lithuania, where the Water Framework Directive is a main legislation act concerning a surface, ground and coastal waters. In the Russian Federation, the National Water Code plays the same role. These two basic documents are in agreement with each other in general, but have some important differences (*see* papers of Kessler et al., and Alexeev in present book). Therefore, there is a need to harmonize approaches recommended in both documents in the everyday practice.

Water use in different parts of a transboundary basin has to be mutually connected. An upper part influences a lower one in terms of water quality. For example, an intensive agriculture at the upper part of a river basin definitely leads to eutrophication problems at a downstream part of this basin. A low quality of water, unattractive image and low transparency of waters, intensive growth of vegetation along a river bank are the factors causing a limitation in usage of water for drinking and recreation in downstream segments of a river.

And, vice versa, an activity at downstream part influences on an upstream one in terms of water quantity, not a water quality. For example, a regulation of a river runoff in downstream segment without taking into account upstream needs might cause problems in upper part of a basin such as lack of water for irrigation and other purposes.

If the river basin is shared, whatever by countries or administrative units of one country, "conflict of interests" in water management is potentially possible. Application of sustainable approach in water management for both administrative units sharing the basin usually means both a limitation in own water consumption and necessity to take into account the neighbour's interests. The general principle is that any activity at the given segment of the river basin influences upstream in terms of water quantity and lower stream in terms of water quality.

The more sustainable management is in case an upstream activity does not reduce the water quality (Fig. 2). For example, an ecological tourism in upstream segments never limits an activity at low segments of the river basin. The worst situation happens in case agriculture is developed at upstream areas, as it strongly limits an economic activity at the lower stream segments because of low quality of water coming from upstream. It's evident, that a potentially problematic situation exists for many of the Baltic Sea river basins, because the very lower stream areas of these basins are densely populated and intended to be used for recreation or tourism, while an agriculture is developed far from the sea at the upstream segments of the catchments.

Transboundary lagoons and river basins of the Kaliningrad Oblast

All the main water systems of the Kaliningrad Oblast are transboundary. These are the coastal waters of the Baltic Sea, the Vistula Lagoon watershed and the Curonian Lagoon watershed.

The Vistula Lagoon is classified as a low salinity non-tidal estuarine lagoon (Chubarenko et al., 2005) and it is a transboundary water body itself (Fig. 3, color inset). Its volume and area equal 2.3 km^3 and 838 km^2 respectively, 64 percent of the lagoon volume (1.472 km^3) and 56.4 percent (472.5 km^2) of the lagoon water area belong to the Kaliningrad Oblast (the Russian Federation), and the rest belongs to Poland (Soloviyev, 1971). Since the Baltiysk Strait, as a single inlet connecting the lagoon with the Baltic Sea, is situated on the Russian territory, the Kaliningrad Oblast is formally responsible for the quality of waters coming into the Baltic Sea from the lagoon.

The watersheds of Vistula and Curonian Lagoons are connected by the Deyma River. Deyma, being an arm of the Pregolya River, outflows from main Pregolya stream at the City of Gvardeysk and connects Pregolya with the Curonian Lagoon. This means an overlapping of the watersheds of the Vistula and Curonian lagoons. Approximately 34 percent of the Pregolya River runoff is turning towards the Curonian Lagoon through Deyma (Silich, 1971). Thus, the watershed of Pregolya River, that is above the City of Gvardeysk, including transboundary watersheds of Lyna-Lava, Angrapa-Wangorapa and Pissa (13 690 km^2 in total), belongs to both the Vistula and Curonian lagoon catchments. This overlapping of watersheds of the two Baltic lagoons isn't usually taken into account (Markova & Nechay, 1960). The total Pregolya River catchment is attributed to the Vistula Lagoon watershed (Silich, 1971), and the only watershed of the Deyma River itself, and the total runoff from Deyma are referred to the Curonian Lagoon (Kucheryavy, 2002).

The northern part of the Kaliningrad Oblast (31.5 percent of its area) belongs to the transboundary water basin of the Curonian Lagoon. The lagoon is a recipient water body for the transboundary Neman River and other small rivers, which watersheds are completely inside the areas of the Kaliningrad Oblast or Lithuania. The Neman River heads in Republic of Belarus, crossing the Lithuania, and then divides the Lithuania and the Kaliningrad Oblast. The state border is passing along the river, and the Kaliningrad Oblast and Lithuanian territory comprise respectively the left and right sides of the catchment for this low segment of the Neman River (Fig. 3, color inset).

The Sheshupe River (*see* paper of Grin & Smirnova in present book), being the main tributary of the Neman in its lower stream part, is also a transboundary river. The runoff of Sheshupe is of 1.12 km^3/yr. The watershed of the Sheshupe is partly of consecutive and partly of parallel types. The Sheshupe heads in Poland, then flows as a border stream, first, between Poland and Lithuania, and, then, between Lithuania and the Kaliningrad Oblast. Finally, it crosses the Oblast and flowing in the Neman River from the Oblast's side.

The southern part of the Neman River delta as well as southern half of the Curonian Lagoon belongs to the Kaliningrad Oblast. All the waters from the transboundary Curonian Lagoon discharge to the Baltic Sea through the Klaipeda Strait on the territory of Lithuania.

The Vistula Lagoon transboundary watershed

The Vistula Lagoon is a typical estuarine non-tidal frozen lagoon (Chubarenko, 2005). Its catchment comprises catchments of the main rivers (Table 1) inflowing the lagoon and small streams between them. The Nogat River was the main stream in the catchment before 1916. Being a branch of the Vistula River it brought of 2200 m^3/sec during spring flood (Vypykh et al., 1971), that was approximately of 20 times more then nowadays spring flood of the Pregolya River. The runoff from the Nogat was practically cut during regulations in 1916, when whole runoff of the Visla was directed towards the Baltic Sea. Since that time, the Pregolya River became the biggest river in the Vistula Lagoon catchment.

The Vistula River runoff was a main source of water and sediment gain for the Vistula Lagoon and even gave a name to the lagoon. After the closing of the Nogat branch at the beginning of the XX century, the new direction of the Vistula Lagoon evolution started. The Vistula Lagoon, which was before as fresh as the Curonian Lagoon, very quickly became a water pool of intermediate salinity (salinity of 3–5 psu). New regimen in a water balance brought dramatic changes to the lagoon ecosystem and sediment balances. The freshwater species were replaced by intermediate salinity ones; sedimentation in the lagoon became less then sediment transport towards the adjacent sea area (Chubarenko & Chubarenko, 2001).

The whole area of the Vistula Lagoon drainage basin equals 23 871 km^2, 60.8 percent of it is in Poland, 38.9 percent is in the Kaliningrad Oblast and 0.3 percent is in Lithuania (Silich, 1971). The basin is formed by the catchments of Pregolya and its tributaries (Instruch, Lyna-Lava, Angrapa-Wangorapa, Pissa, Golubaya) and some other really small rivers (*see* Table 1).

The watershed of the Vistula Lagoon is a transboundary one of consecutive-parallel type (Fig. 4). Both national parts of the lagoon have their own drainage basins. One may indicate only those sub-catchments of national drainage basins, which are entirely within national territories. These sub-catchments form a "parallel" part of the structure of the lagoon drainage basin, as they independently contribute water into the lagoon collecting runoffs from the national territories only (Fig. 4). The area of "parallel" part of the Vistula Lagoon drainage basin equals of 35 percent of its total value, the runoff from it equals of 1.894 km^3/yr or 40.2 percent of the total lagoon runoff. The Nogat, Pasleka, Bauda, Elblag and Szkarpawa rivers comprise a Polish national share in this "parallel" part, which equals of 27.8 percent of the total Vistula Lagoon drainage basin. It supplies of 33.6 percent of the lagoon total runoff. The Primorskaya and Nelma as well as other small streams entering the Vistula Lagoon in the north form the Russian "parallel" part of the drainage basin (7.2 percent of the area and 6.7 percent of the runoff).

In addition, the Russian part of the lagoon watershed contains three transboundary rivers having catchments of "consecutive" type, i.e. the upper parts of their catchments belong to Poland (and Lithuania), while lowstream parts belong to the Kaliningrad Oblast. These are the Pregolya River, the main river of the Vistula Lagoon catchment, which brings of 43.7 percent of the total river runoff to the lagoon, and two small rivers—Prokhladnya and Mamonovka, which totally brings 2.1 percent of the total lagoon river runoff (Silich, 1971).

This "consecutive" part of the Visula Lagoon watershed comprises 65 percent of its total watershed. It heads in Poland (33.2%), and

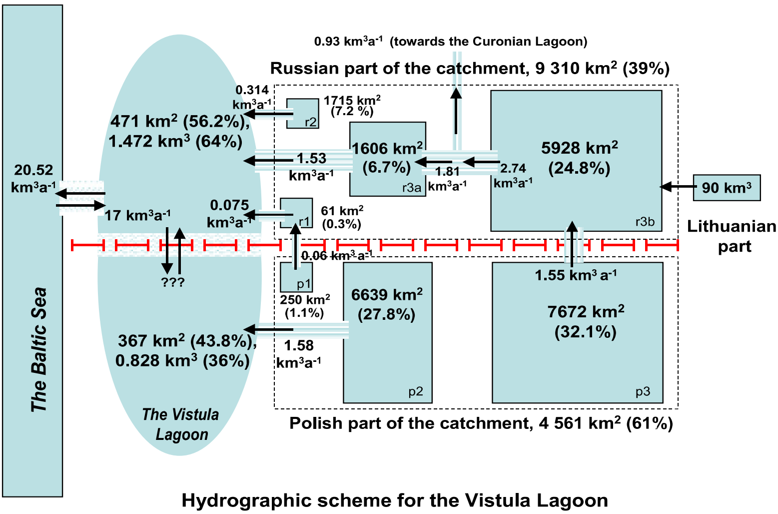

Fig. 4. Principal hydrographic scheme of the Vistula Lagoon catchment. The red line symbolizes the state border which divides Polish (southern) and Kaliningrad (northern) parts of the Vistula Lagoon and its catchment. Each national subcatchment consists of pure national (e.g., p2 and r2) or transboundary watersheds (e.g., p1–r1, p3–r3). The Vistula Lagoon comprises two national parts and has one inlet connecting the lagoon with the Baltic Sea.

the rest (31.8%) belongs to the Kaliningrad Oblast. It consists of two independent parts. The smaller part is formed by the catchments of Prokhladnya and Mamonovka rivers and equals 1.4 percent of the total Vistula Lagoon watershed. The biggest one (63.6 percent of the lagoon watershed) is formed by the transboundary basins of Lyna-Lava and Angrapa-Wangorapa rivers (both are 55.8 percent of the lagoon watershed) and a catchment of the main stream of Pregolya passing across the Kaliningrad Oblast (Fig. 3, color inset). A small part of the lagoon basin (90 km^2 or 0.4%) belongs to the watershed of Vishtynets Lake in Lithuania.

Conclusive remarks

The water resources of the South-East Baltic are essentially transboundary. They are shared by the Kaliningrad Oblast, Lithuania and Poland, which have different legal systems for water issues. This is an obstacle for rapid development of common goals and standards for any given water basin. But, from other side, this is a great challenge and driving force for the international cooperation towards really sustainable development of water resources in the region. As resources are shared, all the stakeholders have to feel a responsibility for sustainable use of these resources. The stakeholders have to remember that they are neighbors within a basin, therefore they depend upon each other.

Only few steps towards harmonization of regulation as well as monitoring programs and other tools supporting decision making process were made (Rassmussen, 1997; ENVRUS, 9803, MANTRA-East, 2004) in the region. More deep efforts of harmonization are to be done, and, first of all, elaboration of the joint river basin management plans for the main transboundary watersheds.

The catchments boundaries don't coincide with national borders as well as internal boundaries between municipalities or other administrative units of the Kaliningrad Oblast, Lithuania and Poland. This mismatching is a basis for scaling of transboundary issues within the countries. National municipalities (as well as countries) have to coordinate their activities in order not to limit their neighbors in water consumption.

The detailed analysis reveals the rather complicated structure of the transboundary Vistula Lagoon watershed (Poland—Russia). The Vistula Lagoon itself is shared by Poland and Russia. The Vistula Lagoon watershed is also shared by these countries, but a small part is in Lithuania. The Vistula Lagoon watershed has two "parallel" national segments, which supply water in the lagoon independently, and the "consecutive" part, upstream segment of which is in Poland but the lowstream one is in the Kaliningrad Oblast. The part of the runoff from this consecutive part never reaches the Vistula Lagoon, as it is flowing towards the Curonian Lagoon through the Deyma River branch directly. The geographical structure of water fluxes in the Vistula Lagoon transboundary watershed is so complicated that their prediction as well as an assessment of natural responses on a human impacts in this water basin are possible only using a numerical model.

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Table 1.

The main rivers of the Vistula Lagoon catchment (Silich, 1971).

River name	Where does it flow into the Lagoon?	Runoff, km^3/yr	Watershed area, km^2
The Pregolya River (transboundary)	Russian part	1.5265	15 500
The Paslenka River (Poland)	Polish part	0.5030	2 329
The Prokhladnaya River (transboundary)	Russian part	0.2717	1 170
The Elblag	Polish part	0.2312	1 488
The Bauda River	Polish part	0.0919	361.1
The Mamonovka River (transboundary)	Russian part	0.0747	311
The Nelma River	Russian part	0.0443	167
The Nogat River and "zhulavy"	Polish part	0.6623	1 336.9
The Shkarpava River	Polish part	0.1010	807.9

Table 2.

The main rivers of the Pregolya River catchment.

River name and where does it flow into the recipient pool? All parametres (runoff, watershed and stream length) are given for this inflowing (MIKE11…, 2002)	Runoff, km^3/yr (Silich, 1971)	Watershed area, km^2 (MIKE11…, 2002)	Length of stream, km (MIKE11…, 2002)
		'Kaliningrad Oblast'+'Poland'='Total'	'Kaliningrad Oblast'+'Poland'='Total'
The Pregolya River itself (from the Chernyakhovsk to the Vistula Lagoon] flows into the Vistula Lagoon, the inflowing is located downstream of Kaliningrad	1.53	7 100+8 400=15 500	123+0=123
The Deyma branch, it flows out the Pregolya River, approximately 45 km upstream the Pregolya mouth, and inflows into the Curonian Lagoon	0.93	313+0=313	37+0=37
Lava (Lyna in Poland) inflows into the Pregolya River 72 km upstream the Pregolya mouth	1.36	1 370+5 750=7 120	65+224=289
The Golubaya River inflows into the Pregolya River 102 km upstream the Pregolya mouth	0.12	564+0=564	59+0=59
The Instruch River inflows into the Pregolya River 123 km upstream the Pregolya mouth	0.26	1 250+0=1 250	101+0=101
The Angrapa River inflows into the Pregolya River 123 km upstream the Pregolya mouth.	0.80	610+1 910=2 520	97+72=169
The Pissa River inflows into the Angrapa River 8 km upstream the point where Angrapa meets Pregolya	0.29	930+240+90 (Lithuania)=1 280	99+5 (Lithuania)=104

Table 3.

National shares of the Vistula Lagoon (VL) and its catchment.

	Russian part		Polish part		Lithuanian part		Total of the VL	
	Abs. value	%	Abs. value	%	Abs. Value	%	Abs. value	%
Vistula Lagoon volume (km^3)	1.472	64	0.828	36	0	0.0	2.3	100
Vistula Lagoon area (km^2)	471	56	367	44	0	0.0	838	100
Area of the VL catchment (km^2)	9 310	38.9	14 561	60.8	90	0.4	23 961	100.0
"Parallel" (independent) part of the VL catchment (km^2)	1 715	7.2	6 639	27.7	0	0.0	8 354	34.9
Consecutively shared part of the VL catchment (km^2):	7 595	31.7	7 922	33.1	90	0.4	15 607	65.1
– the Pregolya River catchment	7 534	31.4	7 672	32.0	90	0.4	15 296	63.8
– the Mamonovka and Prokhladnaya catchments	61	0.3	250	1.0	0	0.0	311	1.3

Table 4.

Shares of the runoff in the transboundary Vistula Lagoon (VL) catchment.

	Russian share		Polish share		Total towards the Curonian Lagoon		Total towards the Vistula Lagoon	
	km3/yr	%	Km3/yr	%	Km3/yr	%	km3/yr	%
Runoff from the VL catchment	1.519	32.3	3.19	67.7	0	0.0	4.709	100.0
Runoff from "parallel" parts of the VL catchment	0.314	6.7	1.58	33.6	0	0.0	1.894	40.2
Runoff from consecutively shared parts of the VL catchment:	1.205	25.6	1.61	34.2	–0.93	–19.7	1.885	40.0
– runoff from the Pregolya River catchment	1.19	25.3	1.55	32.9	–0.93	–19.7	1.81	38.4
– runoff from Mamonovka and Prokhladnaya catchments	0.015	0.3	0.06	1.3	0	0.0	0.075	1.6

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Watershed and administrative division of the Kaliningrad Oblast

Dmitry A. Domnin, Boris V. Chubarenko

Introduction

The Baltic Region includes nine European countries (Sweden, Finland, Russia, Estonia, Latvia, Lithuania, Poland, Germany, Denmark) that are connected not only by the common aquatorium of the Baltic Sea but also the interests in the sphere of economy, social politics and environment.

The geographical location of the Kaliningrad Oblast is such that the region, being the territory of Russia, is located inside the space of the European Union. The existent problems in the sphere of water resources management are similar to those that are in the neighbouring states such as Lithuania and Poland which the Kaliningrad Oblast is connected with not only by the common borders but the common nature-territorial space. The issues of water supply and waste water purification can be considered as the priority directions of cooperation in the ecological sphere. The aspects concerned with the transboundary water systems of rivers and inshore lagoons are of a great importance (Kolosentseva, 2005).

According to the Scheme of Envelopment Protection (2004) the area of the Kaliningrad Oblast is 15 125 km^2, including the south part of the Curonian Lagoon aquatorium of area of 1300 km^2, and the north part of the Vistula Lagoon of area of 472 km^2 that has a name of

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the Kaliningrad Lagoon. Internal administrative-territorial division of the Kaliningrad Oblast (see color inset) includes three towns (Kaliningrad, Pionersky, Sovetsk), three urban districts (Baltiysk, Svetlogorsk and Svetly Urban Districts) and 13 municipalities (Bagrationovsk, Chernyakhovsk, Gurievsk, Gusev Gvardeisk, Krasnoznamensk, Neman, Nesterov, Ozersk, Polessk, Pravdinsk, Slavsk and Zelenogradsk Districts) (Osnovnye pokazateli…, 2006).

The two main river systems of the region are formed by the Pregel River that flows into the Vistula Lagoon and the Neman River belonging to the Curonian Lagoon basin. Besides, within the region there are small river systems belonging to the catchment basins either these lagoons or flowing directly in the Baltic Sea.

The Neman River heads in the Republic of Belarus, where the half of its catchment basin is located. Then it flows across Lithuania, but in its lower stream not a large part of the basin belongs to the territory of the Kaliningrad Oblast. When inflowing the Curonian Lagoon Neman forms the large delta both on the territory of Lithuania and the Kaliningrad Oblast. The Sheshupe River is a large tributary of the Neman River. Its headwaters and the big part of catchment are located on the territory of Lithuania, but the mouth is in the Kaliningrad Oblast.

The Pregel River arises on the territory of the Kaliningrad Oblast by the junction of its two tributaries—Instruch and Angrapa. Apart from Pregel, Instruch and Angrapa themselves, the river basin includes a number of large tributaries, flowing both across the territory of the Kaliningrad Oblast, Poland and Lithuania. The main rivers of Pregel catchment basin are Pregel, Angrapa (Vangorapa is on the territory of Poland), Pissa, Lava (Lyna is on the territory of Poland), Golubaya and Instruch. The river catchment basins in their various combinations belong to the territories of the different administrative units of the Kaliningrad Oblast, the Voivodeships of Poland and the districts of Lithuania.

There are small river basins on the territory of the Kaliningrad Oblast. They are: the basins of small rivers of Vistula Lagoons (Prohladnaya, Mamonovka, Primorskaya, Nelma). The rivers of Deyma (the branch of Pregel), Rybnaya, Dalnaya, Matrosovka, Rzhevka, Nemonin (the braches forming the Neman's delta within the limits of the Russian part) are flowing into the Curonian Lagoon. Svetlogorka, Medveziya, Zabava, Aleyka and Zelenaya are directly falling into the Baltic Sea.

The detailed analysis of spatial correlation between the territories of catchments basins of the main transborder rivers (Angrapa, Lyna, Pissa, Mamonovka, Sheshupe) and the administrative units of the Kaliningrad Oblast was carried out in this article. These relations are illustrated by the schemes of two kinds. For each of the main transborder rivers the administrative units located on the territory of its basin fully or partially are indicated. And vice versa, for every territorial-administrative unit we indicated the parts of the catchment basins forming its territory. Quantitative features (the areas of the basins, municipalities, and its intersected parts, and also the length of the rivers and segments) are presented in tabular form.

Methodology

Determination of the location and the areas of the intersected parts of the territories of the catchment basins and the territorial-administrative units was conducted by dint of GIS software package MapInfo Professional on the basis of source data obtained by means of digitalization the borders of the administrative units and the basins. The data for calculations were read out a raster-type base obtained by means of scanning of the popular paper maps.

The topographic map of open use of scale 1:200 000, of projection Gauss-Kruger—Krasovsky's datum (Naperenkov, 1995) was a basis for the Kaliningrad Oblast. For Lithuania the map of common use of scale 1:400 000, of projection Universal Transfer Mercator—datum WGS 84 (Lietuva. Keliu Zemelapis, 1999) was used. On the territory of Poland it was made use of the map of common use of scale 1:700 000, of projection Universal Transfer Mercator—datum WGS 84 (Polska—mapa samochodowa, 2001). In view of variety of the used materials informativeness of the final numeral basis also has the different scales, correspondently: the Russian part (namely the Kaliningrad Oblast)—1:200 000, the Lithuanian part—1:400 000, the Polish part—1:700 000, and the common projection has been adopted as Gauss-Kruger—Krasovsky's datum.

The coastline, the main streams, the national borders, the borders of the administrative units of the Kaliningrad Oblast, Lithuania and Poland were digitalized by means of a raster-type base, moreover the borders of river basins were marked additionally. All data were read with the accuracy that was on the original raster-type maps. Digitalization of the maps was conducted by hand: the picture of the raster was increasing in 5–10 times in relation to its real size, and the points of marking was fixed exactly inside the raster line.

The original maps didn't contain the borders of river basins, that's why the emphasis on them was conducted on the stage of work with the raster-type base by means of speculative creation of divide line midway between the sources of the neighbouring flows of the adjacent to each other basins. The fault level on such a "hand" construction is about 1/5 out of the mean distance between the sources, so it depends on the scale of the source material. For the map of scale 1:200 000 the average amplitude of variation of the watershed line amounts 0.23 km, on the map of scale 1:400 000—0.5 km, on the map of scale 1:700 000—1 km. These date are the result of visual and metric analysis of every used cartographical source. Thus, the size of the measured on electronic maps areas can vary within limits of ±2–±8 percent depending on the size of the basin.

In the work on calculations and schemes composing the figures about areas of the administrative units and the river catchment basins, received from the electronic maps, were adopted. They are: the total catchment area of the Vistula Lagoon basin is 23.5 thousand km^2—8.7 thousand km^2 is in the Kaliningrad Oblast, 14.7 thousand km^2 is in Poland, and about 100 thousand km^2 is in Lithuania. The catchment area of the Curonian Lagoon is 100 thousand km^2—4.2 thousand km^2 is in the Kaliningrad Oblast, 46.7 thousand km^2 is in Lithuania, 47.2 thousand km^2 is in Belarus, and 1.9 thousand km^2 is in Poland.

For the Kaliningrad Oblast the catchment basin of the Pregel River and other basins of the rivers of the Vistula Lagoons take the most important place. According to the used methodology the basin of Pregel itself amounts 1.7 thousand km^2, the Instruch basin is 1.35 thousand km^2, the Angrapa basin is 2.2 thousand km^2, the basin of Pissa (with the basin of Vishtynets Lake) totals 1.5 thousand km^2, the Golubaya basin amounts 0.54 thousand km^2, and the Lava basin is 7.2 thousand km^2. The catchments of the other rivers of the Lagoon have the following of watershed areas: Prohladnaya River totals 1.3 thousand km^2, Mamonovka is 0.33 thousand km^2, Primorskaya is 100 km^2.

According to the information given in the Table 1, there is a divergence in the sizes of the catchment areas of the basins of the rivers of the Curonian and Vistula Lagoons. The mean divergence between the magnitudes of the areas of the basins amounts about three percent. However, there are data where discrepancy of the magnitudes of the areas in the published sources, and the areas, obtained from the electronic maps, amounts 11 percent (the Angrapa River basin) and 25 percent (the Deyma River basin). The divergences are connected with the error in determination of the basins' borders and the methodology of definition of its areas. There is no possibility to estimate these errors for all papers cited in the tables as their authors haven't

Table 1.

Watershed areas (km²) of the main rivers of the Curonian and Vistula Lagoons.

Name of catchment	Area of catchment (km²)	
	Electronic charts	Other literature
Curonian Lagoon	100 000	100 400 (Hydrometeo Ambient), 100 000 (Maynert)
Vistula Lagoon	23 500	23 869 (Hydrometeo Ambient)
Neman River	99 180	98 200 (Hydrometeo Ambient; Markova; Zotov), 91 800* (Hydrological Yearbook)
Sheshupe River	5770	6120 (Markova)
Deyma River	319	400 (Hydrometeo Ambient)
Pregel River	14 600	15 128 (Hydrometeo Ambient), 14 700 (Hydrological Yearbook), 13 600 (Markova; Zotov; Velikanov)
Lava River	7200	7130 (Markova; Zotov)
Angrapa River	2200	2460** (Hydrological Yearbook), 3960 (Markova; Zotov)
Instruch River	1350	1250 (Markova; Zotov)
Pissa River	1350	1440 (Zotov)
Vishtynets Lake	220	
Golubaya River	540	563 (Zotov)
Prokhladnaya River	1170	1170 (Hidrometeo Ambient; Markova)
Mamonovka River	330	311 (Hidrometeo ambient; Kolosentseva)

* the data about the basin area in the hydrological section line 59 km from the river's offing

** the data about the basin area in the hydrological section line 30 km from the river's offing provided the necessary information. If the calculations of the areas in the framework of the GIS software package MapInfo Professional implemented more careful than with the use of a dot chat (or planimeter that is an instrument for measurement of areas on maps and plans), then the principle of construction of watershed borders midway between two neighbouring water streams which belong to the different basins can make a significant error.

The calculations of the areas of zones of intersection of water basins and dicticts were conducted by means of GIS software package MapInfo Professional. The results are collected in the tables which display the areas of every administrative district in the frame of a separate catchment basin, and the area of the basin within the limits of the district. In the view of existence of some tolerance when definition of areas, the data characterizing little catchment areas within the limits of administrative units shouldn't be taken into account. However, the overall conclusion about belonging of this or that river system to a certain administrative entity should be considered as true.

The results and its discussion

In the GIS software package MapInfo the total map of the basins of the main rivers and the administrative units of the Kaliningrad Oblast and the neighbouring territories of Poland and Lithuania was prepared (see color inset). The map has been created in the form of set of layers, where the national borders between the Kaliningrad Oblast (of Russia), Lithuania and Poland, and the borders of all the territorial units inside the Kaliningrad Oblast (the districts and urban districts) are mapped. The large rivers (Neman, Sheshupe, Pregel, Angrapa, Instruch, Pissa, Golubaya, Prohladnaya, Mamonovka) and the borders of its basins are plotted.

Mismatching of administrative and basin borders is mostly typical for the whole territory of South-East Baltic. Only partially the national borders between the Kaliningrad Oblast (of Russia) and Lithuania are drawn along the little parts of the beds of Sheshupe and Neman. Thus, the border between the Slavsk and Neman districts of the Kaliningrad Oblast and the administrative unit of Silutes (Lithuania) goes along the bed of the downstream of Nemunas. The Krasnoznamensk district of the Kaliningrad Oblast is unique as it is surrounded by the transborder streams from the three sides: in the north along the Nemunas's bed it borders the administrative unit of Jurbarko (Lithuania), in the east along the Sheshupe's bed it has border with Sakui; and in the south-east along the lower stream of the Shervinta River (the left tributary of the Sheshupe River) it borders the administrative unit of Vilkaviskio (Lithuania). The Shervinta River also divides the north-eastern part of the Nesterov district of the Kaliningrad Oblast and the Vilkaviskio district of Lithuania.

Inside the Kaliningrad Oblast there are the reaches of rivers along which the borders between the districts are drawn. There is a border between the Polessk and Slavsk districts, drawing along the Golovkinskiy channel; the part of the border between the Polessk and Gvardeysk districts is drawn along the Deyma River. Between the Zelenogradsk district and the Baltiysk urban district the administrative border is traced along the lower stream the Primorskaya River; the part of the border between the Bagrationovsk and Gurievsk districts is drawn along the Prohladnaya River. There are no any rivers along which the national border between the Kaliningrad Oblast and Poland is traced.

Two kinds of schemes illustrating the belonging of the administrative units to the concrete basins, and vise versa, the combination of the parts of various river basins inside the separate administrative units are created (see below).

Analysis of the schemes shows that all the transboundary—international or internal—river basins belong to not less than two administrative formations, moreover the maximum number of the entities within the limits of the border can reach nine. At the same time any administrative unit of the Kaliningrad Oblast includes from 3 to 7 parts of catchment territories of various ricer basins.

Such a complicated structure in spatial location of the basins and administrative formations creates additional difficulties in water resources management.

Conclusion

The comparative analysis of the issued data about the areas of the river basins which reveals divergence both between the data from the various sources and the new data received by electronic maps is conducted. Divergence in estimation of areas of water basins and other territorial formations depending on difference in the methodologies of calculations arises when changing to a new basis namely electronic maps.

In this research a new set of the data about the quantities of catchment areas for the rivers of the Vistula Lagoon basin is received by meand of GIS. The data obtained due to this new method a little bit differ in the absolute values from the quantities given in the sources but are according to them on the relative rate.

A number of unique schemes illustrating the structure of belonging of the parts of river basins to the various administrative entities of the region, and also sub-division of the basins on the separate parts belonging to the various administrative formations are made up for the Kaliningrad Oblast for the first time.

The structure of correlation of watershed and administrative division in the Kaliningrad Oblast is complicated enough. Any basin (both international and internal) belongs to not less than two administrative formations. The maximum number of the units within the limits of a basin can reach nine, any administrative unit of the Kaliningrad Oblast includes from 3 to 7 parts of catchment territories of the various river basins.

The findings are useful for the municipal administrations and bodies of water management department as it allows to know the neighbours on catchment territories clearly and take this location into account in decision making process on development of water resources management.

Acknowledges

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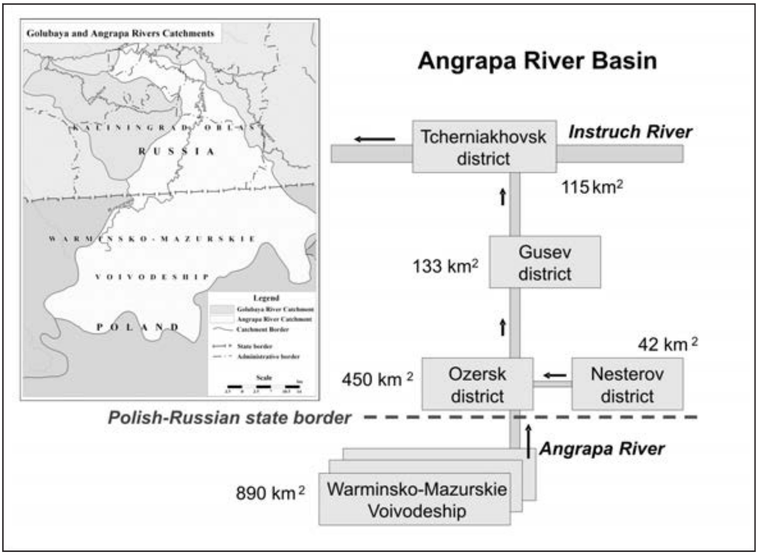
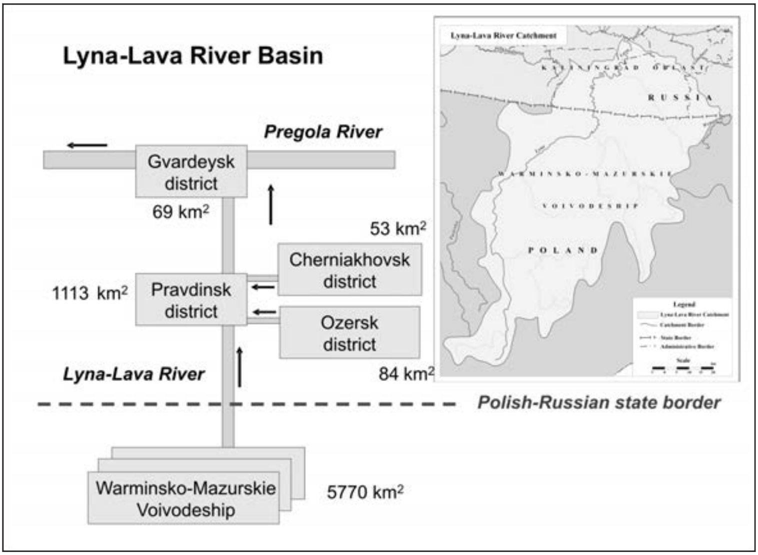
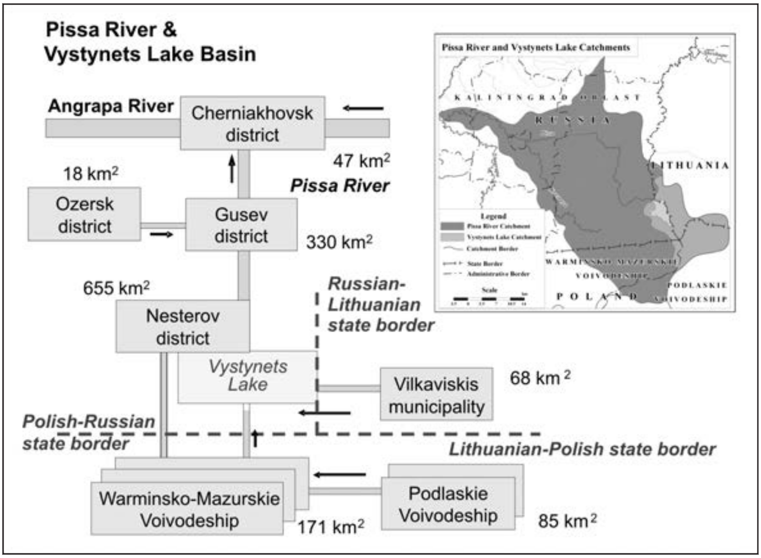
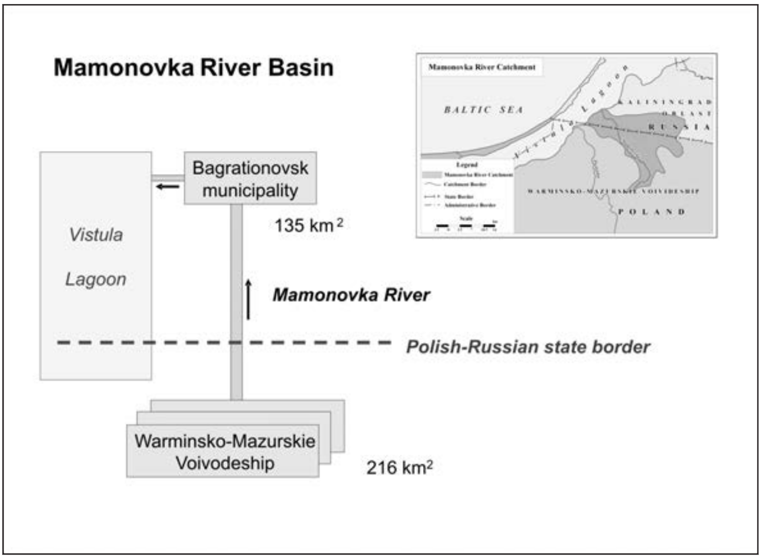
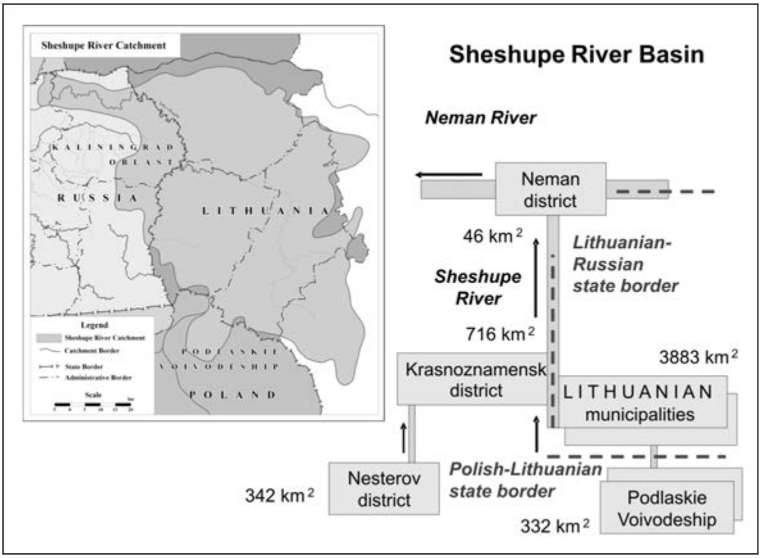

Golubaya and Angrapa Rivers Catchments
KALININGRAD OBLAST
RUSSIA
WARMINSKO-MAZURSKIE
VOIVODESHIP
POLAND
Legend
Angrapa River Basin
Tcherniakhovsk district
Instruch River
115 km²
Gusev district
133 km²
42 km²
450 km²
Ozersk district
Nesterov district
Polish-Russian state border
Angrapa River
890 km²
Warminsko-Mazurskie Voivodeship

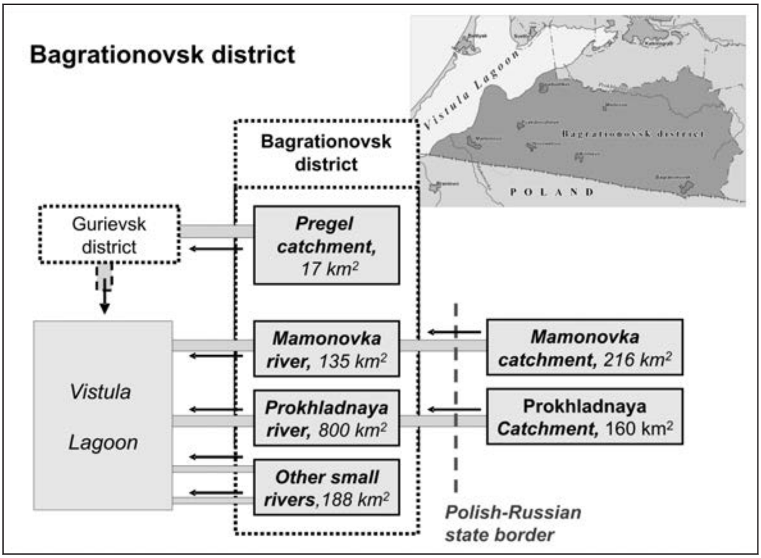

Lyna-Lava River Basin
Lyna-Lava River Catchment
KALININGRAD OBLAST
RUSSIA
WARMINSKO-MAZURSKIE
VOIVODESHIP
POLAND
Legend
Pregola River
Gvardeysk district
69 km²
53 km²
Cherniakhovsk district
1113 km²
Pravdinsk district
Ozersk district
Lyna-Lava River
84 km²
Polish-Russian state border
Warminsko-Mazurskie Voivodeship
5770 km²


Pissa River &
Vystynets Lake Basin
Angrapa River
Cherniakhovsk district
47 km²
Pissa River
18 km²
Ozersk district
Gusev district
330 km²
655 km²
Nesterov district
Russian-Lithuanian state border
Vystynets Lake
Vilkaviskis municipality
68 km²
Polish-Russian state border
Lithuanian-Polish state border
Warminsko-Mazurskie Voivodeship
171 km²
Podlaskie Voivodeship
85 km²
Pissa River and Vystynets Lake Catchments
KALININGRAD OBLAST
RUSSIA
LITHUANIA
WARMINSKO-MAZURSKIE VOIVODESHIP
PODLASKIE VOIVODESHIP
POLAND
Legend
Scale

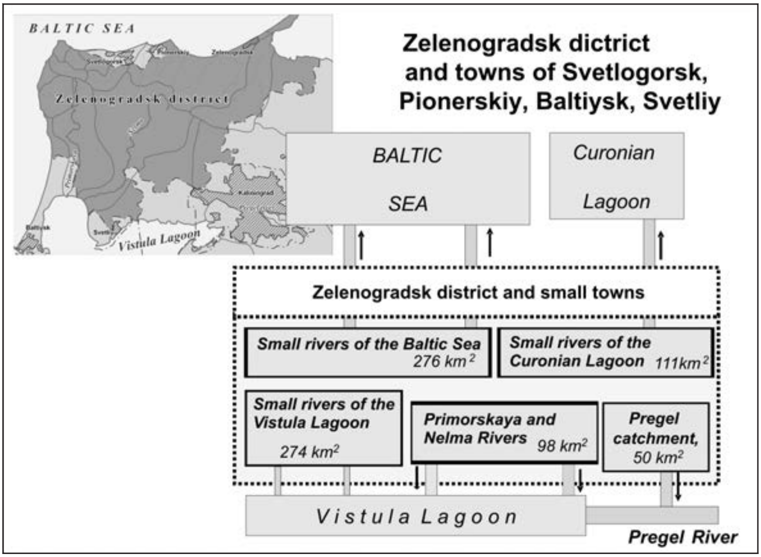

Mamonovka River Basin
Vistula Lagoon
Bagrationovsk municipality
135 km²
Mamonovka River
Polish-Russian state border
Warminsko-Mazurskie Voivodeship
216 km²
Mamonovka River Catchment
BALTIC SEA
Vistula Lagoon
KALININGRAD OBLAST
RUSSIA
WARMINSKO-MAZURSKIE VOIVODESHIP
POLAND
Legend
Scale

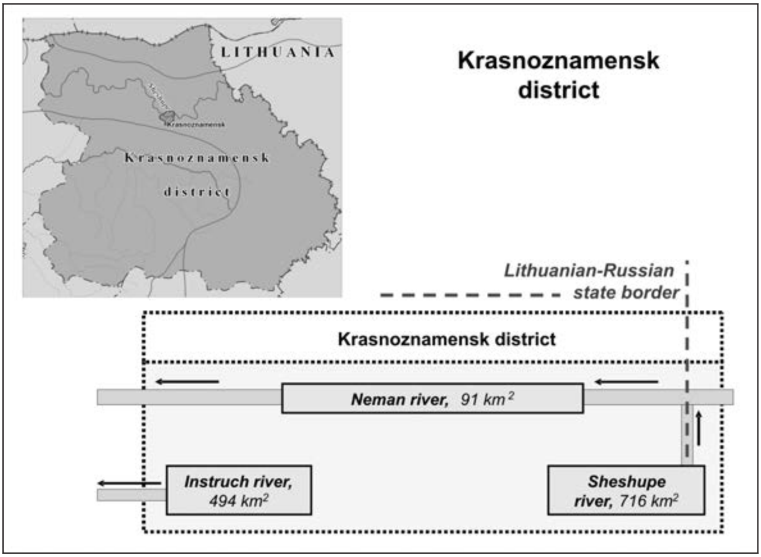


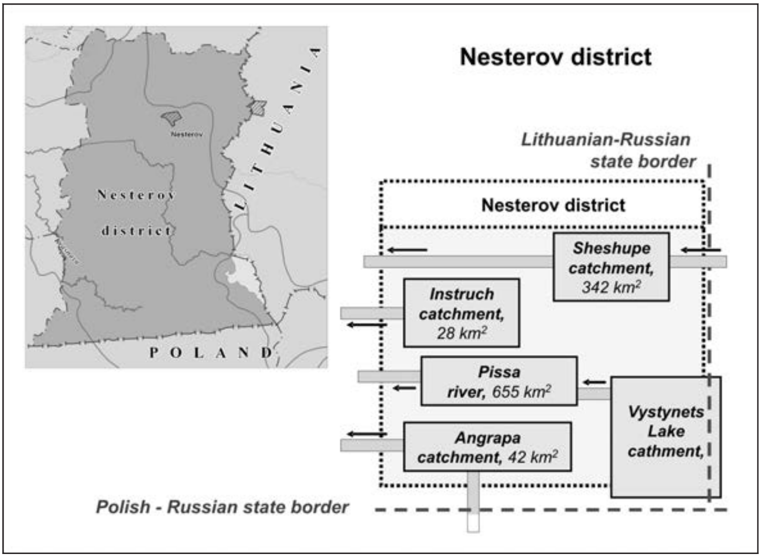
Sheshupe River Catchment
KALININGRAD OBLAST
RUSSIA
LITHUANIA
PODLASKIE VOIVODESHIP
POLAND
Sheshupe River Basin
Neman River
Neman district
46 km2
Sheshupe River
716 km2
Lithuanian-Russian state border
3883 km2
Krasnoznamensk district
LITHUANIAN municipalities
342 km2
Nesterov district
Polish-Lithuanian state border
332 km2
Podlaskie Voivodeship



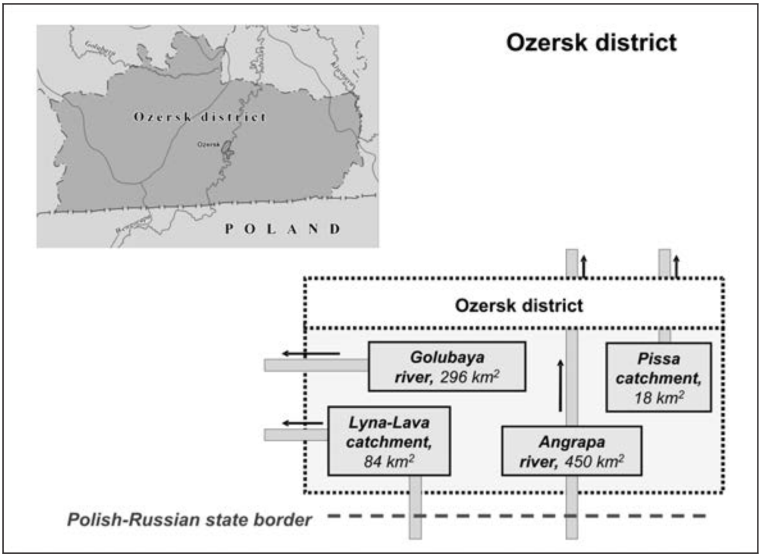
Bagrationovsk district
Vistula Lagoon
Bagrationovsk district
POLAND
Bagrationovsk district
Gurievsk district
Pregel catchment, 17 km2
Vistula Lagoon
Mamonovka river, 135 km2
Mamonovka catchment, 216 km2
Prokhladnaya river, 800 km2
Prokhladnaya Catchment, 160 km2
Other small rivers, 188 km2
Polish-Russian state border


BALTIC SEA
Zelenogradsk district
Vistula Lagoon
Zelenogradsk dictrict
and towns of Svetlogorsk,
Pionerskiy, Baltiysk, Svetliy
BALTIC
SEA
Curonian
Lagoon
Zelenogradsk district and small towns
Small rivers of the Baltic Sea 276 km2
Small rivers of the Curonian Lagoon 111km2
Small rivers of the Vistula Lagoon 274 km2
Primorskaya and Nelma Rivers 98 km2
Pregel catchment, 50 km2
Vistula Lagoon
Pregel River

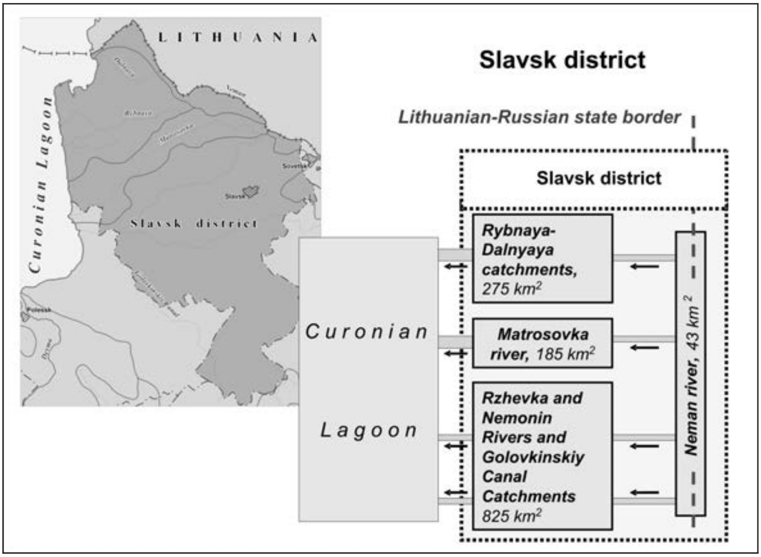

LITHUANIA
Krasnoznamensk
district
Krasnoznamensk
district
Lithuanian-Russian
state border
Krasnoznamensk district
Neman river, 91 km2
Instruch river, 494 km2
Sheshupe river, 716 km2



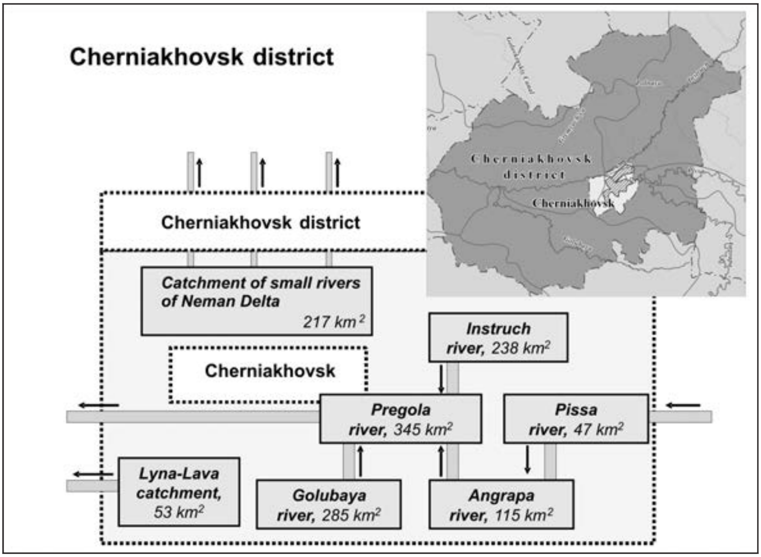
Nesterov district
LITHUANIA
Nesterov
Nesterov district
POLAND
Lithuanian-Russian state border
Nesterov district
Sheshupe catchment, 342 km²
Instruch catchment, 28 km²
Pissa river, 655 km²
Vystynets Lake cathment,
Angrapa catchment, 42 km²
Polish - Russian state border



Ozersk district
Ozersk district
Ozersk
POLAND
Ozersk district
Golubaya river, 296 km²
Pissa catchment, 18 km²
Lyna-Lava catchment, 84 km²
Angrapa river, 450 km²
Polish-Russian state border



LITHUANIA
Curonian Lagoon
Slavsk district
Slavsk district
Lithuanian-Russian state border
Slavsk district
Rybnaya-Dalnyaya catchments, 275 km2
Matrosovka river, 185 km2
Rzhevka and Nemonin Rivers and Golovkinskiy Canal Catchments 825 km2
Curonian Lagoon
Neman river, 43 km2



Cherniakhovsk district
Cherniakhovsk district
Cherniakhovsk
Cherniakhovsk district
Catchment of small rivers of Neman Delta 217 km2
Cherniakhovsk
Instruch river, 238 km2
Pregola river, 345 km2
Pissa river, 47 km2
Lyna-Lava catchment, 53 km2
Golubaya river, 285 km2
Angrapa river, 115 km2

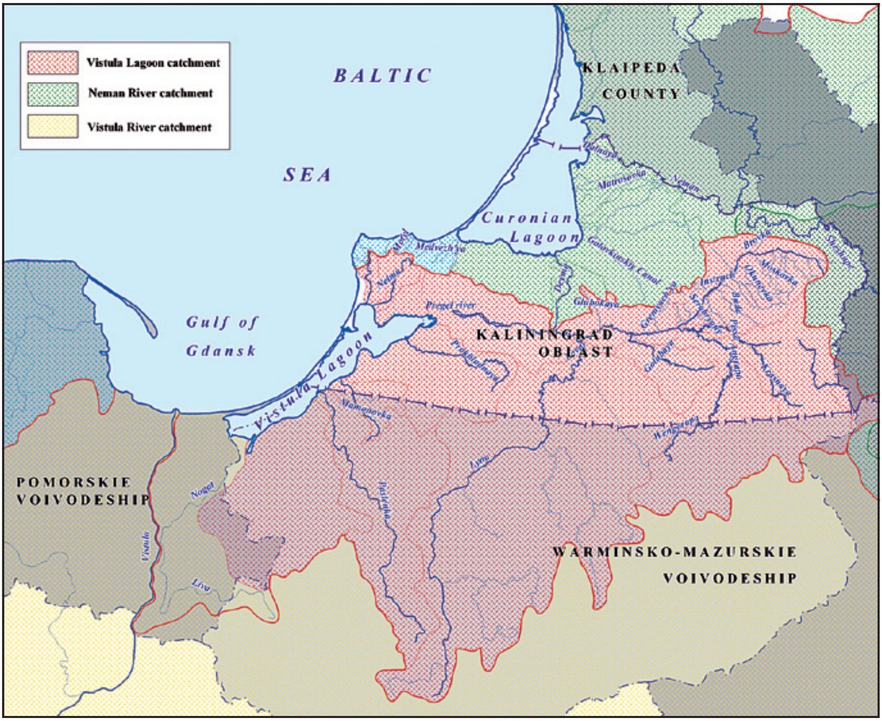
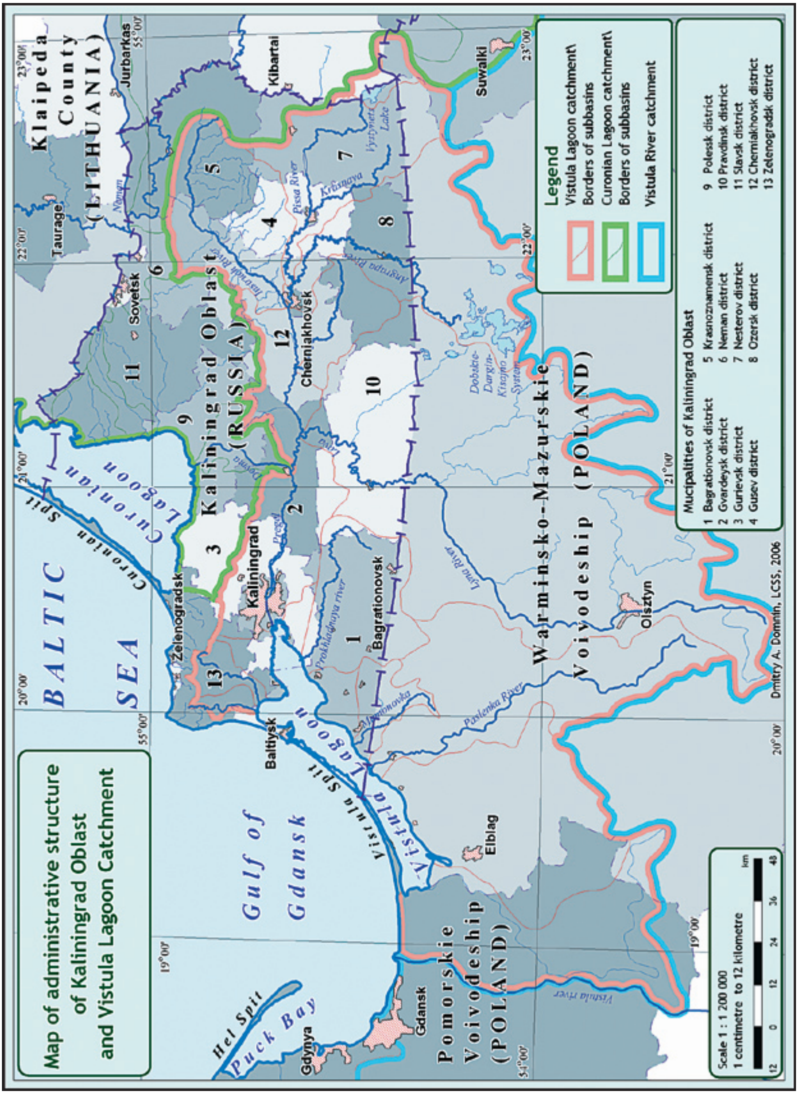
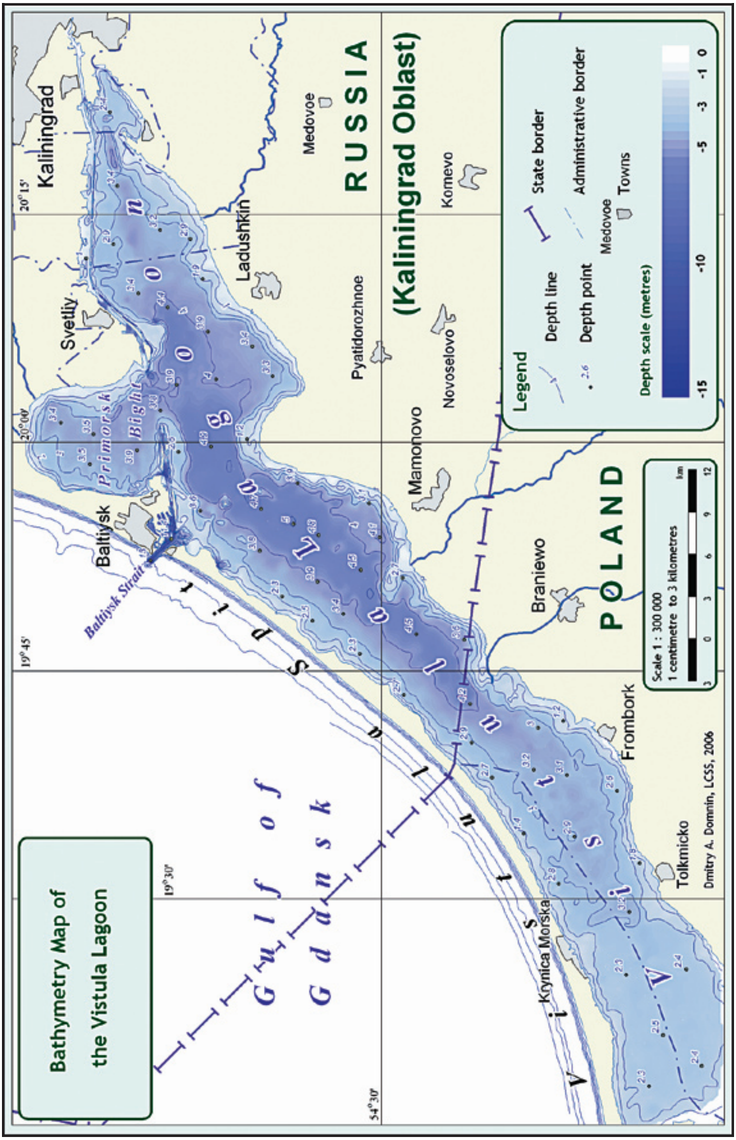


Fig. 3. The Vistula Lagoon catchment and the neighbouring catchments of the Neman and the Vistula rivers. Red bold solid line indicates border of the Vistula Lagoon catchment. Red thin solid lines indicate borders of the sub-catchments of small rivers within Vistula Lagoon catchment. Blue solid bold and thin lines indicate big and small rivers. Brown dash line indicates the national border of the Russian Federation confining the Kaliningrad Oblast.
The map is prepared by D. Domnin (ABIORAS).

Dmitry A. Domnin, Boris V. Chubarenko
Watershed and administrative division of the Kaliningrad Oblast




Bathymetry Map of the Vistula Lagoon
Gulf of Gdansk
Vistula Spit
Vistula Lagoon
Baltiysk Strait
Baltiysk
Primorsk Bight
Kaliningrad
Svetliy
Ladushkin
Medovoe
RUSSIA
(Kaliningrad Oblast)
Kornevo
Pyatidorozhnoe
Novoselovo
Mamonovo
Braniewo
POLAND
Frombork
Tolkmicko
Krynica Morska
19° 30'
19° 45'
20° 00'
20° 15'
54° 30'
Legend
Depth line
2.6 Depth point
State border
Administrative border
Medovoe Towns
Depth scale (metres)
-15 -10 -5 -3 -1 0
Scale 1 : 300 000
1 centimetre to 3 kilometres
3 0 3 6 9 12 km
Dmitry A. Domnin, LCSS, 2006

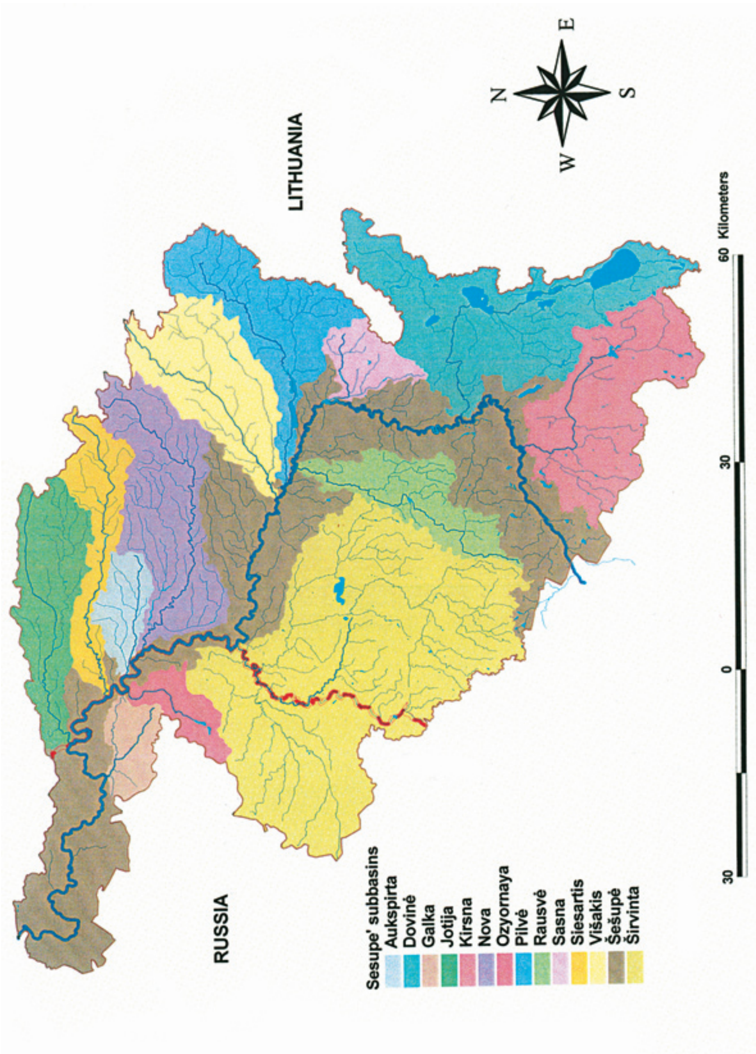


Fig. 1. The Sheshupe basin hydrographic network and sub-basins.

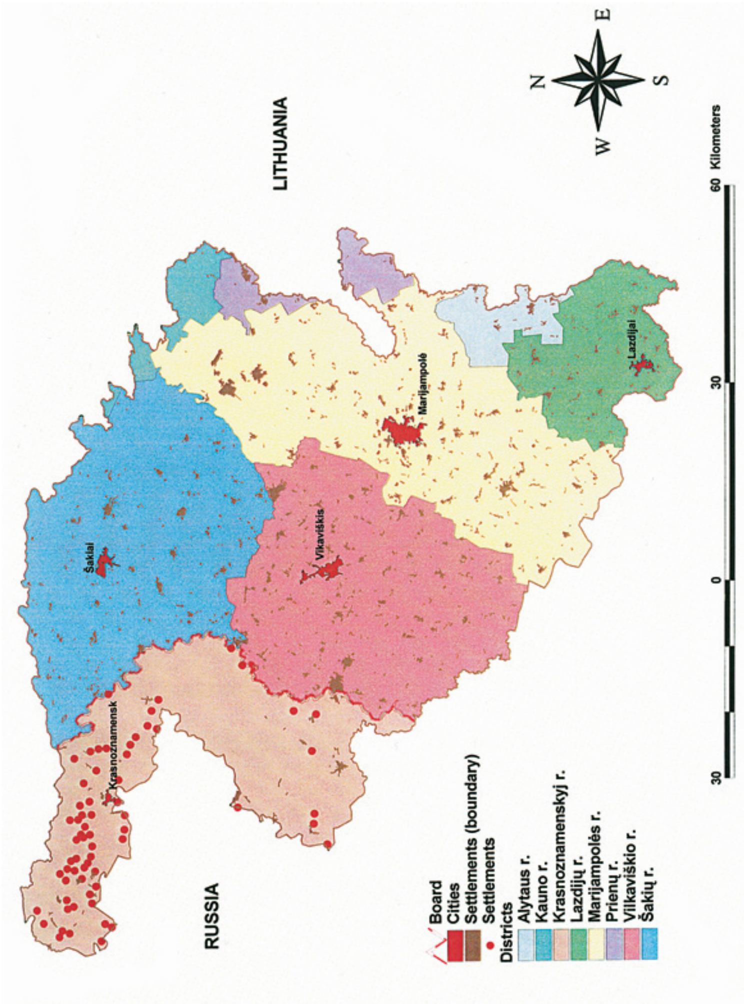


Fig. 2. Administrative map of the Sheshupe basin.

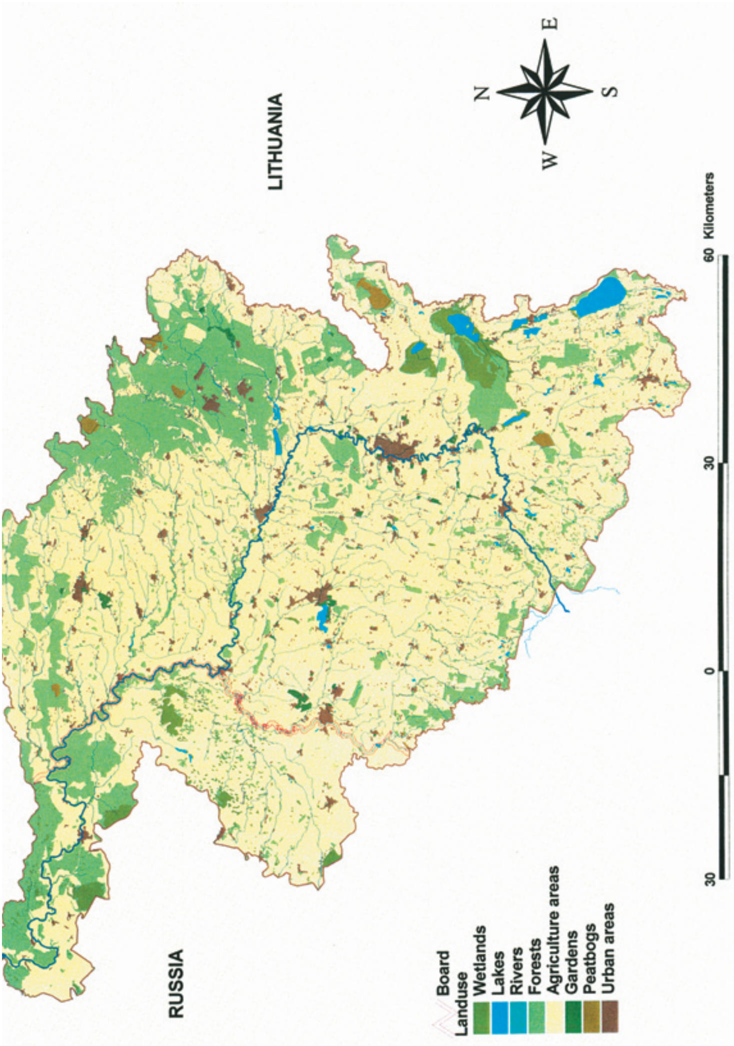


Fig. 3. Land use in the Sheshupe basin.

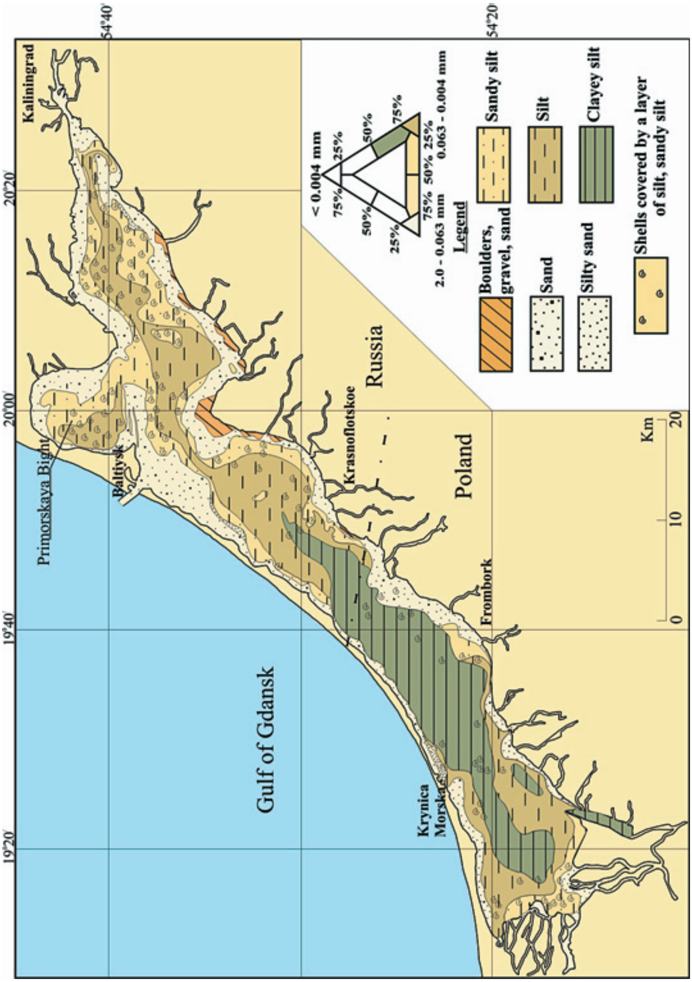


Fig. 1. Joint scheme of distribution of the surface (0–5 cm) sediment types in the Vistula Lagoon in a whole in 1990th developed according to Shepard's classification. Polish part of the lagoon was compiled from (Zachowicz&Uscinowicz, 1995).

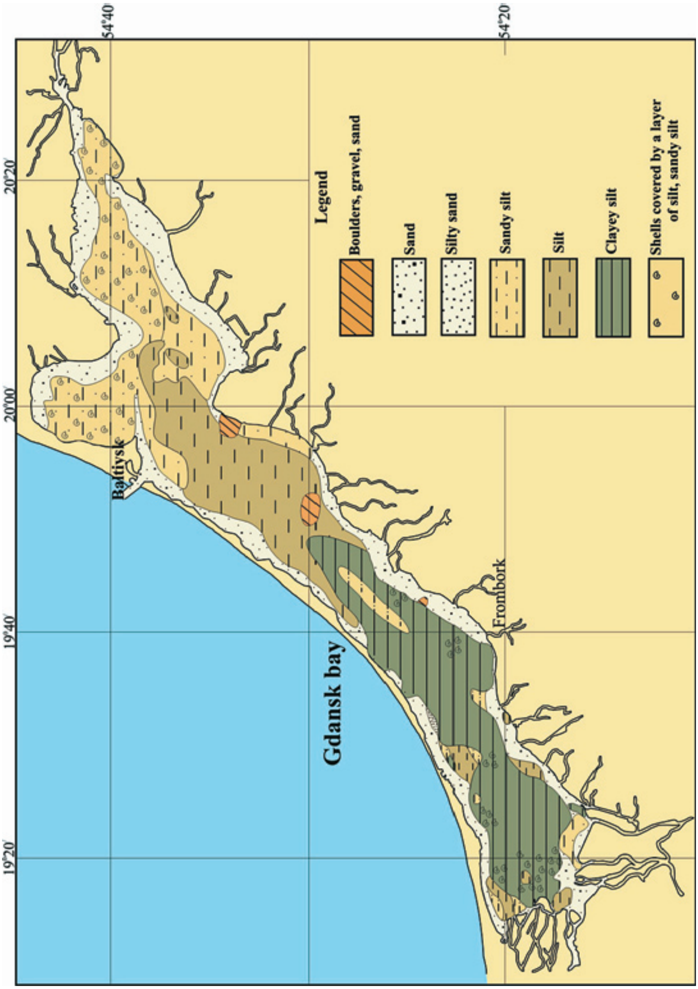


Fig 2. Distribution of the surface (0–5 cm) sediment in the Vistula Lagoon in 1960–1970 (Wypych&Nieczaj, 1975).

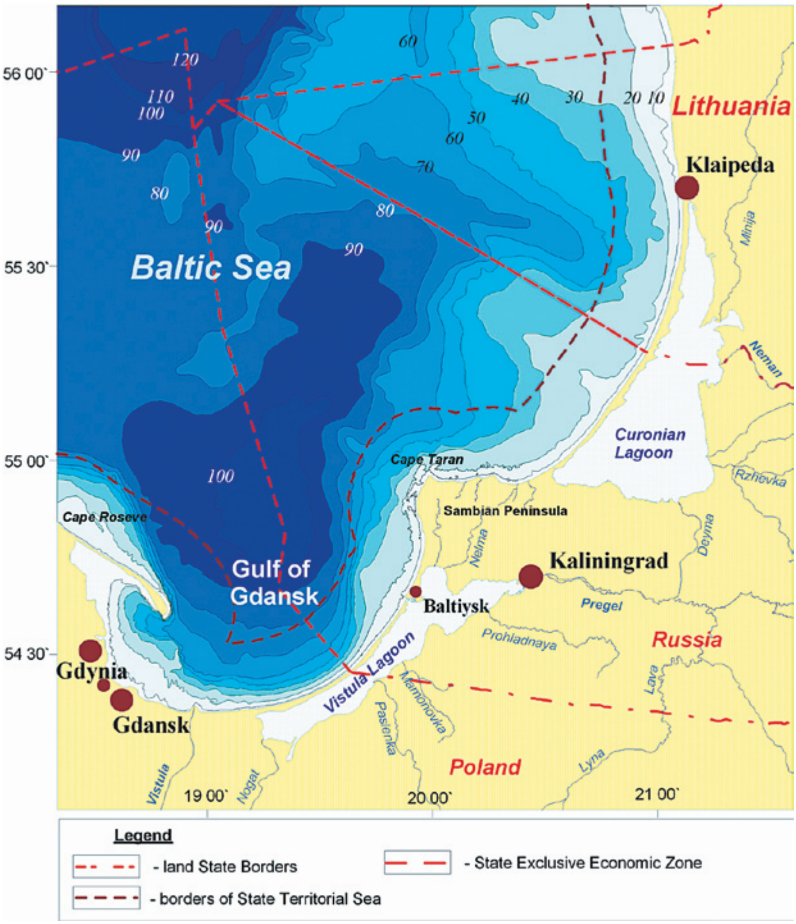


Fig. 1. Transboundary waters of the South-East Baltic.

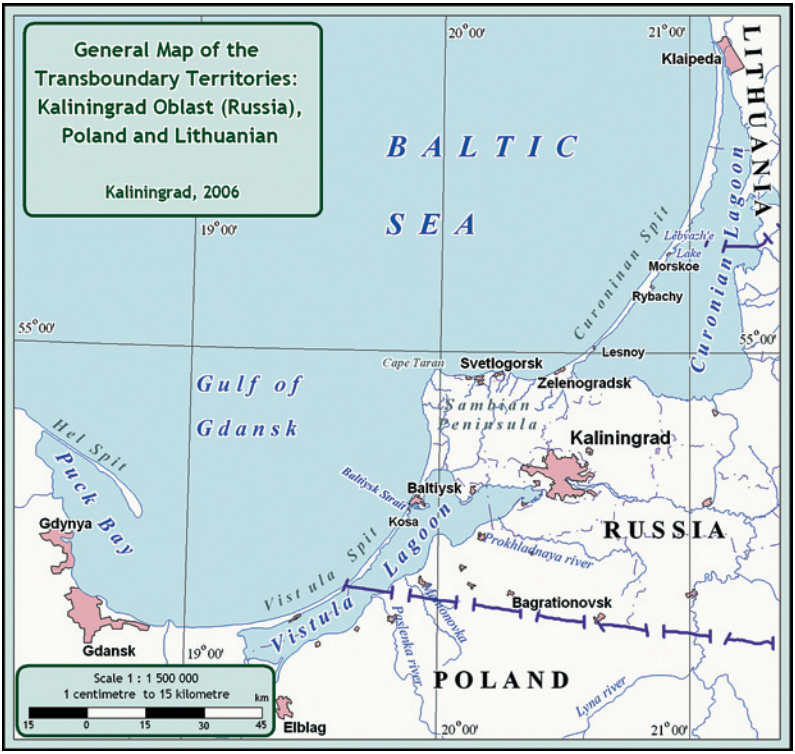


Fig. 1. General map of transboundary territories.

The Vistula Lagoon

Boris V. Chubarenko

Geographical description of the Vistula Lagoon

The Vistula Lagoon (VL) is located on the southern coast of the Baltic Sea (*see* Fig. 1). It is oriented along the Baltic shore and has an elongated shape ca. 91 km in length. The lagoon width varies between 2 and 11 km. The average volume and the water surface area of the lagoon are 2.3 km^3 and 838 km^2 respectively. The average lagoon depth equals 2.7 m, the maximum depth excluding the artificially dredged navigable channel is 5.2 m. The state border between the Kaliningrad Oblast (Russia) and Poland divides the lagoon into two parts which occupy 64 and 36 percent of the water volume and 56.2 and 43.8 percent of the lagoon area respectively. The length of the lagoon coastal line is about 270 km (111 km belong to Poland, and 159 km belong to Russia) (Lasarenko & Maevskiy, 1971).

The Baltiysk Strait being the single lagoon inlet is situated in the Kaliningrad part of the lagoon and has the width of 400 m. Its depth varies in average within 10–12 m along the fairway, and the limited minimal vertical inlet cross-section has an area of ca. 4200 m^2. The navigable channel (the Kaliningrad Marine Canal) connects the Baltiysk Strait and the Pregolya River mouth, passing along the northern lagoon coast. The depth of the canal varies within 9–12 m throughout the length of 35 km. The canal is separated from the proper lagoon by a set of artificial islands with narrow passes between most of them

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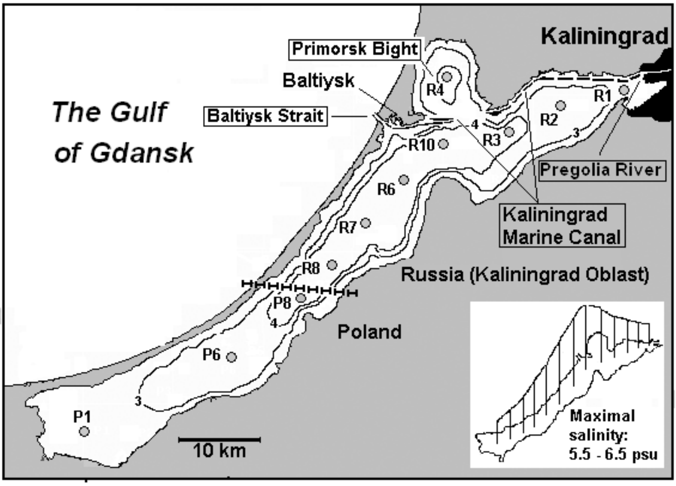

Fig. 1. The Vistula Lagoon. Locations of monitoring stations.

(the width is ca. 20–50 m, and the depth is ca. 1–3 m). The canal has an open segment (ca. 3.5 km long) only when crossing the Primorsk Bight, which is a semi-enclosed bight situated in the northern part of the lagoon. The navigational canal is actually a hydro-technical construction where permanent maintenance dredging occurs, and various small harbours and peers are being developed till now.

The canal was built in 1901 by the Konigsberg trade organizations in order to let big ships fetching into the port of Königsberg (nowadays Kaliningrad). That time the canal was in average ca. 6 m in depth, and dredging work immediately started to make it deeper. Construction of the canal gave rise to economical growth of Königsberg while the economical activity of the port of Pilau (nowadays Baltiysk), which had benefited a lot because of its location exactly at the lagoon inlet, went down. Nowadays there is an opposite situation: the town of Baltiysk (former Pilau) became more popular for cargo-passengers ferry lines and oil bunkering because of intensive deepening of the lagoon entrance and short distance from the Baltic Sea in comparison with Kaliningrad (former Königsberg).

Except the artificial dams bounded navigable canal there is only one island in the lagoon area. It's the covered by trees Nasypnoi Island, which is situated in the deepest central part of the Vistula Lagoon and has the cross width of ca. 50–100 m. There is also a small artificial island built for navigational light in the southern Polish part of lagoon.

The existence of islands makes the lagoon area mathematically doubly-connected domain.

The Vistula Lagoon is separated from the Baltic Sea by a stable sandy barrier which is cut by the lagoon inlet into the long southern part and short northern part. The southern one is called the Vistula Spit, and northern segment is sometimes called the Baltiysk Spit as its area belongs to the town of Baltiysk. The covered by forests Vistula Spit is about 55 km in length; the width of the spit varies from 0.5 to 2 km. The Vistula Spit is divided by the state border between Poland and Russia into two parts (approximately 55 and 45 percent of the spit length respectively). The Polish part being a popular recreation area is intensively developed; there are many hotels and other tourist facilities there. The Russian part was a military area during last 50 years. Unfortunately it lost the massive of open dunes because of reforest activity, but in general, pure nature conditions are conserved here. It is expected that this part of the spit will get a status of national park in 2007 and form a natural marine fringe of the Kaliningrad Oblast together with the Curonian Spit. The Baltiysk northern segment of the spit (11 km) detaches the Primorsk Bight from the Baltic Sea. This spit is ca. 1 km in width and mostly covered by forest. The town of Baltiysk occupies the widest part of the spit adjacent to the lagoon inlet. The harbour of Baltiysk is situated along the part of the Kaliningrad Marine Canal just near the lagoon inlet.

The rooted vegetation is very poor developed in the lagoon area. It occurs only at several places along the Vistula Spit and the northern coast of the eastern half of the navigable canal, at lateral shallow areas of 100–500 m in width and not more than 1 m in depth (Rassmussen, 1997).

The widest polder areas with low altitude are situated in the southern part of the lagoon, where the former delta of the Vistula River, which gave the lagoon a name, was situated. They are protected by the artificial dams.

Hydrographic characteristics of the Vistula Lagoon

The Vistula Lagoon was historically formed as an estuary of the Vistula River, which total average runoff today is more than 30 $km^3 a^{-1}$ (Andrulewicz & Witek, 2002). In former time the Vistula River discharged ca. 8–9 $km^3 a^{-1}$ to the Vistula Lagoon through the Nogat branch. That time the total river runoff falling into the lagoon was of 11–12 $km^3 a^{-1}$. In 1916 the most part of the Vistula River runoff was directed to the

Baltic Sea through the main Vistula River branch, and the discharge of the River Nogat dropped down more then 10 times and became 0.7 $km^3 a^{-1}$ in average. Since that time hydrological and sedimentation regimen of the Vistula Lagoon had changed dramatically and evolved from the completely freshwater plain estuary into the estuarine lagoon with significant influence from the Baltic Sea. The salinity changed from practically zero level to 3.5 psu in average.

The present-day hydrology of the Vistula Lagoon is controlled by marine water inflow (+17 $km^3 a^{-1}$) and freshwater gain (Lasarenko & Maevskiy, 1971). The last one consists of the river runoff (+3.68 $km^3 a^{-1}$), precipitation (+0.5 $km^3 a^{-1}$), evaporation (–0.65 $km^3 a^{-1}$) and ground runoff (+0.07 $km^3 a^{-1}$). The annual variations of the negative and positive components of water balance are characterized by the one minimum and the one maximum and controlled by seasonal variations (Fig. 2). The maximum is in total water gain and the less is in winter, while their minima is in summer months when weather conditions are calm and intensity of water exchange with the Baltic is low.

The marine water inflow is caused by water level variation at the adjacent Baltic Sea area (±10–20 cm in average) and local wind surges (±30–50 cm in average). The semi-diurnal tidal variations (±1 cm) have insignificant influence (Szymkiewicz, 1992).

The Vistula Lagoon drainage area equals to 23.871 km^2. Nowadays the Pregolya River is the largest river in the lagoon catchment. It falls

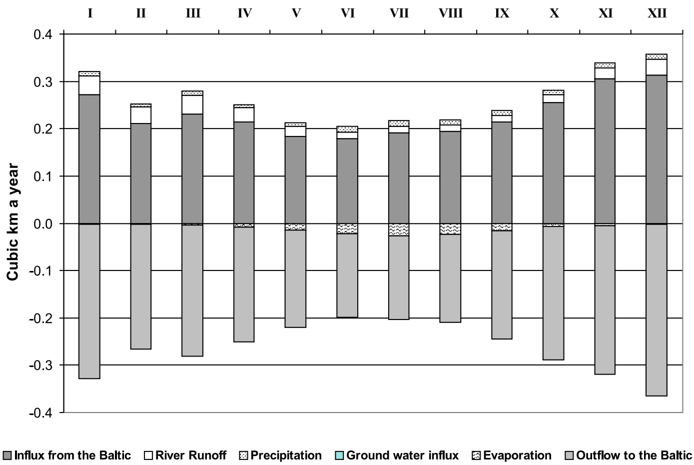

Fig. 2. Annual variations of positive and negative components of the water budget of the Vistula Lagoon (Lasarenko & Maevskiy, 1971)

into the northeastern corner of the lagoon, crossing the biggest city in the catchment, the City of Kaliningrad (former Königsberg). The Pregolya River drainage basin equals to 15 128 km^2 and it is also transboundary: 50.7 and 48.3 percent belong to Poland and Russia respectively. The average runoff equals ca. 1.53 $km^3\ a^{-1}$ (48 $m^3\ s^{-1}$) and constitutes ca. 41 percent of the total river runoff flowing into the lagoon. The Nogat River (1337 km^2, 0.66 $km^3\ a^{-1}$), the Pasleka River (229 km^2, 0.5 $km^3\ a^{-1}$) and the Prokhladnya River (1170 km^2, 0.3 $km^3\ a^{-1}$) make up other 39 percent of the lagoon river runoff (Lasarenko & Maevskiy, 1971).

Transboundary aspects of the lagoon hydography

The Vistula Lagoon could be considered as a transboundary water pool. The Russian and Polish national parts of the lagoon (which surface areas equal to 471 and 367 km^2 respectively) have free water exchange between each other. The single outlet is located on the Russian part of the lagoon. The area of the whole lagoon watershed equals 23 871 km^2. 61 percent belongs to Poland and 39 percent belongs to Russia. The transboundary lagoon catchment is of the parallel-consequence type, i.e. each of the national lagoon parts has its own catchment ("parallel structure"), but the catchment entering the lagoon on the Russian side starts in Poland ("consequence relation"). The drainage area of the very Polish part of the lagoon watershed, which discharges directly into the lagoon, equals 6639 km^2 (27.8%). The rest of the lagoon drainage area meets the lagoon on the Russian territory. It includes the very Russian part (1715 km^2, 7.2%), and the transboundary share: the Polish upper part (7922 km^2, 33.2%), the Russian lower part (7595 km^2, 31.8%). This transboundary segment of the basin is formed by catchments of the two big transboundary rivers (Lyna-Lava and Angrapa-Wengorapa, which are the tributaries of the Pregolya River), and two small ones (the Prokhladnaya and Momonovka rivers), which flow into the Vistula Lagoon directly (*see* the paper "Shared watersheds in the South-East Baltic" of this book).

Hydrological characteristics of the Vistula Lagoon

Salinity. 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 influxes stabilizes during ice coverage and lagoon comes to equilibrium between salting and refreshing processes (Chubarenko & Chubarenko & Baudler, 2005). 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 lagoon water salinity of 10–25 percent (Chubarenko I. et al., 2004).

The well-known value of 3.5 psu for the average lagoon salinity (Lasarenko & Maevskiy, 1971) is a very conventional one. As the fresh water gain is considerable, and the Vistula Lagoon is an estuarine lagoon, variations of the salinity along the lagoon are significant. The average annual salinity value (Fig. 3) declines from the lagoon inlet eastward to the river Pregolya mouth, and southwards along the Polish part. The maximum average range of the annual salinity variations is at the Pregolya River mouth (0.5–5.0 psu), the minimum one is observed near the lagoon inlet (3.5–6.5 psu). The southern part of the lagoon is char-

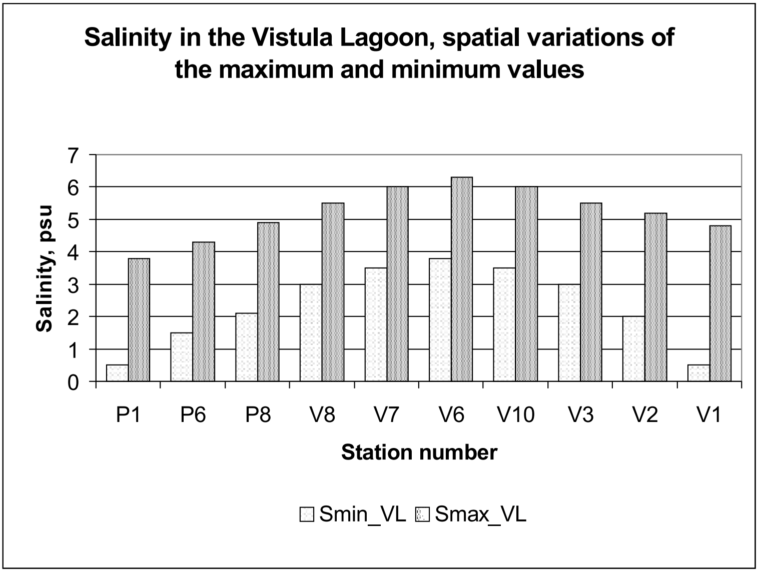

Fig. 3. Variations of annual average maximum and minimum of salinity against the monitoring station number shows spatial heterogeneity of salinity in the Vistula Lagoon (Rassmussen, 1997).

acterized by amplitude of annual variations of 0.5–4.5 psu. The above mentioned annual variations are provided with the seasonal variability mostly. The minimum and maximum of salinity are observed in spring (March–April) and in the beginning of autumn (August–September) respectively. The maximum spatial salinity variations (0.5–5.5 psu in average) and, therefore, spatial salinity gradients are observed also in spring.

Salting of the lagoon waters (after its desalination during spring) starts in summer because of intensification of periodic marine water inflows and wind-induced inner advective mixing. Seasonal increase of the wind amplitude is followed by more spatially uniform salinity distribution in the lagoon in autumn, salinity differences (along the lagoon area) are in within 3.5–6.0 psu in average. In the late autumn and winter time the previous higher, spatial gradients of salinity are reconstructed again.

Above mentioned peculiarities in spatial and temporal variations of salinity exist because of the Vistula Lagoon has the single inlet. The dramatic salinisation of the lagoon and its transformation to totally marine water enclosed bay is forecasting in case of existence of the second inlet, and the longer the distance between inlets, the higher the rate of transformation is (Chubarenko & Tchepikova, 2001).

Although the Vistula Lagoon in average is usually well vertically mixed due to (i) surface night cooling, (ii) Langmouir circulation and (iii) storm wind wave mixing action, a salinity vertical gradient (in average of 0.2–0.5 psu m^{-1}) is usually observed in the vicinity of the lagoon inlet and near the Pregolya River mouth (not much farther than 1–3 km apart), especially in spring and late autumn calm periods. In the inlet area salinity stratification is caused by irregular near bottom saline water intrusions from the Baltic Sea, while in the vicinity of the Pregolya River mouth the reason of stratification is, on the contrary, the upper layer freshwater flow from the Pregolya River.

Temperature. The annual dynamics of water temperature (from –0.2 up to 25–26 °C) is stipulated by solar heating. Horizontal differences in surface temperature between the lagoon remote ends are ca. 0.5–0.8 °C. Active wind mixing results in mostly homogenous temperature structure of the Vistula Lagoon (Chubarenko et al., 1998a). The maximum of temperature is usually observed at the end of July or beginning of August, and it usually happens one and two weeks later the maximum of the air temperature and the maximum of solar irradiation occur respectively.

Ice coverage of the lagoon is not stable. In coldest years permanent ice stays in the lagoon from December to March. In warmest ones this period is very short (1–1.5 months) (Lasarenko & Maevskiy, 1971).

Space distinctions and vertical variations of temperature are very insignificant in comparison with the temporal variations (for example, daily temperature variations during summer is ca. 1–1.5 °C in average with maximum of 3–4 °C (Lasarenko & Maevskiy, 1971). The high vertical gradients are observed only in the vicinity of the lagoon entrance during the Baltic water inflow, when temperature vertical difference could be up to 5 °C.

Annual variation of TS-index looks like a clockwise orientated loop. Annual variations in salinity and temperature are characterised by the one minimum and the one maximum, and these maxima are not simultaneous, the salinity maximum sets in 1–2 months after the temperature maximum occurs (Chubarenko B. et al., 2004).

Flushing time. The "flushing (retention or residence) times" due to the river drain and marine water inflow equal to a ratio of the lagoon water volume to river runoff and marine influx. They are of 198 and 49 days respectively. The actual resulted integral flushing time is to be calculated considering both of these factors (Chubarenko B. et al., 2004) and comprises ca. 40 days in average for the Vistula Lagoon.

The integral flushing time is applied for general estimation of renewal of the lagoon water in a scale of year-to-year variations. For concrete application the local flushing time, calculated for certain parts of the lagoon area, (Chubarenko B. et al., 2004) is more useful. This time is the characteristic time required for an e-fold renewal of water ($e \approx 2.72$, Eulerian number). In another words, this is the time during which the concentration of any admixture in the investigated lagoon compartment drops down till ca. 37 percent of its initial value in connection with lagoon flushing by non-polluted water. The range of a local flushing time is rather high; it varies from half a day to 80–150 days for the areas adjacent to the Baltiysk Straight and for remote corners of the Vistula Lagoon respectively.

Lagoon water dynamics

The Vistula Lagoon is a non-tidal pool, and water exchange with the Baltic is primarily governed by water level differences between lagoon and the adjacent Baltic Sea area. Unsteady flows in the entire lagoon and effective horizontal mixing are driven mostly by wind shear stress. The vertical mixing is caused by the Langmuir circulation during moderate winds (3–9 ms^{-1}) and by wind wave action during stronger winds. The river drain causes very weak currents in the lagoon, and the wind driven circulation immediately damps the drain currents while the wind starts blowing (Chubarenko & Chubarenko, 2002).

Wind action. Southern and north-western winds comprise 60 percent of the wind spectra. The strongest winds come from east and south-east directions. The average wind speed equals to 6.1 m s^{-1} on the marine coast. On the inner lagoon coast the average wind speed equals 5.6 m s^{-1} in Tolkmicko, and 4.3 m s^{-1} in Mamonovo (Bogdanov, 2004). The forested dune chain of the Vistula Spit (the altitude is of 38 m) doesn't protect the total lagoon area from marine winds, but shadows the nearest lagoon surface of 0.5–1 km width. The actual reason of wind speed reduction at the inner part of the lagoon coast is the roughness of the lagoon water due to short and high wind waves in the lagoon. The wind wave action is higher on the eastern lagoon coast, the wave energy fluxes calculated at a depth of 2 m are 10^4–10^5 Ts^{-1} for the onshore component and 10^2–10^3 Ts^{-1} for the alongshore component [1 Ts^{-1}=10^4 J] (Bogdanov, 2004).

Currents and waves. Duration of wind action is of specific importance for the lagoon water dynamics because a wind stress (i) causes the wind surface waves, (ii) directly generates currents and (iii) establishes the level inclination, which is a reason for a compensative near bottom recurrent flow.

Wind waves and currents are being developed immediately while wind starts blowing. The average values of advective currents are of 10–20 cm s^{-1}, maximum is about 0.5 cm s^{-1}. The developed wind waves depend on the wind speed, but usually they are limited by depth: a significant wave height is of 0.8 m for the wind of 10 ms^{-1}, is of 0.95 m for the wind of 15 ms^{-1}, and is of 1.1 m for the wind of 20 ms^{-1}. The waves are rather steep, the ratio between wave length and height usually achieves to value of 7–9 (Lazarenko & Maevskiy, 1971).

Advection processes are very important (Szymkiewicz ed., 1992). A wind only is the main driving force for the whole velocity pattern in the lagoon. Water exchange through inlet is usually reflected at the area that is close to the inlet (5–8 km), the river runoff is manifested even closer.

Near bottom compensative current backward to wind direction occurs when the winds are stronger than 3–4 ms^{-1}. This current develops during time scale of long gravity waves propagation through the lagoon, which value has an order of 5 hours for lengthwise winds and 0.5–1 hour for transversal winds. The inertial period for the Vistula Lagoon equals 14.5 hours. Coriolis force, which influences the motions of this time scale, is important for intermediate and slow currents in the Vistula Lagoon. Heterogeneity of currents in both horizontal and vertical directions makes a necessity to consider a current pattern in the Vistula Lagoon as fully three-dimensional.

There are three main mechanisms of vertical mixing in the Vistula Lagoon. Surface cooling leads to every-night convection, which regularly destroys vertical stratification. For the winds of 3–9 ms^{-1} the Langmuir circulation is developing very well and usually reaches the bottom because vertical stratification is weak. Wind wave mixing becomes significant when wind is moderate or strong (more than 6–7 ms^{-1}). Because of the shallow water conditions waves cause bottom sediment resuspension (Chubarenko, 1994; Chechko & Blazchishin, 2002), and, finally, surface wind sheer stress and bottom friction generate a turbulence, which keeps sediments in the water column for a certain time, and an advection redistributes suspended matter over the lagoon.

Water level. The time scale of the wind induced water level raise equals to time of long gravity waves propagation. For the Vistula Lagoon the level rise at its end begins 2–4 hours after wind starts, the maximum rate of the level rise is established in 5–6 hours while the maximum in water level sets in 6–12 hours during permanent wind blowing (Lazarenko & Maevskiy, 1971). As concerns physical mechanisms, the maximum level rise on the coast of the Vistula Lagoon is caused by the multiple effect of both the level rise in the adjacent Baltic and the local wind induced set-up, and both of these factors contribute to in the similar proportions.

Therefore, the total water level rise is governed by two factors: the marine water inflow into the lagoon caused by Baltic water level rise, and the local wind induced level set-up. For the lengthwise winds, water level in the lagoon continuously raises from one end to another. Because (i) the lagoon inlet is located in the central part of the lagoon, (ii) has small hydraulic resistance, and (iii) the lagoon itself is not narrowed, the level variations along the lagoon could be considered as the arithmetic sum of constant level rise at the inlet and wind induced level set-up varied along the lagoon. The extreme values of water level rise at the remote corners of the lagoon are ca. 1.3–1.7 m, where 0.9–1.1 m is a contribution of wind induced local level set-up. The difference in water levels at both remote ends in a stormy period usually equals 0.5–0.7 m, but could exceed even 1.5–1.7 m (Lazarenko & Maevskiy, 1971).

The induced water level variation at the distinct lagoon ends starts 3–4 hours after the imposed level variation occurs in the inlet, and the lag between set up of the maximum (or the minimum) levels at the lagoon entrance and its remote ends is ca. 10–12 hours.

The role of the Kaliningrad Marine Canal. Existence of the navigable deep canal is very important for general lagoon circulation and inner water exchange (Chubarenko & Chubarenko, 2003). It contributes variously to the water movement of different scales.

First, the canal and deep lower segment of the Pregolya 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 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. 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. As a result, a salt-wedge with maximum salinity of 4.5–5 psu reaches the Pregolya 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.

Such a regular natural seasonal upstream penetration of mixing zone makes a threat to the Kaliningrad water supply system, which intakes are located upstream just above the Kaliningrad City. Under the conditions of intensive and permanent western wind a saline water is shifted upstream and temporary blocks the drinking water intakes. In this case the stored water is used, and the main problem is to forecast normalization of natural conditions and the rate of the store water distribution. In exceptional cases of extreme wind influence saline waters could reach even the Deyma River branch of the Pregolya River

(30 km upstream) and flow through it towards the southern part of the Curonian Lagoon.

This estuary conditions establishing in the canal play the specific part in the water dynamics of the eastern part of the Vistula Lagoon. The described above seasonal transport of salty water upstream the canal towards the Pregolya River mouth causes the salty water inflow going directly to the eastern part of the Vistula Lagoon through the pass between islands of the dam. And this influx is the very reason of rather intensive salting of the water in this remote corner of the lagoon up to the end of autumn.

The wind stress on the water surface of the canal is much less than on the lagoon surface. The canal is much deeper than the eastern part of the lagoon. There are two locations of free intensive water exchange between the canal and the lagoon: the wide pass between the dam islands and the lagoon coast at the eastern end of the canal near the Pregolya River mouth, and the open segment of the canal between the Primorsk Bight and the Vistula Lagoon itself. Because of the above mentioned peculiarities the canal is the pass for intensive compensating flows (backward to the wind direction) occurring under western and eastern winds. For example, during western winds the large water mass is surging towards the eastern lagoon corner, where is a wide pass to the canal and the Pregolya River. The water partially goes upstream the Pregolya River and partially discharges backward along the shadowed navigable canal towards the second wide pass at the Primorsk Bight. This effect of intensive large scale water mixing between the canal and the eastern part of the lagoon provides more homogeneous conditions in salinity and suspended matter fields in the eastern part of the lagoon. On other hand, intensive currents in the middle part of the canal developing in the autumn during western storms make up homogeneous conditions (in vertical and horizontal directions) along the big section of the canal (10–15 km) between the Pregolya mouth and the Primorsk Bight.

Water exchange through the inlet. The level variations in the inlet control the water exchange process. The fluxes through the inlet vary frequently as they are followed by the water level, which could rapidly change (up to 4–5 cm per hour). Short term variations (duration is of 1–4 hours) slightly influence on the actual water exchange between the lagoon volume and marine zone; the same mixed water goes to and from without deep penetration into the lagoon. Every event of level rise initiates the saline intrusions passing along the bottom towards the lagoon deep. But not every intrusion could overstep the inner sandy bar bordered the inlet from the very lagoon cup. Only when level rise has relatively long duration as well as amount of incoming saline water exceeds the certain value, the actual intrusion of saline water towards the lagoon deep happens. Usually it takes more than 4–6 hours when salt-water intrusion overflows the inner bar and reaches the central deep part of the Vistula Lagoon (Chubarenko & Chubarenko, 2000).

The deep navigational canal passing from inlet towards Kaliningrad would be the most probable way for such intrusions. And these intrusions take place when the level rise occurs under the calm or eastern wind conditions. Intensive intrusions occur when strong western wind blows, but, the same wind sets up the water level inclination along the lagoon, and the backward pressure gradient established prevents the marine water penetration into the canal. This case, intruding water turns right and moves southwards the open lagoon overflowing the inner bar (Chubarenko & Chubarenko, 2003).

The average statistics for the currents in the Vistula lagoon inlet is given in (Lazarenko & Maevskiy, 1971): 74.9 percent—inflow or outflow uniform current, 11.7 percent—two layers currents (influx is in the bottom layer and outflow—at the surface), 13.4 percent—two streams currents. Two-layer and two-stream regimens take place in case of currents' reorganization. The maximal currents of 1.34 ms^{-1} and 1.38 ms^{-1} were observed for inflow and outflow respectively. The average velocity of one-direction uniform flow ranges within 0.06 and 0.95 ms^{-1}. The average currents of two-layer or two-stream regimens are usually within 0.1–0.2 ms^{-1}. The historical maximum of the surface currents equalled to 2.5 ms^{-1} was observed in 1894.

The hydrological-hydrodynamic typology of the Vistula Lagoon system

The hydrodynamic system of the Vistula Lagoon includes the lagoon itself (shallow spatially extended water pool separated from the Baltic Sea by a sandy barrier), the Kaliningrad Marine Canal (the semi-isolated deep channel), and artificially deepened downstream of the biggest river (the Pregolya River) in the catchment. The canal springs exactly from the lagoon inlet, passes along the lagoon coast partly being separated from the shallow lagoon area by a number of artificial islands, and partly crosses the open lagoon area. The lagoon itself could be referred to a well-mixed estuarine non-tidal lagoon or, in other words, a non-tidal well-mixed bar-built plane estuary parallel to the shore, with significant horizontal variability of characteristics, and predominant lengthwise gradients between the inlet and remote ends of the lagoon. The Canal and deepened downstream of the Pregolya River could be referred to as wind surge (not tides) induced estuary that is relatively deep in comparison with the adjacent lagoon area, and characterised by seasonal evolution of hydrological characteristic. In summer it is the highly stratified estuary with significant vertical and along-stream gradients, but in winter it is well vertically mixed estuary with brightly exposed along-stream gradients.

The Vistula Lagoon index at the stratification-circulation diagram (Martin & McCutcheon, 1999) corresponds to an estuary of type 2, which is partly well mixed and has flows reversal with a depth. The estuary number E_d (Martin & McCutcheon, 1999) ranges within 5–10, and it points to the fact that the Vistula Lagoon is the water pool of intermediate type that means something between the well mixed and partly mixed coastal waters. Estimation of the Estuarine Richardson Number for the Vistula Lagoon gives the value less than 0.08. According to the acceptable classification (Fischer et al., 1979) it means that the lagoon has to be considered as well mixed, and the vertical variations of characteristics are negligible. But our data prove that the same Estuarine Richardson Number, estimated not for the total lagoon, but for some of it parts (such as entrance area or some places of steep gradients in bottom topography), shows the significance of stratification and therefore the importance of baroclinic effects for the water dynamics.

Such a specific configuration of the cannel-lagoon system as it is in the Vistula Lagoon needs the specific combine modelling approach (Chubarenko & Chubarenko, 2003).

The sediment regimen

The lagoon bottom deposits consist of the three main types of sediments: medium and fine grained sands (fractions of 0.1–1.0 mm are prevailing on the 30 percent of the bottom area), coarse aleurite (0.05–0.1 mm, 22%), and fine aleurite mud (0.01–0.05 mm, 45%). The rest of three percent is represented by aleuro-pelitic mud (0.005–0.01 mm), shells and pebble-gravel deposits. The muddy sediments cover the deeper parts of the lagoon (that are more than 2–2.5 m in depth), while sandy sediments are mostly found along the hydrodynamically active shallow coastal zone at depths of 1.5–2 m. The biggest amount of coarse sands is in the vicinity (1–1.5 km) of the lagoon inlet, where it forms the inner (or reversed) bar inside the lagoon area (the water depth at the bar is of 1.5–2 m) (Chechko & Blazchishin, 2002).

The lagoon average concentration of suspended sediments varies within 4–230 mg l^{-1} with the average value of 30 mg l^{-1} that is 10 times bigger than in the Baltic Sea. In any moment the spatial distribution of the suspended sediments is controlled by the bathymetric structure, and the maximal concentrations are observed in the shallow coastal zones. The biotic component comprises 54 percent of the total amount of annual average concentration of the suspended matter. Seasonal variations are evident—abiotic component is prevailing in a windy autumn period, when it comprises more than 60 percent of the total amount (Fig. 4) (Chechko, 2002, 2004; Chubarenko et al., 1998b).

Wind wave sediment resuspension (Blazchishin, 1998; Chubarenko et al., 2002) is the main effect of sediment dynamics in the Vistula Lagoon. It is responsible for stepwise redistribution of sediments over the lagoon area from its sources, the rivers and eroded segment of the coast. After the Vistula River flow had been redirected to the Baltic Sea, the overall lagoon sediment budget has been changed dramati-

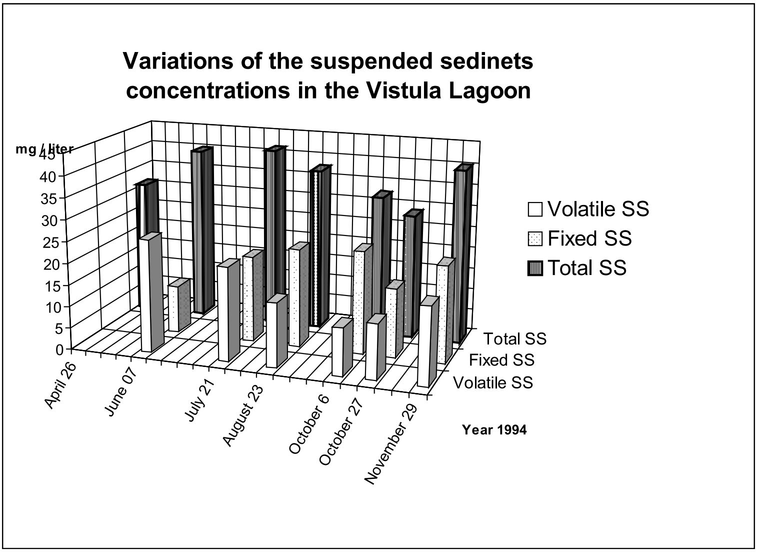

Fig. 4. Spatial variations of suspended solids in the Russian part of the Vistula Lagoon (Chubarenko et al., 1998b)

cally. Nowadays the annual loss of suspended matter from the lagoon to the Baltic Sea (322 000 t y^{-1}) significantly exceeds its annual gain (88 000 t y^{-1} from rivers and 34 000 t y^{-1} from the Baltic) (Chubarenko & Chubarenko, 2001). It happens because of wind wave resuspension, which is the main mechanism of bottom erosion and saturation of the water with sediment. In fact, the Vistula Lagoon is in transition to a new equilibrium in sediment budget when the lagoon depth will become deep enough to protect the bottom from active erosion by waves and currents. The lagoon is nowadays a significant source of suspended matter to the Baltic coastal zone, and one of remarkable features is that intensive bottom erosion in the lagoon is a more powerful source of sediments than the river drain from its whole catchment area (Chubarenko & Chubarenko, 2001).

Remarks on water quality

The areas near the Pregolya River mouth and Baltiysk Channel are the most contaminated parts of the Vistula Lagoon. Oil sleeks, small rubbish are very often observed there. State control authorities very strictly punish those ships or enterprises which break rules of bunkering or loading.

The head parts of the entrance moles of the lagoon inlet are at a depth of 10 m. In case of outflow from the lagoon, lagoon water discharges far from the sea shore. The waters from periphery of the outflow plum may reach the beach, but only after well mixing with marine waters.

In case of inflow, cleaner marine waters dilute the Baltiysk harbor waters. Strong marine inflow follows the Vistula Spit coast to the south and than goes to deeper layer ensuring regular ventilation of the coastal waters along the sandy barrier—the Vistula Spit.

Water transparency in the lagoon is low during a year, (namely 0.3–0.8 m of the Secchi depth). Only in case of strong marine water inflow the transparency may amount 2 m in the area adjacent to Baltiysk Strait. Regular wind induced re-suspension and phytoplankton bloom are the main reasons of low water transparency, which makes bathing in the lagoon not so attractive as in the sea.

The hydrochemical characteristics vary a lot from year to year, because they are strongly depended on pollution load. In general nowadays the load is less than it was in 90th, due to reduction of economic activity in the Kaliningrad Oblast. The content of chemicals lagoon waters are bigger than in marine one. Table 1 illustrates the variations of some parameters both in the lagoon and marine waters by example of the monitoring in 1994–95 during the Danish-Polish-Russian Vistula Lagoon Project (Rassmussen, 1997). Long-term average values (1981–2001) for some important chemicals is given in the Table 2. The Vistula Lagoon is considered as euthrophied water pool (Senin et al., 2004) because of high concentration of chlorophyll in its waters.

Table 1.

Variations of the hydrochemical parameters in the lagoon and marine waters at both sides of the northern (Russian) segment of the Vistula Spit.

No.	Parameter	Vistula Lagoon coastal water	Baltic coastal water
1.	Salinity, psu	3.5–8, till 9 sometimes, average—5.7	5–9, sometimes till 10 average—7.4
2.	Dissolved oxigen, mg l^{-1}	5.3–9.5, average—8.3	8–12, average—9.7
5.	Alkalinity, milimole l^{-1}	0.8–3.8	1.8–2.3, average—2.1
6.	pH	7.5–8.7, average—8.3	7.8–8.5, average—8.1
7.	Suspended solids, mg l^{-1}	4–81, average—39	8–22, average—14
8.	COD, Mn, mgO l^{-1}	3.8–6.8, average—5.3	unknown
9.	BOD5, mgO l^{-1}	2–4.5, average—3.5	unknown
10.	Dry residue, mg l^{-1}	2 550–3 800, average—3 300	unknown
11.	Chlorides, mg l^{-1}	1 150–2 000, average—1 700	unknown
12.	Sulphates, mg l^{-1}	140–300, average—230	unknown
13.	NH4, mcgN l^{-1}	8–35, average—15	7–13, average—10
14.	NO2, mcgN l^{-1}	2–16, average—9	1.4–4.5, average—2.1
15.	NO3, mcgN l^{-1}	6–570, average—96	8–56, average—30 (once—434)
16.	PO4, mcP l^{-1}	6–224, average—53	8–44, average—25
17.	Total N, mcg l^{-1}	190–1 900, average—860	160–750, average—455

No.	Parameter	Vistula Lagoon coastal water	Baltic coastal water
18.	Total P, mcg l^{-1}	75–340, average—152	14–98, average—55
19.	Chlorofill–a, mg l^{-1}	15–90	0.5–17, average—6
20.	Copper, mcg l^{-1}	3–3.2, average—1.7	Unknown
21.	Nickel, mcg l^{-1}	1–28, average—7	Unknown
22.	Cadmium, mcg l^{-1}	0.2–0.3	Unknown
23.	Zinc, mcg l^{-1}	3–70, average—12	Unknown
24.	Lead, mcg l^{-1}	1.5–25, average—8	Unknown
25.	Coli bacteria, no ml^{-1}	0.002–2.6, average—1.25	Unknown
26.	Cr, mcg l^{-1}	0.5–12, average—5	Unknown

Table 2.

Ranges of variation of the mean monthly values of the hydrochemical parameters in the Russian part of the Vistula Lagoon (Senin et al., 2004).

No.	Parameter	Range of seasonal variations for the period from February to November	Long-term annual average for the period 1981–2001
1.	Temperature, C	0.2–20.5	11.1
2.	Salinity, psu	2.6–4.5	3.8
3.	Dissolved oxyen, mg l^{-1}	9.8–14.5	11.0
4.	Mineral phosphorus, mg l^{-1}	15.0–103.8	48.4
5.	Nitrates, mcgN l^{-1}	25.7–865.	201.3
6.	BOD, mgO l^{-1}	3.3–6.4	4.6
7.	Chlorophyll, mg l^{-1}	35.8–51/8	41.7
8.	pH	7.9–8.8	8.5
9.	Secchi depth, m	0.5–0.8	0.6

mg—milligramme, mcg—microgramme

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The Curonian Lagoon

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1. Introduction

The Curonian Lagoon is a large, highly eutrophied, mainly freshwater coastal water body, connected to the South-Eeastern Baltic. The lagoon water circulation is determined by the wind and river discharge, seawater intrusions are frequent and irregular. Main bottom sediments in the lagoon are sand and silt. Northern part of the lagoon is acting as a transitory area of sediment transportation, while the central part is most heterogeneous in respect to bottom geomorphology and sediment type. Muddy bottoms occur in local depressions in the deeper western part of the lagoon.

Both phytoplankton and zooplankton are dominated by the freshwater species, marine species enter the lagoon only during seawater

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intrusions. Seasonal succession of the plankton communities generally follows the pattern, typical for the eutrophic ecosystems, phytoplankton blooms are dominated by *Stephanodiscus hantzschii* in spring, *Aphanizomenon flos-aquae* and *Microcystis aeruginosa* in summer.

The most common fish species are roach, perch, redeye, white bream and common bream. Migratory fish includes Atlantic salmon, sea trout, smelt, twaite shad, whitefish, vimba, eel and lampreys.

Salinity and sediment type are the main factors determining benthic species distribution in the lagoon. The *Nereis diversicolor* and Oligochaeta + Chironomidae communities are the most widespread in the Klaipeda strait, northern part is dominated by *Dreissena polymorpha*, *Marenzelleria viridis* and amphipods in sandy bottom, whereas oligochaetes and chironomids in muddy bottom biotope. Two main biotopes were identified for the central part of the lagoon: the first has a mud as prevailing bottom substrate and favourable for *D. polymorpha* community, the second relates with fine sand and is dominated by oligochaetes-chironomid communities.

General feature of the Curonian Lagoon food web is a very high phytoplankton biomass. Most of the primary production in the system is transferred to the detritus food chain or even exported to the Baltic Sea rather than grazed by zooplankton. The top predators (mainly cormorants) have considerable impact on fish populations, comparable to the fishing efforts.

2. Environmental characteristics

The lagoon area covers 1584 km^2, mean depth is approx. 3.8 m (Žaromskis, 1996); the water ways in the Klaipeda strait (Klaipeda port area) are artificially deepened down to 14 m depth.

The hydrodynamic regime of the lagoon is generally determined by the wind and Nemunas river discharge. Approximately 23 km^3 of fresh water is gained in the form of river runoff; more than 40 percent of this amount is discharged into the Baltic Sea during spring months. Sea water inflows cause irregular rapid (hours-days) salinity fluctuations in the range of 0–7 psu in the northern part of the lagoon (Daunys, 2001). One-to-six days seawater inflows are most common (Gasiūnaitė, 2000); the seawater intrusions are usually restricted to the northern part of the lagoon. 5 km^3 of annually incoming seawater are mixed in the lagoon mostly in autumn months (Pustelnikovas, 1998).

The regime of water currents in the southern part of the lagoon is mainly driven by the wind which creates different circulation sub-systems. In most case the system evolves a dominant gyre, with anticlockwise (wind from west) and clockwise (wind from south-east) direction. In case of south-west wind, the circulation pattern is characterized by a two-gyre system (Razinkovas et al., 2005).

Seasonal water temperature dynamics is typical for shallow temperate lagoons with annual amplitude up to 25–29 °C (Žaromskis, 1996). Temperature stratification of the water column is weak and unstable (Pustelnikovas, 1998). The ice cover in the lagoon is present for 110 days on average (Žaromskis, 1996).

Oxygen concentration fluctuates spatially and temporally (both diurnally and seasonally) (Jurevičius, 1959). Local anoxia may take place in summer at night, and is most probable in the southern part of the lagoon.

The highest concentrations of nutrients are observed in winter–early spring. The concentration of phosphate decreased rapidly in April and started to increase in early summer due to fast regeneration. Nitrogen concentration could decrease to analytical zero in May. Ammonium concentrations have no pronounced seasonal pattern. The lowest silica concentrations were recorded during spring after the diatom bloom, remained low throughout summer and started to increase again in early autumn (Razinkovas & Pilkaitytė, 2002).

The main bottom sediments in the lagoon are sand and silt. The northern part of the lagoon is a transitory area of sediment transportation, while the central part is most heterogeneous in respect to bottom geomorphology and sediment type. Fine sand, mixed with gravel and pebbles, peat and moraine prevailed here, whereas muddy bottoms occur in local depressions in the deeper western part of the lagoon along the Curonian Spit (Olenin & Daunys, 2004).

3. Plankton communities

Plankton communities in the northern part of the lagoon are strongly dependent from the rapid salinity fluctuations. The plankton abundance markedly decreases with increasing salinity (Fig. 1). Brackishwater phytoplankton community entering the lagoon during seawater intrusions is dominated by *Heterocapsa rotundata*, *Achnanthes taeniata* and *Thalassiosira levanderi* in spring, *Skeletonema costatum*, *Heterocapsa triquerta* and *Nodularia spumingena* in summer, *Coscinodiscus granii*, *Skeletonema costatum* and *Teleaulax* spp. in autumn (Olenina, 1997). Brackishwater zooplankton community is dominated by *Acartia bifilosa*, *Temora longicornis, Eurytemora hirundoides, Podon polyphemoides* and *Evadne nordmanni*

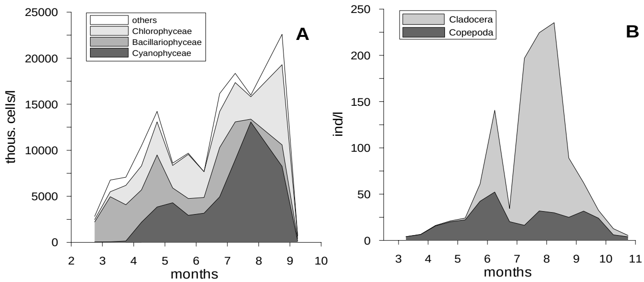

Fig. 1. Seasonal dynamics of phytoplankton (A) and plankton crustaceans (B) in the northern part of the lagoon.

(Gasiūnaitė, 2000). Ponto-Caspian invader *Cercopagis pengoi* could be found in the northern part of the lagoon during sea water intrusions since 1999 (Gasiūnaitė & Didžiulis, 2000).

The structure and dynamics of freshwater plankton communities are typical for temperate eutrophic waters. Phytoplankton succession starts with prevalence of diatoms from January until June, and continues with dominance of cyanobacteria or co-dominance of cyanobacteria and diatoms, until the biomass peak is reached in August–September (Fig. 2). The diatoms are relatively abundant again in late autumn. *Stephanodiscus hantzschii* is the dominant species both in spring and late autumn–winter; potentially toxic species *Aphanizomenon flos-aquae* and *Microcystis aeruginosa* species are responsible for the biomass peak in summer (Olenina, 1998; Pilkaitytė & Razinkovas, 2006; Gasiūnaitė et al., 2005). Nitrogen fixing cyanobacteria are present in phytoplankton community throughout the year, but the maximum concentrations are observed when the favourable weather conditions are coupled with low inorganic N/P ratios (Pilkaitytė & Razinkovas, 2006).

Freshwater zooplankton community is dominated by *Bosmina* spp., *Chydorus sphaericus*, *Cyclops strenuus*, *Daphnia* spp., *Diaphanosoma brachy-*

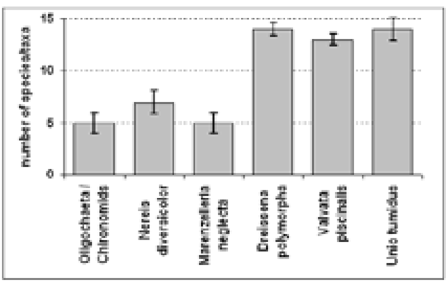

Fig. 2. Average number of bottom macrofauna taxa in samples taken in different benthic communities of the Curonian Lagoon.

urum, *Leptodora kindti*, *Eudiaptomus graciloides* and *Mesocyclops leuckarti*. Rotifers are dominated mainly by *Keratella* spp. and *Brachionus* spp. Cyclopoids dominate in the zooplankton community till May, while large *Daphnia* specimens appear only in the beginning of summer. The shift to small-bodied *Chydorus* is observed later in midsummer and coincides with the dominance of Cyanobacteria in phytoplankton. Cyclopoida are usually dominated in September–October (Fig. 2) (Naumenko, 1996; Gasiūnaitė & Razinkovas, 2004).

4. Fish

Until now 57 fish species are recorded in the Curonian Lagoon, 11 of them are of marine origin. Roach (*Rutilus rutilus*), perch (*Perca fluviatilis*), white bream (*Blicca bjoerkna*) and common bream (*Abramis brama*) are the main commercial species (Repečka et al., 1996).

The migratory fishes in the Curonian Lagoon are represented by Atlantic salmon (*Salmo salar*), sea trout (*Salmo trutta trutta*), smelt (*Osmerus eperlanus*), twaite shad (*Alosa fallax*), whitefish (*Coregonus lavaretus*), vimba (*Vimba vimba*), eel (*Anguilla anguilla*), river and marine lampreys (*Petromyzon marinus* and *Lampetra fluviatilis*) (Repečka, 2003b). The migration of salmon starts in the mid-August and reaches the peak at the end of September–October (Kesminas et al., 2003). The most intense sea trout migration is observed in September–October. Smelt is the most abundant migratory fish in the coastal zone of the Baltic Sea. Smelt enter the lagoon at the end of October, the most intensive migration observed in December–February (Repečka, 2003a).

The juvenile fish assemblage is dominated by smelt and pikeperch (*Stizostedion lucioperca*) in the lagoon pelagic habitats, while roach, perch, three-spined stickleback (*Gasterosteus aculeatus*) and gudgeon (*Gobio gobio*) prevailed in the littoral (Žiliukienė, 1998; Žiliukas, 2003). The fish fry dynamics have pronounced seasonal pattern: three-spined stickleback dominated in the littoral in spring, roach and gudgeon in summer and perch in autumn (Žiliukas, 2003).

5. Benthic communities

The zonation of benthic macrofauna in the lagoon is based on the peculiarities of the salinity regime (Olenin & Daunys, 2004): Klaipėda strait (A-zone) is affected by the sea water inflows and highest anthropogenic pressure; the northern part of the lagoon (B-zone) is influenced by both the Nemunas outflow and episodic inflows of sea water;

central part of the lagoon (C-zone) is strongly influenced by the Neman River outflow. The salinity tolerance limits of main species are given in Fig. 3.

The western side of Klaipeda strait is characterised by the variety of bottom substrates: fine and coarse sand, gravel and pebble bottoms, moraine—clay and stones, patches of mud as well as artificial substrates, such as concrete embankments, submerged wood, etc. The area is inhabited by rather diverse benthic fauna which is able to withstand rapid environmental fluctuations and essential anthropogenic pressure. The number of species, abundance and biomass vary within large limits and are subject to rapid changes. The dominant species are *Nereis diversicolor, Marenzelleria neglecta,* oligochaets and chironomids, *Balanus improvisus, Cordylophora caspia, Mya arenaria, Macoma baltica, Mytilus edulis*.

Muddy bottoms comprise inlets on the eastern side of the strait. The main bottom sediments are black mud with admixture of sand and gravel, containing human litter. The sediments are heavily polluted and inhabited mostly by oligochaetes and chironomids.

Two groups of biotopes are distinguished in the northern part of the Curonian Lagoon: large eastern shallow (depth <1.5 m) area with fine sand and the deeper (depth between 1.5 and 4 m) western area along the Curonian Spit mainly covered with muddy sediment.

The sandy bottom biotope may be sub-divided into variety of lower level biotopes: fine sand with macrophytes; sand with large native unionids (*Unio tumidus*); fine sand and silt with oligochaets and chirono-

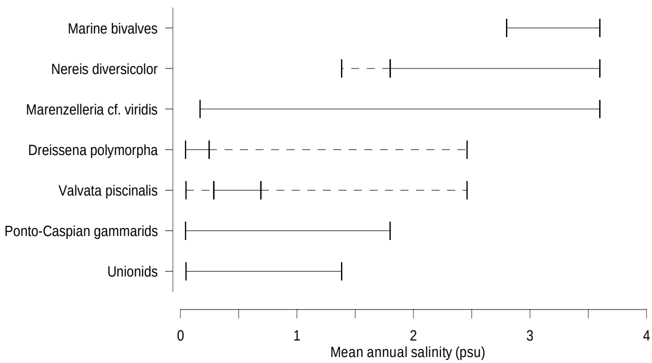

Fig. 3. Occupied salinity range (solid line) and tolerance limits (dashed line) of dominant bottom macrofauna species in respect to mean annual salinity.

mids as well as biotopes with alien invasive species *Dreissena polymorpha, Marenzelleria neglecta* and Ponto-Caspian amphipods of genus *Chaetogammarus* and *Pontogammarus* (Daunys & Olenin, 1999).

The main community in the muddy bottom biotope is dominated by oligochaets and chironomids. Comparatively large part of the muddy bottoms is covered by shell deposits formed mainly by *Valvata* species with admixture of *Bithynia spp., Radix spp., D. polymorpha, Potamopyrgus antipodarum* and *Theodoxus fluviatilis*.

Two main biotopes were identified for the central part of the lagoon: one with mud as prevailing bottom substrate and another with fine sand. Both biotopes alternate each other on the scale of hundred meters. The muddy bottom biotope is formed by the zebra mussel *Dreissena polymorpha*. Shell deposits and clusters of living mussels cover the largest part of the delta area. Because of habitat engineering activity of *D. polymorpha*, community of co-occurring species is rich in species number (about 50 in total). The total biomass (up to 11 kg/m^2) and abundance (up to 100 000 ind./m^2) are the highest in the entire Curonian Lagoon. Sandy bottoms (mainly fine sand and aleurite) in the central part of the lagoon are dominated by oligochaetes and chironomids (Olenin, 1987, 1988; Daunys, 2001).

The large littoral zone of the lagoon is covered by the macrophyte beds, dominated by *Potamogeton perfoliatus, P. pectinatus* and *Cladophora* (Plokštienė, 2002). The Ponto-Caspian mysids *Paramysis lacustris* and *Limnomysis benedeni* are common nectobenthic species in the littoral zone, associated respectively with the open sandy/aleurytic bottom in 1–3 m depth and the submerged vegetation (Razinkov, 1990).

6. Biological interactions

Food web structure based on already known interactions and trophic compartments in the pelagic part of the lagoon was compiled by Razinkovas & Zemlys (2000).

General feature of the Curonian Lagoon food web is that a very high primary production is transferred to the detritus food chain or even exported to the Baltic Sea rather than grazed by zooplankton. Low abundance of pelagic fish also implies that zooplankton is rather recycled within its two compartments than transferred to higher trophic levels. Surprisingly high biomass of the benthic suspension feeders is mainly due to *D. polymorpha* biotopes dominate in the central part of the lagoon (approximately 20 percent of the total area). However, because of the comparatively low bivalve metabolism rates their role in organic matter transformation is less pronounced that the one of deposit feeders including small oligochaets and chironomids. The top predators (birds) have considerable impact on fish populations. This impact is comparable to the fishing efforts and may increase due to the growth of cormorant colonies.

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The characteristics of the Pregolya River basin

Sergey I. Zotov, Nikolay S. Belov

1. Introduction

The river Pregolya is formed by the junction of the rivers of Instruch and Angrapa has the length of 123 km and the area of the basin of 15 500 km^2. The area of 7100 km^2 belongs to the Kaliningrad Oblast (it makes up 53 percent of its territory), and the rest part belongs to the territory of Poland. The catchments of the headrivers of Lava and Angrapa, which are the main tributaries of the Pregolya River, are located here. It possesses parameters of a middle river, and its tributaries, with the exception of Lava, are small rivers. According to the natural-economic features, the Pregolya River basin may be considered as typical for conditions of superfluous wetness in the south-east part of the catchment of the Baltic Sea and the Nonchernozem zone in the European part of Russia. According to its resource and economic potential, it is of a great importance for the Kaliningrad Oblast. About 48 percent of the volume of an annual run-off from the territory of the region (1.4 km^3) are formed in it. About 80 percent of the industrial potential of the region, and more than 50 percent of the areas of the agricultural lands are concentrated here. There is also a tense hydroecological situation that is largely defines the ecological situation in the whole region.

2. Geologic structure and land forms

The rock mass in the basin (the zone of active water exchange is considered here) is generated by upper cretaceous, paleogene and quarternary deposits.

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Upper cretaceous depositions are presented by marls, clays, sandstones and sands. Their power on the territory of the Pregolya basin varies within large limits: from 20 m in the north to 200 m in the south of the catchment. They lie at a depth of 25–100 m.

Paleogene depositions are developed only in the western part of the basin. They are: fine-grained and anisomerous quartz—glauconitic sands, aleurites and aleurolites of power of 10–30 m. They are bedded at a depth of 10–25 m.

Quarternary depositions are everywhere widespread on the territory of the Pregolya River basin. According to the paper "Hydrogeology of the USSR…" (1970) quaternary is subdivided into three glacial complexes. The most ancient of them is the Lithuanian. It is presented by loams, clays and water-glacial depositions. Their power varies from several metres up to 60 m. The Central Russian glacial complex consists of moraine loams and sandy-gravel deposits. Depositions lie at a depth of 10 m in the north of the catchment up to 140 m in the area of Mazurskaya height. Their power fluctuate between 10 and 60 m. The depositions of the Valday glaciation are presented by both fine-grained and small-grained sands and loams. They are deposited at depth of some metres to 60 m and characterized by the power of 10 up to 60 m.

Modern depositions in the Pregolya basin are presented by alluvial, paludal and eolian depositions. The alluvial depositions are widespread in the Pregolya's valleys and the large tributaries of the river. Their power amounts 10–15 m. They are made of sands, rubble, loamy clay and loams. The paludal depositions belong to the coastal part of the Pregolya basin, namely small parts in the rivers' valleys and the hollows between moraine heights. Their power amounts 8–10 m. The eolian depositions are presented only in the delta part of Pregolya.

Gravel, sand, clay and other depositions are widely used as building materials. With this purpose some tens of open-cast mines are quarried in the basin of Pregolya. Influence of opencasts on the natural state of the basin is not significant as a whole. But their local influence is essential.

The drainage-basin topography of the Pregolya River on the territory of the Kaliningrad Oblast includes the Pregolsko-Instruchskuyu lowland, the south part of Sambiisko-Nadruvskoe plateau and the northern extremity of the Mazurskaya height. One may say about the following basic types of the land forms:

- Moraine ridge hill plains;
- Moraine hollow-hilly plains;

• Lake glacial plains.

The first type of the land forms is typical for the south and the south-east part of the catchment where Mazurskaya height is situated. Here the moraine hills of heights of 100 m and higher alternate with the hollows occupied by lakes and bogs. The depth of a vertical partition amounts 50 m. The highest point of the Kaliningrad Oblast (231) is also located here. These heights are attributed to the obviously expressed glacial forms of the relief. In the direction from the northeast to the southwest, the heights become to diminish, and the Mazurskaya height is replaced by the Pregolsko-Instruchskaya lowland. This lowland can be related to lake-glacial flat plains. Its typical heights are 20–40 m, the surface goes down from the east to the west. A part of a right bank of the Pregolya basin occupies the Sambiisko-Nadruvskoe plateau that is a moraine, hollow-wavy plain with the heights of 40–50 m. All the territory of the catchment area is densely indented by the river network; the rivers' bottomlands are partially swamped.

On the great part of the basin's territory the inclines of the area don't exceed several degrees, therefore erosion processes are not developed. Serious measures on prevention of lands erosion should be provided on rather small parts of the basin, mainly on the sides of the river valleys.

3. Climatic characteristics

Climatic features of the Pregolya River basin are determined by the air masses going from the Atlantic Ocean (the western cyclonic transfer). This cyclonic transfer causes winds of western and southwest directions with the mean annual speed of 3.5 km/s, rather low mid-annual temperature of air (7 °C) and great mid-annual magnitude of atmospheric precipitation (over 700 mm). The mid-annual evaporation in the basin amounts 500 mm.

During an annual period the highest monthly average temperatures of air are typical for July (it's from 16.5 up to 17.5 °C), and the least, namely from 3 to 4 °C, are characteristic of January. A frost-free period in the basin lasts 160–180 days on average. The winter is noted for mildness, the number of days with snow cover amounts 60–80, and the ground freezes 30–50 cm deep. The greatest rainfall occurs during a warm season. Thus, monthly norm of precipitations is of 80–100 mm for August, and of 30–40 mm for January.

The flat reliefs, great rainfall, rather low evaporation, low water permeability of sediments lead to over moistening in the Pregolya River basin. These conditions have a great influence on all constituents of the systems, causing a high water-level in the rivers, a high level of groundwater stagnation, and a washing regime of soils. They also lead to the necessity of cultural and wood lands drainage, and agrochemical melioration of cultivated lands.

4. The vegetation and soil cover

4.1. The vegetation cover

The Pregolya River basin is located in the zone of mixed forests. The vegetation mantle in its limits is changed by economic activities of a man. Percentage of forest land is 21 percent, but the rest of the territory is occupied by agricultural lands, cities, roads, and etc.

The forestlands are spotted located on the territory of the catchment: the largest forestlands are in the valley of the middle stream of Pregolya and in the area of Vishtynets Lake. The main species are: oak, fir, birch, pine. The undergrowth presented by mountain ash, bird cherry tree, hazel, and other is well developed. The grassy area is changing according to the dominating species and the land form. A hardbeam and a European beech give originality to the forest tracks. These species are often present in the forest structure in the western part of the basin. Based on the data obtained from the Kaliningrad regional forest management, the phytomass of the forests in the Pregolya River basin can be estimated at 300 t/hectares.

The meadows used for hayfields and pastures occupy about 30 percent of the area. They are artificial and are characterized by high efficiency. The grass of the meadows is presented by grain crop and legumes. They are: bluegrass, timothy grass, clover, lucerne, and etc. In the valley of Pregolya the large part of the area is occupied by the water meadows.

4.2. The soil covering

On the territory of the Kaliningrad Oblast, and in the area of the Pregolya River in particular, the border of the West-European and Baltic soil provinces passes. Sod-podzolic soils, which are similar to brown wood, are characteristic of the West-European province occupying the western part of the basin. The Baltic province is characterized by sod-podzolic soils, which were generated under mixed coniferous-broad-leaved forests. The frequent replacement of the mother beds (clays, loams, sands) leads to the big number of soil diversities in the basin. Turfy soils, sod-gley soils, sod-carbonate soils and bog soils are also widespread. Bog soils are widespread on the low parts of the Pregolya River, and they are spotted presented in the hollows between the moraine hills. Heterogeneity of the soil covering in the Pregolya River basin is determined by the variety of natural conditions and long-term economic use of the lands. Because of the long-term regular melioration, processing, organic and chemical fertilizers application the soils are cultivated on the greater part of the basin. They can be referred to a cultural soil covering.

Humus content is an integrated fertility rate of a soil covering. According to data of the Kaliningrad center of agrochemical service, humus content in the soils of the region amounts 2.8 percent, or 80 t/hectares, at its optimum percentage of 3.5 percent and even more in the sod-podzolics. Taking into account that sod-podzolic soils are the dominant in the basin, increasing of its fertility is one of the vital ecological issues.

5. River and underground waters

To characterize river waters we used the data of the Pregolya River basin obtained from the reference books of hydrological character (Bazovye Gidrologicheskie Kharakteristiki… [The Basic Hydrological Characteristics…], 1974, 1978, 1988), and the results of calculations by means of a simulation model. The stream frequency at the catchment amounts 1 km per 1 km^2, that is determined by low location and surplus wetness of the territory. Due to drainage channels the stream frequency increases up to 1.5 km per 1 km^2 in the lower of Pregolya. The module of an annual flow amounts 6.1 l/sec/km^2 in the basin. The water balance elements in the basins of Pregolya and its main tributaries are presented in the Table 1.

Pregolya and its tributaries have small inclines; the flow velocity of the Pregolya River up to the arm of Deyma amounts 0.4–0.5 km/s. The flow velocities in the small rivers run up to 0.1–0.2 km/s. Mixed feeding is characteristic of the rivers of the basin. The floods are connected with both a spring tide and atmospheric precipitation. The spring tide lasts 40–50 days on average. Onset of waters from the Vistula Lagoon influences on the level regimen of the Pregolya River mouth. Low-water phenomena on the rivers are expressed indistinctly. The freezing-over lasts 2.5–3.5 months. The river waters are attributed to a hydrocarbonate class. The background chemical water analysis is mostly determined by the basin's location in a zone of surplus wetness, and also by the wash-out of chemical substances from the

Table 1

The water balance elements in the Pregolya River basin (the average long-term figures)

A river	A catchment's area, km^2	Annual discharge, m^3/sec	Deposits, mm	Evaporation, mm	Surface runoff, mm	Underground runoff, mm
The Pregolya River (Gvardeysk)	13 600	84.22	712	517	143	52
Lava	7 130	41.65	695	511	130	54
Instruch	1 250	8.1	724	520	152	52
Pissa	1 440	9.22	722	520	148	54
Angrapa	3 960	25.45	723	520	159	44
Golubaya	563	3.84	745	530	161	54
The Pregolya River Bed (from Chernyakhovsk to Gvardeysk)	697	5.18	770	536	176	58

agricultural lands. In the places of the large polluters' location, namely cities, cattle-breeding farms, warehouses of fertilizers, the chemistry is greatly changed.

The number of lakes in the Pregolya River basin amounts less than 1 percent. Vishtynets is the largest lake, located in the basin. Its area is 17.6 km^2. Surface water resources completely provide economic needs of the region. The river network of the Pregolya basin drains the underground waters of the upper cretaceous, paleogene and quarternary depositions. These waters belong to the zone of active water cycle.

Waters of upper cretaceous depositions are presented on the whole territory of the basin. Water-containing depositions consist of marls, aleurolites, aleurites, sands and sandstones. The occurrence depth of the aquifer increases from 25–30 m in the north of the basin up to 50–100 m in the south. Its power runs up to 100–160 m. Salinity amounts 0.5–4.5 gr/l, by the chemistry they belong to hydrocarbonate-chloride sodium waters.

Waters of paleogene depositions are spread in the western part of the basin. Water-containing depositions consist of fine-grained and anisomerous sands, aleurites and aleurolites. The occurrence depth of the aquifer amounts 10–25 m, and the power is 10–30 m. Salinity does not exceed 1 g/l.

The aquifers of quaternary deposits are widely developed in the Pregolya River basin. The interstratal waters of these depositions are presented by the Central Russian-Valdai and Lithuanian-Central Russian intermoraine aquifers. The water-containing sediments of the Lithuanian-Central Russian aquifer are anisomerous sands, with gravel and rubble partially. Its occurrence depth is 55–100 m, and the power is 5–15 m. The water-containing depositions of the Central Russian-Valdai aquifer are sands and sandy-gravel depositions. The occurrence depth of the waters varies from several metres up to 40–50 m, the power amounts 15–20 m on average. By the chemistry the waters of these aquifers are related to hydrocarbonate calcium; their salinity amounts 0.5 g/l on average. They are widely used for centralized water supply of cities, settlements, enterprises and farms.

The groundwater in the Pregolya River basin can be subdivided into the waters of delta, alluvial, sea, glacial, lake-glacial, and other depositions. Along the basin, the level of the groundwater bed is at a depth of 0.5–10 m. The power of the aquifer varies from 1 up to 10 m as a rule. Fluctuations of the groundwater level corresponds to the changes of sediments and balance of the atmospheric humidification. The drainage work has a great influence on the level regimen of the groundwater. The intra-annual regimen of the groundwater is characterized by the amplitude of the level fluctuations within the limits from 0.5 up to 1.5 m. The amplitude of the mean annual figures of the level in a perennial course amounts 1–3 m. The groundwater chemistry is the same as the other quarternary aquifers have, but the mineralization is less than 0.5 mg/l as a rule. The groundwater are used for local water supply.

6. Landscape differentiation

In the Pregolya River basin the following landscapes are presented (Barinova & Zotov & Kochurov, 1994):

(1) Moraine ridge-hilly plains: they are rising and rising sabulous-loamy, boulder sod-podzolic with brown forest soils that are divided by lowerings (valleys of the rivers, lakes, bogs) under fur-oak forests with the plots of pine and beechen forests. The ecologically significant factors are: a washout and scour of the soil, overwetting and marshiness of the lowerings.

(2) Moraine flat-hilly plains: they are rising and low boulder-loamy, boggy with sod-podzolic gleied, sometimes half bog and bog soils under fur and fur-broad-leaved forests that are boggy here and there. The ecologically significant natural factors are: a washout and scour of the soil, overwetting, marshiness, a difficult drainage.

(3) Lake-glacial plains: they are wavy both flat clay and sandy-silty-loamy with sod-podzolic gleyed soils under fur and fur-broad-leaved forests, that are often overwetting and boggy. The ecologically significant natural factors are: a surface layer of a wetness, marshiness, a weak drainage.

(4) Alluvial plains: they are hilly sandy weak-podzolic soils on the surface that are alternating with interhillock boggy hollows under pine forests, sometimes overwetted by fur forests. The ecologically significant factors: sands winnowing and marshiness.

7. Hydroecological situation

To estimate the hydroecological situation we use the approach developed in the works by N.I. Koronkevich, I.S. Zaytseva (1992), N.I. Koronkevich (1995), N.I. Koronkevich, I.S. Zaytseva, L.M. Kitaev (1995), and S.I. Zotov (2001). According to these works a hydroecological situation may be the various states of a water element of natural environment, that are important from the point of view of health, living conditions and man's activity, and providing environmental and resource reproducing functions of water geosystems and geosystems connected with them through a water cycle. We shall correct the basic figures of the estimation of the hydroecological situation taking into account nature-economic peculiarities of the Kaliningrad Oblast that are expressed in a seaside location, specificity of intra-annual flow distribution of the Pregolya River, agricultural specialization, high degree of land-reclamation, concentration of population and industry in the cities.

Last years the annual magnitudes of the Pregolya River runoff were close to the average long-term values and had no great influence on the hydroecological situation. Intra-annual flow distribution of the Pregolya River substantially determines quantitative and qualitative characteristics of the waters. At the winds of the northwest direction, which are observed annually in summertime, onset of the polluted water of the Vistula Lagoon occurs. This water can reach the water intakes above Kaliningrad, and sometimes the city of Gvardeysk that is located 40 km above the mouth. The Pregolya River stops and within the precincts of Kaliningrad the stagnant zone is formed: processes of putrefaction and decay of the polluted bottom deposits become more intense.

The agricultural production has a great man's impact on natural environment in the basin and it is an areal polluter itself. Over 60 percent of the area of the Pregolya River basin is used for agricultural lands, and over half of them are occupied by an arable land. In 1980–91 about 1.6–1.7 million tons of organic fertilizers, 500–600 thousand tons of chemical fertilizers and lime, and 350 tons of pesticides were annually applied to the fields in the basin. There are some tens of chemical fertilizers storages and more than 500 stock-rearing farms on the territory of the basin. The minimum of chemical fertilizers applying was marked in 1992–95. According the data that we received based on simulation, 15 percent of nitrogen and 1.7 percent of phosphorus that are brought to the Pregolya River basin with fertilizers, are usually carried away with the surface runoff, and 5 and 0.6 percent of nitrogen and phosphorus correspondently are carried away with groundwater (Zotov, 2001). For estimation of the qualitative state of the waters, it is necessary to place emphasis on nitride-phosphoric pollution. They were chosen as the main that was determined by superfluous entering of these substances that leads to the exceeded eutrophication of the Vistula and the Curonian Lagoons. The similar situation is typical for all the lagoons of the South-East Baltic.

We estimate the influence of an agricultural production on the waters' state through a degree of economic use of lands in the basins of the rivers. The following values of coefficients of lands use are based on the basis of degree gradation. They are: <0.6 is low; 0.6–0.8 is average; >0.8 is high.

A land-reclamation is another major factor of an areal influence on waters' condition. For elaboration of its degree gradation it's necessary to take into consideration connection of values of the surface runoff and occurrence depth of subterranean waters with the landscape differentiation. The greatest coefficient of the surface runoff (>0.9) and great occurrence depth of groundwater (>5) are characteristic of the landscapes of moraine ridge-hilly plains, therefore the degree of its melioration is low here. Inverse figures of these magnitudes (<0.7 and <2 m accordingly) are characteristic of the landscape of the lake-glacial plains; the high degree of its melioration is connected with it exactly. The mean values of these parameters (0.7–0.9 and 2–5 m accordingly) are marked for the landscapes of moraine hollow-hilly and alluvial plains.

It is also necessary to note, that under the identical proportions of both agricultural and forest lands and the structure of land-use these circumstances lead to that in the basins with the predominance of the landscapes of lake-glacial plains concentration of chemical substances (nitrogen and phosphorus, in particular) in groundwater are heightened. The influence of the examined factors causes more intense hydroecological situation in such catchments.

Enterprises of manufacturing industry and municipal services, concentrated in the cities of Kaliningrad, Chernyakhovsk, Gusev, Gvardeysk are the source of dotted, but strong man's impact. By 1.01.2000 population in these cities totals 426.3, 43.0, 28.0, 12.5 correspondently that amounts 54 percent of the region's population in aggregate. The data of the numbers of waste discharge in the basin in a retrospective review of several years are given in the Fig. 1.

Industrial-municipal runoffs of Kaliningrad and the peculiarities of the intra-annual flow distribution of the Pregolya River determine complication of a hydroecological situation in the mouth part. Mid-annual figures of oxygen content of the mouth waters exceed maximum permissible concentrations. However, constancy of these parameters is provided due to the autumn-winter season. In summertime, there are cases of oxygen lack and hydrosulphuric fish kill. The nitrates and nitrites content does not exceed the admissible values, but the ammonium nitrogen is more than a norm in 2–3 times, above and below Kaliningrad correspondingly. The phosphorus concentrations are characterized by the magnitudes exceeding maximum permissible concentrations above Kaliningrad in 1.5 times, and below the city more than twice. The increased content of easily oxidable organic substances is marked along all the mouth part of the river (BOD_5). In bottom-river deposits the concentrations of copper, arsenic, chrome, nickel, and zinc are increased.

On the basis of analysis of the information about man's impacts, river pollution and in accordance with the five gradation of waters states on a degree of ecological intensity (Koronkevich & Zaytseva & Kitaev, 1995) on the territory of the Pregolya River basin it is possible to point out the following hydroecological situations:

(1) The crisis (extreme) and conflict (complicated) situations have local spread and belong to the sources of severe contamination in the cities. The crisis is typical for the mouth part of the Pregolya River within the precincts of Kaliningrad, and the conflict situation becomes apparent within the precincts of the towns of Chernyakhovsk, Gusev, Gvardeysk, and some kilometres downstream the rivers.

(2) The strained (risk) and satisfactory (rather safe) situation can be considered as background, which is determined by an agricultural

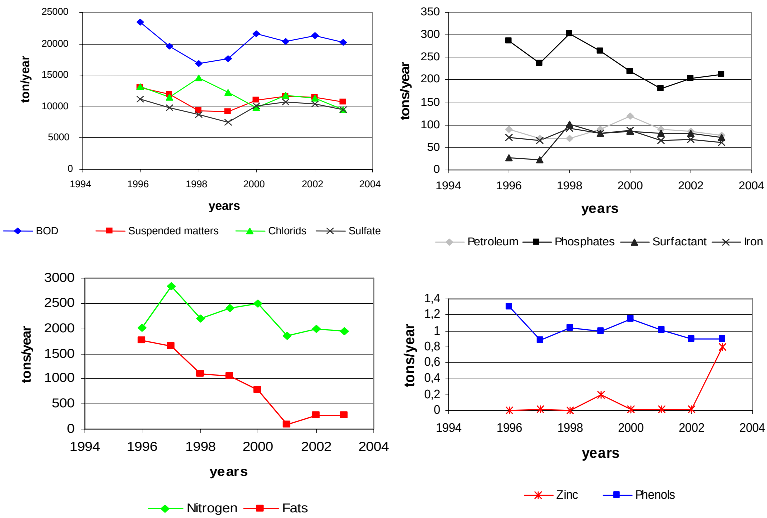

Fig. 1. Dynamics of pollutant load bringing with waste waters into the Pregolya River basin (according to data of the Department of Natural Resources and Preservation of Environment (the Ministry of Natural Resources of Russia)

load. The strained situation inheres in the rivers' basins where high degrees of economic use of lands and melioration of the territory meet. With low and average values of these parameters, the waters' state can be characterized as satisfactory.

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The Prokhladnaya River

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1. Introduction

The basin of the Prokhladnaya River is situated in the south-western part of the Kaliningrad Oblast. For the first time the river basin was interrogated by the researchers of the Department of Bioresources and Nature Management of Kaliningrad State Technical University in 1998. The river passes through the mixed forest (coniferous and deciduous forest) here and there. The riverbed and river banks are densely overgrown with the water coastal vegetation (reed, reed mace, manna, etc.), and the motley grass meadows appeared in many parts of the river floodplain.

2. Hydrological conditions

The Prokhladnaya River belongs to the group of small rivers (GOST, 1988) and its hydrological regimen depends strongly on the local factors. The length of the river is 59.7 km. The Prokhladnaya River is a

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young river as well as all the rivers of the Kaliningrad Oblast and it is characterized by a slight depth of the erosion cut.

The river springs in the swamp in the Ozersk area, flows generally in the western direction into the Vistula (Kaliningrad) Lagoon. The water catchment area is of 1100 km^2, and the average inclination is of 0.0006.

The Prokhladnaya River basin has a spacious and ramified hydrographic network. It is asymmetric as well as the basins of the most rivers in the Kaliningrad Oblast. The river basin pattern is pseudodentritic, the greater part of the water and practically almost all the tributaries flow into the Prokhladnaya River from the south, namely the left bank. Among them, there are also the largest tributaries as Kornevka, Rezvaya, Pokosnaya, the ditch of Shumnaya and the tributary of the second level—the Mayskaya River. The separate land-reclamation canals and the Zametnaya River flow into the Prokhladnaya stream from the north.

The river mouth is in the backwater of the Vistula Lagoon, the stream here is often expressed poorly. The river-bed is canalized 12 km upstream, meandering.

During the last three years, the part of the floodplain that is close to the river mouth was drained and overgrown with scrubs, but the river-bed became several times narrower. It could be mentioned that the summer period is characterized by low water levels than winter one. It can be illustrated with the seasonal dynamics of the highest and the lowest water levels both in summer-autumn and winter time. It proves that the water feed of the river during the warm winters mainly consists of the snow coming into the river at the time of thaws. Summer rain floods increase the river discharge much less. The river discharge depends on the water catchment area and the river network configuration. The insignificant forest area, the large swamped area of the basin, the broken relief of the basin territory and lithologic composition of the rocks promote the increase of the surface flow proportion in the whole volume of the water entering the river.

Bottom sediments of the Prokhladnaya River and its tributaries are represented mostly by muds, sandy muds and sandy-organogenous deposits.

The quantity of suspended matter in the waters of Prokhladnaya and its tributaries varies during a year and it amounted 2.8–12.2 mg/l in 1998. The clearly seen temporal dynamics in suspended matter concentration generally corresponding to the seasonal prevalence of biological processes and absence of the accordance with the hydraulicity changes demonstrate that the natural processes predominate over the anthropogenic ones.

The color of the water in Prokhladnaya and its tributaries usually has yellow-brown hues. It says about high content of organic substances of different origin.

3. Hydrochemical conditions

Waters of the Prokhladnaya River and its tributaries are hydrocarbon-calcious. The type of the water during the months of low water (May, June, August) is mainly the 1st ($HCO_3^- > Ca^{2+} + Mg^{2+}$), during the months of high water (Juli, September, Octoder) it is the 2nd ($HCO_3^- < < Ca^{2+} + Mg^{2+}$).

According to Alekin's classification (Alekin, 1970) the water mineralization varies from average (200–500 mg/l) up to heightened (500–1000 mg/l). The salinity extent in the upstream of the Prokhladnaya River, where the swamp waters prevail, is usually the average, while it is often heightened at the middle stream of the river. The water of the Prokhladnaya River has the average mineralization at the lower reaches of the river during the months of relatively high water levels (July and September). During another period in the 1998th their mineralization slightly exceeded 500 mg/l (at the expense of increase of the underground water proportion).

The dry residue giving detailed opinion about the water mineralization generally confirms these conclusions.

The water hardness in the Prokhladnaya River and its tributaries is the average (3.0–4.3 mg*equiv/l) in compliance with the existing classification (Zenin & Belousova, 1998). The data of 1998 displayed that the water hardness in the Prokhladnaya River basin was weakly connected with the river discharge. Disturbance of seasonal dynamics of this characteristic can be indicative of the river pollution.

The values of water alkalinity in the Prokhladnaya River increase in the lower reaches and it was in the range from 3.2 to 5.2 mg*equiv/l in 1998. The hydrogen ion exponent (pH) in 1998 was within the frames of an alkaline reaction (the maximum up to 8.7) and pH of swamp waters at the riverhead was closer to an acid reaction (about 7).

Oxygen conditions during the whole 1998 were more or less favorable though their common background content should be defined as reduced. Oxygen saturation of water did not exceed 100 percent even in the places of active water vegetation development. Oxygen deficiency was always observed in the river head (16–29%); with only 8 percent in July, 38 percent in October (oxidation processes slowed down when the temperature became lower). It is peculiar to the swamp waters. The oxygen concentration increases towards the lower reaches. Every tributary except the Pokosnaya River brings more oxygen saturated water to the stream. The oxygen monthly average concentrations reflect its natural seasonal dynamics. For instance, the heightened oxygen content was noted in May while the organic substances decomposition got slow because of relatively low temperature. The maximum in the dissolved oxygen dynamics was observed in August; evidently, it was connected with the photosynthesis peak.

The high concentration of organic substances was found in the Prokhladnaya waters in 1998. In accordance with Alekin's classification, the permanganate oxidability often could be estimated as heightened (10–20 mg O/l) and even high (20–30 mg O/l) at the riverhead. The maximum concentration of organic substances especially of hard organic substances was found at the riverhead; its concentration decreases towards the lower reaches. The least concentrations were observed in August and October, but the highest ones in May and July.

Seasonal dynamics of the organic substances content is not expressed clearly. Spring maximum of all the values was monitored in May. However, the concentrations of the examined substances increased and decreased correspondingly in the following months. Their minimal quantity was observed in October. Positive peaks in July and September were evidently connected with the influence of the flood water, which enlarge the wash-out of the organic substances from the river basin territory. Biogenous substances were often present in the examined watercourses. Their concentration mostly depended on the natural dynamics of photosynthesis and conformed to the yearly dynamics of the organic substances.

The maximum of concentration of ammonia nitrogen and nitrates dissolved in the Prokhladnaya River head was typical for the swamp-originated waters. The concentration of nitrogen compounds mainly decreased downstream. High concentrations were found in such tributaries as Kornevka and Mayskaya while the conditions in the Prokhladnaya River and the ditch of Shumnaya were more favorable. More over, in those points where many water plants have grown during the sampling period the concentration of ammonia nitrogen was much less because of intensive absorption. There were only comparatively small remains of ammonia nitrogen in the water. However, the large amounts of nitrites and nitrates were found because they were accumulated during permanent pollution.

In 1998 phosphate concentration at the middle and the lower reaches of the river was 2–3 times more than in the upper part of the basin. The maximum concentration was observed in August at the photosynthesis peak. It shows that the water was polluted by household wastewater.

4. Hydrobiological conditions

Zooplankton of the examined sections of the rivers in the Prokhladnaya basin included comparatively small number of species, namely twenty. Among them there is one species of Rotifera, eleven species of Cladocera and eight species of Copepods. Almost full absence of Rotifera is a peculiarity of zooplankton.

In the widened parts of the river stream zooplankton was present since the end of May (beginning of researches), while at the narrow segments it was found at least a month later.

There was no clear correlation of zooplankton's appearing and disappearing at the separate stations. It could be only mentioned that zooplankton is more probable for such places at summer time than in spring or autumn.

The drift plankton concentration is determined by its quantity in the back waters and widened parts of the stream. The maximum of zooplankton development was observed in July and August when the water temperature was 17–18.7 °C. Temporary ponds of the river flood-lands could serve as zooplankton's depositories.

Eighty-eight species of zoobenthos were discovered in the Prokhladnaya River basin; it is a peak in comparison with the all earlier researched rivers of the Kaliningrad Oblast. It includes 10 species of Oligochaeta, 5 leeches, 14 shellfish, 3 Crustacea, 1 sialid, 2 dragonflies, 12 day-flies, 3 caddis flies, 20 Chironomidae, 11 Trichoptera and others (7). Zoobenthos dynamics was not clearly defined because of the wide range of the dominant groups (Fig. 1). It is natural for such rivers and related to their hydrological pecularities.

It is significant that there are some seasonal dynamics in species composition. The biggest variation in zoobenthos quantity and biomass was observed along the river in May, the least variation was in September–October. Seasonal characteristics of zoobenthos in the Mayskaya River were less variable.

Water quality in the Prokhladnaya River and its tributaries is rather high, betamesasaprobe. It points out to the considerable river self-cleaning ability.

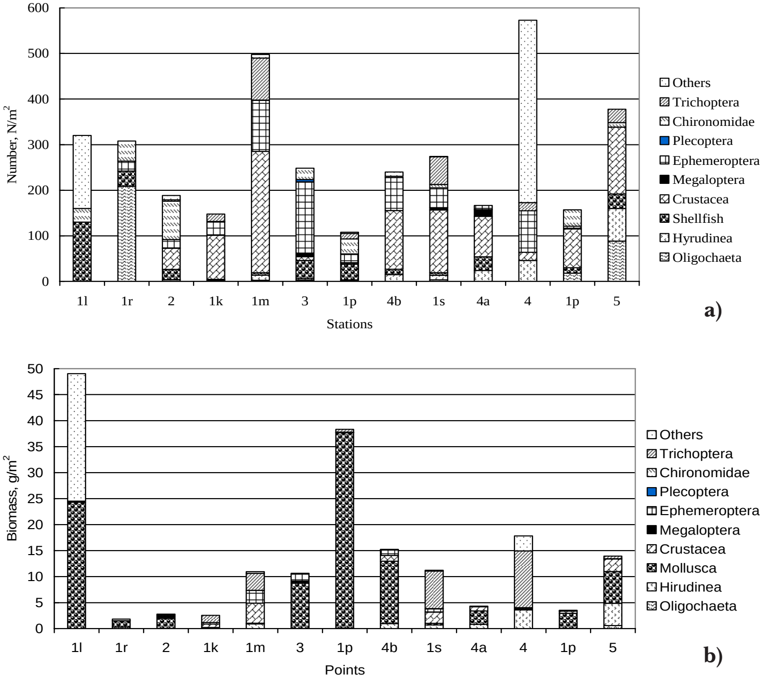

Fig. 1. Quantitative development of zoobenthos according to its number (a) and biomass (b) in the Prokhladnaya River.

5. Ichthyofauna

The data of the ichthyofauna structure and fish reproduction conditions in the Prokhladnaya River basin revealed their difference in the different sectors. The number of fish species increases from upper reaches towards lower reaches of the river. It is also connected with the loss of water quality (*water quality deterioration*) caused by the swamp water feed and anthropogenic pollution.

We discovered 17 species of fish and 1 species of Cyclostomata in the Prokhladnaya River and its tributaries in 1998 (Table 1).

There are many fish species in the Prokhladnaya River, which are common also for the other rivers flowing into the Vistula Lagoon. There is an evident similarity in their living conditions in spite of the existing water quality difference in the different river parts and its tributaries.

Table 1.

Ichthyofauna of the Prokhladnaya River.

Lamprey	Lampetra fluviatilis
Brook trout	Salmo trutta m. fario
Pike	Esox lucius
Roach	Rutilus rutilus
Dace	Leuciscus leuciscus
Bleak	Alburnus alburnus
Owsianka	Leucaspius delineatus
Crucian carp	Carassius carassius
Tench	Tinca tinca
Groundling	Nemachilus barbatulus
Gudgeon	Gobio gobio
Minnow	Phoxinus phoxinus
Burbot	Lota lota
Perch	Perca fluviatilis
Ruff	Gymnocephalus cernus
Sculpin	Cottus gobio
3-spined stickleback	Gasterosteus aculeatus
9-spined stickleback	Pungitius pungitius

Reophile species (sculpin, trout, bulltrout) are more often to be found in the relatively favorable sectors. Limnophile species (roach, crucian, dace and others) inhabit the large part of the river and its tributaries.

The Prokhladnaya River is one of the few rivers in the Kaliningrad Oblast which has favorable conditions for the recreational fishing development especially in the mouth part. Representatives of the most freshwater species of the Vistula lagoon's ichthyofauna are to be found here. It is necessary to realize a complex of nature protective measures on improving of the river reproduction ability. Some parts of the river also need hydrotechnical and water-reclamation works.

6. Conclusion

Our researches testify the necessity of the nature protective measures in the Prokhladnaya River basin. This complex of measures should include:

• Regular observation and control of the river condition and main activities in the catchment area;
• Elimination of the polluters;
• Clearing of the impure river-bed parts;
• Conducting of hydrotechnical and reclamation works in some sectors;
• Organizing of sanitary and water protection zones etc.

Implementation of such works will create prerequisites not only for improvement of the valuable marketable fish species reproduction but also for recreational zone development.

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The Primorskaya River

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1. Introduction

The Primorskaya River is situated in the western part of Sambian peninsula. For the first time the detailed complex investigations of the Primorskaya River basin were carried out by the scientists of the Ichthyology and Ecology Department of Kaliningrad State Technical University in July–October 1999.

2. Hydrological conditions

The Primorskaya River flows along the border of two landscapes: the moraine high hilly plains and plateau and the glacial flat wavy plains. Hilly and flat topography with the heights of 30–35 m predominates in the landscape and it declines from the north-east to the south-west. The natural landscape is damaged by active and old drawn open

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pits and excavations, which are dispersed chaotically over the whole basin's area. Percentage of the forestland of the river basin within this landscape is 1–2 percent, percentage of the area occupied by the lakes is the 3–4 percent.

Agricultural lands are mixed with small asp-oak copses, birch woods, not big oak-ash, and alder-birch groves both in the river basin and in landscape. The part of the water-logged grounds in the landscape is greatly developed in the upstream part. There are also many small saucer-shaped lakes and ponds here. Meadow vegetation is represented by heavily modified perennial meadows (natural and sown ones) and pastures. Motley grass and meadow—marsh complexes prevail in the southern part of the river basin.

The Primorskaya River heads in the small lake, and flows to the south from the settlement of Pokrovskoye. Primorskaya has rather developed river network. The river's length is 15.25 km, the length of the watershed is 48.5 km, the water catchment area is 112 km^2. The river basin is asymmetric, the pattern of the river network is pseudodentritic. The greater part of the water and practically all tributaries flow into the Primorskaya River from the left bank. The only small brook flows into the Primorskaya River from the right.

The Koziya River that is of 4 km long, and the brook 10 km long flowing into the Primorskaya River from the settlement of Povarovka in the south should be mentioned as the most significant tributaries.

The brook drains the northern strongly water-logged part of the river basin and it has the well-developed network consisting of soil-reclamation canals (both drainage and aqueduct ones) and separate springs. At the middle reaches the river looks like a rectified soil-reclamation canal flowing along the wide hollow covered by meadow-marsh coenosis and small birch-alder groves. Towards the south, it flows into the well-defined trapezoid valley with the flat slopes and the narrow distinct flood-lands, which are raised over the water edge up to 1.0–1.5 m here and there. The riverbed is meandering, not wide. The river banks are overgrown with the dense coastal and water vegetation (iris, reed mace, valerian, sedges, nettle). In this part the river bottom is sandy-muddy, stony and rubbly here and there; at the higher reaches it is sandy. At the lower reaches Primorskaya passes along the wide water-logged valley which is drained by the dense land-reclamation network. The flood-lands are water-logged, overgrown with shrubs and bush of the black alder. The river banks are covered with high grassy vegetation (bushgrass, blooming sally, bind weed, five-finger, burdock, sow-thistle, sedge and others). The river bottom is muddy,

muddy-sandy, heavily polluted. About 800 m upstream of the river mouth the canal (the Sadovaya River) flows into the Primorskaya River. It brings the water, which are used for land reclamation and are overloaded with organic and biogenic substances. Numerous drainage canals collecting the pollutants from the whole drainage region flow into the Primorskaya River close to the mouth. The mouth part of the Primorskaya River is on the one hand in the backwater zone of the Vistula Lagoon. But on the other hand, it flats on the low-lying water-logged flood-lands. Influence of these factors becomes especially well apparent during the low-flow. Flow velocity decreases here down to the values less than 0.036 m/s.

Observations in July–September were fulfilled in the low-water season. Autumn rain floods began in October. The amount of suspended solids found in the Primorskaya River was 2/0–18/8 mg/l, the minimum was in September and the maximum was in October. Changes of the suspended solids amount mostly correspond with the river hydraulicity. It can be easily explained by the increasing of discharge of the soil and swamp waters into the river during the high-flow periods.

3. Hydrochemical conditions

Water of the Primorskaya River is hydrocarbon-calcious. The type of the water is the 2nd ($HCO_3^- < Ca^{2+} + Mg^{2+}$). According to Alekin's classification (Alekin, 1970) the water mineralization is the average (200–500 mg/l).

In compliance with the existing classification of water hardness (Zenin & Belousova, 1988), the water of the Primorskaya River is defined as soft (water hardness less than 4 mmol/dm^3) or the average (4–8 mmol/dm^3).0–4.3 mg*equiv/l). It is natural that the water hardness is inverse to the river hydraulicity.

Hydrogen ion exponent (pH) is either neutral or within the frame of alkaline reaction. Oxygen conditions were more or less favorable though their common background content should be defined as reduced. Even in July during intensive photosynthesis the abundance of oxygen in the water did not exceed 85 percent. It could be explained by several reasons. Firstly, the river flows through the water-logged area and accepts numerous land-reclamation canals with the water, poor in oxygen. Secondly, the share of the ground waters that is poor in oxygen is high at the low-water season. Pollution also has an impact on the situation. On the whole oxygen conditions meet the requirements of the maximum allowable concentrations.

The amount of organic substances contained in the water was mainly moderate or heightened. For example, according to Alekin's classification (Alekin, 1970), permanganate oxidability was estimated as the average (5–10 mg O/l) from July until September and as heightened (10–20 mg O/l) in October. COD was usually within the diapason of 15.84–34.85 mg O/l. BOD exceeded maximum allowable concentration for drinking and household waters. Heightened concentration of organic substances in the water could be caused by two reasons. First, amount of organic substances in the water is proportional to the total biomass of the vegetable and animal organisms inhabiting the water object. Secondly, it is the consequence of the pollution. Along the great part of its length the river runs through the deciduous forests, thick alder bushes (mainly a black alder). The river banks and often the river bed are densely overgrown with coastal-water vegetation and cluttered up with the branches of the trees and shrubs (sometimes also with the trunks). It lets the large amount of organic substances come into the water.

Biogenious substances were always present in the river and sometimes their content was rather high. Only concentration of the nitrite nitrogen in some cases decreased down the level "trace". Maximum of nitrogen compounds was observed in October, it was especially well defined in nitrate content. It could be caused by the increase of the share of the surface feed, which brings the heightened volume of the waters from numerous land-reclamation canals including the swamp waters.

The phosphorus concentration varied within the rather small limits namely from 0.025 to 0.037 mg/l during all the months except August. In August it increased up to 0.049–0.068 mg/l.

It should be mentioned that there are comparatively few sources of the anthropogenic pollution at the upper and middle reaches of the Primorskaya River. The river passes here and there through the agricultural lands and relatively small settlements among which Pokrovskoye is the largest. Water catchment area is water-logged, therefore, the river is used for washing of the drainage waters through the network of the land-reclamation and drainage canals, that affects the river's hydrochemical conditions greatly. The swamp waters are poor in oxygen but they contain a lot of organic substances especially hard organics. This water also contains hardly available forms of biogenious substances. The town of Primorsk is a polluter at the reach.

Natural seasonal dynamics of the main hydrochemical parameters (connected with the vital functions of the water life) is to be observed in some sections, particularly at the upper and middle reaches of the river. Therefore, the activity of the natural processes exceeds the intensity of pollution. At the same time, the heightened amount of organic substances and especially organics in the river water should be mentioned once again. Their oxidation causes the deterioration of the oxygen conditions. There is a surplus content of the nitrate nitrogen in the water.

According to the hydrochemical indices, the water of the Primorskaya River can be defined as moderately polluted.

4. Hydrobiological conditions

There were found five species of zooplankton in the Primorskaya River including *Rotatoria Brachionus calyciflorus, Euchlanis sp*. and *Asplanchna priodonta; Cladocera—Daphnia cucullata; Copepoda—Mesocyclops leuckarti*. Besides them benthos and periphyton organisms were among the plankton including *Oligochaeta—g. Nais, Ephemeroptera—Centroptilum luteolum, Chironomidae—daun familia Orthocladeinae, Crustacea—Gammarus sp*., and also larve *Plecoptera, Simuleidae, Coleoptera* etc.

A zooplankton structure was absent. The species were found isolated or in the random combinations.

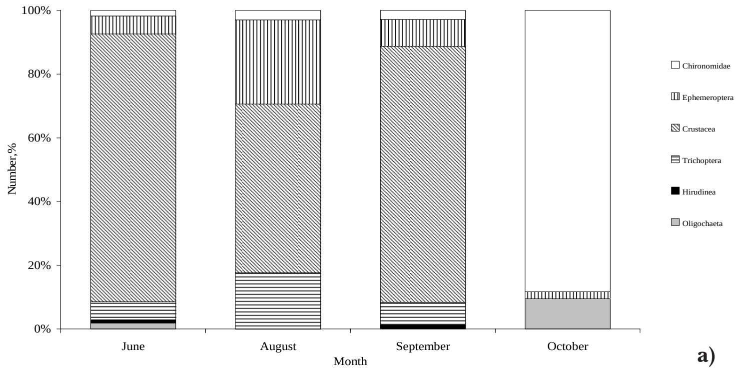
It was rather difficult to observe the dynamics of the allochthonous zooplankton. It did not have a structure and that is why distribution of groups' representatives was random. At the same time, the drift plankton reflected its development in the whole river basin rather than in the river bed.

Zoobenthos of the Primorskaya River consisted of the small number of species namely fourteen, including 3 *of a Mollusca*, 1 of a *Megaloptera*, 2 of a *Ephemeroptera*, 4 of a *Trichoptera*, 2 of a *Chironomidae*, and 2 of the others.

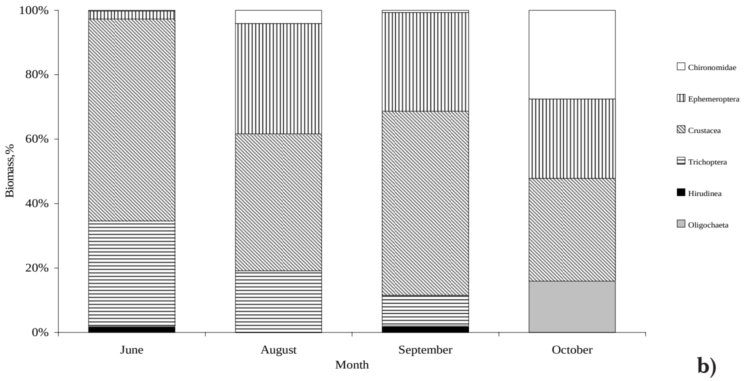
Oligochaeta were represented by the family *of Tubificidae* and mostly belonged to the genera of *Limnodrilus* and *Potamotrix*. They amounted 1.0–14.5 percent of the number and 0.0–2.2 percent of the biomass (Fig. 1).

Crustacea belonged to the genus of *Gammarus* and played an important role in formation of the zoobenthos number (up to 37.5–56.0%) and biomass (up to 31.0–38.0% of the biomass).

Hirudinea belonged to the widely spread species of *Glossophonia complanata* and *Erpobdella octoculata*. They made up a small part of the zoobenthos number (0.7–0.8%) and biomass (0.1–2.3%). *Ephemeroptera—Centroptilum luteolum* and *Ephemera vulgata* formed 0.6–21.2 percent of



a)



b)

Fig. 1. Seasonal correlation of some groups of the benthos organisms according to their number (a) and biomass (b) in the Primorskaya River.

the number and 2.6–16.7 percent of the biomass. *Trichoptera* amounted 0.2–50 percent of the number and 1.0–55.0 percent of the biomass. *Chironomidae* made an essential share of the number (2.9–40%) and a small share of the biomass (0.2–8.0%). During the whole period of investigations, *a Procladius ferrugineus* was discovered.

The sialids *(Syalis lutaria)* were the most common among the other organisms. This group did not have a special meaning for formation of quantitative indices of the benthos making 1.4–8.8 percent of its number and 1.7–5.2 percent of the biomass.

The average level of the benthos development was very low and moderate. Number of Wudewiss biotic index varied from 2 up to 6.

5. Ichthyofauna

Investigations carried out in the Primorskaya River and its tributaries in 1999 allowed us to discover 16 species of fish and 1 species of *Cyclostomata* (Table 1).

Table 1.

The ichthyofauna of the Primorskaya River.

Lamprey	*Lampetra fluviatilis*
Pike	*Esox lucius*
Roach	*Rutilus rutilus*
Dace	*Leuciscus leuciscus*
Bleak	*Alburnus alburnus*
Owsianka	*Leucaspius delineatus*
Crucian carp	*Carassius carassius*
Tench	*Tinca tinca*
Gudgeon	*Gobio gobio*
Minnow	*Phoxinus phoxinus*
Burbot	*Lota lota*
Perch	*Perca fluviatilis*
Ruff	*Gymnocephalus cernus*
3-spined stickleback	*Gasterosteus aculeatus*
9-spined stickleback	*Pungitius pungitius*
German carp	*Carassius auratus gibelio*

Besides the listed fish species, there are typical representatives of the Vistula Lagoon inhabiting the mouth reach of the Primorskaya River. They are: a bream (*Abramis brama*), sander (*Stizostedion lucioperca)*, eel (*Anguilla anguilla*) and others.

The structure of the similar species of the ichthyofauna is observed in the Primorskaya River basin as well as in the other rivers of the Kaliningrad part of the Vistula Lagoon. Some distinctions can be properly explained because of the insufficient period of the investigations and the difficulties of fishing of some species (especially an anadrom and semidiadrom). There are some obstacles to the fish species migration in some parts of the Primorskaya riverbed, namely branches and trunks of trees, household rubbish). Regular sanitary cleaning of the riverbed should be done in order to increase effectiveness of the natural reproduction of the valuable fish species such as brown trout (*Salmo trutta*) and salmon (*Salmo salar*).

6. Conclusion

A special attention should be paid to cluttering up of the Primorskaya River coastal areas (unapproved dump-sites) and of the river itself. It creates unattractive image of the river and it puts obstacles in the way of some anadrom and semidiadrom fish species spawning. To improve the ecological situation of the Primorskaya River and increase its recreational function it is necessary to improve water management, strengthen the control and increase responsibility of water users for the pollution.

It is also considered wise to clear the riverbed away, and get rid of the blockages. It would improve the hydrochemical conditions and reproductive capacity of the river, especially for the valuable anadrom fish species.

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The Mamonovka River

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1. Introduction

The river basin of the Mamonovka River system is situated on the extensive territory in the south western part of the Kaliningrad Oblast and in the northern part of Poland. Complex investigations of the Mamonovka River basin were carried out by the scientists of the Ichthyology and Ecology Department of Kaliningrad State Technical University monthly from May till October 1996. Hydrological researches and sampling were made at the mouth reaches of all tributaries, in the mouth zone of the Vistula (Kaliningrad) Lagoon, namely in the representative points or places of possible pollution at the higher reaches.

2. Hydrological conditions

The southern and south-western parts of the Mamonovka River catchment area are the highest. This part of Varmia Hills called Gurovskiye Heights has a very broken relief with hill ridges. It gives a rise

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to the main tributaries of Mamonovka and determines a character of their hydrological conditions to a certain extent. Many tributaries of Mamonovka spring here. They are: Banuvka, Ignatievka, Ovsyanka, Lavya and other small rivers. Considerable depths of erosion cut and narrow deep valleys with low, often implicit flood-lands are typical for these rivers. Northern part of the basin is different. Its river network is not dense, but broad, waterlogged here and there. Flood-lands and valleys with gentle slopes are characteristic for the most river and water courses (Kucheryavy & Fedorov, 1980).

In accordance with the standard classification (GOST, 1988), the Mamonovka River belongs to the group of small rivers and its hydrological regimen is strongly dependent on the local factors. The Mamonovka River springs from the junction of two rather large rivers—Vitushka and Banuvka (Banal)—in the town of Mamonovo. The Vitushka River is about 25 km long, and Banuvka is of 20 km long. The Mamonovka River is less than 6 km long. The level of the river at the distance of 600–700 km upstream from the river mouth is in the backwater of the Vistula (Kaliningrad) lagoon. The river width between the shores lines at the mouth reach is 15–20 m. The river banks here are overgrown thickly with manna, the bottom is muddy sand covered with sludge sediments with a touch of canalization products. Sometimes the water surface is covered with black roundish clots rising from the bottom. The river flood-lands upstream from the backwater zone are wide. It has gentle-steep slopes overgrown with osier-beds, nettle and other representatives of the meadow motley grass. Sedge grows only along the water line. The river inclination is considerable, the stream is fast. The river flood-lands are littered with twigs and brushwood of old osiers and alder-trees. There are small saucer-shaped logs with moor vegetation. The river banks are abrupt here and there; the valley edge is about 1.0–1.5 high over the shore line.

The Goluba River flows into the Mamonovka River 1.2–1.3 km upstream from the Mamonovka mouth. It heads in Poland. The river-bed of Mamonovka is partitioned by the fallen trees off the Goluba mouth. There is a spacious creek in front of the Goluba mouth. The slopes of the valley are steep; the flood-lands are distinctive but not wide.

The river basin is asymmetric, only 0.1 of its area fall to the share of the right-bank part while practically the whole hydrographical network is situated on the left bank. The basin area is about 400 km^2 and more than its half is in Poland. All large tributaries head in Poland. The only exception is Vitushka which runs through the territory of the Kaliningrad Oblast. All the rest tributaries of the first-order (Banuvka, Goluba), the second-order (Ignatievka or Omaza, the Vilki, Lavya or Lavtya) and the third-order (Ovsyanka) as well as many other small tributaries flow through the territory of Poland.

The Vitushka River is the most polluted watercourse in the Mamonovka hydrographical network. Untreated waste water of the Mamonovo municipal sewerage, household waste water and untreated waste waters from the rearing farm discharge into Vitushka. Water has a dull-grey colors and strong smell of hydrogen sulphide. The bottom is sandy and covered with dark-grey sediments typical for sewage. There are deposits of the sewerage products near the banks. Conditions in the Vitushka differ from ones in the Banuvka River (Banal) which brings transparent water. Its bottom is clean and sandy. The character of these two rivers' junction and their water mixture can be observed distinctly.

There are pump stations at the mouth reach of the Mamonovka River which are intended for the run-off regulating and for the discharging the water excess. However the pumps are damaged and do not function.

The hydrometric characteristics of the Mamonovka River at the lower reaches upstream the back-water zone were the following: the river-bed width between the shore lines varied from 10.0 m in August to 16.9 m in May. The average depth was about 0.5 m, an average maximum was about 0.8 m, the absolute maximum was 1.33 m in May. The average flow velocity was 0.2 m/s, an average water discharge was 1.4 m^3/s. Observations were carried out mostly in the period of low-water when the contaminants concentration rose steeply.

3. Hydrochemical conditions

Waters of the Mamonovka River and its tributaries are hydrocarbon-calcious. The group of water changes to a sodium one only in the places of the strongest discharge household-industrial waste water (outlet of the filling station at the lower reaches of the Mamonovka River and at the mouth reaches of Vitushka). The type of water is the 2nd in May ($HCO_3^- < Ca^{2+} + Mg^{2+}$), the 1st from June till September ($HCO_3^- > Ca^{2+} + Mg^{2+}$), and the 3rd in October ($HCO_3^- + SO_4^{2-} < Ca^{2+} + Mg^{2+}$).

The water mineralization varied from 270.6 to 465.4 mg/l and it could be defined as an average one (200–500 mg/l) according to Alekin's classification (Alekin, 1970). Its temporal changes are on the whole inverse to the river hydraulicity. In accordance with it the minimum mineralization (270.6–279.4 mg/l) was observed in May, the maximum one (445.9–465.4 mg/l) was in August–September. The highest mineralization along the river (279.4–465.4 mg/l) was found at the middle reaches of Mamonovka. Mineralization values did not increase downstream what would expected in natural conditions, it decreased down to 270.6–475.5 mg/l. It could be explained with some self-cleaning of the river at its mouth reach. Therefore, the mineralization increase (due to the river pollution) exceeded the influence of the lagoon even in the zone of the level back-water. Amount of suspended solids was widely ranging. In Mamonovka it decreased gradually from 24.2–29.1 mg/l in May down to 2.1–3.7 mg/l in October. The upper limit was always observed at the middle reaches. It was usually several times higher as in Banuvka. For instance, on the 18th of June 1996, there were found only 4.1 mg/l of SS at the mouth of Banuvka while at the mouth of Vitushka there were 18.0 mg/l, and 13.8–16.1 mg/l in the Mamonovka River (the maximum was fixed at the lower reaches). The same characteristics in the rest tributaries did not exceed 9.0 mg/l. Concentration of suspended solids in the Vistula lagoon was 21.9 mg/l in June.

In accordance with Baranov's classification (Baranov, 1962) the water in the Mamonovka River and its tributaries is usually defined as middle hard (3.0–4.3 mg*equiv/l). Water alkalinity mainly increased (while) as far as hydraulicity decreased from 2.496–2.642 mg*equiv/l in May up to 4.700–4.805 mg*equiv/l in September, but it was a bit less in October (4.493–4.545 mg*equiv/l). Water alkalinity in tributaries was usually lower. Hydrogen ion exponent (pH) was within the frame of an alkaline reaction. In the Mamonovka River it always exceeded 8 varying within the limits of 8.03–8.14 and as a rule maximum was downstream from the town of Mamonovo. Exceptions were observed in June and October in the mouth part (pH=7.98). Big amount of carbon dioxide was always found at all stations even at the time of the intense photosynthesis.

Oxygen conditions were extremely unfavorable in all months, oxygen deficiency was observed in the most cases i.e. its saturation was less than 50 percent and lower than low concentration limit for all types of the waters (Okhrana Okruzhayuschey Sredy [Environment Protection], 1978; GOST, 1981; Spravochnik po Parametram Vody [Reference Book], 1980; SanPin, 1988; Normy Kontsentratsii [Surface Water], 1991) especially for needs of the fish industry. The oxygen concentration decreased downstream the river mouth. Especially bad gas conditions developed in dry and rather warm August when concentration of dissolved oxygen was only 3.93–3.05 mg/l (38–31 percent of saturation). Bad conditions were also in September: (4.73–3.92 mg/l or 41–34 percent of saturation). Hydrogen sulphide was always found at the junction of Vitushka and Banuvka. High content of biogenous substances and particularly ammonia nitrogen was observed. In August its concentration downstream Mamonovo was 9.926 mg/l. It is nine times more than maximum allowable concentration for needs of the fish industry in the water bodies of the superior and the first category and almost four times higher as for the fish-industrial waterbodies of the second category.

There is also much nitrate nitrogen in the water especially in May (2.08–2.27 mgN/l). Nitrite nitrogen was always present as well. Phosphates quantity in August was 0.828–964 mg P/l, it is twice as high as the maximum allowable concentration for drinking and household waters. Big amount of the biogenics is also dissolved in the waters of the Mamonovka tributaries especially in Vitushka in the place of its junction with Banuvka. Concentration of organic substances is high that is testified by the characteristics of permanganate oxidability, COD and BOD_5–BOD_{20}. According to Alekin's classification (Alekin, 1970), permanganate oxidability in May–June and October was estimated as heightened (10–20 mgO/l), at the rest time it was average (5–10 mgO/l) at the mouth reach. The evident decrease of oxidability in June–October could testify the low activity of photosynthesis (it is also proved by low oxygen content and high carbon dioxide content). All this is connected with a very heavy pollution of the river. Water oxidability of in June–August was heightened in all tributaries except Banuvka and at the mouth of the Vitushka River it was even higher (20–30 mg O/l).

COD was also heightened. As a rule in all months it was more than two times higher as the admissible concentration limit for drinking water (Okhrana Okruzhayuschey Sredy [Environment Protection], 1978; GOST, 1981; Spravochnik po Parametram Vody [Reference Book], 1980; SanPin, 1988; Normy Kontsentratsii [Surface Water], 1991) and in May at the river mouth even admissible concentration limit of COD for household was exceeded. It meant that COD was more than four times higher than it is allowed for drinking water. BOD gives the same results and even more catastrophic ones especially in June and July. In these months BOD at the Mamonovka River mouth exceeded admissible concentration limit for drinking water (3 mgO_2/l) in 20–25 times and in 10–14 times for household needs of the population (6 mgO_2/l).

Natural seasonal dynamics of majority of the main hydrochemical parameters is either slightly marked or disturbed. It especially concerns those ones, which are connected with vital functions of the water life one way or another. It can prove that the intensity of the hydrobiological processes in the river during our observations was less than the pollution intensity. And what is more, pollution at this low-water period was so acute that it could oppress the vital functions of the water life. Especially unfavorable characteristics were observed in the dry and hot August.

The most heavily polluted tributaries (among the worst ones) are Vitushka, Ovsyanka, Goluba, sometimes Lavya. The least polluted tributary is Banuvka.

4. Hydrobiological conditions

Zooplankton development in Mamonovka and in the rivers of the Mamonovka basin is typical for the small river systems. Description of the main appropriateness of its development could be found in the fundamental works (Lipin, 1950; Odum, 1975).

But the small size of the rivers determines their individual peculiarities. Recurrence frequency of some conditions finally defines the trophic status of the river as a whole.

During the vegetation period there were found 33 species of zooplankton in the Mamonovka River. In the Vitushka River there were found twelve species of zooplankton. At the mouth reaches of Goluba, Ovsyanka and Banuvka 2–4 zooplankton species were to be observed. A degree of likeness of zooplankton species structure with the rivers in the Mamonovka hydrographical network is not more than 40 percent.

Crustacea form the quantity and the biomass of zooplankton. Rotifera play the minor role. In the beginning of the vegetation period zooplankton has no structure and it could be seen in the diagram (Fig. 1). The exact calculation of the correlation between the biomass of the different groups is impossible because of their small number, and it explains the absence of the May column in the diagram (Fig. 1).

The maximum zooplankton biomass in the Mamonovka River was 0.530 g/m^3; but in Banuvka and in Vitushka it was much less (0.003 g/m^3).

Saprobiological characteristics describe the water in the Mamonovka River basin as moderately polluted (according to the organisms of zooplankton). It is cleaner at the higher reaches (Banuvka, Vitushka).

Among zoobenthos of the Mamonovka River there were found 47 species of the invertebrate including 8 Oligochaeta, 3 leeches, 2 Crustacea, 8 shellfish, 1 sialid, 1 caddis fly, 1 day-fly, 2 Trichoptera, 19 Chironomidae and 2 others.

Distribution of the organisms on the river bottom is extremely irregular. Amplitude of the variations of benthos number and biomass between the stations sometimes exceeds its seasonal changes.

Correlation of species between the stations is variable as well. Benthofauna is the mostly diverse in the end of spring and the first half of summer. In autumn diversity decreases. Chironomidae dominate during the whole period in a number, Chironomidae and shellfish dominate in a biomass (Fig. 2).

Water quality of the bottom layer in the Mamonovka River estimated according to the indicative characteristics of zoobenthos is much worse than the quality of the surface waters. Bottom waters are polisaprobe and alfamesasaprobe.

5. Ichthyofauna

Investigations carried out in the Mamonovka River and its tributaries allowed us to reveal 18 species of fish and 1 species of Cyclostomata (Table 1).

Table 1.

Ichthyofauna of the Mamonovka River.

Lamprey	Lampetra fluviatilis
Brook trout	Salmo trutta m. fario
Pike	Esox lucius
Roach	Rutilus rutilus
Dace	Leuciscus leuciscus
Bleak	Alburnus alburnus
Owsianka	Leucaspius delineatus
Crucian carp	Carassius carassius
Tench	Tinca tinca
Groundling	Nemachilus barbatulus
Carp	Carpio carpio
Gudgeon	Gobio gobio
Minnow	Phoxinus phoxinus
Burbot	Lota lota
Perch	Perca fluviatilis
Ruff	Gymnocephalus cernus
Sculpin	Gottus gobio
3-spined stickleback	Gasterosteus aculeatus
9-spined stickleback	Pungitius pungitius

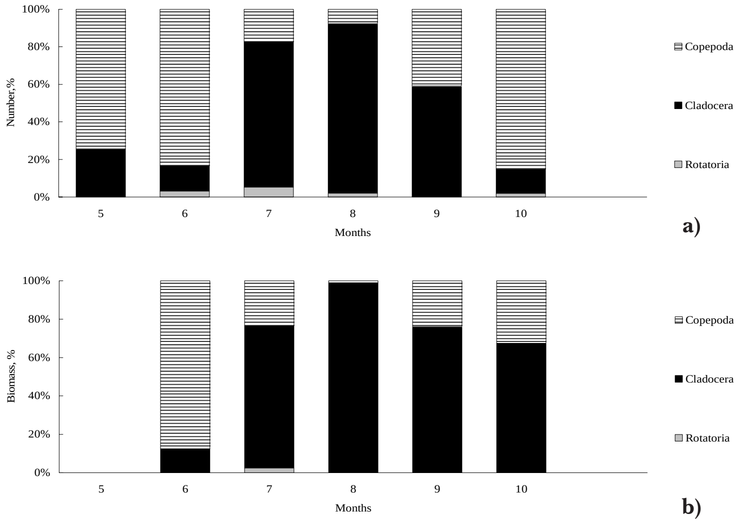

Fig. 1. Correlation of the main zooplankton groups according to number (a) and biomass (b) in the Mamonovka River.

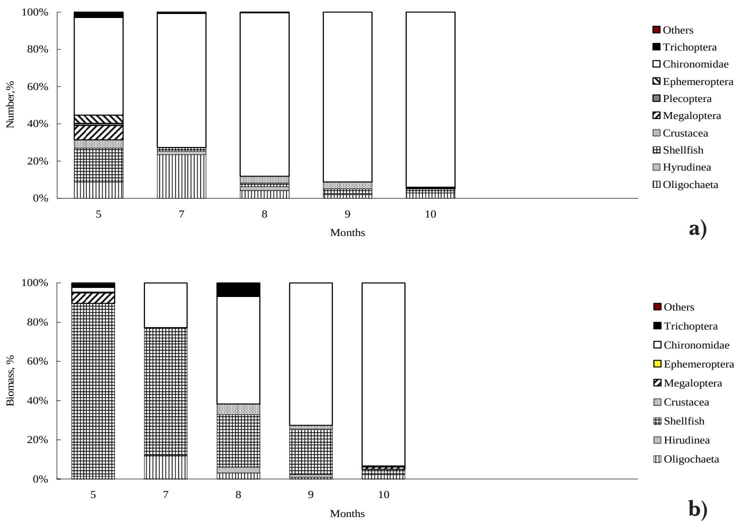

Fig. 2. The number (a) and biomass (b) correlation of the zoobenthos community in the Mamonovka River.

Besides the enumerated fish species, the typical representatives of the Vistula lagoon are: bream (Abramis brama), sander (Stizostedion lucioperca), eel (Anguilla anguilla) and others. They are also to be met at the mouth reaches of the Mamonovka River.

The river basin undoubtedly is of concern for more efficient use of some its parts for the natural reproduction of the valuable anadrom fish such as brown trout (Salmo trutta) and salmon (Salmo salar).

However, the reproductive ability of the river and especially of some its tributaries decreases because of the different barriers including the dams in town of Mamonovo, in the settlement of Novosyolovo and others.

In spite of the river pollution the species diversity of the water life is still preserved. It is possible to achieve the substantial improvement of the ecological conditions of the river, conservation of the species structure of the aquatic animals including the rare and valuable species in case of prevention of the river pollution.

6. Conclusion

Drawing a conclusion it's important to mention the following facts: the water catchment area of Mamonovka and the river itself with its largest tributaries are very interesting as a natural object which has peculiar features of the glacial landscape coming from the Quaternary (Valday) glaciating. The river basin is very specific. It is situated at the turn of two physiographic provinces. The peculiar features of the West European physiographic provinces are more apparent within the boundaries of the river basin: warmer and damper climate, predominance of the deciduous formations in particular pronounced oak-hornbeam, oak-beech and especially beech forests.

Composition and structure of the Mamonovka waterscape and landscape complexes are of the unique value from the point of view of the natural-climatic, geomorphologic and many other conditions.

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The Sheshupe River basin

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1. Characteristic of the Sheshupe River basin

The Sheshupe River basin is located in latitude between 54°34´ and 55°10´ North and in longitude between 23°40´ and 22°10´ East. Its heads in Poland, crosses the Lithuanian territory, then passes along the Lithuanian-Russian border, and finally crosses the Kaliningrad Oblast (Russia) area and inflows into the Nemunas (Neman) River that is a border river between Lithuania and the Kaliningrad Oblast (Table 1).

The Sheshupe River is the second largest left-side tributary of Nemunas, with the basin area of 6105 km^2 and the total length of 297.6 km. It joins the Nemunas River 85 km from the Nemunas mouth, below the Smalininkai settlement (Lithuania) and above the City of Sovietsk (Russia, the Kaliningrad Oblast), and 4 km upstream the junction of the Nemunas River and its tributary, the Jura River.

The main sub-watersheds are: Kirsns (the basin area is 466.3 km^2), Dovine (584.1 km^2), Rausve (206.5 km^2), Pilve (334.1 km^2), Sirvinta (1 297.1 km^2), Visakis (329.4 km^2), Siesartis (200.8 km^2), Jotija (268.2 km^2), Nova (404.1 km^2), Tumannaya and Alsknupe (Fig. 1, color inset). The average annual discharge at the Sheshupe River mouth is of 35.5 m^3/s (or 1.12 km^3/yr), the average annual modulus of flow is of 6 litre/s/km^2. Surface run-off is the main component of water gain. Groundwater inflow is very low. The river bed is formed by clayey soil of the Mid-Lithuanian lowland.

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The Sheshupe River heads at the altitude of 284–280 m above a sea level, its mouth is at 6.4 m above a sea level. The main altitude depletion is at the Poland and Lithuanian segments of the river (Table 1).

Table 1.

The transboundary characteristics of the Sheshupe River basin (Jablonskis & Lasinskas, 1962).

	Basin area, km^2	Length, km from the mouth and length of a segment	Altitude, m above a sea level	Bed slope, m/km	Average annual flow, m^3/s
Poland	172	297.6–273.6, 24.0	284–280	6.6	
Polish-Lithuanian border	172	273.6	120.2		1.03
Lithuania	4899 km^2, approx. 80% of total basin area	273.6–114.4, 114.4 (approx. 53% of total length)	120.2–28.6	0.58	1.03–26.2
Russian-Lithuanian border		114.4–63.0, 51.4	28.6–15.8	0.25	26.2–33.0
Russia and confluence with Nemunas at 85.4 km	919 km^2	63.0–0, 63.0	15.8–6.4	0.15	35.5
Total:	**6 104.8**	**297.6**		**0.00064**	**35.5**

Tributaries.

The Sheshupe River hydrographical network contains about 177 tributaries with a length longer than 5 km and 77 tributaries with a length longer than 10 km. The average density of the river network in the basin is 1.35 km/km^2. The total lengths of the tributaries with a length more and less than 10 km are about 1894 and 6363 km respectively (Jablonskis & Patikslinti, 1998).

The longest tributaries are:
- Kirsna (44 km length)
- Dovine (68 km)
- Rausve (48 km)
- Pilve (68 km)
- Visakis (46 km)
- Sirvinta (76 km)
- Nova (69 km)
- Siesartis (63 km)
- Jotija (49 km)

Lakes.

There are 269 lakes with the area larger than 0.5 ha in the Sheshupe River basin. Fifty seven of them are located in Poland. Eleven are in the Kaliningrad Oblast (its total surface area is 97.9 ha). Lakes (with total surface area of 6822.5 ha) contain 2 percent of the river basin area. They are located mainly in the upstream part of the river basin, upstream the city of Marijampole.

The Zuvintas lake (1027.1 ha or 1.0271 km^2 of the water surface area, the altitude is 87.1 m, the max depth is 3.4 m) and Dusia lake (2334.2 ha or 2.3342 m^2 of surface area, altitude—106.8 m, max depth—32.4 m) are the biggest lakes in the Sheshupe River basin. Both of them are located in Dovine basin (Sheshupe tributary) (Jablonskis & Lasinskas, 1962).

Wetlands.

Several typical wetland areas are located in the Sheshupe River basin. Marshes are dominating in the basin. Water accumulated in the lakes and wetlands during spring floods smoothes a peak of high flows in the river. This water storage feed up river during the summer low-flow period (Jablonskis et al., 1975).

Groundwater supply.

Groundwater is closely related to the geological composition of the Earth crust. All the groundwater could be subdivided into (a) soil water (the subsurface water), filling the soil leaks; (b) groundwater, located on the top of the first water table (aquifer) and (c) pressured groundwater, located between two confined aquifers.

The Sheshupe River is mainly located in the Mid-Lithuanian Lowland, where, in average, groundwater is at a depth of 5 m. Small amount of groundwater could be found in the moraine and limnoglacial plains, which are covered by non-conducting water clay and loam clay soils. These types of the soil are typical for the Sheshupe River basin, and its groundwater supply is very low.

Soil type.

The dry surface of the earth, which can bring a yield, is called an arable land. The upper part of the soil, from which a harvest could be obtained, is called a soil, and the lower parts is called a sub-soil or substratum.

The soil type in the Sheshupe basin is typical for Lithuania and consists of moraine deposits (60%), fluvoglacial and alluvial deposits (23%), limnoglacial deposits (10%), eolic deposits (1%), organogenesis deposits/peat (6%). The predominant soil types here are: turfy gleyic and turfy highly gleyic soils (Jablonskis et al., 1975).

2. The Sheshupe basin monitoring system

The information of the measured parameters and measurement frequency in the Kaliningrad Oblast and Lithuania is presented in the Table 2.

In *the Lithuanian part* of the Sheshupe River basin, the water quality is examined in the four rivers and two lakes. Five sites are in the main river stream, 3 sites are in the Sheshupe tributaries Selmenta, Sirvinta and Seimens respectively, and 2 sites are in the tributary of Siesartis. Such Lakes as Zaltytis, Amalvas, Dusia and Zuvintas are investigated also. Besides, the monitoring is carried out in the Vistynets Lake. This lake is situated on the Lithuanian-Kaliningrad border and is a part of the Pregolya River watershed.

Pollution reports are provided to the Environmental Protection Agency once a month, once a quarter or twice a year depending on discharge and category of permits that polluters have. EPA conducts random control at the point sources to verify the data transmitted by the polluter.

According to the “State Groundwater Monitoring Program, 2001–2005”, compiled in 2000 by the Geological Survey of Lithuania, there are 23 state monitoring stations in the Sheshupe basin, where the groundwater level and chemical composition are observed.

In *the Kaliningrad Oblast* the point sources and diffusive agriculture pollution influence on the water quality in the river. The Specialized Marine Inspection (KSMI MNR RF) took part taking part in the Sheshupe River monitoring from the beginning of 2001 up to the middle of 2002. Monitoring is aiming at investigation of separate parts of the river and tendencies of pollution spreading. A portable device “HYDROLAB” was used for definition of physical and chemical parameters: a pressure; temperature; environment reaction; dissolved oxygen; chloride ions; salinity; conductivity; ammonia nitrogen, nitrates nitrogen and chlorophyll-a content.

Under the state monitoring program, the Sheshupe River water quality is monitoring in the town of Krasnoznamensk (by Federal Service for Hydrometeorology and Environmental Monitoring) and additionally in Lesnoe and Livenskoe settlements by KSMI MNR RF. Samples are taken once a month.

Table 2.

The measured parameters and measurement frequency.

Parameters	Measurements in Lithuania		Measurements in the Kaliningrad Oblast	
Hydrological				
Water level	+ (once or twice per month)		–	
Speed	+ (once or three times per month)		+	
Flow	+ (daily)		+	
Depth	+ (once or three times per month)		+	
Hydrochemical parameters				
Parameters	Monthly	4 times per year	Monthly	5 times per year
Temperature	+		+	
Odour	+			+
Limpidity	+			+
Colour	+			+
SS	+		+	
pH	+		+	
DO	+		+	
BOD	+		+	
ChOD	+		+	
Ammonia nitrogen	+		not everywhere	
Nitrites	+		+	
Nitrates	+			+

Table 2 continuation.

Parameters	Monthly	4 times per year	Monthly	5 times per year
Total nitrogen	+		not measured	
Mineral nitrogen	+		not measured	
Phosphates	+			+
Total phosphorus	+		not measured	
Calcium		+		+
Magnesium		+		not everywhere
Sodium		+	not measured	
Potassium		+	not measured	
Silicon		+	not measured	
Carbonic acid		+		+
Sulphates		+		+
Chlorides	+			+
Iron		+	+	
Detergents		+	not measured	
Oil products		+	not measured	

3. The Sheshupe River basin water quality

Analysis of the data on water quality in the Lithuanian segment of the Sheshupe River allows to draw the following conclusions:

- The average and mean BOD_7 concentrations in the river do not exceed 4 mg/l and satisfies requirements for salmon waters;
- The average DO concentration along the river is high enough to satisfy requirements for salmon waters (100 percent of samples ≥7 mg/l and 50 percent—≥ 9 mg/l;
- The total nitrogen concentration increases in the Sheshupe River upstream the city of Marijampole. The average concentration of the total nitrogen below Marijampole exceeds the maximum allowable concentration (MAC), which equals to 2 mg/l, and the river water quality remains unsatisfactory up to the Lithuanian-Kaliningrad border;
- The total phosphorus concentration at the Lithuanian-Kaliningrad border equals to 0.29 mg/l, which also exceeds MAC for total phos-

phorus (2 mg/l). In the upper part of the river the total phosphorus concentrations satisfies requirements;

• The Siesartis River, one of the biggest tributaries of the Sheshupe River, is characterized by high concentration of suspended solids (10.78 mg/l) and nutrients (the total nitrogen is 5.89 mg/l, the total phosphorus is 1.01 mg/l). It is supposed to be a main reason of increased SS concentrations in Sheshupe at the Lithuanian-Kaliningrad border (13.27 mg/l);

• Absence of the water quality monitoring site exactly at the mouth of the Siesartis River makes difficult to forecast the Siesartis impact on the Sheshupe water quality.

The situation in the Kaliningrad Oblast.

The river monitoring has revealed the fact that ammonia nitrogen concentrations are very high in the Sheshupe and MAC sometimes is exceeded in 1.3–2 times. The minimal concentrations are observed in February and May, the maximum—in June. The lowest ammonia nitrogen concentrations were observed in the Sheshupe River in the period from December to April (0.25–0.38 mg/l), the maximum—from June to September (0.42–0.8 mg/l). The maximum concentrations of the dissolved oxygen were observed in spring and summer seasons (9.45–11.1 mg/l), the minimum—in a winter period (5.2–5.99 mg/l). The temperature of the Sheshupe's water varied from 8.5 to 9.2 °C in spring, from 19.9 to 22.8 °C in summer, from 2.4 to 14.8 °C in autumn and from 1.1 to 3.1 °C in winter.

4. Land use population and in the Sheshupe River basin

The total number of inhabitants in the Lithuania part of the Sheshupe River basin (4899 km^2) was 198.23 thousands in 2000. About 10.4 thousands inhabitants live in the Sheshupe river basin in the Kaliningrad Oblast (Krasnoznamensk) where basin occupies 919 km^2.

Forests in the territory of Lithuania occupy 735 km^2 (15%), lakes—98 km^2 (2%), wetlands—411 km^2 (8.4%), agricultural land—2800 km^2 (57.15%), other type of land—855 km^2 (17.45%) (Jablonskis et al., 1975).

The distribution of the population in the administrative regions is presented in the Table 3, the administrative regions are shown in the Fig. 2 (*see* color inset), land use distribution is presented in the Table 4 and the Fig. 3 (*see* color inset), animal stock distribution is in the Table 5.

Table 3.

Distribution of the population in the Sheshupe River basin in 1999.

	Territory, km^2	Total population	of which		Population density, inh./km^2
			urban	rural	
Lithuanian part					
Marijampole county (Marijampole)	**4463**	**198 236**	**100 764**	**97 472**	**44.4**
Marijampole city	24	52 043	52 043	–	2168.5
Marijampole Region	1540	50 932	14 058	36 874	33.1
Sakiai Region	1613	42 232	12 007	30 225	26.2
Vilkaviskis Region	1286	53 029	22 656	30 373	41.2
The Kaliningrad Oblast (Russia) part					
Krasnoznamensk Region	**919**	**10 339**	**2874**	**7465**	**533 in cities 8 in rural territories**

The main industrial production in the Sheshupe region in the territory of Lithuania per administrative unit is as follows:

• *Marijampole city*: (a) meat, sausage; (b) dairy products: butter, fat cheese, unskimmed dairy products, canned diary products; (c) bread and pasty production; (d) sugar; (e) prepared mixed animal feed; (f) wool fabrics, viscose rayon yarn; (g) prefabricated structural components for building or civil engineering;

• *Marijampole Region*: (a) timber, knitwear; (b) chipboard; (c) bricks; (d) woolen and semi-woolen yarn;

• *Sakiai Region*: (a) timber; (b) drainage pipes; (c) meat; (e) bread and pastry products; (f) prefabricated structural components for building or civil engineering;

• *Vilkaviskis Region*: (a) drainage pipes; (b) axes, spades; (c) meat, sausage; (d) canned food; (e) bread and pastry products; (f) prepared preserved vegetables and fruits, excl. juice and tomato sauces;

• *The Kaliningrad Oblast*: (a) milk production and other dairies; (b) oil pumping, peat extraction; (c) wood industry.

Table 4. Distribution of land use in the Sheshupe River basin in 1999.

	Territory, ha	of which (ha)				
		Agricultural land	Arable land	Meadows, pasture	Orchards, berry shrubs	Non-agricultural land
Lithuanian part						
Marijampole county	**446 255**	**300 906**	**263 263**	**33 304**	**4339**	**145 349**
Marijampole city	2413	191	67	56	68	2222
Marijampole district	154 019	97 306	81 911	13 964	1431	56 713
Sakiai district	161 257	104 167	96 938	5755	1474	57 090
Vilkaviskis district	128 566	99 242	84 347	13 529	1366	29 324
Kaliningrad Oblast (Russia) part						
Krasnoznamensk district	**91 900**	**44 657**	**20 379**	**10 975**	**96.2**	**44 569**

Table 5. Live stock in the Sheshupe River basin in 1999.

	Number of cattle	Number of cows	Number of pigs	Number of sheep and goats
Lithuania part	**897 800**	**494 300**	**936 100**	**38 500**
Marijampole county	**98 029**	**50 077**	**97 992**	**2561**
Marijampole Region Municipality	35 661	17 772	33 212	843
Sakiai Region municipality	34 871	18 230	27 668	812
Vilkaviskis Region Municipality	27 062	13 741	35 661	778
Kaliningrad Oblast	**8535**	**2654**	**6456**	**–**

5. Water abstraction, consumption and discharge

Data on the water consumption by counties are presented in the Table 6, but the wastewater discharge is in the Table 7.

Table 6.

Water abstraction and consumption in the Sheshupe River basin in 1999.

	Water abstraction (thousands m³/yr)		Water consumption (thousands m³/yr)	
	total	ground water	total	ground water
Lithuanian part				
Marijampole county	**14 335.7**	**8396.7**	**12 656.7**	**6740.7**
Marijampole town	4367.0	3676.0	2922.0	2254.0
Marijampole district	6585.7	1361.7	6558.7	1334.7
Sakiai district	1408.0	1397.0	1408.0	1397.0
Vilkaviskis district	1975.0	1962.0	1768.0	1755.0
The Kaliningrad Oblast (Russia) part				
Kaliningrad Oblast	**1148.3**	**1148.3**	**1123.3**	**1123.3**

Table 7.

Wastewater discharge in the Sheshupe basin in 1999 (thousand m³/yr).

Municipalities of towns' and districts'	Sewage discharge into the surface water-bodies				
	Total	Waters meeting quality standards	Waters treated according to standards	Inadequately treated	Without treatment
Lithuanian part					
Marijampole county	**12 518.2**	**4730.0**	**5587.2**	**2171.0**	**30.0**
Marijampole town	5290.0	–	3410.0	1880.0	–
Marijampole district	5391.9	4730.0	529.2	102.7	30.0
Sakiai district	636.0	–	568.0	68.0	–
Vilkaviskis district	1200.3	–	1080.0	120.3	–
The Kaliningrad Oblast (Russia) part					
Kaliningrad Oblast	**363.0**	**–**	**–**	**142.0**	**221.0**

6. Fish stock

In the Sheshupe river 21 fish species were registered. Fluvial-lenthic species prevail, while in the dammed up river segments only lenthic ones are present. Fish species diversity in the various river segments is moderate (H varies from 0.4 to 2.6). Roach, dace, bleak dominate in the community (80–100%). The common species are chub, pike, minnow, bream, riffle minnow, perch, and three-spined stickleback (40–60%). The rare species (V>15%) are asp, owsianka, bitterling, gudgeon, silver bream, gibel, vimba, barbell, stone loach, ruff.

A river trout is an occasional species (V>15%). The total fish density varies from very low (130 ind/ha) to high (9783 ind/ha), while fish biomass is low (5.7–39.36 kg/ha) in the majority of the river segments.

In the Siesartis River 13 fish species were registered. The fish species diversity increases from upstream to downstream. In the middle reaches the fish species diversity is moderate (H=1.06), while it is high (H=3.08) in the lower reaches. Roach, dace, chub, gudgeon, bleak, riffle minnow and stone loach dominate in the community (66.7%). The fish density ranges from 4573 to 7714 ind/ha, biomass varies in the range of 33.52–146.428 kg/ha. In the Lower Siesartis a bleak, gudgeon roach predominate in an abundance, but a chub, bleak, dace, roach and vimba—in a biomass.

The fish community state is fair in the majority of the Sheshupe River sites. The fish species diversity is lower than expected in all the investigated river segments. The most sensitive indicatory species were found only below Kalvarijos and at the Siesartis mouth. The total fish biomass is lower than expected in all the investigated rivers sites, fish trophic structure is skewed.

In the Siesartis River the state of fish community changes from very poor in the river segment below Sakiai to good in the lower reaches. The fish species diversity, number of indicatory species, fish density and biomass increase directly proportional to the distance from the town of Sakiai. The community trophic structure is skewed in all river sites investigated.

The main factors predetermining the fair fish community state in the Sheshupe River are: the altered hydrological regimen because of dams and canalization; occasional deficit of the dissolved oxygen, nutrient supersaturation and pollution.

The fish community state in the Siesartis River depends directly on the prevalence of pollution: the index of biotic integrity, qualitative and quantitative indices of fish community are changing inversely proportionally to the indices of total pollution.

About 30 fish species could be found in the lakes, 30 percent of them are pike, pike-perch, bream and eel.

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The Vishtynetskoye Lake

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1. Introduction

The Vishtynetskoye Lake is the largest and the most beautiful lake in the Kaliningrad Oblast. It is a shared lake; its eastern part belongs to Lithuania. According to its hydrological characteristics, the Vishtynetskoye Lake can be called "the Baikal in miniature". It also does not yield to the Baikal in its significance for the region. Since 1965 the scientists of the Ichthyology and Ecology Department of Kaliningrad State Technical University carry out the systematic complex investigation of the lake.

2. Hydrological conditions

The lake area (Fig. 1) is 16.7 km^2, the maximum depth is 54 m (Orlyonok et al., 2001). It contains almost 258 mln m^3 of water, the coastline length is 25 km (Alexeev et al., 1976). There is the Tikhaya Bay in the western part of the lake. The northern vastly isolated part is called

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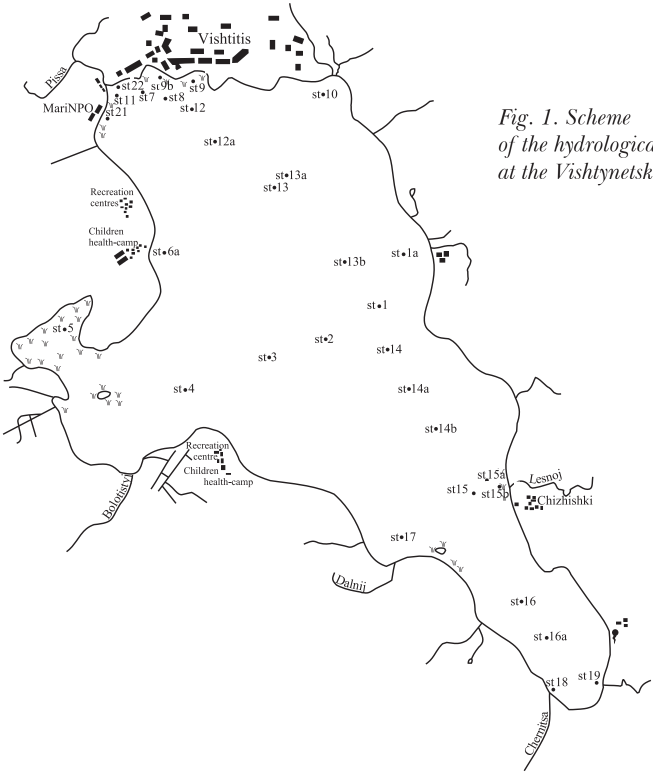

Fig. 1. Scheme of the hydrological stations at the Vishtynetskoye Lake.

the Utiny Creek (the Duck Creek). This creek is densely covered by water vegetation in the warm period of a year. There are many water birds here including swans, and cormorants, which build their nests at the bay coast during the last years.

The bottom topography of the lake is very complicated. The lake is divided by the high sill into two spacious basins, northern and southern ones. The water depth over the rapids is not more than 15 m. There are three isolated bottom depressions in the northern basin, their depth is more than 40 m. The southern basin has two depressions of the same depth. The depth of the Utiny Creek does not exceed 1–2 m. The southern slopes of the lake are extremely steep, the northern ones are rather gently sloping. The northern coast is partly waterlogged (Orlyonok, 2002).

More than ten watercourses flow into the lake. The only five of them flow the whole year round, other streams either dry up during summer months or do not have any flow in winter. Two small rivers, Chernitsa and Bezymyannaya, flow into the southern part of the lake from the territory of Poland. The Bezymyannaya River also runs through Lithuania. The water runs out the lake through the Angrapa River which connects the lake with the Pregolya River.

The height of baroclinic seich clearly revealed in the pycnocline can reach 10 m and more. Water transparency of is very high, Secci depth is up to 6–8 m in the central parts of the lake.

Thermal processes in the lake develop in accordance with classical scheme, which is typical for fresh deep water bodies where wind-induced waves do not penetrate into the bottom. Thermal bar can be observed in the beginning of spring and at the end of autumn when “a wall” of the densest water (with the temperature of 4 °C) appears near the coast and isolates littoral shallow water. Thermal bar divides the lake into two parts. The water stratification of the coming season arises in the coastal part and the water stratification of the outgoing season still remains in the open part. As the spring (or autumn) processes are developing, thermobar moves aside from the coast, the water temperature in the open lake becomes constant (about 4 °C) in the whole water column i.e. the spring (or autumn) homothermy occurs and thermobar disappears gradually. Direct stratification forms during the warm period of a year, the thermocline with a high (up to 2.5 °C/m) vertical gradient develops in summer (Fig. 2). No matter how epilim-

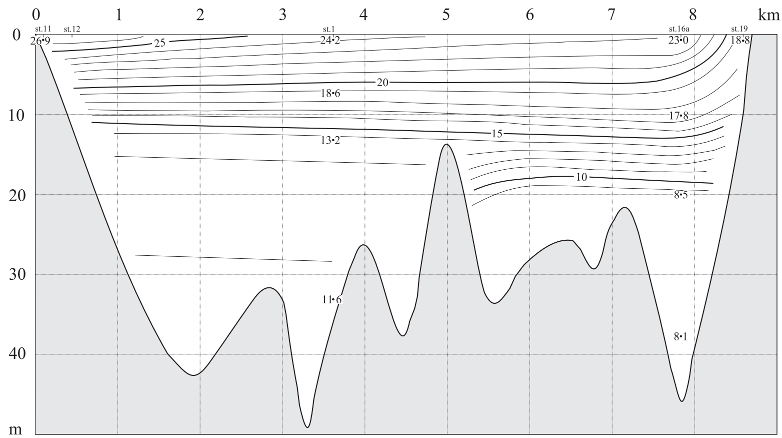

Fig. 2. Vertical transect of water temperature (°C) in the Vishtynetskoye Lake, 30–31.07.2003.

nion is warmed up; as a rule the water temperature in hypolimnion is not higher than 8–9 °C and in the near-bottom layer it is of 6 °C and less. In winter, the water temperature increases against the depth (from 0 °C on the surface up to 4 °C in the near-bottom layers), i.e. the inverse stratification begins.

The lake is ice-covered about four months during a year. The freezing-over duration and the ice thickness depend on winter's severity and weather conditions of every concrete year.

3. Hydrochemical conditions

The water in the lake is poorly mineralized (mineralization is of 190–270 mg/l), it is of hydrocarbon-calcious water of the 2nd type ($HCO_3^- < Ca^{2+} + Mg^{2+}$). Such kind of water is typical for the most freshwater water and soft (total water hardness is 2.1–2.6 mg·equiv./l) water bodies.

The lake is oligotrophic with some features of the mesotrophicity in the coastal parts, especially in the Tikhaya Bay.

Gas conditions are mainly typical for oligotrophic water bodies. Seasonal changes are expressed relatively slightly. Oxygen saturation of the water in epilimnion is close to 100 percent during the whole year. Even at the photosynthesis peak, the lack of oxygen usually does not exceed 105–110 percent. Only in the Tikhaya Bay (in the Utiny Creek), the saturation can be much higher at the period of the intensive development of vegetation (up to 110–120 percent). Oxygen amount in hypolimnion is sharply reduced in summer. Besides oxygen conditions are closely connected with the character of the water warming up. Oxygen concentration decreases noticeably during hot period especially and oxygen content in epilimnion can be 10–20 percent less than usually; there is undersaturation everywhere. Oxygen saturation of the water can drop down to 70 percent at the top of the thermocline and to 50 percent at its lower limit. Oxygen concentration in hypolimnion is rather homogenous. Oxygen deficiency is observed often, and oxygen saturation of the water is less than 50 percent. Sometimes there is a very sharp deficiency, about 19 percent. As far as the mixing develops and thermocline disappears, oxygen concentration equalizes in the whole water column.

According to Alekin's classification (Alekin, 1970) permanganate oxidability was estimated as low in the lake (2–5 mgO/l), and average in the Utiny Creek (5–10 mgO/l). It is important that the value is bigger in the southern part of the lake (st. 16a).

COD was determined in the southern and north-eastern parts of the lake where it proved to be rather high. It was especially high on the surface in the southern part of the lake and at a depth of 10 m in its northern part.

The loss of water quality was observed in the southern part of the lake in the end of the 80th, the beginning of the 90th. It manifested in an appearance of oxygen depletion, increasing of permanganate oxidability, and COD exceeding of the maximum allowable concentration for drinking and sanitary water.

4. Hydrobiological conditions

During last time zooplankton of the lake was studied in July 2003 and it consisted of 16 species of Crustacea; Rotatoria were absent (Figs. 3–6).

The level of zooplankton development corresponded to the mesotrophic degree of the lake eutrophication. Trophic status has increased since the end of the 90th. Before this time the lake belonged to the oligotrophic-mesotrophic type according to the level of zooplankton development in summer. It also should be mentioned that at the present time the oligotrophic species predominantly provide a basis of zooplankton quantity and biomass.

In July 2003 zoobenthos included only few species (12). It is twice less than at the same period in 1997. Caddis flies inhabiting Chara-bed in the shallow water (littoral zone) were not found. There were no also day-flies. Quantity of *Chironomidae* species decreased as well.

Seven taxonomic groups of zoobenthos were registered in the littoral zone. They are: *Oligochaeta, Chironomidae, Mollusca, Crustacea. Chi-*

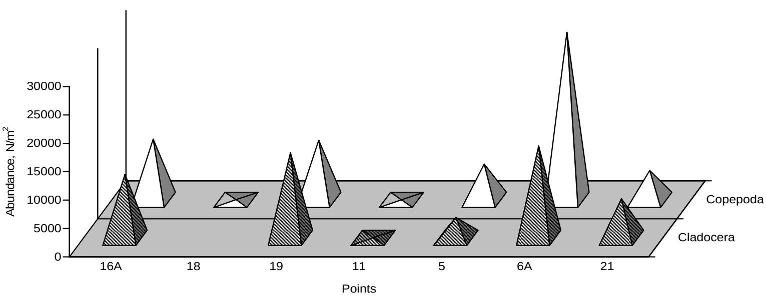

Fig. 3. Zooplankton abundance in the southern (stations 16a, 18, 19) and north-western (stations 11, 5, 6a, 21) parts of the Vishtynetskoye Lake, July 2003.

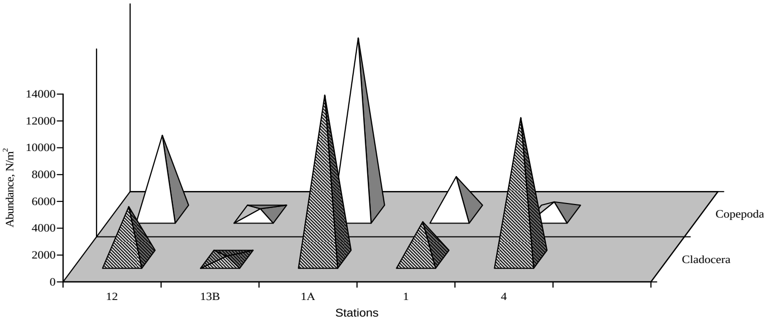

Fig. 4. Zooplankton abundance in the north-eastern Lithuanian (stations 12, 13b, 1a) and widened (stations 1, 4) parts of the Vishtynetskoye Lake, July 2003.

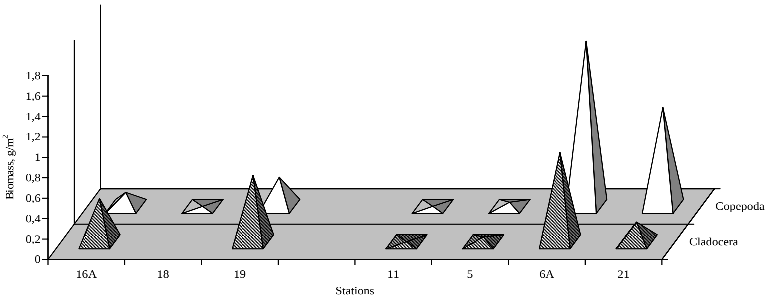

Fig. 5. Zooplankton biomass in the southern (stations 16a, 18, 19) and north-western (stations 11, 5, 6a, 21) parts of the Vishtynetskoye Lake, July 2003.

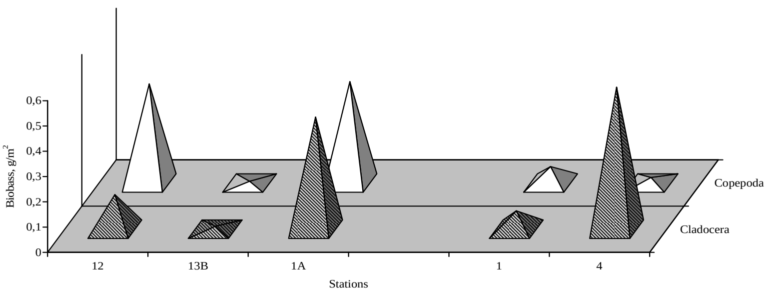

Fig. 6. Zooplankton biomass in the north-eastern Lithuanian (stations 12, 15b, 1a) and widened (stations 1, 4) parts of the Vishtynetskoye Lake, July 2003.

ronomidae and shellfish contributed mostly in benthos quantity and biomass both in littoral and profundic zones.

During the investigations in 2003 not only species diversity decrease was determined but also considerable reduction of its quantity was observed, especially in the near-shore zone. The most probable reason of qualitative and quantitative zoobenthos degradation in the lake was the oxygen deficit in the bottom layer and the anomalous water warming-up which intensified the oxidizing processes in the whole water column of the lake and especially at the bottom layer. Additional nutrients are released, and it could cause the intensive reproduction of phyto- and zooplankton. Their extinction supplemented the organic substances even greater and its oxidation again demanded extra oxygen.

During preceding years, this period on the contrary was characterized by maximum level of benthos quantity and biomass (Figs. 7–8).

5. Ichthyofauna

The ichthyofauna of the Vishtynetskoye Lake is unique among the inner water bodies of the Kaliningrad Oblast due to the specific hydrological conditions in the lake. It includes the relics related to glacial oligotrophic waters, as cisco (*Coregonus albula*), zope (*Coregonus lavaretus*), burbot (*Lota lota*), and such representatives of the boreal-submountain complex as minnow (*Phoxinus phoxinus*), dace (*Leuciscus leuciscus*), sculpin (*Cottus gobio*). The boreal-flat complex is represented by roach (*Rutilus rutilus*), pike (*Esox lucius*), pope (*Gymnocephalus cernus*) and others.

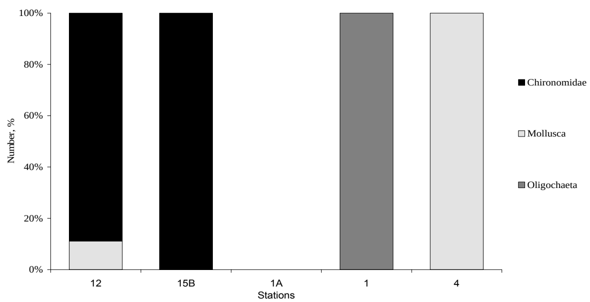

Fig. 7. Structure of zoobenthos community in the littoral and profundic zones of the Vishtynetskoye Lake, July 2003.

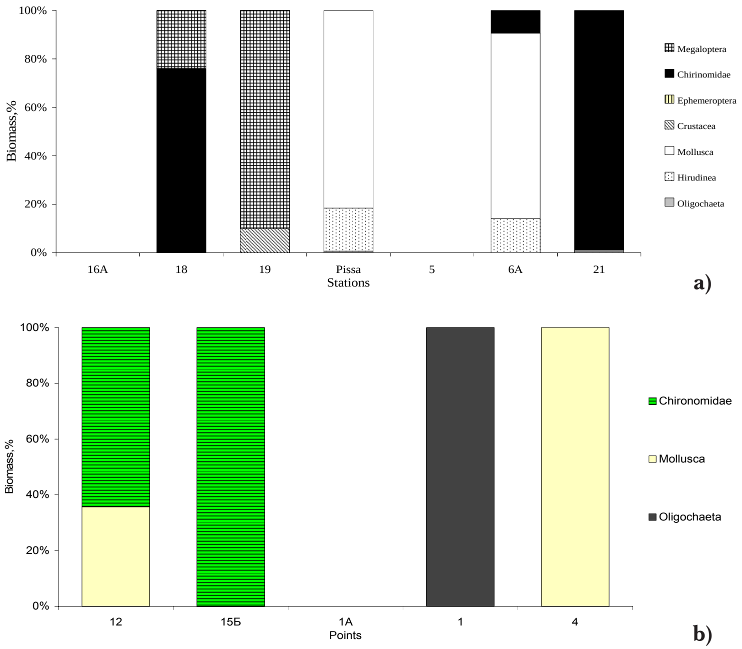

Fig. 8. Structure of zoobenthos community (in biomass) in the littoral (a) and profundic (b) zones of the Vishtynetskoye Lake, July 2003.

Altogether there are 22 fish species in the Vishtynetskoye Lake. According to the exisiting fish-industrial classification it is the only water body of the cisco-whitefish type in the Kaliningrad Oblast. The fish stock of the lake is used by fishery. A European cisco and roach form the catch basis. A baltic whitefish, pike, perch, eel, tench, crucian carp, burbot and other fish species can be also found in the catch. Fish production of the lake is of 21 kg/ha.

6. Conclusion

Thus, the species structure of both fish and other representatives of water life indicates that the ecosystem of the Vishtynetskoye Lake is in conditions of a relative ecological balance. And we should aim at keeping this condition and saving the lake as a unique protected nature object. But from the middle of the 90th the alarm situation arouse at the Vishtynetskoye Lake. It was connected with water quality change and revealed through the increase of nutrients and organic substances content. This situation demands an extra attention and control. If the existing tendency does not change, the oligotrophic lake can transform to the mesotrophic one, and the lake itself will loose its significance as a unique water ecosystem. In addition, such a valuable food fish as *cisco* can disappear from the lake ichthyofauna structure at all.

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Transboundary coastal waters of the Kaliningrad Oblast

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Introduction

The length of the Baltic Sea coastline of the Russian Federation within the Kaliningrad Oblast is about 150 km, including 48 km of the coast of the Curonian Spit and 25 km of the coast of the Vistula Spit. Lithuania to the north and Poland to the south are riparian neighbors. Sweden is a neighbor located on the opposite side of the Baltic Sea.

We will consider the coastal marine waters from the root of the Hel Peninsula, Poland (in the south) to the border between Lithuania and Latvia (in the north) as transboundary coastal waters of the South-East Baltic (Fig. 1, color inset), which belong to Poland, the Kaliningrad Oblast (Russia), and Lithuania. The southern part of this area includes the Gulf of Gdansk, which belongs both to Poland and the Kaliningrad Oblast and is bounded by the line from the Cape Roseve (Poland) to Cape Taran (Kaliningrad Oblast). The northern part of the transboundary area includes coastal waters along the northern coast of the Sambian Peninsula (Kaliningrad Oblast), Curonian Spit and Lithuanian coast (Fig. 1, color inset).

According to administrative division the waters of the South-East Baltic include the areas of the State Territorial Sea (a 12-mile marine zone along the coastline) and the part of the Exclusive Economic Zones

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of Poland, the Kaliningrad Oblast (Russia) and Lithuania. The area of the Russian (Kaliningrad) Territorial Sea is 2800 km^2, the area of the Russian (Kaliningrad) marine economic zone is of 5000 km^2 (Sostoyanie Okruzhayuschey… [Condition of Natural Environment…], 2001) (Fig. 1, color inset).

The transboundary coastal waters of the South-East Baltic include both the Curonian and Vistula lagoons. These lagoons are the shared water pools. The Russian-Lithuanian state border divides the Curonian Lagoon and the Curonian Spit into two parts. The Vistula Lagoon and the Vistula Spit are shared by Poland and Russia (*see* other papers of this book).

The Russian waters' area in the South-East Baltic is of 9600 km^2. It include: (a) inner coastal waters with the area of 1800 km^2 and comprised by Russian parts (1300 and 472 km^2) of both the Curonian and the Vistula Lagoons; (b) territorial waters of the Russian Federation that are of 2800 km^2; and (c) the marine economic zone of the Russian Federation that is of 5000 km^2. The area of Russian territorial waters has a triangle shape; the top of this triangle is 60 miles from the coast.

The purpose of this article is to describe transboundary seawaters of the Kaliningrad Oblast, the bottom morphometry, hydrologic characteristics and main affecting factors.

The seawaters of the Kaliningrad Oblast are affected by general circulation of the Baltic, weather conditions and freshwater runoff, as well as by anthropogenic influences. Outflows from mouths of the rivers and lagoons as well as ship traffic are potential pollution sources in the area.

The main ports in the region (from the south to the north) are: Tree-City Gdansk—Gdynia—Sopot (Poland), Baltiysk—Kaliningrad (Russia) and Klaipeda (Lithuania). The mouths of the two biggest Baltic rivers, namely Vistula and Neman, are located in the region. The Vistula River inflows directly into the Gulf of Gdansk. The Neman River flows into the Curonian Lagoon (Lithuania/Russia), a biggest lagoon in the Baltic, which has one outlet (Klaipeda Strait, Lithuania), where the Klaipeda harbor (Lithuania) is situated. The lagoon is separated from the Baltic by the sandy barrier, namely, the Curonian Spit, which is of 98 km long and 0.4–4 km wide (Fig. 1, color inset).

The second lagoon in the region, the Vistula Lagoon (Poland/Russia), is separated from the Baltic by the Vistula Spit (35 km of this barrier spit is within the Kaliningrad Oblast) and has one outlet, the Baltiysk Strait (Kaliningrad Oblast). The harbor of Kaliningrad (Russia) is located inside the lagoon. Navigation pass, namely, artificially dredged Kaliningrad Navigation Canal, goes from Kaliningrad along the northern lagoon coast towards the lagoon outlet, where harbor of the city of Baltiysk (Russia) is situated.

Thus, each of the three neighbouring countries has one personal significant coastal source of fresh water. These sources are responsible for nutrients, pollution and suspended-dissolved matter load of both natural and anthropogenic origin coming from the catchment areas, which are also transboundary.

Currents in the Baltic provide intensive along-shore and cross-shore water exchange without regards to state borders. Therefore, any anthropogenic impact existing in the region is transferred much far from its source, crossing state borders.

The bottom relief

The waters of the Kaliningrad Oblast belong to the Gdansk Basin, which covers the South-East part of the Baltic Sea. The Gdansk Basin is distinguished owing to morphological depression, called the Gdansk Deep. This deep (the maximal depth is 118 m) is bounded by the coastline to the south and east, and is separated from other basins of the Baltic by bottom elevations to the west and northwest. The maximum depth of the Gdansk Deep is more than 90 m (Rudenko, 2002), and as the isobath of 90 m is not a closed circuit, the Gdansk Deep is actually a depression on the general slope of the Baltic coast, which in its turn descends towards the Gotland Deep (Fig. 1, color inset). The mean inclination of the bottom slope below the depth of 30 m is of 1 m per 150–200 m on the eastern and western sides of the Gdansk Deep. It is higher than the slope on the southern side of this deep, which equals 1 m per 300 m.

The Gdansk Basin can be theoretically limited by a imagine line passing across the sea area from the Cape Roseve (Poland) up to the latitude about 55°20′ to the north, and then to the north-east, to the Lithuanian coast. In the south-west the Gdansk Basin is connected with Bornholm Deep through the Slupsk Furrow. The basin's area amounts ca. 11 243 km^2, ca. 85 km (45 miles) in width and about 135 km (73 miles) in length (Rudenko, 2002). The Gulf of Gdansk occupies the southern part of the Gdansk Basin, it is located to the south from the line between Cape Roseve (Poland) to Cape Taran (Kaliningrad Oblast).

The wide Klaipeda Bank to the north and the Gdansk-Gotland Sill to the west are the morphological borders between the Gdansk Basin and the Gotland Basin which depth is up to 249 m (Gelumbauskaite et al., 1999). The Klaipeda Bank is a considerable bottom elevation in the form of a saddle which breaks the weakly sloping plain of the underwater slope. The top of the saddle has the rolled bottom with depths 50–55 m (Blazhchishin et al., 1970). The slopes of the Klaipeda bank, as everywhere in shallow areas near the Sambian Peninsula, were formed during historical sea level variations, which were manifested in the form of small terraces, located at depth from 16–18 m up to 68–69 m (Blazhchishin et al., 1970; Gaygalas et al., 1974).

The Gotland—Gdansk Sill is represented by barrier-like elevation with a depth of 70–87 m on top ranging (Sviridov, 1975). Analysis of a geological role of bottom currents shows that the surface of a barrier-like elevation is periodically subjected to strong erosion, that's why friable deposits are entrained only in the inter-ridge depressions (Sviridov et al., 1997).

The depth of 35 m may be considered as an outer border of the coastal zone, as this depth is 10 times exceeds the average height of a maximum stormy wave equaled to 3.5 m in the Gdansk Basin. But some segments of the coasts have their own natural outer borders. For instance, the coastal zone of the Sambian Peninsula is "bounded" by an ancient coastal terrace at a depth of 10–30 m. The sediments bedded below this terrace are greatly different from those that form this terrace (Boldyrev, 1999).

Underwater benches, flat areas, small hills and terraces are the main morphological features of the bottom relief along the Sambian Peninsula slope. There is the occurrence of moraine deposits outcrops (Blazhchishin, 1974). At depths of 18–20 m and 28–30 m the bottom slope is compound, it has ancient coastal terrace and cliff (Lukoshevichus et al., 1974; Gaygalas et al., 1974).

The relief of the east and south coastal parts of the Gdansk Basin is sufficiently heterogeneous. The coastal shallow water area of the Gdansk Basin varies both in width and depth; it depends on the geological structure and exogenous processes taking place in the past. The outer edge of the coastal shallow area is marked by sharp rise of the bottom slope. Its depths can vary from 15–20 m (Vistula Spit) to 40–50 m (Curonian Spit—Pra-Neman valley).

The shallow water area of the Sambian Peninsula extends in width up to 11–13 km (6–7 miles) to the west, but it stretches like a narrow band (several kilometers only) along the Vistula Spit. The shallow water area is tapered out near the southern base of the Hel Spit (Rudenko, 2002; Blazhchishin et al., 1970). The Curonian-Sambian underwater plateau, which situated to the north of the Sambian Peninsula, includes Pra-Neman valley (opposite the central part of the Curonian Spit). Its depth is up to 30–40 m, the width is about 25–40 km.

The Pra-Neman valley manifested on the outer edge of underwater slope at a depth of 25–28 m is one of the most important elements of the bottom relief of the Gdansk Basin (as well as underwater ancient terrace of the Sambian Peninsula). The Pra-Neman valley emphasizes incontestable existence of the Neman River in the past. It is assumed that this valley existed at times of the Ioldian Sea. The valley's width along the outer edge amounts 15 miles. The slopes are covered with sediments, however at a depth of 37, 45, 56 and 61 m there are slightly visible terraces, origination of which is also connected with the sea regression (Litvin et al., 1972; Gelumbauskaite, 1986; Litvin et al., 1972; Gelumbauskaite, 1986).

To the north of Pra-Neman valley, up to Klaipeda, the shallow water area preserves the form of a waste plain, where topographical elements and traces of abrasion-accumulation processes of post-glacial period are evident (Gaygalas et al., 1974; Aber, 1993).

The shallow-water area and the coastal slope of Sambian Peninsula incur the intensive erosion, especially under storm conditions. The eroded material is transported along the coast of the peninsula towards both Vistula and Curonian Spits, exerting considerable influence on the morphology of these regions (Rudenko, 2002). The sediment transport flow along the Hel Spit brings material from the Western part of the Baltic Sea to the Gulf of Gdansk (Geologiya Baltiyskogo Morya [Geology of the Baltic Sea], 1976), and affects a general sediment balance and distribution of sediments in this area.

The hydrology

Hydrological characteristics of coastal water areas depend on many factors, such as geographical location, climate and weather conditions, coastline configuration, bottom relief, coastal sea currents, rivers inflows, water mixing and exchange with open sea.

The Kaliningrad Oblast and the neighbouring parts of Lithuania and Poland are situated in a moderate humid climate zone. The mean annual *air temperature* at the seaside (near Baltiysk) is about 7.5 °C, the average temperature of the coldest month (January) is about 0.5 °C, and of the warmest one (July) is about 15.8 °C, (Sivkov & Chubarenko, 1997). Winters are usually without strong frost, ice cover occurs only on the Curonian and Vistula lagoons. Annual precipitation is ca. 620–780 mm with maximum in summer and autumn (Barinova, 1999). The inflow of main rivers (Table 1) is formed within deep landward catchments.

Wind is the main driving force for currents, water exchange and mixing. The westerly direction of winds and waves dominates. The west quarter winds (NE, E, SE) has a repetition of 40–45 percent, and south and southeast winds can be observed in 25–31 percent (Barinova, 1999). The higher a wind speed is the greater a probability for western winds is. Average wind speed varies within 3.6–7.3 ms^{-1}. Low winds (less than 5 ms^{-1}) occur in 56–60 percent, moderate winds of 6–9 ms^{-1} are of occurrence in 27–32 percent, and storm winds are observed in 5–7 % (Generalnaya Skhema… [Scheme of Anti-Landslide…], 1999).

The system of *coastal currents* is not stable and depends on local winds. During weak winds the system of circulation is formed following the margin deformation of the general South-East Baltic circulation on the bay-shape disturbances of the coastline. The direction of circulations depends on a wind history. During strong winds the alongshore currents are prevailing and driven by alongshore component of the wind. The higher a wind stress is the wider a zone of strong alongshore currents is (Babakov, 2003). Predominant western winds cause eastward and southward drifts of sediments at northern and western segments of the Kaliningrad coastline respectively (Boldyrev, 1999; Generalnaya Skhema… [Scheme of Anti-Landslide…], 1999). It doesn't mean that there is a permanent drift of these directions. Each instant wind forcing causes the original situation of alongshore drift (direction, intensity and duration), but in average, during a year, all these situations form a general alongshore eastward and southward movement of sand from the very north-western corner of the Sambian Peninsula (Cape Taran).

Wave intensity depends on weather conditions. Usually in open sea areas weak waves (Beaufort numbers of 2–3) are prevailing. The wave intensity can achieve the figures of 5–6 in the investigated area during high cyclonic activity (Berenbeym et al., 1999). The maximum waves may reach 10 m height outside the coastal zone, while at a depth of 10 m a wave height doesn't exceed 4–5 m. In the coastal zone weak and moderate waves (0–0.75 m) occurrence is of 54–62 percent. The occurrence of significant waves (0.75–2 m) is of 30 percent, and occurrence of waves, which exceed 2 m, is of 5–10 percent (Babakov, 2003).

West winds and waves cause intense rising of *sea level* near the shore. This level rise can achieve 1.5–2 m even during several hours (Berenbeym et al., 1999). The maximum storm surges occur at the western coast of the Kaliningrad Oblast and may run up to 1.3–1.8 m (Generalnaya Skhema… [Scheme of Anti-Landslide…], 1999). Strong waves accompanied by the level rising cause general coastal erosion everywhere along the Kaliningrad coast (Babakov, 2003). During western winds sea waters can flow into the rivers, flood lowlands and coastal settlements. It is regularly happened with the Pregolya River in autumn, when waters of the Vistula Lagoon flow far upstream, and even may flow into the Curonian Lagoon through the Deyma Branch (Terziev, 1985). Tides are not considerable in this part of the Baltic; their amplitude is not exceeding 5–10 cm (Berenbeym et al., 1999). Eastern winds cause an outflow of surface water from the coast and a set up of coastal upwelling when colder and more salt waters go up to the surface from deep layers.

Under low wind conditions *water currents* are formed by interaction between “global” Baltic circulation and local mesoscale vortexes. These local current structures have length scales of 10–50 km, but its lifetimes are from several hours to several days. The currents are usually of 5–10 cms^{-1} (Babakov, 2003), the vortexes migrate at speed of the same order of magnitude. Alongshore currents occur in the coastal zone everywhere when wind blows intensively. The width of the zone of alongshore current increases while wind intensification.

The catchment area of the investigated region of the Baltic Sea includes watersheds of the Vistula River, which flows directly into the Baltic, and water basins of the transboundary Vistula and Curonian Lagoons (Table 1). The Vistula Lagoon gathers waters from the Kaliningrad Oblast and Poland and discharges it into the sea through the Baltiysk Strait (Kaliningrad Oblast). The Curonian Lagoon collects waters from the transboundary Neman River and some small rivers in Russia and Lithuania and discharges them into the sea through the Klaipeda Strait (Lithuania).

Freshwater inflow to the sea from the Kaliningrad coast through the Vistula Lagoon (the Pregolya River and other small rivers) is much less than from Poland (the Vistula River) and from Lithuania (the Curonian Lagoon / Neman River). The total annual runoff into the Vistula Lagoon is about 3.67 km^3 (including 1.53 km^3 of the Pregolya River). It is rather small in comparison with Neman and Vistula rivers’ discharges. Freshwater inflow into the Curonian Lagoon is 23.7 km^3 (the Neman runoff is 21.6 km^3) (Terziev, 1985) and the Vistula River brings about 30 km^3 of fresh water per year (Mikulski, 1970).

Outflow currents from the Curonian Lagoon to the Baltic Sea are prevailing in the Klaipeda Strait during a year. The frequency of these currents is about 80 percent in the surface layer and 60 percent in the bottom layer; the average velocity is 10–20 cms^{-1}. The frequency of outflow currents from the Vistula Lagoon to the Baltiysk Strait is 44 percent (two times less then in the Klaipeda Strait), the frequency of inflow currents from the sea is of 21 percent. In rest cases currents go in both directions forming two-layer and two-side currents. The average velocity of currents is 30–40 cms^{-1} (Berenbeym et al., 1999). In case of two-layer currents existence in the straits a bottom layer is formed by inflowing marine water, while an upper layer is formed by out-flowing lagoon water.

Table 1.

Hydrographic characteristics of the main rivers of the south-east part of the Baltic Sea (Andrulewicz & Witek, 2002; Berenbeym et al., 1999, Mikulski, 1970; Terziev, 1985).

River	Catchment area, km^2	Average annual river flow, m^3/s	Average annual runoff, km^3
Vistula	194 000	1081	30
Neman	98 000	600	21.6
Pregolya	13 600	80	1.53

Table 2.

Seasonal variations of the upper layer salinity (‰) in the coastal waters of the South-East Baltic (Terziev et al., 1992).

Place\ month	J	F	M	A	M	J	J	A	S	O	N	D
Klaipeda	5.97	5.41	4.88	3.6	4.47	5.79	6.12	5.55	5.82	5.7	5.71	5.81
Svetlogorsk	7.59	7.56	7.51	7.26	7.66	7.31	7.18	7.18	7.23	7.3	7.28	7.28
Baltiysk	6.04	5.87	5.38	4.93	5.21	5.56	5.67	5.56	5.68	5.88	5.81	5.95
Gdynia	7.46	7.41	7.35	7.15	7.09	7.06	7.18	7.14	7.24	7.26	7.28	7.43
Hel	7.49	7.51	7.44	7.17	7.11	7.07	7.22	7.18	7.2	7.28	7.34	7.43

The rivers bring 21 millions tons of *dissolved matter* into the Gdansk Basin. This amount 10 times exceeds the total supply with suspended material and coastal erosion (about 2 millions tons) (Blazhchishin, 1984).

Shallow coastal waters belong to the upper Baltic isohaline layer, while the deep water area of the Gdansk Basin is characterized by a stratified water mass which is typical for the Baltic. Temporal and spatial distribution of *salinity* in the coastal area depends on rivers run-off and is characterized by seasonal variability. The seasonal change of surface salinity in the coastal zone of the Baltic Sea is greater than in the open sea. There is a tendency of the water salinity drop in the spring-summer period, i.e. during increase of the river run-off and when the seaward winds are predominant. This tendency is more pronounced in the places of rivers mouths and lagoon straights (such as Klaipeda, Baltiysk) than near the continental coast (Svetlogorsk), *see* Table 2. Some increase in salinity may be also found in autumn and winter, when a mixing zone penetrates deeper owing to severe storms (Kravtsov et al., 2002).

Fresh water discharge of the Neman and Vistula rivers influences on water salinity near their mouths considerably. In the coastal, shallow-water regions the river runoff forces the salinity to decrease below 7‰. This influence may be found also in the surface layers of the deepest regions of the Gdansk Bay (mainly during spring months). The Vistula River waters mix with marine water and form a thin upper layer of more fresh water. Water of the recent on-land origin can be readily distinguished as it is moved back by the 7–8‰ salinity water (Kravtsov et al., 2002).

The impact of the Curonian Lagoon on the coastal waters can be also noticeably observed in the upper (5–7 m) layers at a distance of several tens of kilometres. Fresh waters can be observed at a distance of 7–8 miles (12–15 km) to N-NW. Water under the salt wedge (even nearby the Klaipeda Strait) has salinity of 9–10 ‰, that is typical for the investigated coastal zone.

Apart from the seasonal variations of salinity in a year cycle, there are also short-time salinity variations up to ±2–3 ‰ (Kravtsov et al., 2002), which are supposedly associated with the wind-driven up- and down-welling effects. The result of seaward (landward) wind is a co-directed flow on the surface layer and a landward (seaward respectively) compensatory flux near the bottom.

Apart from the places that are under the influence of rivers plumes, seawaters salinity is uniform down to the depth of 60–70 m and usually ranges within 7–8 ‰ (Andrulewicz & Witek, 2002). During a year, seasonal changes of salinity at the open areas are not as distinct as in the coastal zone. A halocline occurs below a depth of 70 m, separating the upper isohaline layer from more saline bottom waters. The salinity in the bottom waters mainly depends on remote influence of the inflow from the North Sea. In the deep part of the gulf (Gdansk Deep) salinity may be lower than 10‰ during stagnation periods and exceeds 14‰ during intense inflows (Wojewodzki & Grelowski, 1992). The bottom waters, which are separated from the upper layer by the halocline, usually suffer from oxygen deficit (Andrulewicz & Witek, 2002; Wojewodzki & Grelowski, 1992) as the oxygen conditions there depends on the inflow of the North-Sea waters into the Baltic.

Temporal variations of *temperature* of coastal waters are more pronounced than spatial variations. The last ones depend mainly on regional factors, such as river runoff, snow and ice formation (or melting), wind affecting. Seasonal and daily variations in water temperature are greatly influenced by wind mixing and seasonal or night convection. Seasonal changes of air temperature and insolation cause a change of water temperature in the upper sea layer, but in the shallow coastal zone these factors influence practically on the whole water column.

In winter the temperature either increases in depth, or remains uniform throughout the water column in the all littoral zone. From April till August, the temperature tends to grow in the surface layer both in deep-water areas and the coastal zone, but temperature of the shallow coastal waters rises faster.

Table 3.

Annual variations of the surface temperature (C) in the coastal zone of the South-East Baltic (Terziev et al., 1992).

Place/ month	J	F	M	A	M	J	J	A	S	O	N	D
Klaipeda	0.9	0.6	1.2	4.9	10.5	14.4	17.3	17.9	14.7	10	5.5	2.4
Baltiysk	0.8	0.6	1.4	5	10.6	15.3	18.1	18.4	15.6	11	5.9	2.4
Gdynia	1.4	0.9	1.6	5.2	10.2	14.9	17.8	18.5	16	11.6	6.9	3.6
Hel	1.6	0.9	1.6	4.6	8.7	14.1	17.3	18.2	15.9	12.1	7.7	4

The upper isothermal warm layer is separated from the lower layer of the minimum temperature by the thermocline in the deep areas. Water temperature in the bottom layer ranges within 4–6 °C, and in the deep areas the annual amplitudes do not exceed 1.6 °C. While the depth exceeds 60 m, a slight temperature increase can take place. The highest temperatures of the bottom layer are observed in the deepest areas of the basin (Sivkov & Chubarenko, 1997).

The thermocline is more evident in July and August when water temperature on the surface reaches its maximum annual values (from 16.5 to 18 °C), the thickness of the thermocline runs to 30 m (depth layer 20–50 m), the temperature gradient in the thermocline equals to 0.4–0.7 °C/m (Sivkov & Chubarenko, 1997). Since September the surface water layer starts cooling down, and summer thermal stratification gradually disappears. Autumn and winter convection combined with wind mixing causes a vertically homogenous temperature distribution.

This order may be broken, for example, by cold upwelling to the surface due to influence of continued east winds, which push warm surface waters away from the coast. At the coastal areas near the rivers mouths the water temperature varies under the influence of freshwater plumes. The most significant impact is from the Vistula River.

Quick heating of the Vistula waters in spring time, and subsequent spreading of these waters over the surface of the Gulf of Gdansk result in appearance of sharp temperature gradients in the surface water layer, thickness of which lessened while the distance from the shore increases. In May, during the events of the most intensive inflow of the Vistula River, its waters cover almost the whole area of the Gulf of Gdansk. The maximum value of vertical temperature gradients is of 0.4 °C/m. During other seasons the impact of the Vistula River runoff is not so considerable, it influences only on the area above the Hel Spit. When the runoff is minimal, the influence is evident only on the coastal strip of 2–5 nautical miles and can be observed at the end of the year. The zone of the Vistula waters' influence has right-hand skewness against the Vistula River mouth. Prevalence of western winds causes deviation of the mixing zone to the east, north-east towards and along the Vistula Spit (Kravtsov et al., 2002).

The Curonian Lagoon (actually the Neman River) inflow mixes with seawaters in the surface layer, and penetrates towards northwest several tens of km under the acting of the prevailing currents.

Anthropogenic load

The whole Baltic Sea suffers strong anthropogenic influence. Mostly it concerns the coastal regions. Harmful substances are discharged mainly by rivers, municipal sewage outflows, coastal industries (shipyards, ports activities), chemical and petrochemical industries. There are several cities, ports and industrial centers on the South-East coast of the Baltic (from the north to the south): Klaipeda (Lithuania), Pionersk Baltiysk and Kaliningrad (Russia), and Tri-City area: Gdansk, Gdynia, Sopot (Poland).

In addition, rivers bring a lot of suspended and dissolved substances of both natural and anthropogenic origin (agriculture, industry, domestic sewage) from significant catchment areas, including places distant from the sea. The most pronounced pressure from the rivers is due to nutrient loads, which can achieve considerable amount. For the period 1993–98 the Vistula River brought in average 118 000 t/y of total nitrogen and of 7 000 t/y of total phosphorus. The substances can spread by the Vistula River waters along the coastline (Andrulewicz & Witek, 2002; IMGW, 1987–1999).

Nutrient load causes eutrophication of considerable coastal areas and changes in the coastal aquatic ecosystem. This process is well pronounced in the transboundary Curonian and Vistula lagoons.

Oil pollution of the Kaliningrad coast occurs regularly. The source of this pollution is very often unknown. The main probable reasons are pollution from port activities (Gdansk/Gdynia, Baltiysk/Kaliningrad, Klaipeda) and the ships navigated the region. Oil pollution easily achieves the Kaliningrad coasts from any point of the Gulf of Gdansk. Also oil blurs can be brought from the distant sea areas by prevailing west currents.

There are four main permanent point sources of suspended sediments in the Kaliningrad segment of the Baltic coastal zone. They are as follows: the discharge of the Vistula Lagoon waters through the Baltiysk Strait, two damping sites for dredged material on the western and northern coast (near the Baltiysk Strait, and near the Port of Pionerskiy) and, finally, the permanent discharge from the Amber Mining Plant on the western coast. Erosion of the Sambian Peninsula coast is a diffusive source of sediments. Annually it brings 1.05 million tons to the Gdansk Basin (Blazhchishin, 1984). The erosion rate of the main eroded sites is of 0.3–0.7 m per year in average. According to Trimonis & Stryuk (2002) shore abrasion and bottom erosion supply up to 2.33 million tons of sedimentary matter to the Gdansk Basin.

According to estimations (Chubarenko & Chubarenko, 2001) the annual average total discharge of sediments from the Vistula Lagoon is of 320 thousand tons per year. The big part of it is formed by resuspension of the lagoon bottom material, and the Vistula Lagoon nowadays is loosing sediments, which were storaged in its pool during the previous ages (*see* the article on the Vistula Lagoon in this book).

Nowadays the dumping site near Baltiysk (a depth of 10–15 m, 3 km to the north from the Baltiysk Strait) is in regular use. The annual capacity of damped material here is of 0.5–2 million tons per year. It is mostly the coarse material which is dredged from the Kaliningrad Navigation Canal during maintenance dredging or prospective deepening of some segments of the canal.

The average annual capacity of the dumping site near the Port of Pionerskiy is of 19–45 thousands tons per year (Trimonis & Stryuk, 2002). This is the marine sand that is dredged from the Port of Pionerskiy.

During 1880–1973 the Amber Mining Plant discharged into the Baltic Sea about 100 million tons of spoiled material. The discharge was the highest in the 90th, and in 1993 it equaled 2.5 million tons.

Conclusion

The following peculiarities of the Kaliningrad coastal zone are essential for formation of ecological status of coastal waters:

• there is no significant river directly inflowing into the sea along 150 km long marine open coast of the Kaliningrad Oblast, there are only small streams on the northern coast of Sambian Peninsula;

• approximately 80 km of the coastline belong to the drainless coast of the Curonian and Vistula spits;

• the surface water runoff discharging towards the Baltic from the Kaliningrad Oblast is formed in the watershed significantly larger than the area of the Oblast; all main catchments are transboundary and their upper parts are within other countries;

• the major part of the surface waters' runoff doesn't discharge directly into the Baltic Sea, but to the Curonian and Vistula lagoons at first, and therefore, there are a certain time lag and chemical transformation of water quality before these waters discharge into the Baltic coastal area.

The coastal waters of the South-East Baltic are essentially transboundary. Hydrodynamic conditions are favorable for easy transportation and waftage of any kind of pollution along the coast as well as from the open Baltic areas towards the coast. Poland, Russia, and Lithuania, that are sharing these waters, are closely "connected" via the marine area that doesn't feel administrative borders. And being the neighbors, they have to share not only water and other resources, but common responsibility for quality maintenance and sustainable use of these exhaustible natural recourses.

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The legislative basis of international cooperation of Russia for sustainable management of water resources of transboundary waters

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Introduction

Since May 2004 the Kaliningrad Oblast became fully enclaved by the EU countries. Partly their common border passes directly through the water bodies—Curonian and Vistula Lagoons, Nemunas, Vishtynetskoe Lake, the Baltic Sea. Several small rivers begin in the neighboring countries and are finished at the territory of the Kaliningrad Oblast.

Global concerns on conditions of aquatic environment on the Earth within last decades have led to understanding of need for global system

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of water resources management. Many countries have certain provisions of their national legislation to facilitate international cooperation on implementation of efficient joint management of transboundary water resources.

Since the entry into force the EU Water Framework Directive in 2002 the European Union is particularly active in facilitating cooperation on joint actions system in transboundary water basins. Various bilateral and multilateral international projects have addressed achievement of this objective. Large number of projects within this theme can be explained by multiplicity and complexity of the problem: there one could find both diplomatic, economic and technical aspects, questions of safety, various methodological approaches and so on. However any kind of cooperation on above aspects could start only after appropriate analysis of existing legal basis is done and respective gaps are going to be covered.

The below article represents sketch comparison of some definitions of the EU WFD with parallel definitions of major laws of Russia in the field of environmental and water protection and also briefs the content of recently completed project on Russian-Polish agreement for establishment of joint management system for water resources of the Vistula Lagoon.

EU-Water Framework Directive and Russian Water Law

The comparison of the legislative systems of the EU and Russia was done with financial support of the German Ministry of Environment in 2004 in the frame of the project "Implementation of the EC-Water Framework Directive (WFD) in the transboundary river basin management Republic of Lithuania—Russian Federation (Kaliningrad Oblast). The comparison of water laws of Lithuania and the Russian Federation relating to the WFD" for 12 most actual criteria (to be compared):

- Objectives
- River basin approach
- Protected areas
- Protection for drinking water resources
- Monitoring programs
- Emissions limit values / Environmental quality objectives
- Program measures
- River basin management plan
- Public information and consultation

• Strategies against pollution of water
• Best available technology
• Permits for water uses required

The main task was in comparison of the above mentioned WFD's definitions with their treating in the following Russian laws:

• Water Code of the Russian Federation (No. 167-FZ of 16.11.1995).
• Russian Federal Law on Environmental Protection (No. 7-FZ, on 10.01.2002).
• Draft of the revised Water Code of the Russian Federation (prepared by the Ministry for Economic Development & Trade, reviewed and approved by Russian Government in January 2004).
• **The Law of the Kaliningrad Oblast On Environmental Policy in the Kaliningrad Oblast (11.02.1999).**

The draft new Water Code of Russia was taken in the version of the Ministry for Economic Development and Trade because the version of the Ministry of Natural Resources has less differences from the old Water Code. Besides, the Convention on the Protection and Use of Transboundary Water-courses and International Lakes (hereinafter—ECE Convention, done at Helsinki, on 17 March 1992) was analysed. It is ratified by all the EU countries and Russia. As a result some kind of matrix was prepared. Each cell of it contains specific provisions on analyzed definitions of respective documents.

Surely, each of the documents has its own treating of analysed definitions, which are rather different. However their common content is generally complimentary.

So, the definition of *Objectives* in all legal systems mainly concerns preservation of water systems from deterioration, improvement of water quality and sustainable water use. The definition of *River Basin Approach* is only missing in ECE-Convention. The EU WFD on the matter mentions that "all programmes of measures are coordinated for the whole of the river basin district" (Clause 3, 4), while the Russian Water Code reflects it as "combination of basin-management and area-management principles" (Clause 69). The Basin principle of management is also present in the draft new Russian Water Code. The definition of *Protected Areas* is also missing in ECE-Convention. The EU WFD and draft new Russian Water Code simply require presence of protection zones for water bodies. Acting Russian Water Code mentions detailed definitions of "protected zones", "zones and districts of sanitary protection", "zones of extreme ecological situation and ecological disaster on the water bodies", "particular protected water bodies", "particular protected water bodies of international importance" and also regulates precisely any kind of activities (Clause 102, 111–119). The matter of *transboundary management of waters or river basins* is particularly important in recent time for Russia and Eastern European countries, where the status of international river basins were obtained by many rivers which have had the federal importance before and have got the international one now. International basin commissions are to be established for regulation of usage and protection of transboundary waters. Analysis of functions of such commissions shows, that traditional problems of water basins' management are surplused by approximation of norms and standards which are accepted in water use activities in neighboring countries, coordination of monitoring on water bodies' basins; establishment of additional organizational structures which implement regulatory functions for international water relations or assignment of these functions to existing territorial agency, committee; resolving of problem of juridical and financial self-sufficiency of international institutions and their economic independence. The basic document for striking of intergovernmental agreements between Russia and neighboring states about specifically protected water bodies of the international importance has became the ECE-Convention. These agreements declare the need of cooperation in the field of use and protection of transboundary waters on the basis of equal rights and mutual understanding principles of involved parties.

Draft new Water Code also requires introduction of special protected zones but does not prescribe them in detail. The EU WFD provisions on *"Protection for drinking water resources"* require accounting of all water bodies to be used for drinking water supply purposes, their monitoring and protection (Clause 7). ECE-Convention requires, in case of transboundary water bodies, development, adoption, implementation and, if possible, coordination of legislative, administrative, economic, financial and technical measures, including prohibition of economic activities, to secure good quality of drinking water and to use additional special measures for protection of ground water from pollution (Clause 3). The Russian Water Code prioritizes the usage of water bodies for drinking water supply and allows such water intake only from protected surface and ground water bodies (Clause 133). In the draft new Water Code such requirements are kept almost without changes (Clause 2, 58).

WFD requires from EU Member States under the notion of *"Monitoring programs"* to establish specific programmes in order to obtain coherent and comprehensive overview of state of waters (Clause 8, 1). ECE-Convention prescribes the following on this matter:

• Riparian Parties shall establish and implement joint programmes for monitoring the conditions of transboundary waters, including floods and ice drifts, as well as transboundary impact;
• For these purposes, the Riparian Parties shall harmonize rules for the setting up and operation of monitoring programmes, measurement systems, devices, analytical techniques, data processing and evaluation procedures, and methods for the registration of pollutants discharged (Clause 11).

The analysed Russian laws provide only common terms for state water bodies monitoring are considered, while none of them mentions the need and obligation of joint monitoring actions with neighboring countries. *"Emissions Limit Values / Environmental Quality Objectives"* under the WFD are combined, while the first category falls mainly into national standards (Clause 10). ECE-Convention on this matter requires setting up *emission limit values* for wastewater discharge, *emission values* for pollutants' concentration from point sources into surface water bodies, based on BAT (Best Available Technology), target indicators of water quality objectives and approves criteria of water quality for prevention, limitation or reduction of transboundary impact (Clause 3). The Russian Water Code also sets up limits for water use (Clause 90), while norms of maximum allowable harmful impacts on water bodies presume to set up basing on:
• maximum allowed anthropogenic load, long-term impact of which will not cause deterioration of ecosystem of water body;
• maximum allowed mass of harmful substances, which can be loaded into water body or its watershed (Clause 109).

The draft new Water Code sets only the term of "water quality objectives in water bodies", which is not explained anyhow (Clause 54). Under the *"Action plan"* the WFD requires from the EU Member States to set up action plan for achievement of objectives (Clause 11). Countries, which have ratified ECE-Convention, shall elaborate, approve and implement appropriate legal, administrative, economic, financial and technical measures (Clause 3), as well as cooperate in research and development in the field of efficient methods of prevention, limitation and reduction of transboundary impact, having in mind scientific activities of respective international forum, shall strive to perform or facilitate when needed on bilateral or multilateral basis respective research programmes (Clause 5). The actual Russian Water Code presumes:
• development of comprehensive plans of water protection and use for the purpose of setting of water management and other measures to satisfy the prospected needs of society in water resources, provision of

wise use and protection of water bodies, as well as for prevention and response to harmful impacts on waters (Clause 76). The way of development of such plans is set up in the Ordinance of the Government of Russia No. 1097 of 13.09.96. The plans of comprehensive use and protection of transboundary waters shall be developed in accordance with the international agreement of Russia;

• development of federal public, as well as basin and territorial state programs for wise planning, recovery and preservation of water bodies.

In contrary, the Draft of New Water Code has no terms on it.

As for the *"River Basin Management Plan"* the WFD states, that EU Members shall guarantee elaboration of river basin management plan (Clause 13), pattern contents of which are prescribed under Annex VII of the WFD. ECE-Convention provides nothing on this matter. In the Russian Water Code such *Plan* is to our opinion called *"Basin Agreement on protection and recovery of water bodies"*, which is dedicated for the purpose of coordination and joining of all activities, aiming at protection and recovery of water bodies (Clause 120). Moreover, the *Comments to the Water Code* (Bogolubov et al., 1997) provides more detailed description of "*basin agreement*", its content and composition.

Under the draft new Water Code the *Plan* is meant by the *Comprehensive Plan for management and protection of water bodies*, which shall contain systematic research materials on the state and use of water bodies' basins (Clause 52). There is common understanding of importance of public awareness and consultations' process in the EU. Hence, *"Public information and consultations"* within the WFD does not create any exception from this rule. Clause 14 of it states that "schedule, work program for elaboration of plans, interim review of substantial matters of water management and drafts of river basin management plan shall be made available to public comments within appropriate period of time". The ECE-Convention also requires from the coastal states to provide public with results of assessment of water quality, list of issued permissions and fulfillment of objectives (Clause 11, 16). The acting Russian Water Code does not provide such terms. However, they are present both in the Federal Law on Environmental Protection (Clause 13, 74) and the Kaliningrad Regional Law on Environmental Policy (Clause 5). The draft new Water Code of Russia states "participation of citizens and NGOs in decision-making process if these matters are related to theitr property rights on water bodies and obligations to sustain them in good condition" (Clause 2, 10) as one of the basic principles. Under *"Strategy to prevent water pollution"* the WFD requires by the power of the Parliament and Council to undertake special measures to prevent contamination of waters (Clause 16). This Chapter also prescribes the List of 33 priority pollutants to undertake more stringent control after them. The ECE-Convention obliges to create joint bodies to elaborate limit values for waste water discharge and assess efficiency of pollution mitigation programmes, as well as to develop coordinated action programmes to reduce pollution load (Clause 9). The acting and forthcoming Russian law does not have any specific terms to require strategic approach towards water contamination. The next provision on *"Best Available Technology"* is mentioned only under Annex I of the WFD, where the definition of *BAT* from another EU Directive (EC **96/61/EC** of 24/09/1996) on integrated pollution prevention and control is cited. Meanwhile, firstly the definition and basic provisions about *BAT* were included in the text of ECE-Convention, which states that the Parties shall develop exchange of *BATs* (Clause 13). In the Russian law the definition of *BAT* is for the first time introduced by the Federal Law on Environmental Protection (Clause 1), where it is stated that one of the environmental protection principles in Russia shall be "provision of reduction of negative impact of any economic activity on natural environment in accordance with set norms in the field of environmental protection, which can be reached by means of application of BATs, taking into account economic and social factors" (Clause 3). The last provision, which was compared between the legal systems was *"Necessary permissions for water use"*. There is no specific document to be required by the WFD for such purpose. The same applies to the ECE-Convention. It only states the requirement towards the Parties to provide the public with information of the list of issued permissions and their terms and conditions to de complied (Clause 16). Acting Water Code of Russia sets the need of two kinds of permissive documents for water user: the license on water use (Clause 48) and the agreement of water use (Clause 54). The forthcoming Water Code leaves only one of these two documents—the water use Contract (Clause 21).

As we could see from this comparison of legislation of Russia, EU and UN Convention, there are no major contradiction for further development of cooperation in the field of transboundary water management. We can only state substantial differences towards long-term planning, as Russia has no legal requirements on strategic approach to the management of water resources, as well as there are no norms in the Russian law which would prescribe provisions of joint monitoring actions. But the WFD has legal deadlines to reach the objectives: the good water status has to be reached within 15 years after the entry into force of the WFD.

Prospects of further cooperation of the Kaliningrad Oblast in the field of transboundary managemant of water resources: case of Vistula Lagoon

Currently a lot of efforts are undertaken to strengthen the existing cooperation between the Kaliningrad Oblast and Poland. The need of such activity is obvious for both sides: for Poland—first of all, development of cooperation with Russia has important value for approximation of the national law with the EU standards, for the particular case, to comply with provisions of the WFD, while for Russia it is mainly connected with the point that sufficient number of watercourses of the Kaliningrad Oblast, being consequently the sources of drinking water intake, take their start at the Polish territory, hence there is a need for the control after water quality of transboundary waters. Other reasons to develop more active cooperation in this field have lower priority, e.g. the Kaliningrad Oblast formally is not obliged to follow the norms of EU law, while Poland has sovereign right not to inform Russia about the state of waters at its own territory. However, one shall not forget about existence of the number of International Convention, which both Russia and Poland are the parties of. Firstly, it's already mentioned ECE-Convention on Transboundary Watercourses and secondly, it is the Convention for Protection of Marine Environment of the Baltic Sea Area (HELCOM). Unfortunately, both of these acts are so-called "soft law", which do not allow to apply their requirements and provisions within national legal systems, but needs consequent changes into the national law to be introduced. Moreover, most of decisions of the abovementioned Conventions represent so-called "recommendations" or "guidance". Thus, the bilateral Russian-Polish transboundary cooperation shall be based upon bilateral agreements, which are achieved both at federal and regional level. They include, among the others, the following relevant to our topic:

- Agreement between the Government of the Republic of Poland and the Government of the Russian Federation on transboundary cooperation of 02.10.1992,
- Agreement between the Government of the Republic of Poland and the Government of the Russian Federation on cooperation in the field of environmental protection of 25.08.1993,
- Cooperation Agreement between the Pomeranian Voivodship (Republic of Poland) and Administration of the Kaliningrad Oblast (Russian Federation) of 27.02.2002.

However, the question is how to make them working in practice.

The Project on "Restoration of transboundary water management of the Vistula Lagoon", being initiated and performed by the Administration of the Kaliningrad Oblast together with the Self-Government (Office of the President) of the Pomeranian Voivodship within EU TACIS Cross-Border Programme of Micro Projects, has allowed to test the model of direct bilateral dialogue between concerned authorities from both Polish and Russian side in the matters of transboundary water management. As a tool for development of such dialogue the Russian side has proposed already elaborated within one of previous TACIS Project ("Water Environmental Monitoring and management for the Kaliningrad Oblast") a database structure for management of monitoring data for surface waters. The Russian side has proposed to use this structure as a pattern tool for unification (harmonization) of data about the water quality of transboundary waters of the Vistula Lagoon from both sides. Having this instrument will allow more precise description of the actual state of environment of the lagoon and, consequently, take more adequate and comprehensive decisions on improvement environmental situation for the whole lagoon, as well as to forecast development of environmental situation due to different applied scenario of various water protection measures taken. Hence, the base for creation of joint comprehensive management of the water body is formed. The second step of the project was the preparation of bilateral agreement between the authorities, which are responsible for monitoring of surface waters—the Polish Institute of Meteorological and Water Management and Kaliningrad Center for Hydrometeorology and Environmental Monitoring of the Federal Service for Hydrometeorology and Environmental Monitoring of Russia. While discussing the Agreement both parties decided, that it is worthwhile to go step-by-step. Henceforth, it was proposed that at the beginning there is a need to test the matter so practical cooperation on exchange and analysis of data about the state of environment within the frame of technical agreement between monitoring bodies, and then start preparation for signing of general agreement between the Kaliningrad Oblast and neighboring voivodships of Poland on the matters of joint management of water resources with final aim to create joint management body for the Vistula Lagoon in accordance with the EU WFD and ECE-Convention. Parties of the Project were looking after the example of successful cooperation within Russian-Estonian cooperation of Peipsi/Chudskoje Lake (EU MANTRA Project), within which Joint Management Commission is formed and Acton Program is elaborated and under implementation. By the moment of completion of the project, the Russian side has prepared and agreed with the Federal Service for Hydrometeorology and Environmental Monitoring of Russia the text of technical agreement, which has been delivered to the Polish side for the review and approval. The structure of the surface waters monitoring database was also adopted into Polish interface and installed at Polish institutions for testing and training.

It is expected that work on actual information exchange of Vistula Lagoon monitoring data will start as soon as the Agreement is signed from the Polish side. It is also foreseen to develop similar Agreement with Lithuania, as so far there is only the agreement on exchange of monitoring data on transboundary rivers.

Hence, the existing legal basis of international cooperation of Russia on provision of sustainable management of transboundary water resources does not contradict with basic principles of the WFD and allows to utilize unique geopolitical situation of the Kaliningrad Oblast for mutual beneficial cooperation with European Union in the field of environmental protection and sustainable development.

Remark: The latest version of the Water Code of the Russian Federation was adopted by the Duma of the Russian Federation in 2006.

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Public initiatives in environmental protection process in the Kaliningrad Oblast

Raisa A. Gouseva

1. Introduction

The Kaliningrad Oblast takes an active part in the development of the international cooperation with EU's countiries especially the countries of the Baltic Region. The Kaliningrad Oblast is a member of international associations. The Euroregion "Baltica" united the bodies of local government of Sweden, Denmark, Lithuania, Latvia, Poland and the Kaliningrad Oblast of Russia is one of such kind of associations. Many experts consider this region a "development corridor" in the economic system of the whole Baltic Region.

At the present time a simple economical model connected with natural recourses use is developing in Russia. The President has set the task to double GDP. The matters connected with possible outputs of using of the existent economical model and ways of achieving the task set by the President, more and more make those who concern on future, especially the advanced science circles think about. Still there is an opinion that ecology is an expensive thing, that's why it's necessary to reach a high level of economic development first and only then solve ecological problems. But there are more scientists who consider such statement of the issue as illegal. Among the scientists and politicians there is the view that economical and ecological interests should be joined and the ways to achieve it should be found. This opinion is strengthening.

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Possibility of harmonization of interests of economical development and ecological protection in the regions of Russia is extremely urgent. The time comes when the resource economy changes for the modern innovative economy and policy. This was the issue discussed at the joint meeting of the Economic Policy sector and Ecological Policy sector of Science&Expertize Council under the Chairman of the Federation Soviet of the Federal Chamber of the Russian Federation S.M. Mironov on 29 November 2004. The issue discussed was about "Possibilities of Harmonization of Interests of Economic and Ecological Development and Ecological Safety in the Regions of Russia".

Eonomical development and ecological safety are both state and public demands. For the Kaliningrad Oblast, being a Russian remote and situated in the center of Europe, harmonization of economical and ecological interests is of a great importance. Benefit economical and geographical location, abundance of natural recourses and qualified labor forces are the favorable pre-conditions for economic development of the Kaliningrad Oblast. However, the outside influence of EU countries upon the Kaliningrad Oblast, high population density and high economical utilization of the territory predetermine the relevance of ecological problems of the unique in its natural environment region.

Most of the economic and ecological problems could be solved under condition of the active public participation in ongoing activities and win-win international crelations. In order to solve these problems the instruments of economical development and ecological safety management of the Kaliningrad Oblast under conditions of the exclave geographical location and harmonization of state and public interests have to be found.

2. Public in Ecological Decision-Making Process

One of the main instruments of harmonization of economical interests and ecological safety is the joint consideration of both governmental and public interests which often conflict. As a rule government and business express economical interests and NGOs express public ones. In 1999 most of the active public ecological organizations (NGOs) of the Kaliningrad Oblast came to conclusion that it was necessary to set activities on cooperation with the government and business going, and provide the real public participation in decision-making process on environment protection issues. As a result the Kaliningrad Regional Ecological Public&Political Movement was organized (in 2004 it was re-organized into the Center for Ecological Policy). Later the process developed after creation of the Public Chamber in the Kaliningrad Oblast in May 2001, the time when under initiative of the Kaliningrad Regional Ecological Public&Political Movement the Council of Ecological public organizations had been created in its structure. It allowed the NGOs not only elaborate the general opinion on ecological problems in the region but also propose the ways of its solution to the authorities.

Representatives of the regional administration, the department of environmental management and nature protection of the Kaliningrad Oblast as well as the representatives of the local authorities and business take part in the Council meetings. This structure is a new form of public, power and business inter-relations in the field of environment protection, and one of the forms of protection of citizens' ecological rights. The ecologists learn not only how to cooperate and elaborate applications of the joint projects but also how to carry on a dialogue with the authorities and business, to find compromises on issues on nature protection and public health in case of conflict of interests. The Council's activities under the Public Chamber gives an opportunity to establish cooperation between ecologists and women's, youth, migration and rights defensive public organizations. Such cooperation allows to champion a wide range of public interests including ecological ones more effectively. When considering the issue of Ecological problems of the Kaliningrad Oblast and the ways of its solution the representatives of more than 100 NGOs of the different sectors of public movement took part in the discussion held at the Public Chamber meeting in May 2003.

To improve the ecological situation in the Kaliningrad Oblast and the Baltic Sea Region as a whole, we need to use the existing European experience of public participation in work on ecological problems. Obviously, the work of the Council that is a part of the model of cooperation of three sectors of society needs further improvement. Otherwise, strengthening of the role of the third sector and sivil society development are impossible in the Kaliningrad Oblast. With this aim the joint Russian-Swedish project "EcoMan" (a TACIS program) "Elaboration of the Mechanisms for Implementation of the Regional Ecological Policy for Sustainable Development of the Kaliningrad Region" has been implemented. The experts of the Council representing public, administrative and business structures participated in the project. A range of the findings received in the framework of the project served a base for the further development of the regional legislation and improvement of the cooperation between the authorities and the NGOs' in the process of establishment and implementation of the ecological policy.

Last years the ecological supervision has been relaxed in Russia. There are some attempts to change the law "On Ecological Expertise", concerning environment protection and restriction of irrational natural resources use. At that the principal of legality, ecological and economical advisability is being broken. At the same time environmental protection issues are becoming a great concern for inhabitants. It's clearly seen in the areas where economical situation is better. All these processes occur in the Kaliningrad Oblast as well. The third sector's role including "green movement" is strengthening in making decisions on social matters. The exhibition on Social Service and NGOs' projects supported by the Governor of the Kalinigrad Region conducted in May 2003, as well as the high appreciation of the project results by the regional administration prove the above-metioned fact. The representatives of the Council of the Ecological Public Organizations of the Public Chamber are involved in the international projects implemented by the Regional Administration, the Regional Duma, the Immanuel Kant State University of Russia, and other scientific institutions and business structures. They also actively participate in arrangement and realization of public discussion of the projects on the planned economical activities. The main projects are the following:

- "EcoMan";
- "The Development Strategy of the Waste Treatment System in the Kaliningrad Region";
- "Waste Treatment System Maintenance at the Enterprises of the Kaliningrad Region";
- "Landscape Planning in the Kaliningrad Region";
- "Development Strategy of the Euroregion "Baltic";
- "Construction of the Terminal for Ferry-railway-automobile communication Ust-Luga—Baltiysk—German Ports";
- Seagull RC—Russian component of the development strategy of the Euroregion "Baltic".

However, during last time there is the situation, when one would think protecting the ecological rights of the inhabitants some NGOs pursue other objects, and even selfish ends. It was especially seen during the public discussions of the projects dealing with construction of oil-pass point of the "Baltnaft" Ltd., and reconstruction of the bunker base for loading the ships with oil and oil transfer to the tankers on the territory of the joint-stock company "MPB" and the Ltd "BaltHoltz" to the address 1, Rybatskaya Str, the city of Svetly. The opinions of the NGOs were different. Most of the them considered projects implementation economically and ecologically advisable but the Kaliningrad NGO "Ecozashita" (EcoProtection) and "My City" were absolutely against. In the framework of the project "Reconstruction of the bunker base for loading the ships with oil and oil transfer to the tankers on the territory of "MPB" and "BaltHoltz" to the address 1, Rybatskaya Str, the city of Svetly" the Kaliningrad Regional Ecological Public&Political Movement carried out the public ecological expertise with the framework of which according to the strategy of Professor of the State University of Management, Doctor of Economical Sciences O.E. Medvedeva the evaluation of the ecological&economical effectiveness of the project has been carried out. The experts said the project gave the city more pluses than minuses.

Public discussion and public ecological expertise included the following:

- public survey of the project;
- public awareness of the project;
- public hearing;
- public ecological expertise;
- environmental health evaluation of the City of Svetly;
- public health evaluation of Svetly.

Public debate was conducted step by step as the current legislation demands:

1st step—to inform and develop technical proposal drafting on evaluation of the impact on the environment (from June 9 to August 9, 2004);

2nd step—to discuss the preliminary environment health evaluation materials (from August 10 to September 16, 2004);

3d step—to elaborate the final environment health evaluation materials (from September 17 to October 16, 2004).

The representatives of the NGOs, entering the Public Chamber of the Kaliningrad Oblast took part in this work. They are: Kaliningrad Regional Ecological Public&Political Movement, Kaliningrad Regional Public Ecology Foundation "XXI Century", Kaliningrad Center of Public Initiatives Support, Kaliningrad Regional NGO "Systems 21", Association of Mothers-With-Many-Children, Kaliningrad Regional Public Foundation "Stanovlenie" (Recovery), Kaliningrad Ecological Union "Right to Life" and others.

The draft Regulations "On Public Discussion of the Planned Economic Activities" was submitted to the Administration of the Svetly District. On its base the administration of the municipal formation elaborated the Regulations "On procedure of the Public Discussion on the Objects of the State Ecological Expertise on the territory of the municipal formation "Svetly Urban District" that was adopted by the District Council of Deputies later on.

During the public discussions the following forms of the work with the inhabitants have been used:

- Public reception;
- Public survey;
- Public hearing;
- Focus of the group;
- Collection of signatures for and against the project;
- Information materials dissemination via mass media, radio, TV and booklets;
- A trip of the inhabitants of Svetly to the City of Dresden to learn about the oil-pass point;

Public suggestions and remarks appeared during the discussons were summarized and submitted to the administrations of the Svetly District and the Ltd. "Moscow Production Base" for analysis and consideration while preparing the materials on evaluation of the impact on the environment in the framework of the project.

The Kaliningrad Regional Ecological Public & Political Movement submitted the amendments to the Regulations "On Procedure of the Public Discussions on the Projects liable to the "State Ecological Expertise" and their proposals on improvement of theecological situation in the district to the local authorities.

However, in spite of the wide work on public awareness, the projects got no public support and the initiative group headed by "Echozashita" organized a referendum that took place on 22 May 2005. The referendum took place but 300 voices were lack. Now the proceedings is to be on the referendum results.

On the one hand the event has positive results as it shows public awareness that stimulates civil society formation. But on the other hand, fairly analysing the situation one may come to the conclusion that that we are still far from the civil society which is able to evaluate current situation impartially and derive the real public interest from it. Under these conditions development of the civil society through strenthening of the non-governmental sector, increasing of ecological culture of the inhabitants, and, finally, increasing in ecological production, analysis and using of the domestic and foreign experience become the main directions of providing of elaboration and implementation the ecology policy. As the experience of the Center for Ecological Policy of Russia shows, public organizations exactly and NGOs in particular can initiate elaboration of important ecological problemns and make constructive contrubution to solve it. In the Kaliningrad Oblast creation of the Expert Commission under the Council of Ecological Public organizations of the Public Chamber will be an important step in this direction. That will allow to attract Kaliningrad professional and scientific ecological public to of the important environmental problems solving, to set a constructive dialogue between public and business, and to solve conflict situations in a better way.

3. Public Involvement into Elaboration of the Regulatory Legal Acts

The first experience of public involvement into development of statutory acts is the work of public experts on environmental protection issues in the Consultative Council under the Ecology & Nature Utilization Council of the Kaliningrad Regional Duma (1996–2000). Right during this time the most statutory acts including the laws in the field of ecological law focused on development of the regional systematic ecological legislation have been adopted. First of all, it relates to development and adoption of the Law “On Ecological Policy in the Kaliningrad Region”. The law provides creation of the common legal base to provide ecological sucurity of the population, environment protection, rational utilization of natural resources and sustainable development for the sake of today’s and future generations on the base of the Constitution of the Russian Federation, and taking into account geographical location and specific regional conditions (1999).

The next step in this direction was participation of the public ecologists as the experts in “EcoMan” TASIS project. The project objective was to provide effectiveness of the activities of regional and local authorities, and authorized bodies in implementation of the ecological policy in the Kaliningrad Oblast. The project result was development of the system of the statutory acts, providing the legal basis for effective cooperation of the local authorized federal bodies in the field of natural resources use and environment protection, the regional administration and the municipal authorities in implementation of theb regional ecological policy.

The program of law-making activity was not based to the activity of the permanent Committee on Land, Nature Management and Ecology of the Regional Duma. However, thanks to the activity of the Ecology Policy Center in the framework of the work of the Council of Ecological Public Organizations this program began to realize. In May 2003 the Public Chamber considered the issue “On Ecological Problems and Ways to Overcome”. The result of this discussion was the Agreement on cooperation in the field of environment protection concluded with the regional administration in 2004. The draft “On Environment Protection in the Kaliningrad Region” and draft of Regulations “On Public Ecology Control” were developed in the framework of this agreement. On the basis of the developed drafts of the statutory acts in the framework of the “Seagull” project the REFERENCES on public Ecological control at the objects, that are in the competence of the Kaliningrad Oblast, and the REFERENCES on development of the Statement “On Public Discussion and Hearing on Environment Protection, Nature Management and Ecological Safety on the Territory of a Municipal Formation” were prepared. A list and review of the statutory acts of the Russian Federation and the Kaliningrad Oblast regulating public involvement into decision-making process was done.

At the present time the public initiative on creation of favourable environment for harmonic development of a person presented in the form of the innovative program “Sunny Home” is elaborated. The work on the project “Landscape Planning in the Kaliningrad Region” is coming to the end, and the Council of Ecological Public Organizations will have to prepare and conduct the public discussion of the project of “Landscape Program”, and submit its proposals on the program legal status to the regional administration. The next step is the final work on the draft “On Environment Protection in the Kaliningrad Region”, on the draft Regulations “On Public Ecological Control in the Kaliningrad Region”, and inserting amendments into the Town-Planning Code of the Kaliningrad Oblast due to the changes in the Construction Code of the Russian Federation. Besides, we plan to assist “Rosprirodkontrol” (the Russian Nature Supervision) to give a legal status to “the nature protection scheme”, prepared in the framework of the Russian-Swedish project.

The two pilot documents were prepared by the public organizations. They were: “Methodic references on development of the regulations “On conduction of public discussion and public hearings on environment protection issues, nature management and ecological safety on the territory of a municipal formation”, and “Methodic references “On public ecological control at the objects in the Kaliningrad Region”.

The main terms and definitions are provided in these documents. The procedure of holding of public discussions on nature protection issues and nature management is also studied. The main principles of holding of public discussions are provided here. They are: obligatoriness of holding of public discussions on environment protection issues, nature management before the bodies of the state authority and local goverment make any decisions; end-to-end assessment of presented to the discussion documents; data adequacy and completeness; universality of a discussion; equality of rights of citizens in participation; freedom of the will of participants of a discussion; neutrality, transparency and publicity of a discussion; validity of acception of decisions; obligatoriness of acception of decisions on the basis of results of the public opinions; experts independence; scientific validity, neutrality and legality of decisions; responsibility of privies, the participants of public discussions for organization and conduction of public discussions, and quality of accepted decisions. A person who may be a participant and initiator of a public discussion is determined. The stages of preparation, organization, conditions and holding of public discussion also viewed. Holding of a public ecological expertise in accordance with the Federal Law "On Ecological Expertise" is considered. The attention is paid to the issue of public inspection of the objects of nature protection.

The example of realization of the principles, provided in these documents, may be the Statement "On holding of a public discussion of the objects of the state ecological expertise on the territory of the municipal formation" approved by the Board of the Deputies of the municipal formation "Svetlovskiy Urban District".

4. Conclusion

Drawing a conclusion of all the above-mentioned one may say that the ecological public organizations of the Kaliningrad Oblast take an active part in civil society formation. Not everything done is perfect; especially in harmonization of economic development and ecological safety, but the experience gained during the last decade, and actively developing international cooperation stimulate the successful implementation of the planned goals.

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Water resources management in the Kaliningrad Oblast; expedience and perspectives of applying the principles and norms of the EU Water Frame Directive

Felix E. Alexeev

1. Introduction

The Kaliningrad Oblast is surrounded by countries of the European Union (EU), which use the water legislation following the principles and general recommendations established by the EU Framework Water Directive (http://ec.europa.eu). In Russian Federation (RF) all these issues are regulated by the Water Code of RF (12.04.2006, http://www.akdi.ru). How these two legal acts correlate with each other? How could they be superposed in order to be utilized in the practical activities on management of trans-boundary water basins located across the Kaliningrad Oblast? Is it reasonable to apply the ideas of the Framework Water Directive in the Kaliningrad Oblast? Which positions could be useful and on which basis it is possible to harmonise the efforts aimed at improvement of situation with inland water resources and the Baltic Sea? All these questions naturally arise from the need to develop the joint development strategy in the common ecological space of the Baltic.

In this paper the legislative issues arising from the neighbourhood of the Russian territory with the EU countries are analysed. The overview of the strategies for development of water resources in the Kalin-

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ingrad Oblast is provided. In the conclusion the recommendations for the inclusion into the joint development strategy of the Euroregion "Baltic", which have been elaborated together with B.V. Chubarenko, are provided (Chubarenko & Alekseev, 2005).

2. Legislative issues

The legislative basis regulating the economic activity in the national parts of the trans-boundary basins is different. In Russia the Water Code of RF adopted in 1995 and amended in 2001–05 is in force now. In the neighbouring countries the legislative basis is grounded on the principles and recommendations of the EU Water Framework Directive (WFD), which was introduced later in 2002 and accumulated the most up-to-date approaches to water resource management elaborated for that moment.

The prerequisites for evaluation of the appropriateness of applying the principles and norms of WFD in practice of the water resources management in the Kaliningrad Oblast could be divided into two groups.

2.1. Prerequisites connected with geographical and geopolitical location of the Kaliningrad Oblast

The fact that the Kaliningrad Oblast shares common water ecosystems with the border regions of the neighbouring countries is the objective prerequisite for cooperation in the sphere of use and protection of water resources. After Lithuanian and Polish entry into the EU the legal norms for protection and use of surface, transitional, coastal and ground waters determined by the EU Water Framework Directive have been introduced in these countries.

According to the paragraph 5 of Article 3 of WFD, the EU Member State or Member States "shall endeavour to establish appropriate coordination with the relevant non-Member States", with the aim of achieving the objectives of WFD throughout the river basin districts, which extend beyond the territory of the Community. This norm directly concerns Poland in part of trans-boundary rivers and Vistula lagoon and Lithuania in part of Vishtynetskoye Lake, the river basin of Neman and Curonian Lagoon.

It is evident that the jurisdiction of WFD does not extend on the territory of the Kaliningrad Oblast of RF. However, the need for bilateral and multilateral cooperation on investigation and protection of trans-boundary water bodies follows from the obligations undertaken by Russia according to international conventions and agreements ratified by RF. First of all, these include the Convention on Protection of the Marine Environment of the Baltic Sea Area (1974 and 1992), Convention on the Protection and Use of Transboundary Watercourses and International Lakes (1996), as well as the UN Convention on Wetlands of International Importance (Ramsar Convention, 1977) and Convention on Biological Diversity (1995).

Aspects of cooperation between the Kaliningrad Oblast of RF and Lithuanian and Polish regions in the sphere of environment protection are determined by the special agreements between the Governments of Russia, Poland and Lithuania. The draft of the trilateral agreement (Russia—Lithuania—Byelorussia) on use and protection of water resources in the basin of Neman River is in the process of preparation.

Besides, the interaction with neighbouring regions in the sphere of environment protection is provided by several legal acts of the Kaliningrad Oblast, including the Law of the Kaliningrad Oblast "On Environmental Policy in Kaliningrad Oblast" (1999), the draft of the "Territorial Complex Scheme of Spatial Planning Development of Kaliningrad Oblast and its Parts" (2004). This scheme (TCS) particularly identifies the formation of developed nature frame integrated into the environmental space of the Baltic Sea Region as one of the major goals.

Therefore, the unity of the ecological space of the Kaliningrad Oblast of RF and neighbouring EU member states is the objective prerequisite for cooperation with the EU in the field of protection and use of waters, while acting international agreements and treaties provide sufficient legal basis for such interaction.

International cooperation on use and protection of waters presupposes the need for harmonization of legal, organisational (administrative), economical and technical managerial tools. From this point of view the evaluation of the appropriateness of applying the principles and norms of WFD seems to be justified and desirable.

2.2. The Water Framework Directive as the example of contemporary approach towards the water resource management

The specific advantages of WFD as a working tool introduce the second group of the prerequisites for applying the principles and norms of WFD in practice of management of the Kaliningrad Oblast water resources.

In contrast to the Water Code of RF, which has a clear focus on resources, the WFD distinctly formulates the environmental orientation of the policy in the sphere of protection and use of waters (Articles 1, 4).

The WFD defines the river basin (river basin district) as the main unit for management of water resources. The Water Code of RF does not contain such clear notation and does not define the basic management unit.

The WFD declares the individual approach towards the nature objects—river basins, while the Water Code of RF set the uniform approach on a national scale, although Russia possesses greater nature diversity than the EU.

The WFD accents the ecosystem approach towards the water management with the priority of achieving and preserving a certain quality of waters. Water quality of water bodies is assessed on its ecological and chemical condition.

The WFD demands the clear formulation of the goals of water policy, identification of the target indicators of effectiveness of planned measures and determination of the set and consequence of actions on realisation of policy in the sphere of water quality management.

The WFD clearly defines the time frames for implementation of measures on legal, organisational (administrative) and information provision of the water policy and specific terms of realisation of intermediate and final goals of this policy.

The WFD includes in the list of objects of water policy and management not only the water and surface ecosystems, and the wetlands, which directly depend on water ecosystems, but, that is particularly important, prescribes to consider the groundwater as the part of the basin.

Moreover, one should underline that the WFD together with its Appendixes I–XI represents the compact document, which contains the "model of the desirable future" and the legislative basis, determines the organisational structure, the time plan and major methodological approaches towards the realisation of the water policy of the Community.

The Water Code of RF contains many reference notes, which often are not provided by necessary regulatory legal acts determining the aims, organisational basis, economic and financial provision and terms for achievement of the target indicators (i.e. "the mechanisms of realisation"). As a result, the emphasis in the Water Code of RF has obviously shifted in the direction of water use regulation to the detriment of protection and restoration of water bodies (Chapter 11 "Protection of water bodies" abounds in declarative notions and almost does not contain Articles of direct action). Particularly this results in failure of realisation of the basin management principle, which is introduced in the Water Code of RF.

The WFD represents a good example for adoption of a number of conceptual and normative provisions and could be considered as a tool for realisation of the water policy under specific conditions of the Kaliningrad Oblast. Adoption of a number of principles and norms of the WFD in practice of the water resource management in the Kaliningrad Oblast seems to be appropriate.

2.3. Analysis of possibilities for using the principles and norms of the Water Framework Directive in practice of the water resource management in the Kaliningrad Oblast

The Constitution of RF provides the governmental bodies of entities (oblasts) of the Russian Federation with rather large powers: particularly, Article 72 determines that issues of possession, use and disposal of … water and other natural resources, as well as the nature utilization and protection of the environment belong to responsibilities of entities.

According to Article 34 of the Water Code of RF adopted in 1995, the water bodies are state owned (with the exception of the isolated water bodies, which could be either state-owned or in municipal or private property). According to Article 35 of the Water Code of RF, the water bodies could be in state-ownership of the entities of the Russian Federation if: their basins are located within the territory of the corresponding entity of the Federation and they are not included into the federal property list (article 37 of the Water Code of RF). At that the water bodies could be declared as the property of the entities of the Federation upon coordination with "the corresponding federal bodies of executive power" (article 37 of the Water Code of RF).

For the time being all water bodies in the Kaliningrad Oblast are in federal property, as soon as the regional executive authorities have not applied to the Government of RF on the issue of transfer of the water bodies to the property of the Kaliningrad Oblast.

According to the norms of Articles 36 and 37 of the Water Code of RF, the majority of the surface waterways must be referred to the objects of federal property only. According to Article 36 of the Water Code of RF, the management of the federal property on water bodies is carried out by the Government of RF. The same article provides for the possibility of transfer of the part of powers on management of the federal property on water bodies to the executive authorities of the entities of RF. For the time being, the Administration of the Kaliningrad

Oblast doesn't have such powers. At the same time (article 38 of the Water Code of RF), "the issues of possession, use and disposal of the state-owned water bodies referred to the joint jurisdiction of the Russian Federation and its entity", the Kaliningrad Oblast.

Delimitation of powers between the bodies of the state authority of the Russian Federation and entities of RF could be determined by the special agreements on delimitation of jurisdiction and powers. For the moment, there is no such delimitation for the Kaliningrad Oblast based on the agreement.

Therefore, the system of management of water bodies in RF *de facto* was highly centralized. This particularly refers to the Kaliningrad Oblast, as soon as all more or less important water bodies on its territory are trans-boundary (border) and, according to Article 36, belonged to the property of the Russian Federation. That meant that the possibility of applying the principles and norms of WFD in practice of the water resource management in the Kaliningrad Oblast referred to the competence of the federal bodies of executive power.

At the same time "the elaboration, approval and realisation of the territorial state programmes on use, restoration and protection of water bodies" (article 66 of the Water Code of RF) is under jurisdiction of the entities of RF. According to Article 6 of the Federal Law "On environmental protection" the following powers are under jurisdiction of the entities of RF as well:

- "identification of the major directions for environmental protection on the territories of the entities of the Russian Federation";
- "elaboration and promulgation of laws and other legal acts of the entities of the Russian Federation in the sphere of environment protection taking into consideration the geographical, natural, socio-economic and other peculiarities of the entities of RF";
- "elaboration and approval of norms, state standards and other legal documents in the sphere of environment protection, containing the corresponding requirements, norms and roles not below the limits established at the federal level";
- as well as the other functions connected with organisation and conduction of the environment monitoring, state control in the sphere of environment protection, establishment of natural reserves.

Other (additional) powers in the sphere of relations connected with environment protection could be transferred to the region (entities) on the basis of the special agreement of delimitation of jurisdiction and power between governmental bodies of RF and entity of RF (article 9 of the Federal Law "On environmental protection").

The Federal Decree No. 122-FZ of August 22, 2004 made radical changes to the Water Code of RF. In particular, every water body (with the exception of the isolated water bodies, which were either in private or municipal property) was referred to the objects of federal property only. And, accordingly, all the powers of federal authority bodies of RF entities in the sphere of use and protection of water bodies were cancelled, and centralization of these functions was driven to absolute.

In 16 months the next important alterations of water-protection legislation were made. The Federal Decree No. 199-FZ of December 31, 2005 gave back some of the functions on state management in the sphere of use and protection of water bodies to federal authority bodies of RF entities. They were given a right to "elaborate and approve regional programmes on use, restoration and protection of water bodies situated on the territory of RF entities" (in coordination with the corresponding federal bodies).

In general, important changes in water-protection legislation (and in nature-protection on the whole) following one by one are evidence of the fact that national policy in the sphere of use and protection of water bodies is still on the stage of formation.

Theoretically, applying of principles and norms of the WFD on the territory of the Kaliningrad Oblast in principle could be approved by the Government of RF on the basis of consideration of the specifics of the geographical location of the region and uniformity of its environmental space with one belonging to the territories of neighbouring countries, which are the EU Member States. Certain opportunities are also provided by the Convention on the Protection and Use of Transboundary Watercourses and International Lakes, as soon as according to the Russian environmental legislation, particularly the Water Code of RF and the Federal Law "On environmental protection", the norms and roles of the international agreements of RF have priority over the laws of RF.

Therefore, in accordance with the current Russian environmental legislation, there are certain legal possibilities for utilisation of principles and norms of the WFD in practice of water resource management in the Kaliningrad Oblast. Realisation of these possibilities requires the elaboration and adoption of the legal acts of the bodies of state authority of the Kaliningrad Oblast, and it is also advisable to have special agreements between the governmental bodies of RF and the Kaliningrad Oblast.

However, in addition to possibilities, there are also obstacles for real harmonization of the foundations of the water management in the Kaliningrad Oblast and neighbouring countries. At that the major obstacles are not legal rather than economical ones.

Potential possibilities of the region in terms of elaboration and adoption of the legal acts and programmes for water resource management are limited by the financial resources of the regional budget. The federal financing of the programmes of the cross-border cooperation is still scanty. Opportunities for attraction of the foreign financial assistance until recently were not too large, particularly, owing to different financial zones established for RF and the Baltic States (Tacis and PHARE programmes correspondingly). Since 2006 the programme of joint projects Interreg-Tacis Neighbourhood is being implemented. And, possibly, the certain success may be achieved in the framework of this programme.

Another obstacle for adoption of principles and norms (especially norms!) of the WFD for the Kaliningrad Oblast is the unfavourable environmental situation in the region, connected with the pollution of surface (and ground) waters. Nine HELCOM's hot spots are located in the region; the majority of towns and settlements don't have efficient household and industrial sewage purification systems; environmental condition of many major water bodies is unsatisfactory. During many years financing of environment protection and particularly water protection programmes from the federal and regional budgets was extremely limited, hereupon the environmental situation in water ecosystems of the region in general is much worse than in cross-border areas of the neighbouring countries (basins of Vistula and Curonian lagoon).

Under such conditions the motivation of regional authorities for cooperation with neighbouring countries in the sphere of management of transboundary water bodies on the basis of principles, norms and established terms of realisation of the activities by the WFD couldn't be high, while the cooperation on the level of border municipalities despite of importance of its development can't be effective enough as regards to management of water resources, which are in federal property.

The most optimistic scenario is the following: in the foreseeable future cooperation of the Kaliningrad Oblast with the neighbouring countries in the sphere of water resources management on the basis of principles and norms of the WFD shall be mainly determined by the possibility for attraction of additional financial resources of the member states of the EU on the basis of the special international agreements.

3. Strategies for the water resource management

Geographical location of the Kaliningrad Oblast, the community of its main water ecosystems with the border areas of neighbouring countries objectively determines the need for international cooperation in the sphere of water resource management.

The need for integration of the Kaliningrad Oblast of RF into international (European) system of environment protection and specific international projects on spatial planning, environment protection and water resource management is stipulated by a number of documents concerning the environmental policy of the Kaliningrad Oblast (the Law of the Kaliningrad Oblast “On environmental policy in Kaliningrad Oblast”, the “Territorial Complex Scheme of spatial planning development of Kaliningrad Oblast and its parts”, “Scheme of environment protection of Kaliningrad Oblast”, “Strategy for socio-economic development of Kaliningrad Oblast as the region of cooperation for the period up to 2010” and others).

In 1990s a number of international programmes on the topic of water resource management were elaborated for the Kaliningrad Oblast. The largest ones were the Plans for Integrated Coastal Zone Management for Curonian and Vistula lagoons by Poland, Lithuania and the Kaliningrad Oblast of RF elaborated within the Management Plans for Coastal Lagoons and Wetlands project (MLW PITF HELCOM 1995). Unfortunately all these plans were left on the stage of elaboration and didn’t receive further development in the Kaliningrad Oblast.

In 1999–2001 the region participated in the elaboration of the Strategy for decreasing the eutrophication in the Baltic Sea Region BERNET (PHARE). Within this project the major activity directions for participating regions on sewage management, agriculture, forestry, wetlands, monitoring of water environment and water quality planning were identified. The final BERNET document (September 2001) determined the strategic goals on all identified activity directions.

Realisation of these strategic goals on the territory of the Kaliningrad Oblast is connected with the need to solve a number of legal, organisational and financial issues. These obstacles could be overcome during elaboration of the second phase of BERNET programme with participation of the federal body—Department of Natural Resources and Environment Protection at the Ministry of Natural Resources of Russia on the Kaliningrad Oblast and Kaliningrad Oblast Administration (which didn’t participate in elaboration of the first phase). However another reorganization of the natural protection system of RF (2004) again created certain difficulties for further realisation of the BERNET project in the Kaliningrad Oblast.

In 2002 the first phase of the international project on elaboration of the joint Russian-Lithuanian-Byelorussian Programme for water resource management of the Neman River basin was completed. The project was accomplished with the support of the Swedish Environment Protection Agency (SEPA) (The report "Hydro-ecological situation of the Neman River and issues of development of the trilateral cooperation in the sphere of use and protection of water resources in its basin", Stockholm—Kaunas—Vilnius, 2002). The project contains the detailed recommendation for creation of the system of water resource management and sustainable development of the river basin area, improvement of the existing system of use and protection of water resources, goals of the common management and tasks, which should be solved in order to achieve these goals.

Implementation of the project requires the intergovernmental agreement on use and protection of water resources of the Neman River, establishment of the legal, administrative and financial-economic basis etc.

The Programme documents elaborated in the Kaliningrad Oblast at the end of 1990s and early 2000s, which determine the major direction for regional development, as a rule, contain special chapters on environment protection issues. These chapters contain specific measures on use and protection of water bodies, primarily the construction of the purification facilities in Kaliningrad, Sovetsk, Neman and several other towns. But unfortunately the most important actions on environment protection, planned by these programme documents, were not implemented, as soon as the plan did not specify the sources of financing.

The Federal Target Programme of the Kaliningrad Oblast development until 2010 provides for completion of construction of the sewage collector and purification facilities for Kaliningrad and several municipal centres in the region. However the financial sources for these objects were determined only partially. Along with grants, loans and financing from the federal and regional budgets, a significant share of financing for these project is identified as "other sources", in other words, it is not determined at all.

"The Strategy of Socio-economic Development of the Kaliningrad Oblast as the Region of Cooperation for the Period up to 2010", which was elaborated in 2001–03, declares the "sustainable regional development" as the fundamental principle. Environmental situation in the region is identified in the Strategy as "difficult (almost crisis)". It is underlined, that "the goals of overcoming the economic, social and environmental crisis should be solved concurrently".

The need for strengthening of interaction with the neighbouring countries—Poland and Lithuania—and the EU in general and elaboration and application of quantitative indicators of sustainable development comparable with the indicators of the neighbouring regions of Lithuania and Poland (i.e. actually with the EU indicators) are considered as the fundamental conditions for optimisation of the environmental situation and provision of sustainable development. The Strategy underlines the objective need for cooperation with the EU on environmental initiatives, access for the Kaliningrad Oblast to the EU and Nordic Dimension programmes aimed at regional development and cross-border cooperation, particularly in the field of environment protection. At that the need for "rapprochement of norms and standards, transfer of modern technologies" is mentioned as well. The Strategy establishes a fact that there is lack or insufficiency of the acting Russian and regional legislation providing for the liberalisation of the exclave region development, which is required for the effective interaction with the EU and participation in the cooperation projects in the Baltic Sea Region. The Strategy once again puts a question on the need of the legislative acts providing for delimitation of powers in the field of nature use and environment protection between federal and regional governmental bodies and institutions of local self-governance. It is essential, that the Strategy considerers the strengthening of the role on environmental NGOs in solving the problems of environmental protection as one of the key tasks for achieving sustainable development. At the same time the Strategy determines only the general directions of the regional sustainable development and presumes, that concretization of activity on these directions will be provided in the corresponding regional programmes, which are currently under elaboration.

The sub-programme "Water Resources and Water Bodies" of the Federal target programme "Environment and Nature Resources of Russia" (2002–2010) the actions on restoration and reconstruction of the waterworks at the Neman and Matrosovka rivers were provided, as well as elaboration of the projects of water protection zones and coastal shelter belts for the rivers of the Curonian lagoon basin, monitoring of water bodies and other tasks. These activities are mainly financed from the federal budget and in small volumes from the regional budget.

In 2002 the Ministry of Nature Resources of Russia started elaboration of the National Programme "Water of Russia—XXI century", which should also include the measures in the Kaliningrad Oblast with focus on construction of purification facilities, prevention of floods and development of the water protection zones of the water bodies. Announced volume of financing for the programme activities in the Kaliningrad Oblast (2003) was 18.4 billion rubles. The Programme is in the process of elaboration.

The Department of the Neva-Ladoga basin management, which includes the territorial department of water resources of the Kaliningrad Oblast, is elaborating the "Scheme of the Complex Use and Protection of the Water Resources of the Baltic Sea Basin". The Scheme particularly provides for identification of major directions and actions on water resource management in the Kaliningrad Oblast, which should further be elaborated.

In conclusion of the chapter it should be emphasised that national programmes of RF entities on use, restoration and protection of water bodies, which are in the federal property, could be approved and implemented only "in coordination with the federal bodies of executive power, which exercise functions on policy-making and regulation in the sphere of use and protection of inventory of water resources" (Article 65 of Water Code of RF in the edition of January 1, 2006).

4. Conclusion

The priorities in use and protection of waters in the Kaliningrad Oblast mainly focus on the resource side of the issue. These first of all include drinking water supply, fishing and use of water bodies for the recreational purposes. Nature protection aspects, including the issues of conservation and restoration of biological diversity in general are often set aside.

The major problems of the water resources in the Kaliningrad Oblast include: (a) surface and ground waters pollution with industrial and household sewage, storm run-off, drainage waters from agricultural lands and forests, filtrates from the dumps for industrial and solid domestic waste, dung-yards, poultry factories and cattle-breeding complexes: (b) eutrophication of Curonian and Vistula lagoons and other small reservoirs of the Kaliningrad Oblast (c) violation of the regime of water protection areas and coastal shelter belts; (c) underflooding and flooding of the areas; (e) insufficient control over the pollution sources; (f) underdeveloped and multi-departmental subordination of systems of water bodies monitoring. The result of it is deficit and unsatisfactory quality of the drinking water, the real threat of loss of water biological resources and recreational potential of water objects and connected with them territories.

Approaches used for solving the major water problems in general are insufficiently coordinated, not distributed according to the objective priorities and insufficiently effective. Thus, the provision of acceptable quality of drinking water from the surface sources is achieved by increasing costs of water preparation, while there is lack or complete absence of measures on improvement of the conditions of water supply sources (for example, the Pregolya River).

The principle of decrease and prevention of pollution in source is not implemented or is fulfilled fragmentary and inconsistently. The resources are not concentrated on realisation of few priority programmes and projects and solving the key problems (for example, the water purification facilities in Kaliningrad have been constructing since 1976!).

The fixed standard pays for pollution of water bodies don't stimulate improvement of technologies in the wet industry and communal services; the principle of "full payment of water rate" isn't fulfilled by consumers.

These and many other drawbacks of water management to a great extent could be explained by lack of the common strategy, distribution of priorities, clear formulation of goals and indicators. Over the last decade the major activity directions for the Kaliningrad Oblast in spheres of water management, preservation and restoration of water ecosystems and their biodiversity have been identified within the framework of international programmes (MLW PITF HELCOM, BERNET and others). At the same time, there is no approved water management strategy in the region.

Determination of such a strategy, as well as the programmes and projects in the sphere of water management is (in accordance with the current legislation) the prerogative of the Federal Water Resources Agency of the Ministry of Natural Resources of Russia and its basin district water departments. Kaliningrad Oblastal Administration together with the bodies of local self-government will have every reason for elaboration of strategic documents only after signing of the special documents on delimitation of powers and transfer some of the functions from the federal level to the regional one. Equal participation of public and municipal bodies in this process is the necessary condition for realization of the policy in the sphere of environment protection (including also the issues of use and protection of water ecosystems).

Surface and ground waters within the limits of trans-boundary basins of the Kaliningrad Oblast are exposed to human activities accomplished in both the Kaliningrad Oblast and neighbouring countries. As a result, all these factors influence the quality of coastal water of the Baltic Sea. As soon as the basin approach to water management is rarely used for the moment, the efforts on different levels are required to establish the basin commissions for separate trans-boundary basins (Neman, Sheshue, Lava, Angrapa, Mamonovka, etc.) with compulsory inclusion of corresponding municipalities of the Kaliningrad Oblast, as well as the joint commission for every basin of Curonian and Vistula lagoons.

This work should be conducted in close cooperation with the neighbouring regions. One can be give as an illustration the experience of the work of the group on water resources of the Euroregion "Baltic" (Chubarenko & Alekseev, 2005), which have recommended:

- to improve bi-, and multilateral cooperation in the sphere of environment protection and particularly in the water management sector:
- to concentrate the efforts on several pilot water areas and educational activity on all levels (from schools to administrations);
- to organise intensive experience exchange on issues of pubic and municipal participation in management using the Swedish model as the basic pattern;
- to launch projects on development of nature-protection legislation of the Kaliningrad Oblast using the positive ideas of the EU WFD;
- to promote the elaboration of plans for joint management of trans-boundary water catchment basins and organisation of corresponding basin commissions with broad participation of representatives of wide public, municipal bodies and scientific circles.
- to elaborate and put into practice the common criteria of public participation in water resources management, the criteria of use of common modern information instruments of decision-making process and common environmental impact assessment procedure for elaboration of projects (especially those of trans-boundary influence). The idea of establishment of the Water forum to organize dialogue and effective information exchange between experts, public and politicians can be rarely seminal.

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Numerical modeling of the Curonian and Vistula lagoons revisited

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Short descriptions of the Curonian and Vistula lagoons

The Curonian Lagoon is a shallow transitory freshwater basin, connected with the South-East Baltic by the narrow Klaipėda strait, which is of 400–550 m wide (Fig. 1). The narrow sandy Curonian Spit separates the Curonian Lagoon from the Baltic Sea. The lagoon is of a triangle shape. Its southern broadest part is of 46 km wide. The lagoon length (from north to south) is more than 90 km. The lagoon surface area is of 1584 km^2; the water volume is of 6.2 km^3; the mean depth is 3.8 m; the maximum depth is in the southern part and reaches 5.8 m approximately. The artificially deepened Klaipeda Harbor is located in the Klaipėda Strait, the depths are of 10–12 m. The southern and central parts of the lagoon are fresh because of a discharge from the Neman River, which brings 21.6 km^3 annualy. The salinity in the northern part varies from 0 to 8 psu, depending on wind activity affecting brackish water inflow from the Baltic Sea. Predominant flow of water is from the south to the north. Brackish water intrusions mostly happen during August to October and bring 70 percent of the total annual salt water input to the lagoon.

Dominated sediments in the Curonian Lagoon are land originated. In the middle part sand and silt predominate, while in the deeper places and in zones of weak hydrodynamics fine-silty mud and silt-clayey mud occur. Boulders and gravel are in zones of active waves and currents. Fine sediments are in the southeastern and southern part of the lagoon, while in the northern part fine sand dominate. Peat, mollusk shell or some other type of sediments can be found in some parts.

Fig. 1. The Curonian and Vistula lagoons in the South-East Baltic.

The Curonian Lagoon is a temperate estuarine lagoon, the lowest water temperature (0.0–0.1 °C) occurs during the period from January to February, when the lagoon is ice-covered. The highest temperatures 25–27 °C are observed from July to August. Ice cover lasts 110 days approximately, while continuous ice cover doesn't form during warm winters at all.

Western and southern winds predominate in the lagoon area. Usually winds are not strong, just of 1–5 ms^{-1} (55%). The winds stronger than 15 ms^{-1} occur during autumn and winter. Waves are short because of small depth, wave height is developing along short fetch distance and usually limited by depth.

The Vistula Lagoon is located 50 km to the south from the Curonian lagoon. The lagoon has an elongated shape, its length from south-west to north-east is of 91 km. The average lagoon width is about 9 km, the maximum one is of 13 km. The surface area is 838 km^2, 472.5 km^2 of which belongs to Russia, and the other one belongs to Poland. The water volume is of 2.3 km^3. The coastline length of is about 270 km, the average depth is of 2.7 m, and the maximum depth is of 5.2 m.

The Vistula Lagoon is separated from the Baltic Sea by the Vistula Spit (a sandy barrier that is of 55 km long), and has the only inlet, the Baltiysk Strait of 400 m wide. The artificially deepened Kaliningrad Marine Canal (8–10 m depth, bounded by a number of artificial islands) connects the inlet and the mouth of the Pregolya River. The lagoon bottom is basically muddy. Sandy mud and sand prevail along the coast.

Ice in the shallow Vistula Lagoon is formed practically annually, but with significant variation of ice-cover period duration from year to year. The average duration is about 67–75 days. Ice covers the whole lagoon area, except the Kaliningrad Marine Canal and the Baltiysk Strait.

In contrast to the Curonian Lagoon the Vistula lagoon is under considerable marine influence. The average salinity during the spring–autumn period is of 2.5–4.3 psu in the eastern part of the lagoon; it is of 3.9–5.0 psu in the central part and 1.0–3.4 psu in the southern part.

The south-western wind prevails. The average speed changes from 4 up to 6 ms^{-1}. In 51 percent of cases the wind is in the range of 2–5 ms^{-1}. Repeatability of wind of 6–9 m/sec is 31 percent. The waves are short and steep, and are limited by depth as well as in the Curonian Lagoon.

Modeling of the Curonian Lagoon

Data availability for modeling

Bathymetry data is available to make a fine resolution grid (grid cell is 50–100 m) for the entire lagoon and the Klaipeda Navigation Canal (20–40 m grid cell).

Regular hydro-meteorological measurements are the following:

- a water level is measured at the hydrometeorological stations in Nida and Klaipeda (both are in Lithuania); there is one point of water level measurements on the Russian side, it is located in the southern part of the lagoon at the mouth of the Deyma River;
- the closest to the lagoon point of water level measurements in the Neman River is located in the town of Sovietsk (the Russian side);
- water discharge from the Neman and Deyma rivers is calculated on the basis of the known hydrographs for these rivers.

Historical hydro-meteorological data sets for coastal stations exist for the time period from the 50th till now. Data for the lagoon water quality are available from the 70th.

The existing lagoon water quality monitoring network comprises 5–8 points on the Russian side (in total) and 8–10 points on the Lithuanian side. Different agencies have their own monitoring networks. For example, stations of both nationals monitoring network are presented in Fig. 2 (Stagina, 2007; Ferrarin, 2007).

Fig. 2. Monitoring stations in the Curonian Lagoon, which belong to national hydrometeorological agencies. Km and Rm*— are stations of Lithuanian and Russian monitoring networks respectively. Water level variations are measured in four points: L1 (Klaipeda), L2 (Preila), L3 (Nida) and L4 (Polessk). Meteorological stations are located in Klaipeda (Mt1) and Nida (Mt2).*

On the Russian side of the Curonian Lagoon the state water monitoring is conducted by Kaliningrad Centre for Hydrometeorology and Environmental Monitoring, CHEM (Stagina, 2007), which carry out monthly measurements during 5–6 months in the ice-free period. Despite many other parameters of national standard like BOD, water color, nutrients are measured in terms of concentrations of NO_3, NO_2, PO_4, NH_3 in 5 points on the Russian side of the lagoon. The same hydrochemical measurements are held in the Neman River (the town of Sovietsk). Measurements are usually made during 5 months a year at the minimum (e.g. January, April, July, October, and December).

Moreover, the Atlantic Institute for Fishery and Oceanography of the Fishery Ministry of the Russian Federation provides its own monitoring of the lagoon water quality from the 80th. Nutrients and other parameters important for fish food chain are measured seasonally or monthly every year. In 2004–05 federal authority, the Kaliningrad Marine Inspectorate, made its own hidrochemical monitoring of the Russian part of the Curonian Lagoon (Grin' & Yarceva, 2007). Locations of their stations slightly differ from CHEM network.

On Lithuanian side monitoring activities are nowadays carried out by the Centre for Marine Research (state monitoring), which is continuing the investigations started in 50th by Hydrometeorological service. Scientific monitoring is fulfilling by Coastal Research and Planning Institute of the Klaipeda University during several years (Ferrarin, 2007).

Modeling efforts

There are several computer models for the Curonian Lagoon. In times past they were used by different institutions in the area:

• In Atlantic Branch of P.P. Shirshov Institute of Oceanology of Russian Academy of Sciences the scientific finite element model (only hydrodynamic one) was used in the 90th to study the principal current patterns in the lagoon (Chubarenko & Chubarenko, 1995).

• MIKE21 in Lithuanian Energy Institute (hydrodynamics, sediment transport) was used for analysis of sediment dynamics in the lagoon inlet (Kriaučiūnienė & Gailiušis, 2004; Kriaučiūnienė et al., 2006).

• The ECOPATH model was used to balance steady state matter flows in the trophic network of the Curonian Lagoon ecosystem.

• BSHcmod for Lithuanian coastal waters, using data of the regional model for the North and Baltic Seas (known as BSHcmod and closely related to the HIROMB model).

• The finite element model (SHYFEM) developed in collaboration between Klaipeda University and ISMAR-CNR, Italy.

The last two models have shown promising results. They are described below:

The model for coastal Lithuanian waters

The three-dimensional hydrodynamic model was adapted for the Lithuanian marine waters. This model enables to obtain the time series of the hydrodynamic parameters in the real-time. By using this model, the analysis of the heterogeneous activity concentration distribution of ^{137}Cs in the Lithuanian waters was carried out. The results also enabled to estimate the influence of the Neman River on Lithuanian marine waters.

The circulation patterns in the Curonian Lagoon and their influence on the distribution of the Neman River waters as potential source of contamination were analyzed using the hydrodynamic model BSHcmod. Real time periods were simulated and the fresh waters distribution on the Lithuanian coast was studied. The following objectives were met in this study:

• to adapt the circulation model of the Baltic and North Seas (*BSHcmod*) for the Lithuanian marine waters and to perform its validation.

• to analyze the Neman River influence on the Lithuanian marine waters.

• to estimate possible sources of the heterogeneous distribution of activity concentration observed in case of ^{137}Cs.

The finite element model for the Curonian Lagoon (SHYFEM)

The hydrodynamic model used in this work is the two-dimensional finite element model developed at the CNR-ISMAR of Venice (Umgiesser, 1997) and successfully applied to the Venice Lagoon. The finite element method gives the possibility to describe morphology and bathymetry of the modeled system correctly and represent the zones where hydrodynamic activity is more interesting and important (e.g. the Neman River delta and the Klaipeda Strait). The model uses the finite elements for spatial integration and a semi-implicit algorithm for time integration. Divergence terms in the continuity equation, the Coriolis term, the pressure gradient and the bottom friction in the momentum equation are treated implicitly. All other terms are treated explicitly.

Modeling of the Vistula Lagoon

Data availability for modeling

Bathymetry data is available to make a fine resolution grid (grid cell is of 50–100 m) for the entire lagoon and Kaliningrad Navigation Canal (grid cell is of 20–40 m).

The existing coastal monitoring network (Fig. 3) comprises the seven water level points: Baltiysk, Kaliningrad, Krasnoflotskoe on the Russian side and at least four points along the Polish coast. Water quality measurements are carried out at the same coastal stations. Stand-

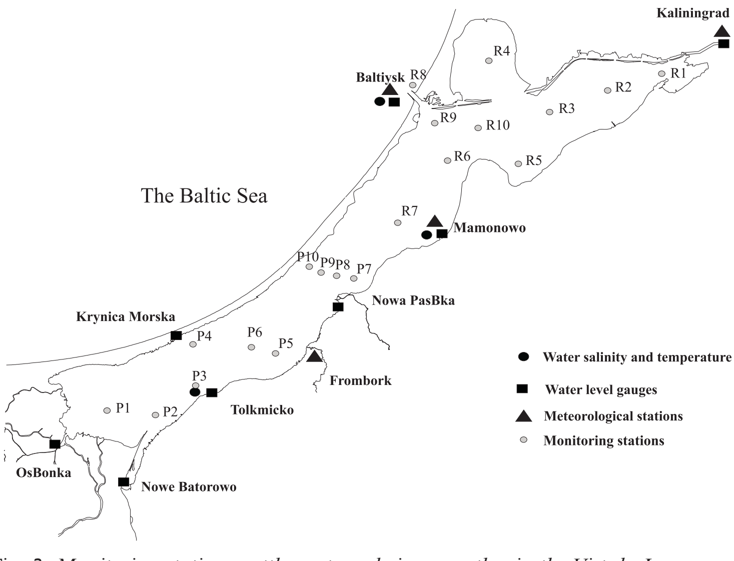

Fig. 3. Monitoring stations, settlements and river mouthes in the Vistula Lagoon.

ard meteorological measurements are carried out in three points. Four grid points of the regional meteorological model HIRLAM cover the lagoon area.

Existing monitoring network for lagoon water quality comprises 10 points on the Russian side and 10 points on the Polish side. Russian monitoring stations follow the deeper parts of the lagoon and are situated along the main lagoon axis. Polish monitoring stations are along the lagoon coast (Fig. 3).

Historical hydro-meteorological data sets exist for the lagoon inlet since the 18th century and for the Pregolya River mouth and the central part of the lagoon since the 19th century. Lagoon water quality data on the Russian part of the lagoon were collected in a regular way by National Hydrometeorological Service starting in 1970.

Modeling efforts

Several computer models for the Vistula Lagoon exist. They were used by following institutions:

• GEOMOR and Regional Management Board (Poland), Atlantic Branch of P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences and Kaliningrad Department for Natural Resources and Nature Conservation (Kaliningrad) have got the MIKE21 2D horizontal model (hydrodynamic, transport, water quality and eutrophication modules) in 1995 (Rasmussen, 1997).

• Atlantic Branch of P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences and Kaliningrad Centre for Hydrometeorolgy and Environmental Monitoring implemented the demonstration version of the MIKE11 (1D river-network model for hydrodynamic, transport, water quality and runoff-rainfall) in 2002.

• The 2D vertical baroclinic model for principal simulatiton of near-bottom intrusion of salt water and the principal catchment model for nitrogen dynamics in the Pregolya River basin were applied by professors Gritsenko V.A. and Zotov S.I. (respectively) at Immanuel Kant State University of Russia (former Kaliningrad State University).

• 2D finite difference personal scientific model (R. Szymkiewicz, Institute of Hydro-Engineering of Polish Academy of Sciences) was applied in 80th. Nowadays the institute uses the Delft3D FLOW module (had been applied during 2003).

• The personal scientific model of A. Jankowski (Institute of Oceanology of Polish Academy of Sciences) was applied in the 80th.

The following principal international projects, which were devoted to or contain the numerical modeling component for the Vistula Lagoon, were implemented:

• The Danish-Polish-Russian project "Prioritizing Hot Spot Remediation in the Vistula Lagoon Catchment: Environmental Assessment and Planning for the Polish and Kaliningrad parts of the lagoon" in 1994–97: implementation of MIKE21 hydrodynamic, transport and eutrophication modules, training of personnel, assessment of scenarios (Rasmussen, 1997).
• TACIS ENVRUS 9803 Project "Water monitoring and management in the Kaliningrad Oblast" in 2000–02: first attempt to implement MIKE11 1D river-network model (hydrodynamic, transport, water quality and runoff-rainfall modules), introductory training of personnel, demonstration simulations of salt wedge dynamics and assessment of scenarios.
• MANTRA-East "Integrated Strategies for Trans-boundary Waters Management on the Eastern European Fringe" extended by additional "the Vistula Lagoon case study" in 2003: application of MIKE BASIN, MIKE21 (hydrodynamic, transport and water quality modules) and Delft3D FLOW module for assessment of scenarios of water quality improvement in the lagoon.
• Environmental Impact Assessment of New Port Development in Ust-Luga and Kaliningrad (Russia), EBRD, 2003: MIKE21 (hydrodynamic and sediment transport modules) was applied for impact assessment of navigational channel maintenance and port development in the inlet of the Vistula Lagoon (Jurgensen, 2004).

Similarities and differences between the Vistula and the Curonian Lagoon

Both lagoons are shared by two countries. This makes monitoring efforts difficult, but challenged. Data exchange between the countries is absent, there is no regulatory agreement.

Connection between the Curonian Lagoon and the Baltic Sea occurs thought the Klaipeda Strait, which is several kilometers long and of 400 to 800 m wide. The only Lithuanian port is situated in the Klaipeda Strait; economically important actives are taking place here. Therefore modeling of the Klaipeda Strait is of great importance for the port administration (and Lithuanian authorities). MIKE21 hydrodynamic and transport modules were applied, for example, before performing dredging activities in the Klaipeda Strait (Kriaučiūnienė & Gailiušis, 2004; Kriaučiūnienė et al., 2006).

In case of the Vistula Lagoon the Kaliningrad port is situated inside the lagoon. The artificial ca. 40 km long canal partly separated from the lagoon by artificial islands connects the Baltiysk Strait with the Kaliningrad port situated in the mouth of the Pregolya River. The port administration recognizes the importance of modeling results in the decision making process. To make a coupled model for the lagoon and the canal is one of the challenges.

MIKE 21 was applied both to the Vistula Lagoon and Klaipeda Strait. But it was not applied to the Curonian Lagoon itself.

The personal scientific model (on the basis of a finite element approach) was applied to the Curonian Lagoon only for scientific estimation of current structures during a western storm (Chubarenko & Chubarenko, 1995). Nowadays, another scientific model, the SHYFEM, is applied to the Curonian Lagoon. It is a finite element model developed in ISMAR-CNR (Italy) and implemented by Coastal Research Planning Institute of Klaipeda University. The BSHcmod model was applied for Lithuanian coastal waters, using data of the regional model for the North and Baltic Seas.

There are still no operational models for both lagoons. The marine institute in Gdansk (Poland) has started setting up of the operational model of the Vistula Lagoon using HIROMB data at the open boundaries and HIRLAM data for forcing. Nothing is still done for the Curonian Lagoon.

The similarities of the lagoons are:

- Both lagoons are equally shallow, their depths are ca. 2.5–3.5 m in average, the maximum depth does not exceed 5.5 m.
- Both lagoons have the only one connection to the Baltic Sea, artificially maintained channel of 400 m wide;
- Both lagoons are transboundary waters;
- Both lagoons have a problem of eutrophication; this problem starts in their watersheds;
- For both lagoons the euthrophication and new biological species invasion are the main reasons of ecosystem reconstruction;
- The Vistula Lagoon has a deep artificially dredged canal passing along the lagoon coast, and the proper lagoon is separated from it; the deep navigable canal in the Curonian Lagoon is located just in the inlet. For both lagoons the canals control the marine water inflow into the lagoon area;
- Sedimentation in the Curonian Lagoon is river dominated, sedimentation in the Vistula Lagoon is equally influenced by river and marine water inflows;
- Fish stocks are stable and determined by current eutrophication levels and salinity regimen.

The main basic hydrographic differences which lead to consequent differences at hydro-chemical and hydro-biological levels are:

• The Curonian lagoon hydrology is completely controlled by fresh-water discharge of the Neman River, while the Vistula Lagoon is under equal influences of both water exchange with the Baltic Sea and fresh water influx;

• The Curonian Lagoon is practically fresh and may be considered as a running-water lake, while the Vistula Lagoon has an intermediate salinity (2–4 psu in average) varied seasonally;

• The Curonian Lagoon collects sediments coming with a river drain. The Vistula Lagoon in general discharge sediments into the Baltic (stormy resuspension prevails net sedimentation in the most part of the lagoon except the lateral shallow areas, it leads to resulted washing of sediments from the lagoon to the sea)

Innovative modeling and resolution of physical processes

Progress in understanding of ecosystem functioning, links between physical, chemical and biological processes is coupled with advances in modern computer tools and techniques. Here emerges the question as to improvement of operational models and models used for management purposes. These models are supposed to resolve more and more complicated processes, to embrace wider ranges of relationships and to deal with more systemic problems.

Several processes in the Curonian and Vistula lagoons were pointed out. For the Vistula lagoon, the water exchange with the Baltic Sea should be resolved accurately and described in terms of inflow/outflow events, with their own (different) mixing features. Additionally, marine water transport upstream the Kaliningrad Marine Canal has to be taken into account. A sediment re-suspension is of a great importance for biochemical processes in both the Vistula and Curonian lagoons. Composition and pollution of bottom sediment must be included in both physical and chemical-biological modeling. However, model complexity causes difficulties in its use and significant data increase required for model calibration, verification and operation. Management practice indicates some ways of these contradictions balancing. Conceptually, today there are several ways of possible development of environmental models to simulate processes in more and more fine details.

One methodology is to develop several separated modules (or models), working one after another, providing information flow from background physical processes to biological characteristics through chemical features simulation. Such a system is flexible and easily adapted to both very accurate simulation of particular process (or particular small areas) and simulation of wide range of resolved processes. The alternative methodology is a development of coupled models containing from modules, calculating different processes.

Modern environmental models deal with large water bodies, catchment areas etc., i.e., with large-scale objects. Thus, not only direct contact measurements, but also remote sensing data can be widely used, especially for large-scale forecast simulations.

Problems of the Curonian Lagoon

• The Curonian lagoon is the transboundary lagoon. Despite already existing agreements at the governmental level more practical steps could be taken. There is a need in management at the international level because of the trans-boundary status of the Curonian Lagoon.
• The Curonian Lagoon is mostly used for fishery and recreation. However, the Klaipeda port situated in the Klaipeda Strait carries more diverse functions. Limited vessel traffic takes place in the Lithuanian part of the lagoon.
• Water quality issues are highly related to the discharges from the catchment area, which is huge (97 924 km^2) as compared to the lagoon area (1584 km^2). Therefore the management plan for the catchment is of high priority. However, being hyper-eutrophic, the lagoon water quality (including heavy cyanobacteria blooms) is mostly controlled by the ambient physical factors such as wind climate and temperature (Pilkaityte & Razinkovas).
• In spite of quite extensive monitoring efforts (mainly from 1984) covering both water quality as well as hydro-biological, hydrological and climatic parameters, measurements of water levels in the Baltic Sea outside the Curonian Lagoon are missing.
• Extensive dredging allows greater vessels to navigate the Klaipeda Port, but deepening of canal changes the flushing rate of the lagoon.

Problems of the Vistula Lagoon

General issues

• The Vistula lagoon is the transboundary lagoon. The lagoon itself as well as some enterprises and water treatment plants in the lagoon catchment are included in the Baltic Sea HELCOM list of prioritized "hot spots".

• The Vistula Lagoon is used for different purposes: transportation (oil, dry cargos, containers, ferry connection), fishery and recreation. Kaliningrad Navigation Canal is the hydro-technical construction which plays the main part in lagoon water dynamics. “Conflict of interests” between different economic sectors as well as trans-boundary issues make the Vistula Lagoon management complicated. A joint comprehensive international management plan should to be elaborated on order to balance national and regional interests and avoid the conflicts.

• The lagoon water eutrophication is rather high; blooming of different phytoplankton species starts in spring and continues until the beginning of autumn. Eutrophication as a problem is mostly connected with poor water treatment in the catchment area and diffusive agricultural sources. The diffusive load is difficult to predict and to manage directly.

Information and data exchange

• Joint international monitoring is not conducted yet. An international committee should be established at the political level to solve problems arising while data collection and exchange, measurement campaigns and joint activities are taking place.

• Considerable amount of data have been collected for the Vistula Lagoon, but these data are spread among different organization. During joint Polish-Russian projects the only two data sets suitable for hydrodynamic and water quality simulations were compiled, namely the data sets of boundary conditions for 1994–95 and 1998–2000 periods.

• The data collected for modeling are of different accuracy. The data on water level and wind variations are measured with frequency of hours. River discharge usually is not measured, but estimated using a river hydrograph. In other words, the river discharge is calculated on the basis of water level variations data for only those rivers where level variations are measured. The most problematic are the data on nutrient load from point and diffusive sources in the catchment. Official statistics is poor and presents annual average loads only.

• The open boundary is another problem arising when a numerical model is applied to the lagoon. If the open boundary is specified in the open sea, a model is able to simulate a lagoon and coastal zone together. Data measured in the inlet may be used as verification data in this case. The weak points of this approach are: (a) real conditions at the remote boundary are unknown and (b) simulation grid has to be very fine to resolve both the lagoon-marine domain and narrow channel. If the open boundary is specified in the inlet, the simulation domain is smaller and data measured in the inlet are used as boundary conditions. But, in this case hydrodynamic features of water exchange in the very inlet cannot be modeled precisely.

• The logic of model development forces scientists to include more and more details in a model. Finally, it makes a model too complicated and data capacious. However, decision makers are very often overwhelmed by detailed scientific information, and a challenge is to aggregate and simplify this information in a way management agencies can work with this data. Applied models as a tool for management should be constructed in view of necessities of environmental administrations.

• Models as a tool for management were applied for the Vistula Lagoon very poorly. The capacity of scientific and consultancy (of scientists and consultants) groups in Poland and Russia is high, but in practice, especially in Russia, most of evaluations, impact assessments and environmental forecasts are developed by managers without regards to modeling results.

Conclusions and recommendations

General issues

• It is recommended to use modeling as a powerful tool for impact assessment of scenarios of socio-economic development, industrial and construction activities in the coastal and catchment areas. Although some modeling applications have showed obvious advances, they have not been introduced into real management practice for the Curonian and Vistula lagoons.

• Modeling is useful for forecasting assessment of short- and long-term changes of the lagoon water quality under natural conditions, especially for assessment of climatic changes consequences, which became very obvious in the region.

• Unification of modeling tools is recommended because of the transboundary status of the Curonian and Vistula lagoons. Implementation of equivalent models by environmental authorities of the Kaliningrad Oblast, Lithuania and Poland will bring equal level of problems understanding. The same model used by these countries will provide a vital force for elaboration of a common data base and guide the process of monitoring and data collection for these lagoons.

Monitoring

Monitoring of physical and biochemical properties is important for the scope of numerical modeling. The most important quantities to monitor are:

• water level variations (almost continuous measurements are desired);
• river discharges (daily measurements are desired);
• temperature and salinity (continuous measurements are desired at the open boundary, weekly or monthly measurements are desired inside the lagoon), and its vertical structure;
• water quality variables (monthly measurements are desired for the entire lagoon, but more frequent measurements are necessary for river loading);
• meteorological parameters as wind, radiation, air temperature, humidity, precipitation and evaporation, etc. (hourly measurements are desired.

The quality of data should be checked all the time. Regular intercalibration of sensors for measurements of water level, temperature, salinity, weather conditions will provide reliable boundary conditions for modeling.

Long term scenarios

In general, 2-dimensional models are sufficient to analyze pollution load consequences in the lagoons (except the cases of the very vicinity of the inlets). A spatial resolution of 1 km could be acceptable for explored periods of several years duration. Those models could be used for long-term pollution management, fishery management and definition of Total Daily Maximum Loadings (TDML).

The problem of sediment transport, erosion and deposition can be described by more complicated models using the 3-dimensional approach. It is especially important for navigation (shipping channels) and coastal protection.

Operational models

The available framework should be used in order to implement the local operational model. In the case of the Curonian and Vistula lagoons the coupling of the lagoon model with the HIROMB Baltic Sea model is needed. HIROMB will provide the lagoon model with the necessary boundary conditions at the open boundary, while the available HIRLAM atmospheric model will provide atmospheric forcing forecast (48 hours).

The local model should be integrated seamlessly into this framework in order to produce flood and storm warnings, possible oil pollution forecast on the coast and inside the lagoon, and to help with rescue operations.

In case of a short-term analysis a 3D model would be more appropriate.

Coordination of activities

Monitoring activities of countries shared the lagoons should be agreed in terms of (a) comparable distribution of sampling point in national areas (spatial density of sampling) and (b) simultaneous sampling in both national sides of lagoon. Methodologies of sampling and analysis treating should also be uniform.

Acknowledgement

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Recommendations on ecosystem approach and decision making for sustainable use and development of the Curonian and Vistula lagoons

The following recommendations were developed by Ecosystem Group and Decision Making Group of the NATO CCMS Pilot Study on Ecosystem Modeling of Coastal Lagoons for Sustainable Management in a frame of International Seminar on "Problems and prospects of coastal lagoon modeling by the example of the Vistula and Curonian lagoons, the Baltic Sea" (Svetlogorsk-Jodkrante, May 19–26, 2004).

1. Recommendations on ecosystem approach and biogeochemistry for the Vistula and Curonian lagoons

Twelve senior and young scientists from the Kaliningrad Oblast (Russia), Lithuania and Poland and NATO-CCMS Pilot Study, most of them working on the hydrobiology and ecology of the Vistula Lagoon, participated in the discussion which was focused on the "Ecosystem and Biogeochemistry" approach for development mathematical models as tools for sustainable use and adaptive management. The group discussions were held in Hotel "Universal", Svetlogorsk (Kaliningrad Oblast, Russia), on 21 of May, 2004.

Six young and one senior scientists from Lithuania and the Kaliningrad Oblast (Russia), working on the ecology of the Curonia Lagoon, together with two senior scientists belonging to the NATO-CCMS Pilot Study, have attended the session focused on the evaluation of past and current ecological research approach as well as of the use of collected data and information about "biogeochemistry and ecology" of the Curonian Lagoon for mathematical modeling and adaptive management. Session was organized in Jodkrante (Lithuania), on 25 of May, 2004.

Goals of discussions:

(i) to assess and identify in what extent "ecosystem and biogeochemistry" approach was applied and the historical ecological data have been used for mathematical modeling of the Vistula and Curonian lagoons?

(ii) What have been achieved? And in what extent this approach is used as a tool for policy and decision making process or the adaptive management of the local socio-ecological complex to which both lagoons belong to;

(iii) What gaps and shortages in the ecological data and information have limited the implementation of this approach for both lagoons? Which other constraints have had the impact?

(iv) What measures are required? And how to implement them?

Synthesis for the Vistula Lagoon

(i) Mathematical modeling has been applied successfully only for understanding and description of hydromorphological and physico-chemical dynamics of the Vistula Lagoon. The developed models are available and they can serve for both managerial activities and ecological investigations. However, these evident achievements are not properly used for ecosystem modeling and management.

Due to many reasons the modeling of changes in species composition, of tropho-dynamic structure and of the ecological processes are missing. Among the limiting factors which explains the current situation, the following have been listed: lack of interest of the both scientists and users; very sectoral way of investigation; lack of some type of data concerning the processes; lack of appropriate financial resources to support an expensive research of this type; limited cooperation among experts, research teams and institutions.

However, there is a huge bulk of data concerning changes in the structure (species composition, population size, biomass, Chl-a, spatial distribution) of primary producers, zooplankton and benthic communities which has been accumulated since many years. These data have been correlated with those describing the dynamics of physico-chemical properties in order to bring proves about eutrophication of the lagoon. They can also be used for formulation of the general tropho-dynamic model and to calculate different indices like: biodiversity index or BII (Biological Integrity Index).

(ii) Hydrobiological and ecological data have been used (especially Chl-a, primary production and phytoplankton's species composition) for water quality assessment in the last years. As was stated before, even existing data which describes major changes occurred in the trophic structure are not properly integrated in some mathematical model or used for testing and validation some of the existing models, which can after be used as efficient tools in supporting decision making by different users of the lagoon's resources.

However, this type of historical data could be very valuable for defining the reference state of the lagoon and the trend of its dynamics. Unfortunately, up to now these data have not been used in the policy and management plan development for land use and economic development within the catchment area, in order to control the pressure of main driving forces.

This type of data would serve for economic valuation of the Vistula Lagoon at the reference and current states and would indicate on costs and benefits of the past management. In case of adding of literature information about the functioning role of dominant species to data collected the main functions (e.g. production and regulation functions) and respective services might be roughly estimated.

(iii) The most critical issues for the region are following: an etrophication of the Vistula Lagoon; structural changes by opening new canals and building new ports; intensification of water transport; establishing new oil terminals; sewage discharges from Kaliningrad city and industry; unregulated tourism; increased probability for oil spills.

An absence of *well structured and accessible data base* is one of the main constraint for applying the ecosystem approach and adaptive management in order to achieve rehabilitation of ecological integrity of the lagoon system; sustainable use of resources and services provided by the lagoon and development of the local economy and assuring social security.

Lack of data concerning major ecological functions and processes and non revealed correlations of ecological changes in the Vistula Lagoon against driving forces and loads are the main reasons why there is no mathematical ecological model, which might together with the "date base" describe the structural and functional dynamics of the Vistula Lagoon under pressure of major driving forces from its cathement.

Fragmented operational infrastructure within the Kaliningrad Oblast and among Russian and Polish authorities as well as weak cooperation among research institutions, teams and experts on one side and among scientists and decision makers on the other side were emphasized during discussions.

(iv) Suggestions:

• Ecosystem modeling of the Vistula Lagoon should starts from proper ecosystem identification. That should include (a) description of the physico-chemical compartment or hydro-geomorphic unit; (b) the tropho-dynamic structure of biological communities; (c) species composition; (d) main processes (e.g. nutrient or other chemical cycling; energy flow; resilience) and ecosystem functions (production, regulation, support and information/cultural); and (e) the external driving forces and pressures acting at the catchment scale.

• The current and previous monitoring activities carried in the Vistula Lagoon should be adapted and improved according with the needs for integrated and adaptive management. That should be done based on close cooperation among Polish and Russian scientists, managers and decision makers. However, in addition to monitoring activities, the joint extensive and intensive research program should be designed and implemented to fill up the identified gaps in the knowledge base.

• The designed common data base and knowledge base should rely on the integration of all historical data and information deposited by different institutes, agencies or research teams. The knowledge on lagoon ecosystem dynamics as well as on the past and current policies and management plans from both countries shared the lagoon and its catchment area should be collected and free for analysis.

• After filling up the designed data and knowledge base with historical and quality assessed data and information's, the first version of the information system to support integrated and adaptive management of the Vistula Lagoon should be available for the users. Moreover, the gaps and shortages in data and knowledge could be identified and considered to focus data collecting (monitoring) and research.

• Data and knowledge should be effectively made available for decision making and scenarios development through a package of dynamic mathematical models describing structural and functional changes in the lagoon, under different driving forces and pressures. There is a need for mathematical models of different complexities in order to meet the wide range of requirements for decision making (e.g. specific models for water quality; dynamics of fish resources; but also complex models able to describe the overall lagoon processes under major driving forces). The assessment of the lagoon's economic value (TEV—total economic value) is a fundamental condition for decision making.

• Ecologists and ecological modelers have to plan in advance a common working program which takes into consideration: types of required data (parameters and state variables); methods for data collecting; data quality assessment etc. Networking among research institutions, research teams, end users, policy makers are strongly needed.

Synthesis for the Curonian Lagoon

(i) Findings:

• a well documented data base concerning the structure and dynamics of fish species assemblage and the dynamics of fish catches exists;
• a comparative analysis of the trends in the dynamic of populations and catches, on one side and, the dynamics of fish eating bird species and eutrophication, on the other side, has been carried out;
• a consistent data base about the changes in composition and population size of the phytoplankton and zooplankton is established by using data derived from monitoring activities;
• the influence of hydrodynamics and hydrochemistry (in particular nutrient loads) on species composition and abundance of phytoplankton and zooplankton has been investigated in the last 5 years, by designing and implementing appropriate field experiments. This type of activity carried out by young scientists might be considered the starting point for a more comprehensive and long term research program focused on understanding and modeling of the ecosystem functioning;
• based on historical data concerning the composition, abundance and trophic spectrum of dominant species, the structural model (network of trophodynamic modules) of the Curonian Lagoon has been developed. We stressed that this is the first step for designing a long term monitoring and research of the lagoon system and for development the package of mathematical models which have to serve as tools for adaptive management;

(ii)&(iii) The statements included in the report for Vistula Lagoon are entirely valid also for Curonia Lagoon.

iv) Accepting that the system identification for the Curonian Lagoon is in an advance stage comparing with the Vistula Lagoon case it was also stressed that all the other suggestions made for the Vistula Lagoon have to be applied in case of the Curonian Lagoon too.

2. Recommendations on decision making for the Vistula and Curonian Lagoons

Recommendations below were formulated by experts of NATO CCMS Pilot Study on Ecosystem Modeling of Coastal Lagoons for Sustainable Management after detailed discussions within Decision Making Groups on 21 of May, 2004 (Svetlogorsk, Vistula Lagoon problems), and on 25 of May, 2004 (Jodkrante, Curonian Lagoon problems).

The purpose of this report is to suggest a basic framework for making informed decisions and taking positive actions for sustained use and development of the Vistula and Curonian lagoons. Russia, Poland and Lithuania have conventional decision making processes, although the countries differ on the level of authority provided and exercised at federal and regional levels of government.

There are an interjurisdictional / trans-boundary agreements for management of resource uses and issues. They address management of transportation, water quality, fisheries, environmental protection, and others.

There are following agreements for the Curonian Lagoon area:

- Agreement between the government of Lithuania and the Russian Federation on the long-term cooperation between the regions of Lithuania and the Kaliningrad of 29 June, 1999;
- Agreement between the government of Lithuania and the Russian Federation on the cooperation in the field of environmental protection of 29 June, 1999;
- Agreement between the Lithuanian Environmental Protection Agency and Lithuanian Hydrometeorological Service under the Ministry of Environment and the Kaliningrad Centre for Hydrometeorology and Environmental monitoring on cooperation in the field of monitoring and data exchange on the trans-boundary water bodies of 21 October, 2003;
- Draft agreement between the government of Lithuania, government of Belorus and the government of Russian Federation on cooperation in use and protection of water resources of Nemunas river basin.

However, the key missing element for informed decision making and taking positive actions for sustained use and development is a Catchment / Watershed Area Organization. Such an organization is recommended and should include: (1) regularly scheduled meeting for technical work; (2) consistent membership/involvement of individuals on technical work groups; (3) a formal working group at the Policy Level that meets regularly; (4) involvement of top leaders for each Country in establishing goals for sustained use and monitoring program implementation; and (5) stakeholder involvement.

Terms and Principles

Terms and Principles to be applied in implementing sustainable use and development practices:

1. Sustainable management is managing to meet present needs as well as providing for future generations to meet their own needs. Conceptually it requires the awareness and consideration of the ecological system. It, also, requires measurement of, and accountability of the

values that an ecological unit, such as the lagoons and their catchments (watershed areas). It, further, requires measurements of and accountability for the values that the ecological unit provides to society.

2. Sustainable management is a conscious social decision that provides for the long term health of both the ecological and economic systems of the ecological unit. The finite capacity of the ecological unit's natural capital can not meet the growing demands of society without a plan for sustainable management.

3. The use of the best available information, knowledge, and tools needs to be infused throughout the decision making process. A monitoring program is a key factor in management for sustainable management.

4. The use of models as tools in the decision making process will enhance awareness of the interrelationships within the ecological unit, especially its input and output variables. This will further enhance accuracy of predictions for, and awareness of the consequences of decision on management actions.

5. Decision making should involve all interested parties including government (federal/national, regional, and local), non-government organizations (NGO's), scientific institutions, business users groups and industry, agriculture, and tourism, and general public.

6. Management of decision making requires a formal cooperative institutional structure (CIA) that is empowered through appropriate policy and legal authority.

7. The CIA should have a written Charter or Agreement that commits the parties to work cooperatively to address the goal of sustainable use and development of the natural capital.

8. A conflict resolution process should be identified that provides ample and open consideration of differing view and interests.

9. Environmental education is essential in order to insure long-term sustainability of a participatory process. Education should be at two levels: (1) public awareness of the problems of the environment, especially the linkages between catchment area/watershed activities and consequences on the downstream water body and; (2) formal education of young people in order for them to understand the central role of the natural environment in their future welfare.

Basic recommendations

The following recommendations are respectfully provided as guidelines. They are based on successful work directed at sustained use and development of natural capital / resources in interjurisdictional / transboundary situations. It should be recognized that in different countries with different cultures the recommendations may need to modified to address unique interests of those involved.

1. Establish a Cooperative Institutional Structure (CIS), empowered through appropriate policy, legal, and financial instruments. An example is provided in Appendix 1.

2. Establish a Charter, a formal Letter of Agreement that commits cooperation between National and Regional governments. The signatories should be at the highest levels of the respective governments, and this group will serve as an Executive Committee. (Existing Agreements need to be inventional and referenced as basic tools for guiding management decisions.)

3. Establish a Policy Committee and identify specific staff to service and manage the CIA. The Policy Committee will identify policy / legal needs and seek consistency in management of trans-boundary issue. The staff needs to include experts in lagoon management and conflict resolution. The Policy Committee also should serve a functional role in directing representatives from the technical working groups (noted below) priority work issues.

4. Establish Technical Working Groups. The following working groups are recommended: Water Quality, Nutrients, Toxics, Hydrologic, Hydrobiological, Coastal Monitoring, Fisheries, Exotic/Invasive Species, Dredging, Migratory Birds. Working Groups should be established to address local needs and national interests. These groups will establish plans to address agreed upon (at Executive and Policy Committee levels) goals and objectives. These groups also will recommend goals and objectives to Executive and Policy Committee for adoption.

5. Establish Advisory Committees for the general public (citizens), scientific and technical interests, local governments, and non government organizations (NGO's). Other Advisory committees also may be appropriate to meet local interests and needs.

6. Invite stakeholder involvement from all businesses that have an interest in the Vistula and Curonian lagoons and their catchment / watershed area. This should include representatives from industry, agriculture, fisherman, tourist industry (developers and managers), and others.

7. Hold Round Table meetings at each level of the CIS on a regular basis. For example, annual for the Executive Committee, semi-annual for the Policy Committee, and quarterly for the Working Groups.

8. Facilitate decision making process by modern and joint tools for trans-boundary management, like united data base and modeling tools for impact assessment. Establish procedures of data base replenish-

ment and access to data base resources as well as exchange of information for environmental impact assessment and operational needs.

9. Establish a formal dispute resolution process. Differences of opinion need to be elevated to higher authority within CIS to ensure that sectoral competing interests for national capital are fully considered.

10. Establish an environmental education program directed at (a) public awareness of the problems of the environment, especially the linkages between catchment / watershed area activities and consequences on the downstream water body(s) and; (b) formal education of young people (education curriculum for primary and secondary levels) in order for them to understand the central role of the natural environment in their life and life of future generations.

11. Establish a planning process. The planning process can be simple. It can be described as the following seven step process on components listed below:

a) Set the goals for sustainable use and development of the Vistula and Curonian lagoon and their catchment area / watershed.

b) Define problem(s)—describe the problems/conditions that affect the lagoon ecological and social-economic structures.

c) Define the system—Vistula and Curonian lagoons' ecological and socio-economic structural components.

d) Develop and use an effective decision support system, a CIS.

e) Develop and integrate this plan into the infrastructure by function (committees and workgroups of the CIS).

f) Formulate Action Plans to address identified needs for information, policy, and legal framework.

g) Evaluate progress on a regular basis (at least annually by the Executive Committee and Policy Committee).

Lithuania, Poland and Russia should take great pride in the level of collaboration that is occurring. The recommendations provided are suggested as guidelines to improve their working relationship. Specifically, to improve the effectiveness and efficiency of decision making on interjurisdictional / trans-boundary issues for the purpose of sustained use and development of the Vistula and Curonian lagoons.

Acknowledgements

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Bilateral agreements between Hydrometeorological and Environmental Monitoring services of Lithuania, Poland and the Kaliningrad Oblast

Yuri V. Velikas, Nataliya V. Shchagina, Tatiana L. Laleko

Introduction

Geopolitical location of the Kaliningrad Oblast dictates specific approaches to arrangement and implementation of state environmental monitoring. Most of the catchment basins of the region are transboundary; all of them belong to the Baltic Sea basin, and integrated assessment of state of ecosystems is impossible without information exchange on water state between the Kaliningrad Oblast and the states, which have shared catchment basins.

Nowadays the most careful attention from the Baltic Sea states is paid to the issues of protection of the Baltic Sea. That is why an interest of the neighbouring Lithuania and Poland in cooperation with the Kaliningrad Oblast in the sphere of surface water monitoring could be easily explained.

International projects aimed at investigation and observation of state of water ecosystems are being implemented on the territory of the Kaliningrad Oblast for some years. Kaliningrad Centre for Hydrometeorology and Environmental Monitoring takes an active part in these projects together with other organizations.

At the time being the neighbouring Lithuania and Poland start implementation of the EU Water Framework Directive and toughen the requirements for monitoring of water objects. In these states a moni-

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toring network grows all the time, a number of determined pollutants increases steadily, in the framework of research monitoring a number of investigated water objects also grows.

Agreement with the Republic of Lithuania

In 2002, under support of the Tacis project ENVRUS 9803 "Monitoring and management of water resources of the Kaliningrad Oblast", the agreement on information exchange on transboundary streams among Kaliningrad Centre for Hydrometeorology and Environmental Monitoring and two Services of the Department of the Environment of the Lithuanian Republic, namely Lithuanian Hydrometeorological Service and Joint Centre for Research, was concluded. Afterwards, in September 2003, after structural changes in the staff of the Department of the Environment of the Lithuanian Republic, the title of the agreement had been amended. It had been titled as "Agreement between Lithuanian Environmental Protection Agency and the Lithuanian Hydrometeorological Service under the Ministry of Environment of the Republic Lithuania and the Kaliningrad Centre for Hydrometeorology and Environmental Monitoring of the Federal Service of Russia for Hydrometeorology and Environmental Monitoring on co-operation in the field of monitoring and date exchange on the state of transboundary water bodies". The exchange of hydrological and hydrochemical data on transboundary streams, the rivers Neman—Nyamunas, Sheshupe, Matrosovka—Giliya, obtained in the course of the state monitoring, is taking place in the framework of this agreement.

The positive feature of international information exchange is the fact that laboratories, when carrying out a quantitative chemical analysis, follow the standard requirements, provided in international standards ISO 17025−2000 "General requirements for the competence of testing and calibration laboratories" and ISO 5725–2002 "Accuracy (trueness and precision) of measurement metods and results", parts 1–6.

Intercalibration of measurement methods is being conducted in the framework of the agreement annually. The procedure of intercalibration includes (i) one-shot water sample at the given monitoring transect of the river, (ii) quantitative chemical analysis of the shares of this sample at the national laboratories, (iii) discussions and presentation of the reports at the work meetings.

The following water quality parameters are to be analyzed:

(1) Dissolved oxygen

(2) Suspended matter

(3) pH
(4) Electrical conductivity
(5) Biological oxygen demand over 5 days
(6) Chemical oxygen demand (dichromate oxidizability)
(7) Nitrites
(8) Ammonium nitrogen
(9) Phosphates
(10) Total Ferrum
(11) Oil-products
(12) Synthetic Surfactants
(13) Hydrargyrum
(14) Pesticides (Aldrin, Dichloro-diphenyl-trichloroethane (DDT), Dieldrin, Gamma hexachlorocyclohexane)

Preparing of the agreement with Poland

Nowadays the Federal Service for Hydrometeorology and Environment Monitoring negotiate with representatives of the Institute for Meteorology and Water Management of Poland on cooperation in the sphere of climatology and environment monitoring. Joint long-term research programmes are being elaborated. The draft of the agreement "Hydrochemical data exchange in border regions" is being discussed now in the Federal Service for Hydrometeorology and Environment Monitoring of the Russian Federation and Kaliningrad Centre for Hydrometeorology and Environmental Monitoring.

To ensure successful cross-border cooperation, the Kaliningrad Centre for Hydrometeorology and Environmental Monitoring has offered to include information exchange and joint monitoring of the Vistula Lagoon and catchment basins of the rivers Mamonovka—Bonuvka and Lava—Lyna in the agreement, and elaborate common criteria of unfavourable and dangerous hydrometeorological phenomena and extremely high pollution of environment; and also to find methods of latest update dissemination. Implementation of the above mentioned activities will require additional investments.

Conclusions

The general level of work that is being implemented on the territory of the Kaliningrad Oblast in the framework of the system of monitoring of environment pollution does not provide implementation of international liabilities arising from international Conventions and Agreements, in which the Russian Federation takes part, in full. Moreover, today it is necessary to solve a number of new tasks on monitoring of separate environment components and objects.

The negative in joint transboundary monitoring and assesment of water ecosystems state is the fact that there is no one generally accepted approach to classification and assesment of ecological state of water ecosystmens in the world practice. There are some differences in approaches to surface waters typology and elaboration of monitoring programmes; the criteria of allowable levels of pollution content also differ.

To achieve ecological well-being of transboundary objects and elaborate a common strategy of water ecosystems management, the states on the territory of which transboundary surface waters are located, should formulate international monitoring network of ecological quality of surface waters.

First of all, it is necessary:

• To formulate a common programme of monitoring of transboundary streams. Updating and optimization are strongly needed with engaging of model estimates of location of monitoring sites on transboundary streams and reservoirs, and choosing of dates for one-shot sampling.

• To use a basin approach, which let to obtain the whole characteristic of water system state, and estimate risks from anthropogenic sources when constructing a transboundary monitoring network.

• To conduct express-observation for the purpose of identification of unrecorded diffuse and point pollutant sources.

• To harmonize the methods of quantitative analysis and load on water system.

• To compare databases of water monitoring for conduction of information exchange on transboundaty streams quality.

• Organize an urgent alarm system on emergency situations on water objects in connection with extremely high pollution and dangerous hydrometeorological phenomena.

• To elaborate common methods of forecasting of spreading of gross pollution zones.

To implement the numerical models allowing forecasting the behaviour of ecosystems at development of situations anabling to have negative impact on water environment.

Vistula Lagoon as a trap of nutrient pollution

Jan Kwiatkowski, Boris V. Chubarenko,
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1. Introduction

Vistula Lagoon is a shallow (average depth of 2.6 m) estuarine lagoon of the southern Baltic Sea. It has an area of 838 km^2 and is connected with the Baltic Sea by a relatively deep (8–12 m) and narrow (400 m) channel. The lagoon is strongly influenced by water exchange with the Baltic Sea as well as by excessive nutrient load from its catchment (23 870 km^2—(Lazarenko & Maevskiy, 1975). Agriculture and wastewater treatment facilities are the main sources of nutrients in the watershed. The total load of nutrients has been estimated to be 15 513 tons of nitrogen and 2537 tons of phosphorus for the beginning of 90th. The main sources of nutrients were the Pregola river and the Kaliningrad sewage collector on the Russian side and rivers Pasleka, Elblag and Nogat on the Polish side.

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In the framework of an international, transboundary project "Environmental Impact Assessment and Planning for the Polish and Russian parts of the Vistula Lagoon", a mathematical model of the Vistula Lagoon has been established (Rasmussen, 1997; Kwiatkowski et al., 1997). The eutrophication module of this model simulates the cycling of nutrients in the ecosystem (Kwiatkowski, 1996). The model is a powerful decision-supporting tool, which is currently used to evaluate the scenarios of water management of the Vistula Lagoon (for example, (Chubarenko & Tchepikova, 2001).

The lagoon is a natural trap for nutrient pollution. A large part of the nutrient load reaching the lagoon from its catchment is finally immobilized in the sediments and does not move to the Baltic Sea. In the present study, the eutrophication module has been used to calculate the nutrient balance in a series of simulations assuming various degrees of nutrient discharge reductions in the Polish and Russian sources. On the basis of results of each simulation the flux of nutrients from the Lagoon to the Baltic Sea has been calculated.

2. The numerical model of the Vistula Lagoon

The MIKE 21 system of Danish Hydraulic Institute—Water and Environment has been applied for the Vistula Lagoon (Rasmussen, 1997; Kwiatkowski et al., 1997). MIKE 21 is a comprehensive modeling system for two-dimensional free surface flows where stratification can be neglected.

The simulation system used in this study comprised three modules which describe the hydrodynamics, advective and dispersive transport of dissolved and suspended material and eutrophication (water quality) processes (MIKE 21…, 1993). The eutrophication module describes the temporal variations of carbon, nitrogen and phosphorus in phytoplankton, detritus, zooplankton and sediments as well as the dissolved oxygen concentration.

The calculations were carried out on a 1000×1000 m bathymetry grid (780 water points). A 300 s time step was used for the hydrodynamic and advection-dispersion modules while the eutrophication processes were calculated with a 3 hour time step. The model was run for the whole year of 1994. One open boundary (the Baltiysk Strait), 28 point sources (20 rivers and 8 sewage discharges) were defined in the model. The hydrodynamic processes were driven by inflow of freshwater from the sources, water level variations in the Baltic Sea and wind forcing.

A special monitoring program has been carried out in 1994–95 to prepare the input and calibration data for the eutrophication module. Hydrochemical and biological parameters were measured in the Vistula Lagoon and in the point sources. Total nitrogen and total phosphorus were not directly measured on the Polish side of the lagoon that time; so, they were estimated using correlations between parameters for the Russian side. Direct measurements of the nutrient load in the Kaliningrad sewage collector were doubtfully low, and it was estimated according to number of Kaliningrad citizens. The radiation data, necessary for simulation of primary production, were based upon daily measurements. The boundary concentrations in the Baltiysk Strait were defined by monitoring measurements carried out in the Baltic Sea near its outlet. The initial concentrations in the lagoon were assumed uniform for the whole lagoon and were estimated on the base of earlier monitoring measurements in 1994. The calibration of the eutrophication module was fulfilled on the basis of monitoring measurements in 22 points on both Polish and Russian sides of the Vistula Lagoon in 1994. The calibration process comprised a series of simulations in which the calibration parameters were adjusted until a good correspondence between the measurements and simulations was achieved.

3. Results

A series of model simulations were carried out assuming various values of nutrient loads from the sources. The calculations covered reduction by 10, 20, 30, 40 and 50 percent of the nutrient load, first, on the Polish side, then, on the Russian side, and, finally, on both sides. For every one of these simulations as well as for the basic situation (without reductions) the transport of nutrients through the strait connecting the Vistula Lagoon with the Baltic Sea was calculated. The values of load of nitrogen and phosphorus from the Lagoon to the Baltic Sea are presented in Table 1.

The resulted linear approximation functions (Figs. 1 and 2) for transport of nutrients through the Baltiysk Strait as a function of two variables (percent of reduction of nutrient discharge in Polish and Russian sources) were found:

$$TP = 887 - 0.9 \cdot x - 6.5 \cdot y, \quad (1)$$

$$TN = 3357 - 3.8 \cdot x - 29.4 \cdot y. \quad (2)$$

where *TP* and *TN* are phosphorus and nitrogen load to the Baltic Sea (tons per year),
x—percent of reduction in Polish sources, *y*—percent of reduction in Russian sources.

Although, several non-linear functions (logarythmic, exponencial), were tested as well, the linear one was selected as a best fitting relationship with minimum mean square deviation.

4. Discussion

The Vistula Lagoon operates as a natural sediment trap for nutrient pollution. The basic simulation (reflecting the situation in 1994) indicates that only about 3353 tones of nitrogen (22 percent of the total inflow) and 881 tones of phosphorus (35 percent of the total inflow) are transported from the Vistula Lagoon to the Baltic Sea. The calculated nutrient balance for 1994 shows that 10 786 tones of nitrogen (69 percent of the total inflow) and 1288 tones of phosphorus (51 percent of the total inflow) were accumulated in the sediments and used as a food for plankton growth.

The accumulation in the sediments is a part of total balance of nutrients for sediments. The nutrient release is an opposite term of balance. Even in the case of complete removal of nutrient load from sources, the lagoon will transport nutrients to the Baltic Sea. The application of formulae (1) and (2) for the estimation of this nutrient release is wrong, because these relationships are valid only within the range where they were developed.

The results of simulations (Nos. 12–16) assuming uniform load reduction in the whole lagoon show that the percent of reduction of nitrogen transport toward the Baltic is nearly the same as the percent of reduction in the very sources. A 50 percent reduction in all sources causes over 49 percent reduction of the load to the Baltic. The reduction of the phosphorus load to the Baltic is not as high as the assumed reduction in the sources. For example, a 50 percent reduction in all sources causes ca. 40 percent reduction of the load to the sea.

The results of simulations assuming reductions only on one side of the Vistula Lagoon (Nos. 2–11), either Russian or Polish, indicate that the Russian sources contribute to the nutrient load to the Baltic Sea to a greater extent than the Polish ones. This can be explained by the fact that the Russian nutrient loads to the lagoon are bigger (75 percent of the total nitrogen load and 83 percent of the total phosphorus load) and, the Russian sources are located closer to the lagoon outlet.

Relationships (1) and (2) were developed on the example of the data for one year only, namely, for 1994. Even thought they might be considered as conventional, these simple linear links reflect the major trends in response of total nutrient load from the Vistula Lagoon toward the Baltic Sea to the reduction of the loads toward the lagoon. Coefficients in these relationships evidently reflect the difference in influences of Polish and Russian parts on total nutrient load toward the Baltic Sea. Loads of phosphorus (1) and nitrogen (2) towards the Baltic are more sensitive to reduction of corresponding load in Russian part of the lagoon than in Polish one. One percent of the phosphorus and nitrogen reduction in Russian part is 7.2 and 7.7 times respectively more efficient than in Polish part.

Reduction of the load from both lagoon parts on 50 percent reduces the phosphorus and nitrogen transport toward the Baltic Sea respectively to 58 and 50.5 percent of existed in 1994. Reduction by 50 percent for Polish sources gives only 5 and 6 percent of total load reduction, whereas, 50 percent reduction for Russian part gives 37 and 44 percent of reduction for phosphorus and nitrogen loads respectively.

5. Conclusions

Within the framework of an international transboundary project "Environmental Impact Assessment and Planning for Polish and Russian parts of the Vistula Lagoon", an integrated modeling system MIKE 21 was applied to the Vistula Lagoon. The input and calibration data were prepared on the basis of a special monitoring program carried out in the year of 1994. The model included 20 rivers, 8 sewage discharges and one open boundary—the Baltiysk Strait connecting the Lagoon with the Baltic Sea.

The total load of nutrients onto the lagoon in the year 1994 was calculated on the basis of river monitoring: 15 513 tons of nitrogen and 2537 tons of phosphorus. The results of the basic model simulations (situation in 1994) indicate that about 22 percent of the nitrogen load and 35 percent of the phosphorus load onto the Vistula lagoon is finally transmitted toward the Baltic Sea through the Baltiysk strait. Large part of nutrients (according to model applied, 10 786 ton of nitrogen and 1288 ton of phosphorus) is immobilized in the Vistula lagoon, first, in plankton growth, and second, in sediments as detritus.

Apart from the calculation of nutrient transport through the Baltiysk Strait in the present situation (1994), the calibrated eutrophication model was used to simulate the transport in several cases of hypothetic reductions of the nutrient load from Polish and Russian sides. On the basis of the model results, the mathematical relationship of the outflow of nutrients from the lagoon towards the Baltic from percentage of nutrient load reduction on Polish and Russian sides of the lagoon has been formulated.

According to international agreements for the Baltic, its rehabilitation is to be done by the reduction of nutrient load in its catchment. For example, according to the Helsinki Commission Agreement, the load of nutrients reaching the Baltic Sea is to be reduced by 50 percent. However, in the case of a transboundary water recipient like the Vistula lagoon, the assessment of the necessary reductions of nutrients in each country is a complicated task. The present study principally showed that the reduction of nutrient transport from the Vistula lagoon to the Baltic sea might be achieved mainly by reductions in Russian sources.

According to the simulation results, a 50 percent reduction of the nutrient load from all the sources will cause approximately an immediate 50 percent reduction of nitrogen transport toward the Baltic Sea and a 40 percent reduction of phosphorus transport. The 50 percent reductions on Polish or Russian sides separately give a decrease of the transport of phosphorus by 5 and 36 percent, and a decrease in nitrogen transport by 6 and 44 percent, respectively.

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Table 1.

Nitrogen and phosphorus loads in the basic situation (no reduction) and after the reductions in the sources.

Simulation run	% of load reduction		Transport through the Baltiysk Strait	
	Polish side	Russian side	TN [tones per year]	TP [tones per year]
1	0%	0%	3353	881
Reductions in the Polish sources				
2	10%	0%	3338	880
3	20%	0%	3293	870
4	30%	0%	3250	860
5	40%	0%	3207	850
6	50%	0%	3165	840
Reductions in the Russian sources				
7	0%	10%	3052	823
8	0%	20%	2756	764
9	0%	30%	2463	704
10	0%	40%	2176	644
11	0%	50%	1894	582
Uniform reductions in all the sources				
12	10%	10%	3035	821
13	20%	20%	2693	751
14	30%	30%	2357	677
15	40%	40%	2027	609
16	50%	50%	1704	537

Table 1 continuation.

Simulation run	% of load reduction		Transport through the Baltic Strait	
	Polish side	Russian side	TN [tones per year]	TP [tones per year]
17	50%	30%	2275	660
18	50%	10%	2865	781
19	30%	50%	1784	557
20	30%	10%	2949	801
21	10%	50%	1867	578
22	10%	30%	2441	701

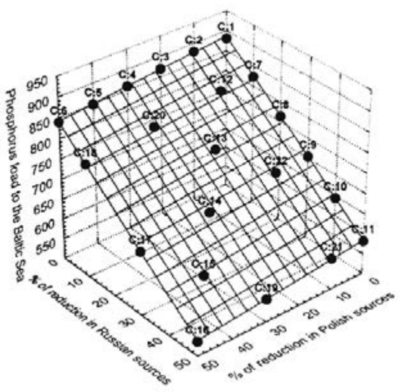

Fig. 1. Total phosphorus load from the Vistula Lagoon to the Baltic Sea against percentage of reduction in total phosphorus load for Russian and Polish point sources. The linear approximation is based upon point C1, … C21 corresponded to the results of simulations on MIKE 21 model.

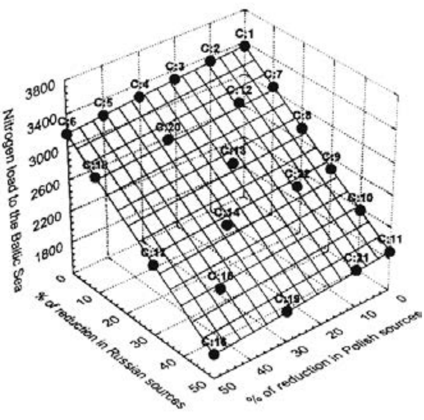

Fig. 2. Total nitrogen load from the Vistula Lagoon to the Baltic Sea against percentage of reduction in total nitrogen load for Russian and Polish point sources. The linear approximation is based upon point C1, … C21 corresponded to the results of simulations on MIKE 21 model.

Water monitoring database as a tool for transboundary cooperation for management of water resources

Sergey V. Shibaev
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1. Introduction

Effective water resources management needs an adequate system of observation of the ecological state of water-bodies. Russian Governmental Decrees demand to establish united system of ecological monitoring for any region to supply authorities with relevant information for decision-making in field of water resources management and protection. The most important documents are a Decree No. 1229 from 24.11.93 "On Establishment of Integrated State System of Environmental Monitoring" and a Decree No. 1425 from 15.11.97 "On Information Services in the Field of Hydrometeorology and Natural Environment Pollution Monitoring".

Government Decision No. 1229 from November 1993 provides for a unification of monitoring structures into a single Unified State System of Environmental Monitoring aiming to present comprehensive data on a common basis and at different levels of synthesis useful to

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regional and national decision-makers. To present day, the progress in implementing this decision has been limited.

Government Decision No. 1425 refers to providing operative/forecasting and analytical information, general-use data on current conditions, and special-use information in the field of hydrometeorology and natural environment pollution monitoring.

Despite of desire of the Russian government to create a uniform system of monitoring of an environment including water monitoring, it was not possible up to now to create the uniform system in the Kaliningrad area providing effective supervision over water bodies and management of them.

Besides, for the Kaliningrad Oblast, the harmonization of system of ecological monitoring with neighboring countries is very important. It allows providing more effective protection against transboundary pollution and, as a whole, more effective water monitoring.

The aim of the article is to describe some results on creation of unified system of water monitoring by means of organization of a regional water-monitoring database. This approach could be fruitful for transboundary cooperation as well. Positive results of development of the integrated fishery research database (Shibaev, 1996, 2004; Shibaev at al., 2001) were used for the water monitoring.

2. State of water monitoring system in the Kaliningrad Oblast

During years 2000–02, in a framework of TACIS project "Water monitoring and management in Kaliningrad Oblast" (ENVRUS 9803), an existing system of water resources observations and control in the Kaliningrad Oblast has been examined. The following characteristics have been subjected to research:

(1) the list of organizations, which, to a various extent, carry out supervision over hydrological, hydrochemical and biological parameters of superficial waters;

(2) the list of parameters under control, and methods of their analysis;

(3) the system of the organization of monitoring in different organizations;

(4) methods of analysis and interpretation of the results of water monitoring.

It was recognized, that there are a number of organizations, which collect samples and make some ecological assessment for different water-bodies in the region. Among them, there are three types of organizations.

(1) Federal organizations, authorized by national government to implement different aspects of ecological monitoring (Kaliningrad Centre for Hydrometeorology and Environmental Monitoring, Kaliningrad Sanitary/Epidemiological Control Centre (SanEpidNadzor), Committee for Natural Resources, Special Marine Inspection),

(2) State scientific and educational organizations like Atlantic Branch of Institute of Oceanology of Rusian Academy of Sciences, Atlantic Research Institute for Fishery and Oceanography, Kaliningrad State Technical University,

(3) Municipal organizations, like Vodocanal, which deal with water supply of population and industry.

Total number of points where any organization is taking samples from surface waters more than once, is of about 260 (Fig. 1). Out of these, there are about 64 points for observation of hydrological and chemical parameters of natural waters and wastewaters performed by federal organizations. In the remaining points, other scientific organizations conduct their own research—for example hydrobiological and fishery monitoring. The total number of parameters has been estimated for about 60. These are hydrological, chemical, microbiological and hydrobiological parameters. Average frequency of sampling ranges from once per year to once per month.

At first sight, it seems that there is wide and comprehensive system of water monitoring in the Kaliningrad Oblast, but really this is not true. An analysis has shown that the situation is in serious discrepancy from requirements. Federal bodies undertook and undertake efforts

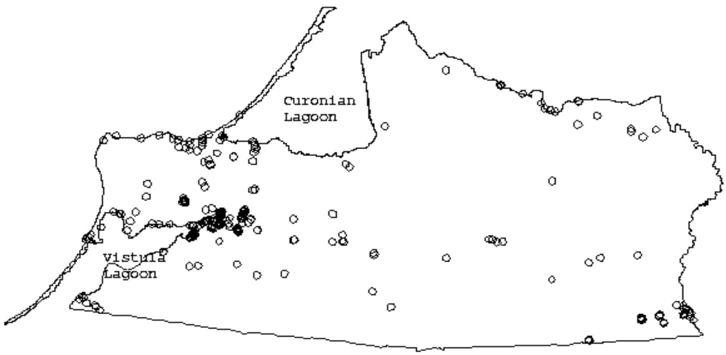

Fig. 1. Distribution of water monitoring points of different organizations in Kaliningrad Oblast.

on performance of obligatory for them programs of monitoring within the framework of opportunities available for them. But resources, which they have, are essentially limited: absence of financial assets, shortage of experts and proper equipment. The situation is even more aggravated by existing disagreements between various organizations that lead to duplication in carrying out of measurements and analyses, and, sometimes, even their functions. Besides, the information collected at a local level by representatives of federal bodies, is centralized in their higher structures instead of being used for optimization of water resources management at a level of the Kaliningrad Oblast.

There were no chances to have a complete review of ecological state of water resources in the Kaliningrad Oblast or even in some sub-catchments, because different methods and techniques of collection and analyses of information on hydrology, hydrochemistry, and hydrobiology are used in the region.

It was assumed, that only the integration of information about the water bodies by means of regional database of water monitoring could provide an adequate informational basis for effective water management.

Currently, during 2004–05, the administrative system of the Russian Federation has been changed considerably. However, the results of the research described in the article, could only benefit in improving, developing and adopting the system to the new reality.

3. Structure and functioning of the database

Development of unified and integrated system of water monitoring at a level of the Kaliningrad Oblast might be possible in frame of integrated database. It means that all organizations, which are responsible for carrying out water monitoring, could transfer their data into the common database. Then, when the information has been integrated, they could use it for realization of their sectoral and governmental tasks.

As a result of such integration essential improvements of the monitoring system could be reached. Using of single database by all participants brings elimination of duplication in gathering of the information by various organizations. More complete and effective usage of the existing equipment, when specialization of the organizations on estimation of specific parameters—chemical or biological—is possible, with respect to available experience of the organization and sectoral tasks. With unification of all available data we obtain an opportunity of the multivariate analysis of the information and estimation of an ecological situation at a level of one water-body, catchments area or region as a whole. Unified structure of the information for the database will be a basis for further development of an information exchange with neighboring countries—Poland and Lithuania.

Studying of an existing situation showed that there are certain problems and conflicts connected to supply with information of monitoring. They are as follows:

• different structure of information in the organizations involved into the water monitoring, different frequency of sampling, absence of a uniform network of stations of study;

• poor formalization and often use of verbal descriptions of results of researches, absence of system of storage of the initial information;

• poor technical and program supplying (this problem has been partly solved within the framework of project Tacis);

• absence of interest in integration of the data of monitoring, its representation at a local level, including publication;

• presence of sectoral and governmental restrictions on monitoring data exchange and problems on the proprietary right to the data, transmitted to the common database.

Despite of the described above problems, an adequate way of integration had been found during discussions with participants of monitoring. It includes the following:

• using of the database should be introduced into routing activity of interested organization; it shall help in implementation of their sector tasks without additional effort;

• all the involved organizations get a benefit by accessing to the data of other organization through the database. Everybody can use data only for assessment, making decisions and scientific tasks, but not for commercial use. The details of data usage were established in General Agreement on maintenance of the database of water monitoring in the Kaliningrad Oblast, which was signed by all interested organizations under the leadership of Regional Administration (Fig. 2). Coordinating Council for Regional Water Monitoring Database was established.

So, integrated water monitoring database has to be a tool for informational support of water management in local and transboundary context, helpful in solving of the following tasks:

• integration of the relevant data for solution of common problems of the region;

• collecting and maintaining of historical and current data, automatically data exchange between involved organizations via Internet or modem connection;

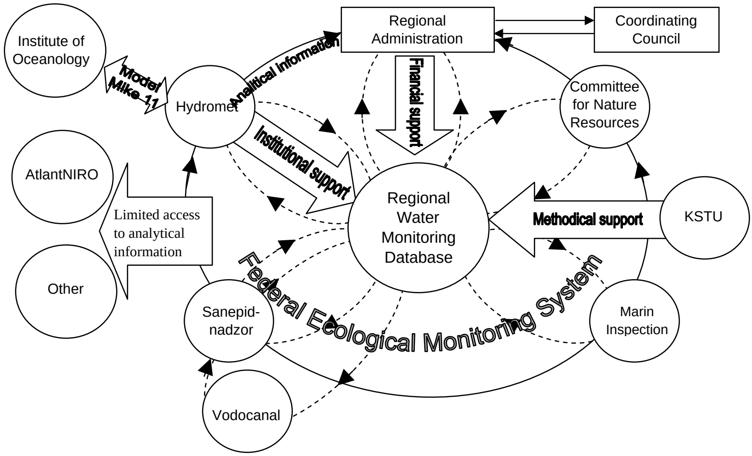

Fig. 2. Scheme of regional water monitoring database for the Kaliningrad Oblast.

• harmonization of sampling points and parameters;
• including reference books with information about Russian and EU water quality standards;
• carrying out a multidimensional analysis (including GIS) of water monitoring data to assess the ecological state of water in reservoirs, watersheds and in the region as a whole, and providing data for forecasting and modeling.

From the technical point of view, the database was designed as a computer tool for specialists and was introduced into existing monitoring activity. In the framework of the Tacis project, for the first time in the region, unique information on water quality conditions in different water bodies in the Kaliningrad Oblast was collected as a result of involvement of different organizations in the joint work. The data available in the Former Regional Committee for Environmental Protection, the Regional Sanitary and Epidemiological Centre (Sanepidnadzor), the Kaliningrad Centre for Hydrometeorology and Environmental Monitoring, the Kaliningrad State Technical University, the Kaliningrad Vodokanal were collected and compiled into the database. The regional water-monitoring database contains information for years 1995–2000 about 47 water-bodies, 9701 samples and 140 922 measurements and analyses.

The database allows the following main queries:
• standard statistics (minimum, maximum, average, standard deviation) for any hydrological or hydro-chemical parameter for different

sampling point, or water-body, or town, or region, and for any day or month, or season, or year;

• estimation of ecological state of any water object in accordance with Russian and EU standards of water quality. Detecting of "hot spots";

• dynamics of ecological status and water quality for any water object in terms of space and time.

The examples of implementation of the mentioned tasks are shown in Figs. 3–5.

4. Transboundary approach

Development of universal structure of the regional water-monitoring database makes it suitable for application in any region or country. Due to this feature, the previous experience was used in realization of a new international Tacis project with Poland titled "Restoration of cooperation between Russian and Polish institutions responsible for transboundary water management of Vistula Lagoon".

Both Poland and Russia conduct water monitoring in few transboundary water-bodies. These are: the Baltic Sea, the Vistula Lagoon and rivers: Mayskaya, Lava, Angrapa. In this regard, integration of the information is very important.

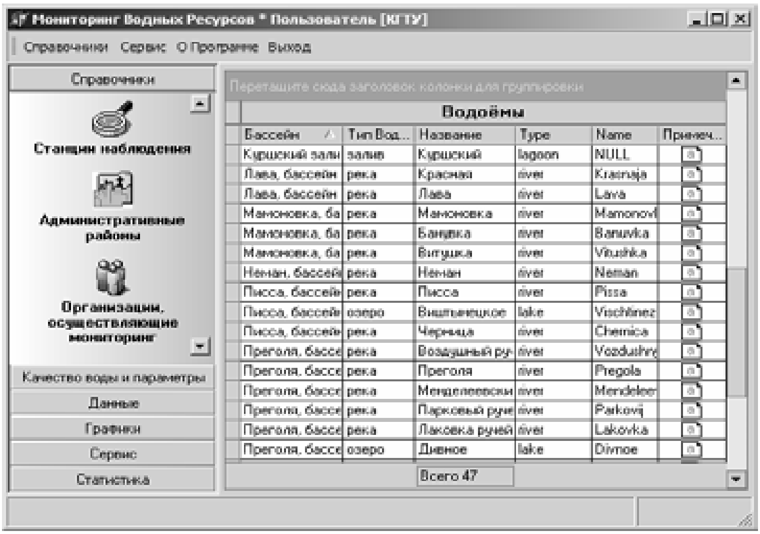

Fig. 3. Cadastre of water-bodies in database.

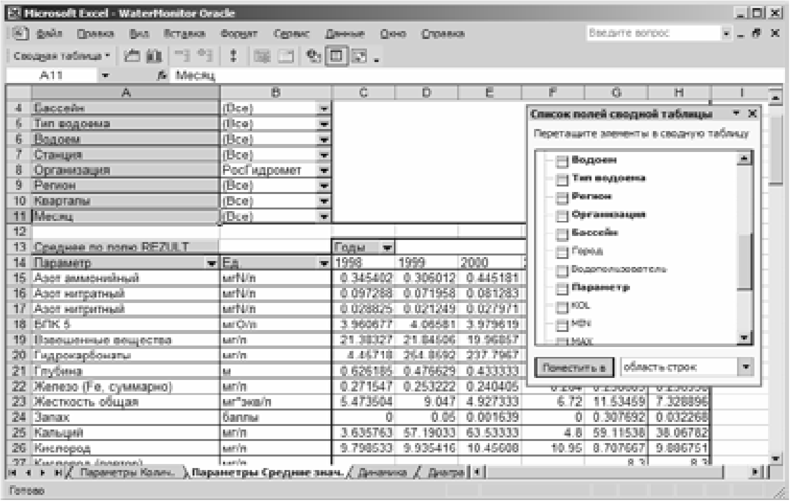

Fig. 4. Analysis of database in pivot tables.

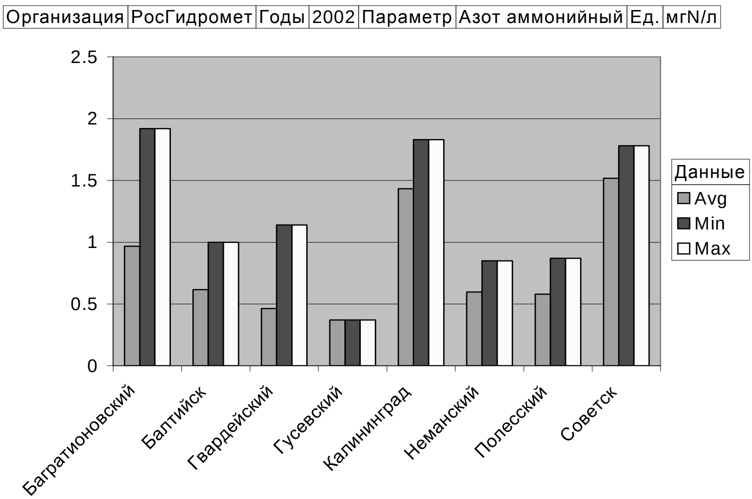

Fig. 5. Analysis of database in diagram.

In the framework of the mentioned above project, the Vistula Lagoon basin was a subject of interest. Most important issues identified in the Vistula Lagoon and its basin in transboundary cooperation context concern (Bielecka & Lewandowski, 2004):

• Data availability in terms of possible exchange between both sides and partners. Hydrological and biochemical measurements are carried out by different institutions (those responsible for the state monitoring, and scientific institutions). Information exchange between them (inside the country as well as between the two countries) is difficult, however a common data base for the Kaliningrad Oblast already exists in Kaliningrad. These problems are the result of different internal regulations and legislation. In order to acquire, use, share and exchange data between countries and partners it is necessary to sign special agreements between institutions from project to project. No general agreement exists to solve this problem.

• Data availability in terms of sampling stations location, measured parameters, frequency, periods of measurements (no winter measurements)—as a main source of uncertainties. Not too many stations are located around the Lagoon and sometimes they are not situated in most optimal spots. For instance, in Russian part of the lagoon stations are located in central part, whereas in Polish part—along the shores of the lagoon mainly. This makes interpretation of measurements more difficult and not comparable. Not all water quality parameters are measured, frequency of measurements in Polish and Russian parts of the lagoon is different and during the winter period (December–March) no measurements are carried out at all. Not all rivers discharging into the lagoon are monitored and even in those monitored, discharges are not measured. As a result, lots of uncertainties occur and analysis of ecological status of the lagoon as well as set up and calibration of numerical ecological models become very difficult and even problematic.

• Data accuracy and comparability—different analytical methods are used, which have different accuracy. Those differences do not only occur between countries but also between laboratories within one country. This is another source of uncertainties that again influences proper ecological status assessment as well as ecological modelling.

• Coordinated monitoring for the whole Lagoon does not exist; therefore spatial distributions of water quality and ecological parameters in the whole Lagoon are not available for the same period of time (not even day or week).

Therefore, it was adequate to implement a common monitoring data base structure and show a possibility for the data exchange between both countries. Within the Tacis project, the Polish side has been acquainted with the Russian experience of creation of the integrated information software and the Polish version of the interface for the database has been designed. As a result, the structure of monitoring information collected both in Russia and Poland has currently become unified, and there is no technical problem for data exchange. However, in order to implement it in practice, a political decision has to be taken.

This type of work is to be continued with the Lithuania: there is already an agreement on a joint management of transboundary waters, too.

Acknowledgements

Authors are very thankful to Roberto Lo Cicero Vaina, the leader of the TACIS project "Water monitoring and management in Kaliningrad Oblast" (ENVRUS 9803), in frame of which this research has been implemented.

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Coasts of Vistula and Curonian Spits as transboundary territories

Vadim L. Boldyrev,
Valentina P. Bobykina

Introduction

Vistula and Curonian Spits belong to transboundary territories on sea coast of the Kaliningrad Oblast. They are geographically separated by present-day state borders (Fig. 1, color inset).

25 km-long northern part of the Vistula Spit belongs to the Kaliningrad Oblast, whilst the other one, extending for 40 km, is possession of Poland. The state border between the Russian Federation and Lithuania is in the middle of the Curonian Spit, which has the length of 100 km.

Regardless of their national belonging, each spit is a single whole natural formation, developed under influence of wind waves and current systems of common general coastal hydrodynamic field. These conditions stipulate washing-out, transport and accumulation of sediments in the coastal zone. In a historical aspect, sea level variations basically determined the formation of the Spits as united accumulative formations of complicated structure.

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The process of the Spits' development was rather complicated, and took, in geological scale, rather short time period. The origination of ancient spits was directly connected with Littorina transgression (6.0–5.5 thousand years BP) and following sea level fluctuations (Geologiya baltiyskogo moray [Geology of the Baltic Sea], 1975; Blazhchishin et al., 1982; Boldyrev, 1992; Badyukova et al., 1996; Zhindarev & Kulakov, 1996).

Long-term investigations of the coasts of South-East Baltic Sea and monitoring data of the shores carried out at AB IORAS over last six years make up the basis of the present paper. In spite of their formal similarity, Vistula and Curonian Spits have differences both in history of their development and present-day dynamics of the coasts.

In this paper, the formation of the Spits (so-called moving sands), their development, present-day structure and dynamics of the coasts are considered.

The Vistula Spit

History of the Vistula Spit formation is debatable to a great extent. Polish scientists recon that the Spit had began its formation and development from the Vistula river mouth, which is located at the coast of the Bay of Gdansk, near the very Gdansk (Mojski, 1988; Tomczak et al., 1989). The formation of the coastal accumulative forms is usually connected with the sources of their feeding by sediments. However, if we have a look at historical maps, particularly, on the map of year 1300, revised by Bertram, we can see that the Vistula Spit was once joining the sea coast of Gdansk. The eastern part of the Vistula delta had not been completely formed yet, and Elblong was situated directly at the lagoon coast. Besides, there was no delta completely formed from the rear side of the Vistula Spit. There were numerous lakes-lagoons connected by numerous Vistula branches. One of the Vistula branches had been stretching parallel to the coast along the western part of the Vistula Spit.

According to published data, the basic sediment run-off from the Vistula River went through the Nogat river-bed to the eastern part of the Vistula Lagoon, and made up about 400 thousand tons per year on average, what finally resulted in a formation of the present-day Vistula delta. In addition, wave fetch should also be taken into account, since it causes alongshore sediment transport. For the location of Gdansk, the fetch of southwestern and southern waves is practically zero. Two more Vistula river beds—Stegno and Swibno—were formed later, both bringing their waters to the Bay of Gdansk. The Swibno was an artificial canal built in 1910. In 1916, a dam was constructed at the mouth of Nogat, and the main sediment run-off from the Vistula River went through the Swibno River-bed. As a consequence, bottom accumulative form began to grow quickly at the mouth of the Swibno—a sand shoal, which caused ice blockage and spring floods at the Vistula River delta. It urged the necessity of building the protective dam at the mouth of the river, which extended for 2 km long into the bay and completely blocked the alongshore sediment transport from the Gdansk area.

Our investigations at the western coast of the Baltic Sea—from Cape Taran to the town of Baltiysk and the Vistula Spit coast—show that in the past the Vistula Spit received the basic feeding from the west Sambian peninsula coast abrasion, and since 1958—from the sand supplies entering the sea coast at the Yantarny—Pokrovskoe area. These sandy sediments supply the Vistula Spit, including Polish coasts.

Over the history of the Vistula Spit formation and development, the sea level varied repeatedly. The present-day sea level marks were exceeded by about 4–4.5 m. There were at least 5 such exceedings for the last 5 thousand years (Tobolski, 2005). The periods of sea level rise were followed by those of its falling down up to 7–9 m. During the periods of recession of sea level, all available sandy material went to the coast, so that sandy-sediment deficit ensued to the time of its termination. During a subsequent sea level rises by 4–5 m, sea water came through the Spit repeatedly at several locations. Small canals formed during this process, changed their location every time. A new supply of sediments followed, resulting from the coastal and sea-bed abrasion, and the Spit was gradually restored to its original condition. The latest breach of the Spit occurred at Baltiysk in 1510 with the formation of the Pillau Channel (the Baltiysk Channel, at present), the shores of which were strengthened by stoned slopes in the middle of 19th century.

The Vistula Spit has the shape of a concave arch on a chart. Sand beaches 20–25 m wide are stretching along the Spit at the sea side. Behind them there is a foredune up to 8–10 m high. Numerous blowing-outs have been formed in the foredune due to the activity of aeolian processes, and in the rear part of these, there formed aeolian hills up to 12–15 m high. At present there are up to 30 blowing-outs on the Spit. In the 60–70s of the past century, a foredune in several blowing-outs was partially restored and strengthened by brushwood cages and by planting willows and pine-trees. In the last decade of the 20th century, due to the absence of sand-retaining and restoration works, the former blowing-out processes became active again.

Today, the Spit is covered with forests, with the exception of the settlement of Kosa There are only a few open glades of limited area on the Vistula Spit nowadays.

In the southern part of the Spit, a leveled deflation plain is formed behind the foredune. On the proper spit territory, right behind the foredune, the parabolic dunes are situated, extended up to the lagoon coast. Only on the southern end of the Spit, 21–23 km apart from its tip, there is a dune, which is now forest-covered, but it used to be mobile in the 50s of the last century. This dune is the highest of all reaching up to 38 m and having gentle windward and steep leeward slopes. The presence of parabolic dunes on the basic part of the Spit proves the fact that this part of the Spit was always covered with forests. There was a vast open glade from the sea side near the high mobile dune. Today it is half covered with the forest.

The Vistula Spit is formed by sand. However there are patches of moraine loam and peat-bogs close to the surface. These places are notable for swamps and alder forests.

From the lagoon side, alternate eroding slopes of ancient dunes and reed thickets form the coast. Small part of the shores has accumulative or man-caused character (Bobykina, 2002).

The westernmost part of the Spit, from the Swibno river-bed to the Dead Vistula mouth was gradually divided into a number of local segments with short migratory flows of sand in them. Apparently, alluvium from the Vistula River is transported to the east of the Swibno mouth in a limited amount. It may be conditioned by the construction of the eastern dam, which had been pushed forward into the Bay of Gdansk to provide the river-bed for the Vistula River. Consequently, the eastern side was filled with sand at the point where the dam meets the coast. However, at a distance of 10–20 km to the east of the Swibno mouth, an arch of eroded coast is formed due to the deficit of the sand, coming to the Spit from the river mouth. The situation confirms the fact, that there is a limited supply of alluvium for the Spit from the Vistula River. The further will the protective dams of the Swibno move into the Bay of Gdansk, the more intense coast erosion would take place on a greater part of the Polish side of the Spit. At present, as well as in past, the Vistula Spit receives its basic feeding from the western coast of Sambian Peninsula. Since the time of the Spit formation, the main part of its nourishment came from the coastal and bottom abrasion. Beginning from the 60s of the past century, the sand from the Yantarny area began entering the Spit in great amounts. It was the sand from the Yantarny Amber Mining Factory that had been damped into the sea since 1958. By the present time, the total volume of the sediments dumped into the sea has reached 70 million m^3 (Boldyrev et al., 1992). Owing to this circumstance, the large sand supply of the sea turned the abrasive-kind of coast into the accumulative one to the south of Yantarny. The sand has been accumulating on the beaches and made them wider, the bar-shaped foredunes formed close to the coves, and formerly active abrasion terraces were covered by the leaned foredunes at the whole coast extension right up to Pavlovo (the Baltiysk area). This sand is drifting along the coast, bends around the moles of port of Baltiysk and reaches the Vistula Spit. As the result, the sea coast there has become relatively stable during the latest decades. Only a 5-km long northern-most segment of the Spit coast, starting from the root of the southern Baltiysk jetties, has been subject to constant erosion for more than 100 years, since the time, when the Baltiysk Sea Port jetties were made longer. It may be explained by the fact, that the port jetties deflect the alongshore sediment flow towards the sea, so that the sand returns to the spit coast only 5 km further to the south (Boldyrev & Bobykina, 2001; Bobykina, 1999).

The coast near Baltiysk, judging by the outlines of the underwater sand bars on the map, is oriented perpendicularly to the direction of prevailing wave propagation (Boldyrev, 1991, 1992). This fact may indicate the possibility of sand migration there-and-back along the arch of the Russian part of the Spit, with a little excess of westward sediment transport.

From the lagoon side, the eroded segments of the coast step back at a rate of about 0.5 m to 2–3 m/year. Mainly, the parabolic dunes have been washed out. At present, their tops are completely washed away. In the lagoon, at a distance of 0.5 km off the shore, there are 0.5 to 1.5 m deep sandy bars as the direct their extension. According to the morphology of the beaches at the lagoon side, where sand fills the south-western sides of reed bushes (Boldyrev & Bobykina, 2001) the basic transport of sand in the lagoon is directed to the north-east.

One more interesting moment should be pointed out: in 1993 our research group discovered the outcrops of ancient lagoon silt, which was found on the eroded shore terrace at the lagoon side of the Spit, near the 23d km. A flat low terrace at a height of +2.5 m underlies one of them, which has absolute age of about 1000 years. The second layer of the thick silt has the top mark at +2 m, total thickness exceeding 3 m and stretches into the lagoon. The age of that thick silt has been estimated as 2000 years BP. The presence of these silts at the lagoon side testifies that the sea level exceeded the present one by 4–4.5 m, respectively. The sediment supplies from Vistula River evidently formed all this silt.

The Curonian Spit

The Curonian Spit, as well as the Vistula Spit, began forming about 6.5–7.0 thousand years BP, i.e. at the end of the Ancylus—the beginning of the Littorina Period. Accordingly, in our region the southeastern Baltic Sea coast formation began at the mark of water level of 30–35 m. It passed a more complicated way in its development than the Vistula Spit. During the first period there were three protruding segments on the Baltic Sea coast: Sambian Peninsula, Rybachy Plateau and Palalnga Prominence. Between them, two stretches of moving sands were formed, separating the lagoon from the sea. The mentioned above shore prominences gradually submerged and were smoothed by the abrasion processes. Simultaneously, the northern coast of Sambian Peninsula was undergoing the abrasion processes and stepped back from the sea bringing the sand for nourishing the Curonian Spit. Following the retreat of the Sambian Peninsula coast, the Curonian Spit also stepped back. The latest outlines of the Spit shores gradually moved into the Curonian Lagoon, until the Spit joined the root shore in the vicinity of Klaipeda. Thus, the contemporary moving-sand-kind of Spit was formed. The evolution of the Curonian Spit during the Littorina and Post-Littorina Periods are described in two papers (Blazhchishin et al., 1982; Boldyrev, 1992).

Morphologically, the Spit, as pointed out by V.K. Gudelis (1954), has the following relief characteristics. Sand beaches, 20–55 m wide, with pebble and gravel admixtures, are stretched parallel to the sea. Along the rear side of the beach there is a foredune of 4–5 to 8–10 m high and of 15–20 to 40–45 m wide. Still further away from the beach the leveled deflation plain with low hills can be found, which is called "palve" in Lithuanian. Along the lagoon shore there are ridges of high dunes of 40 to 62–65 m high and 700–1200 m wide. Huge tracts of high mobile dunes with steep leeward slopes come abruptly to an end right at the lagoon. Here and there low terraces up to 2.5–3.5 m high separate high dunes from the lagoon. There are no dunes along a 10-km long root segment of the Spit, with only a few exceptions. Several separate fragments of the foredune 10–15 m wide have been left there. At the 4th and 7th km from the root of the Spit, the sea has smoothed the low ancient dunes, lowering them to 12–15 m high, which revealed two or three layers of ancient soils. Separate dune tracts, round in shape, remained on the "palve" to the south and north of Rybachy.

The longitudinal profile of the Spit shows that the contemporary body of the Spit drew close to the basement of glacier loam covered here and there by peat bog (gyttja). By present time, the area of sand sediments deficit at the sea bottom has reached the 30th km of the Spit, denudating the glacier loam and peat bog at the bottom, right at the water boundary. Ashore casting of the peat bog is found everywhere along the beach, starting from the root part of the Spit and stretching to Morskoje.

The whole prominence of the sea coast with the settlement of Rybachy situated on it is a peninsula with outcrops of the moraine loam. Contrary to it, the shore prominences from the lagoon side towards the north are sandy accumulative formations, formed during the latest 1.5–2 thousand years.

Our monitoring on the Curonian Spit shores started since 1960 with a thorough inventory work performed during the period of 5 years. It revealed considerable changes of the Spit shores both from the sea side, and from the lagoon. The sea side foredune of the Spit, 35–50 m wide along the first 30 km, and having the width from 70–80 to 120 m at the further part of the Spit, has been almost completely washed out in recent time. It almost did not exist at the first 9 km of the Spit, when the investigation started. The root shore and the old dunes, having two or three ground layers, clearly seen in the precipice, had been also washed-out. To the north-east of Lesnoe, the foredune was almost completely washed out here and there during the mentioned above period of time, and its width at four segments reaches only 1.5–2 m at the top, and 10–15 m at the root, where its height is only 4.5–5 m. Simultaneously, very intensive aeolian processes are recorded there. They bring about the formation of aeolian cushions in the upper part of the beach, which has already taken the shape of the rudimentary and leaned foredune. The intensification of aeolian processes in the beach area resulted in an increase of coarse-grained sediments on the beach and the formation of pebble sheets in some places. A considerable amount of pebble carried out from the bottom of the sea close to the littoral coastal zone brought about a progressive reduction of the bottom sand supplies. Thus, the zone of sand deficit at the underwater coastal slope reached the 28th km of the Spit. Here, at the sea bed, there was discovered a stratum of boulder-pebble deposits two years ago, which was replaced by peat bog and moraine loam outcrops at a distance of 2–3 m of the shore.

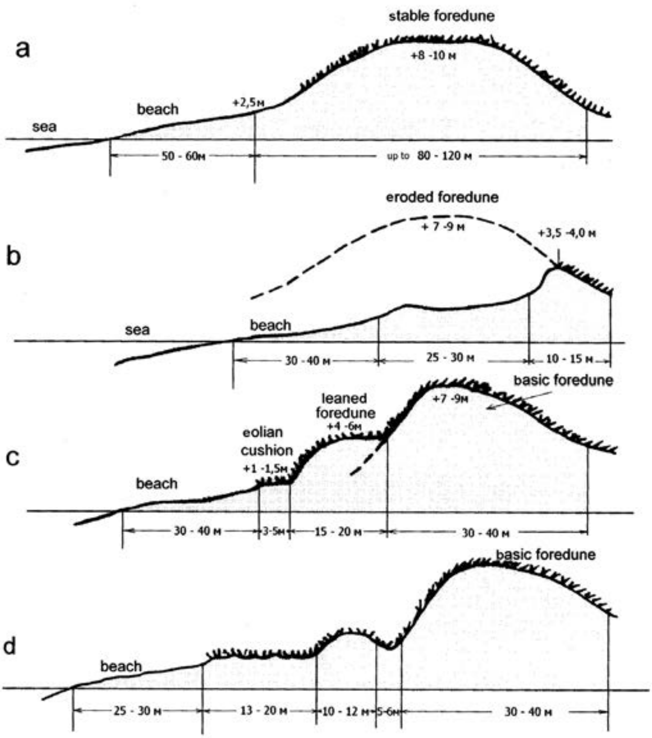
On the whole, we revealed stable, transitional and eroded segments along the Spit shore (Fig. 2). The stable segments are characterized by development of broad aeolian cushions and a rudimentary or leaned foredune in the rear part of the beach. All foredunes, both young and basic, are usually covered with vegetation. (Fig. 2a). Along the transitional segments of the shore the traces of recent washing-out of the foredune base can be noted, which is covered by steep aeolian slopes of sand or by a narrow aeolian cushion. These are usually formed by the time of the regular monitoring. Along the sea side, on the eroded segment of the foredune, a terrace can be observed sometimes reaching of the top of the foredune. (Fig. 2b).

Both eroded and stable segments are also distinguished on the lagoon shore of the Spit. Transitional shore segments cannot be so clearly seen here, as they are supplied with considerable amount of sand from the eroded lee-side slopes of the high dunes (Povilanskas, 1998).

According to the research data of the year 2004, eroded shores constitute 48 percent of the total length of the Curonian Spit from the lagoon side, transitional segments amount to 7 percent, stable coasts—16 percent, and man-caused sections—30 percent. The Vistula Spit has the following data: 50 percent—eroded shores, 33 percent—stable coasts, 14 percent—man-caused, 3 percent—accumulative shores (Bobykina, 2002; Boldyrev & Bobykina, 2005).

However, the situation constantly changes on the lagoon coast, and, particularly, on the sea coast of the Spits, because of the increasing storm activity in recent years, and of progressing sand sediments deficit in the area of the underwater coastal slope. For the period of 25 years, 17 extremely powerful storms came down to the sea coast of the Kaliningrad Oblast, as, for example, in December of 1999 (Bobykina, 2001), 2 more storms in November 2004 and in January 2005.

Artificial feeding of the coastal zone by sand supplies from the sea bed or from the spoils of dredging works is extremely necessary for restoration and preservation of the unique natural character of the both Spits (Bülow K. von, 1900). There are large amounts of sand supplies left free from washing out at the base of the relic ancient Curonian Spit, that is located in the sea opposite the present Curonian Spit. The sand is kept at the depth of 25–28 m at a distance of 8–10 km from the southern part of the Spit (Blazhchishin & Boldyrev, 1999). To stop the washing-out along the tip 5 km of the Vistula Spit at the settlement of Kosa, it is necessary to bring there the sand sediments (spoils) re-



a—stable coast; b—coast with almost washed-off foredune; c—coast with partially restored foredune; d—coast with active accumulation sand sediments.

Fig. 2. Transverse profiles of beach and foredune of the Curonian Spit.

ceived from the Baltiysk Channel dredging works. The sand should be carried via the base of the southern jetty directly to the beach within the settlement Kosa.

The second problem concerning the restoration and preservation of the natural character of the Spits is connected with elimination of numerous blowing-outs up, which amount up to 30 on the Vistula Spit, and up to 170—on the Curonian Spit.

A unique lake of aeolian origin—Lebed, situated to the northeast of Morskoje at the lagoon side of the Curonian Spit, is at the brink of disappearing. The strip of land separating the lake from the lagoon is only 2–5 m wide at present. Two ravines are already noticeable on this narrow strip, through which the lagoon waters enter the lake during the periods of wind surges. In 1961 the strip was 20–25 m wide, but gradually it was washing out. There is a possibility that in 2–3 years or even earlier the narrow strip of land might be completely washed away by the lagoon waters, and the lake would cease to exist. To avoid this, a new strip of land 25–30 m wide and 700 m long should be on-washed urgently, which will demand up to 30 thousand m^3 of sand. The sand for this purpose could be mined from the bottom of the lagoon, close to the adjacent coasts. It will definitely require additional measurements, such as sounding of the lagoon bottom and ground surveying.

Conclusions

Morphodynamic investigations of individual coastal segments of the Spits showed that they are closely connected, owing to transboundary alongshore sediment transportation within 2 km-wide littoral zone. The sea coasts conditions are mostly determined by the regime of this sediment migration. The conditions of sea coasts on the Lithuanian part of the Curonian Spit entirely depend on sand supplies from the Russian part. It is not so clearly seen on the Vistula Spit though, but the cessation of sand transport from the Russian part of the Spit towards the Polish one due to insufficiently considered hydro technical considerations may cause serious washing-out processes on the Polish side of the coast.

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Transboundary environmental monitoring in the Curonian Spit protected territories

Zita Rasuolė Gasiūnaitė, Jari Hanninen, Artūras Razinkovas, Ilppo Vuorinen

1. Introduction

Being considered naturally, culturally or historically, the Curonian Spit (*see* Figure in the paper Boldyrev & Bobykina of present book) is a uniform peninsula, featuring the same landscape, faunal and floral complexes. Nowadays however it is divided administratively into two parts. The northern 52 km long stretch of the Spit belongs to Lithuania, while the rest (46 km) is a part of the Kaliningrad Oblast, Russia. Both territories are national parks: Kuršių Nerija National Park (KNNP) and Kurshskaya Kosa National Park (KKNP), respectively. In 2000, Curonian Spit was included into UNESCO World Heritage List as a valuable international natural and cultural landscape; this consequently requires a transboundary integration of environmental monitoring and data management.

Lithuanian and Russian parts of the Curonian Lagoon and coastal zone of the Baltic Sea are even more interconnected since both ecosystems are transitional ones and strongly influenced by hydrodynamic

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transport. Therefore, all the human activities in the lagoon and sea may have potential transboundary effects. Dredging of the Klaipėda port area is linked, at least in part, to the increased sea water inflows into the lagoon (Dailidienė & Davulienė, 2005) and subsequent changes in ecosystem biota (Žaromskis, 2005). The construction of oil platform at the D6 oilfield in the territorial waters of Russia, 22.5 km offshore the coastline of the Curonian Spit has raised concerns over possible oil spills (Pichuzhkina & Sivkov, 2005). Hence, the environmental problems, e.g. coastal erosion, water quality, spreading of invasive species etc., are common and could be solved only on the basis of bilateral agreements and concerted actions.

The area of KNNP includes 36.9 percent (9774 ha) of land, 15.9 percent (4200 ha) of the Curonian Lagoon and 47.2 percent (12 500 ha) of the Baltic Sea water, whereas the territory of KKNP is limited to land only (6621 ha). This unconformity leads to the differences in management possibilities in both protected territories. Even terrestrial environmental monitoring programmes of national parks are not yet harmonized and it is very hard to obtain a comprehensive information on both parts of the Curonian Spit.

2. Scientific studies and environmental monitoring in the national parks

The knowledge about the environmental characteristics in the protected territories comes from three different sources: observations performed by the specialists of the parks, investigations of different scientific organisations and state and regional monitoring data.

The environmental observations of the park specialists are focused mainly on phenology and organised as questionnaires that are designed for mushrooms, different plant and animal groups. No formal analysis had been performed up to now, because data series are still very short (since 1998 in both parks); long-term data could definitely be more valuable for the analysis of climate-related changes in ecosystems. Special attention is also paid to plant and animal species included into the Red Books or protected by EU Directives.

Specialists of the parks are also involved in the environmental projects. An example of such kind of projects is an identification of key habitats in KNNP started in year 2002 as a part of Lithuanian-Sweden pilot project "Inventory of Key Habitats in Lithuania".

Scientific studies of the Curonian Lagoon and adjacent territories began already in the second part of nineteen century, and were focused on geological issues mainly (Berendt, 1869). Later, detailed litho-dynamic investigations provided a background for the coastline classification, understanding of erosion and sediment accumulation processes as well as dune dynamics (e.g. Gudelis, 1967; Michaliukaitė, 1967; Mardosienė, 1988; Pustelnikovas, 1998; Povilanskas & Chubarenko, 2000).

Hydro-biological investigations, started in the beginning of twentieth century with the species inventory (e.g. Szidat, 1926; Willer, 1935), were extended later to various aspects of ecosystem structure and functioning and became more regular. The results of joint Lithuanian-Russian survey of the Curonian Lagoon ecosystem were summarized in the monograph compiled by Jankevičius et al. and published in 1959. This book is still the most comprehensive source of hydrobiological knowledge regarding the Curonian Lagoon. Afterwards, a number of publications appeared concerning various aspects of ecosystem structure and functioning (e.g. Krylova, 1985; Naumenko, 1996; Olenina, 1997; Daunys & Olenin, 1999; Repečka, 2003; Gasiūnaitė & Razinkovas, 2004; Pilkaitytė & Razinkovas, 2006).

Terrestrial biological studies are focused mainly on species biology and biodiversity issues; existing data covers almost all major taxonomic groups. The investigations of the plant cover of the Curonian Spit have started more than one hundred years ago, and territory of the Curonian Spit is comparatively well investigated. Extensive studies were carried out by R. Bandțiulienė, G.G. Kucheneva, A. Nicenko and others, however, the results have never been summarized in a single publication. Similar situation is characteristic for insect and mammal studies as well.

National and regional monitoring data on environmental biology (forestry, birds, mammals, insects, terrestrial vegetation, aquatic vegetation, soil, fish, biodiversity), environmental physics (meteorology, temperature, radioactivity in biota), environmental chemistry (air pollutants, hydrochemistry), environmental geography (coastline, erosion, landscape) are available for both national parks. Animal monitoring is the most developed part of the monitoring, especially concerning bird populations.

For the KNNP, the results of monitoring and summarised scientific investigation data are available in Annual Reports. The procedure of data submission is not yet formalised, thus in some cases the available information could not be used for further analysis. First attempts to establish a system of monitoring in KKNP started in 1996–97 (Chubarenko, 1998), but till know the monitoring system is under development.

3. Recommendations for the transboundary monitoring system and conclusions

The monitoring activity is very similar in both national parks. Two approaches could be used for further improvement of environmental data management:

(1) to collect data useful for park visitors; this approach could be called a "recreationally oriented" one;

(2) to collect an information on environmental parameters in the parks for scientists, environment protection officers and economic decision-makers. This approach could be called a "factually oriented" one.

Recommended criteria for a selection of sustainable *recreationally oriented* monitoring parameters include general features, such as:

- Cost effectiveness. Observations must be cheap in order to facilitate the monitoring activity into foreseeable future, and also make it possible to arrange the monitoring in large enough scale (adequate number of parameters, monitoring localities and personnel).
- Simplicity. The monitoring results must be easily understandable to the monitoring personnel (they could be not specialists) and wide public, which is intended to be the audience.
- Accessibility. The monitoring should be ended up with numeric information in order to be easily transferred between the monitoring parties and the audience. The monitoring data could also be combined with data from international and national monitoring programmes.
- Applicability. The data should be useful for forecasts; short-term predictions could be made.

The phenological observations should be organized in a way to fulfil most of these criteria and, therefore, the phenological monitoring could form the basis of tourism information system. Park authorities could also perform a general survey among visitors to delineate the observation priorities. A provisional list of recommended phenological monitoring parameters to be included in the tourism information system is:

Biological phenological monitoring

- Seasonal migrations of birds and mammals, including seals and possible other aquatic animals, such as migrating fish species.
- Timing of reproduction in the biota, e.g. flowering and seeding of trees and other plants, birds having chicks, berries and mushrooms appearing, fish spawning.

Physical phenological monitoring

- Ice cover.
- Temperature of air and water.
- Meteorological phenomena.

Geographical phenological monitoring

- Erosion of walking routes and landscape
- Changes in coastline
- Changes in landscape
- General long-term and anthropogenic changes.

As for the *factually oriented* information, joint or partly shared monitoring and data management systems should be developed for both national parks, including databases, quality assurance and harmonization of methodology with existing international standards. Scientific analysis of existing data, e.g. by applying reliable numerical models, is necessary to predict possible consequences of anthropogenic activities in the parks and neighbouring areas. Park authorities should also initiate a publication of books related to the environmental situation in the protected territories.

At present, the both parks have different spatial structure, since the KKNP does not comprise the aquatic part (of both the Curonian lagoon and neighbouring Baltic Sea). This situation does not facilitate the improvement of environmental management and protection for the aquatic part of the ecosystem, which is a highly transitional one. Problems related to, e.g., discharges from the local municipalities, waterfowl protection and development of oil industry could be solved only on the transboundary bases, when the legislative status of the territories is similar. Therefore, it could be recommended to extend the protected territory of the KKNP to the same extent as it is in the Lithuanian part.

Harmonisation of the territorial structure of the parks will contribute as well to the implementation of Water Framework Directive in the related water bodies. At present, monitoring programmes do not cover explicitly the aquatic part of the protected territory of KNNP. Consequently, national parks did not include into the existing agreements between Lithuania and Russia a transboundary Curonian lagoon water quality monitoring. It is suggested that both national parks could initiate an extension of already existing state monitoring programmes in both countries to cover their territories. This extension should be coordinated and approved by both park authorities.

In the both parks, much of the environmental observations are performed by various scientific institutes. In many cases, these investigations are very fragmentary and non continuous. However, data from those investigations could be used to reveal certain environmental problems and to update existing monitoring system in protected territories. It is foreseen, that both national parks should put more efforts into initiation of specific research projects focused on the current needs of the environmental conservation as well as take more active part in defining the topical content in such studies. Participation of the park administrations together with scientific institutions in join projects (e.g. INTERREG, LIFE) could be one of these mechanisms.

At present, most of the environmental data are fragmentary and scattered across a number of reports, books or scientific journals. Park authorities should initiate the creation of a transboundary data management system, which will facilitate improving of existing monitoring systems and assist in search of the data.

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Spatial structure and evolution of bottom sediments in the Vistula Lagoon

Vladimir A. Chechko

Introduction

The Vistula lagoon is a transboundary water body: 56 percent of its territory is under the jurisdiction of Russia, 44 percent—of Poland. It has problems, caused by shared economy use of its area. They concern both rational use of biological and mineral recourses, and design of engineering constructions, and conducting of water-protection and recreational actions, and investigation of existing ecological changes as well as prediction of possible ones in future.

So, the data about bottom sediments becomes of importance since they serve as integrate indicators of sedimentation conditions and environment. Bottom sediments can be widely used to assess the scale of man-caused impact upon coastal/marine ecosystems, recognition of qualitative content of pollutants and their transport pathways (Aibulatov & Artyukhin, 1993; Hirschberg et al., 1996). The data about granulometric composition may be useful for understanding of regularities of accumulation of metals and organic pollutants in sediments, since relationship between the content of chemical elements and components in sediments and their granulometric fractions was revealed (Moshenko et al., 2001; Windom et al., 1989). Relation to natural potential of the lagoon as a single whole stipulates the presence of contemporary con-

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ceptions about distribution of the basic types of bottom sediments over the entire lagoon area, based on its uniform classification.

The first scheme of sediments, illustrating the distribution of its basic types over the whole lagoon territory was composed about 35 years ago on materials of surveys in 1959–65 (Wypych & Nieczaj, 1975). The lagoon is shallow, and, taking into account a wind-wave activity (Chubarenko, 1994; Blazhchishin & Chechko, 1997), one may assume, that during past time in the upper part of the sediments some changes might occur, and modern pattern of sediment distribution can be essentially different from those observed 35 years ago.

In 1995, the scheme of sediments based on F. Shepard's classification (Shepard, 1954) was developed in (Zachowicz & Uscinowicz, 1995) for south-western (Polish) part of the lagoon. The scheme, characterizing the distribution of sediments in north-eastern (Russian) part of the lagoon and based on P.L. Bezrukov's and A.P. Lisitsin's (Bezrukov & Lisitsin, 1960) classification of bottom sediments was developed in (Chechko & Blazhchishin, 2002).

It was impossible to develop the joint scheme of spatial distribution of bottom sediments because different classifications of sediments have been put in the basis of the above mentioned two schemes. In this paper, the scheme displaying contemporary state of bottom surface sediments over the whole lagoon territory according to Shepard's classification is presented and analyzed.

Methods

For south-western part of the lagoon, the scheme based on the results of treatment of bottom sediment samples from 89 stations in the Polish part of the lagoon (Zachowicz & Uscinowicz, 1995) was constructed. For north-eastern (Russian) part—the author's data are used, obtained on the material of surveys in 1992–96 at 105 stations. The samples were collected by Petersen's grab, piston corer (d=72 mm) and Niemisto corer from board of research boat with 0.7 m draught. Both schemes are made for the upper layer of sediments 0–5 cm.

The joint scheme of spatial distribution of the upper bottom sediments (Fig. 1, color inset) was created by combination of available scheme for the Polish part of the lagoon (Zachowicz & Uscinowicz, 1995) and the new scheme of the sediments for the Russian part of the lagoon developed according to Shepard's classification. The following granulometric types of deposits were distinguished in the lagoon: sand, silty sand, sandy silt, silt and clayey silt.

Results

The joint scheme for the whole lagoon is presented in Fig. 1, color inset. Comparatively small parts of the bottom surface are covered by boulders-gravely deposits, which are confined to moraine outcrops of the last glaciation. Those are usually located at small depths (1–1.5 m), frequently off capes on the southern coast.

About 29 percent of the bottom surface is covered by sands, which are mainly medium- and fine-grained. Sand is present along the lagoon coasts (down to the depth of 1.5–2 m) and in hydrodinamically active shallows, where the sediments experience continuous re-suspension so that finer fractions are transported away from this place. Coarse sands are found locally and are commonly adjacent to pebble-gravel deposits developed on moraine. Medium sand is the most widespread material. Large bodies of such sands, existing as migrating ridges, are concentrated on the south-east shallows of the estuary zone, where they are genetically connected with out-wash plains on land (Chechko & Blazhchishin, 2002). The largest area of fine sand is situated in the central zone just in front of the Baltic Strait and in the eastern part of the Primorskaya Bight. At the south-western coast, fine sand is more common, too. Silty sand was found on a rather small area of the bottom to the north-east of Krynica Morska, at 1.0 to about 2.0 m depth (Zachowicz & Uscinowicz, 1996) and along south-east coast.

Sandy silt covers about 17 percent of the lagoon bottom. Sandy silts are found as narrow bands that stretch along margins of sand deposits within the depth range from 2.0 to 2.5 m. The broader stripe of sandy silt was found in the central part of the lagoon and along the south-west part of the Primorskaya Bight.

Silt is the most widespread type of recent bottom sediments in the Vistula Lagoon. These sediments are found over 29 percent of the surface and cover all deeps on the bed at the central, in north-eastern parts of the lagoon, as well as in the Primorskaya Bight. In south-western part of the lagoon, silt separates the zone of coastal sand and sandy silt from the clayey silts, which cover the central areas of the south-western part of the Vistula lagoon (Zachowicz & Uscinowicz, 1996).

Clayey silts are abundant only in south-western part of the lagoon. The boundary between sands and clayey silts is located at 1.5–3.0 m depth, and only locally is closer to the coastline.

Shell deposits are made up mostly by shells of freshwater mollusks. Their detritus are usually filled up with fine sand and silty particles and are found over fairly large areas in south-western and north-eastern parts of the lagoon and in Primorskaya Bight. A layer of shells is usually 5–15 cm-thick and is periodically exposed on the bed surface, but most frequently it is covered by relatively thin (up to 10–15 cm) layer of sediments. Shell layer origination was caused by changes of lagoon hydrology as a result of regulating of the flows of the Vistula River and its arm Nogat in 1910–13, when water of the lagoon has become saltier and bulk of freshwater mollusks died (Lundbeck, 1928, 1935).

Discussion and conclusion

The comparison of the new presented scheme with the one (Fig. 2, color inset) published 35 years ago (Wypych & Nieczaj, 1975) allows estimation of in the ratio of areas, covered by different types of sediments in 1960th and in 1990th. The most valuable changes occurred in 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 percent.

Bottom area adjacent to the lagoon inlet (Baltiysk Strait) is characterized by serious changes in 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 narrow coastal band). At present, it became much narrower near the inlet and is almost completely replaced by coarse sediments—sandy silt and sand. At the same time, silt appeared in deepen parts of the bottom of north-eastern part of the lagoon and Primorskaya Bight.

Areas, covered by sandy silt, are generally reduced—from 23 to 17 percent. As before, this type of sediments is the most widespread in north-eastern part of the lagoon and Primorskaya Bight. Areas, covered by sand, have increased—from 21 to 29 percent. Coastal areas and 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 al., 2005). Coarse fractions are located in energetically most active areas of the proper lagoon—in shallows and in coastal zone, while fine material is accumulated in deeper, calmer areas. Deep area near inlet is covered by coarse material because fine sediments are brought out into the sea by water exchange currents.

Basic changes in spatial distribution of bottom sediments in the Vistula Lagoon are caused by regulation of the Vistula River drain in the beginning of XIX 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.

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The Lyna-Lava transboundary river basin: ecological assessment and recommendations for monitoring

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1. Introduction

The Kaliningrad Oblast shares surface waters with Lithuania and Poland, which recently entered the European Union. Therefore, the common surface water resources are considered as transboundary ones, and attract particular mutual interest regarding its sustainable use.

According to both EU Water Framework Directive and Convention on Protection and Use of Transboundary Watercourses and International Lakes a modern water management is to be characterized by a holistic river basin approach aiming at good quality and quantity of ground and surface waters as well as its sustainable development. Using a river basin as the basis for water management, all kinds of different activities affecting quality and quantity of waters can be handled in an effective way. The river basin approach also makes management of transboundary waters when two or several states are sharing a river

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basin more efficiently. Realization of these approaches should be implemented by the joint river basin administration under river basin management plan (Directive 2000/60/EC, 2000). Since the Lyna-Lava River is a transboundary stream shared by Poland and Russia, its basin management is to be executed in accordance with the Russian Water Code and European Water Framework Directive.

There were no data on biological communities (Tsybaleva, 1981) since 1979, and there were some very general data about species composition of benthos in 1991–96 (Shibaeva, 2000).

This article covers the results of the investigations of the Lava River in 2002 and 2003 and provides the new scheme of transboundary Russian-Polish monitoring.

2. Study area description

The Lyna-Lava River springs from the Mazurskie lakes in Poland 30 km southward Olsztyn, runs to the north and flows into the Pregolya River near the city of Znamensk. Total river catchment is 7120 km^2, the Russian part is 1370 km^2 (19.2%). Only 65 km of the Lyna-Lava River (that amounts 22.5 percent or 289 km of the total length) belongs to the Kaliningrad Oblast (Gidrologicheskiy Ezhegodnik [Hydrological Annual], 1979; Vodhye Resursy SSSR [Water Resources of USSR], 1963). Another part belongs to the Poland territory, and it is called “Lyna” here. The Lyna-Lava River belongs to the Vistula Lagoon catchment and it is the largest tributary of the Pregolya River. The average annual discharge is 41.65 m^3/sec, that is a half of the Pregolya River discharge (Zotov, 2001).

Field investigations were carried out in autumn 2002 and summer 2003. It aimed at elaboration of transboundary monitoring scheme and estimation of distribution of the undermentioned parameters along the river. The hydrological, hydrochemical and hydrobiological parameters were investigated at 5th and 6th stations (“station” is hereafter referred to as ‘st.’) from upstream to downstream in 2002 and 2003 respectively (from the Russian-Polish border to the confluence of Lava and Pregolya). The characteristics were the following: temperature, salinity, total and organic nitrogen and phosphorus, ammonia nitrogen, nitrite, nitrate, phosphate, dissolved and relative dissolved oxygen, pH, Eh, calcium, chlorides, sulphates, carbon dioxide, BOD, iron, silicon, hydrocarbonates, water hardness, suspended matter (organic and inorganic), water clarity, chlorophyll-a, species composition, abundance and biomass of zooplankton and benthos.

In the upper flow of the river within the Kaliningrad Oblast (Pravdinsk Water Reservoirs), where the river depth is of 5–10 m and the width is of 60–100 m, Lava forms a scroll that caused erosion of the left bank. It is a precipice with clay sediments, almost without aquatic and riverside vegetation. There are reed communities with cat's tail and a sedgecane admixture on the right bank, where an organic matter accumulates. There are bushes of wilgers except reeds at the upstream station.

Below the dam of the city of Pravdinsk the hydrological river regimen is changing. Flow velocity increases; the width of the river is of 5–7 m here. The sediments are formed by sand. Reed dominates by separate specimens of sedgecane in the plant communities.

The flow's velocity remains the same order Downstream (Rodniki settlement), the width of the river stream is of 10 m. Sediments are composed of mud and sand of organic content. The bank erosion decreases. The riverside vegetation is in a form of separate reed communities. The wilder brushes present vegetation on the both banks near the city of Znamensk.

Table 1.

Sampling stations (numbered in order from upstream towards the river mouth) during field investigations of the Lava River in October 2002 and June 2003. In the proposed monitoring scheme a number of the station (Fig. 4) is indicated in brackets.

Number of station	No. 1	No. 2 (6)	No. 3 (5)	No. 4 (4)	No. 4a (3) (in 2003 only)	No. 5 (1)
Geographic coordinates	54°24.00′	54°26.5′	54°27.55′	54°31.71′	54°34.00′	54°37.10′
	21°01.5′	21°00.5′	21°01.29′	21°12.36′	21°00.5′	21°13.58′
Location	Temkino settlement	Pravdinsk reservoir	Shevchenko settlement	Rodniki settlement	Telmanovo settlement	The city of Znamensk

The Lyna-Lava River Basin is an area with excellent ecological qualities and potential for sustainable development. Besides, the stream is valuable as fishery resource and has a corresponding status under Decision of Kaliningrad Oblast Administration (Vodoemy… [Water-bodies…], 2002). A big part of the river basin has a nice landscape that makes this area more attractive for tourism. Ideas of ecotourism are one common basis for developing of transboundary cooperation. Ecotourism is also dependent on high quality waters.

3. The methods

Zooplankton samples were taken via vertical hauls of the Nansen net (21 cm in diameter, mesh No. 57) in the middle of the river stream. In October at the st. 5 the sample was taken via the Apstein net (of 50 l filtration) of the same mesh near the river bank. Zooplankton was preserved in 4 per cent formalin and treated by standard method (Salazkin et al., 1984). In order to reveal specificity of the communities Konstantinov's (Konstantinov, 1986) and Sörensen's (Hallowell, 1977) indices of similarity for each pair of adjacent stations were calculated, in order to assess ecological state of the river saprobity index by the Pantle and Buck method (Pantle & Buck, 1955) was calculated.

Petersen grab (square of capture is of 0.025 m^2) was used for benthos sampling, and three replicate samples per each point were done. All samples were sieved through 0.4 mm mesh and preserved in 4 per cent neutral formalin. Samples were treated by standard methods (Salazkin et al., 1984). Invertebrates were identified to genus or species, excluding Oligochatea, Ostracoda and Insecta larvae that were the groups of difficult identification. The Vorobyov's index of density according to the formula $I=\sqrt{BP}$, where I is the Vorobyov's index of density, B means biomass of a species within boundaries of given community, P is frequency of occurrence (Vorobyov, 1949) was used for detail revealing of bottom communities.

Hydrochemical sampling was carried out at each station from the bottom to surface layers using 5-liter Niskin bathometer. Then samples were treated by Kaliningrad Center for Hydrometeorology and Environmental Monitoring in accordance with the standard methods specified in the management directives on determintation of water pollutants.

4. Zooplankton

General species composition

Holoplankton of the Lava River was presented by 35 species: 2 species of Protozoa, 10 species of Rotatoria, 15 species of Cladocera and 8 species of Copepoda. Rotifers mainly consisted of predatory species of *Asplanchna* genus and filtratory *Brachionus calyciflorus, Keratella quadrata* and *Euchlanis dilatata*. The families of Chydoridae and Daphniidae were the most diverse among Cladocera in the river. Most species of the Chydoridae family recorded in the river are characteristic for the coastal zone of inland water bodies; the part of them is characteristic near-bottom layers and other species are for pelagic parts. Two predatory species (*Leptodora kindtii*, *Polyphemus pediculus*) were found at st. 1. Some mid-sized, predatory species of Cyclopoida (e.g., *Eucyclops speratus, Megacyclops latipes*) and its larvae stages formed the Copepoda group. Apart from it, meroplanktic larvae (Bivalvia, Polychaeta) and representatives of the bottom fauna occurred at some stations: Bivalvia larvae, Chironomidae, Ostracoda, and Turbellaria were found at st. 1; Bivalvia larvae, Turbellaria, Nematoda, and Ostracoda were at st. 3, and Plecoptera larvae was observed st. 4 and 5.

Dominant species

In October 2002 filter-feeding rotifers (*Brachionus, Keratella, Filinia*) dominated in the upstream segment of Lava, while Cladocera (*Bosmina longirostris, Alona* sp., *Chydorus sphaericus*) dominated in the downstream one. In summer (June 2003) the structure of dominant species changed and thermophilic species were found: *Bosmina longirostris* was dominant species in the upper stream segment of Lava, while *Chydorus sphaericus* and *Daphnia cucullata* dominated in the downstream segment.

Number of species (Fig. 1) varied from 7 to 11 (October 2002), from 10 to 26 (June 2003), but in general species composition was more diverse in the area of the stations 1–3 than in the river segment presented by the stations 4 and 5.

It is noticeable, that number of rotifer species, being the largest at st. 1, gradually decreased downstream, and disappeared from community at the 4–5 stations area at all.

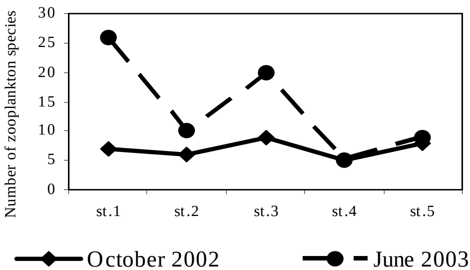

Fig. 1. Number of zooplankton species at the stations along the Lava River in 2002 and 2003.

Structure of the communities

The structure of the community was different in October 2002 and June 2003 (Fig. 2). In upstream segments (st. 1–3) Rotifers and Copepoda dominated (st. 1–3) in October, and Rotifers and Cladocera dominated in June. Cladocera dominated in the downstream segments in both months.

The share of rotifers in zooplankton communities decreased along the river (from st. 1 to st. 3): from 50.0 to 10.8 percent in total zooplankton abundance, and from 11.7 to 6.9 percent in its biomass in October, from 41.1 to 3.6 percent of its abundance in June till its extinction in plankton at st. 4. Relative content of Cladocera displayed an opposite tendency in October: they were not found at st. 1 (0%) and gradually increased along the river to 74.2 percent (in abundance) or 62.7 percent (in biomass) at st. 5.

Total zooplankton abundance

Total zooplankton abundance (Fig. 2) and biomass gradually decreased downstream, from st. 1 to st. 5. The following values were recorded in October 2002: abundance was 0.36–0.009 thouth.ind./m^3 at the st. 1–4 area, 0.68 thouth.ind./m^3 was at st. 5, biomass was 3.32–0.04 mg/m^3 at the st. 1–4 area, 6.10 mg/m^3 was at st. 5. In June 2003 abundance was 28.49–0.30 thouth.ind./m^3 at sts. 1–5. In June total abundance was 14–133-fold higher than in October, that is obviously because of intensive development of biological communities during summer. High values of zooplankton concentration at st. 5 in October was due to location of sampling point in the aquatic and semiaquatic brash of rooted vegetation (not in the middle of stream as in other stations) where an influence of the river flow on zooplankters was low.

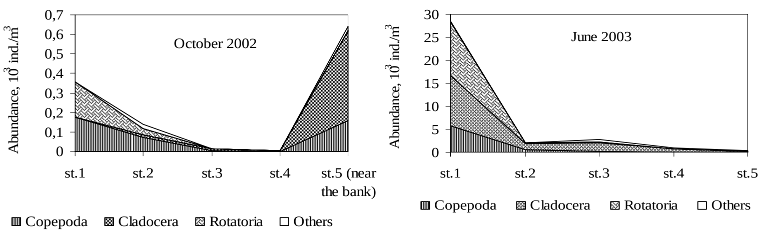

Fig. 2. The structure and abundance of the zooplankton community in October 2002 and June 2003.

Station similarity

The Konstantinov's and Sörensen's indices were used for analysis of station similarity. The indices ranged from 25.8 to 42.8 percent, from 28.6 to 46.2 percent respectively in October 2002 and from 24.0 to 46.7, from 23.3 to 65.5 respectively in June 2003. Judge by these indices, the station similarity is low (<50% with only two exceptions) that means that zooplankton communities have relatively high level of specificity.

Ecological state

About 80 percent of zooplankton species, recorded in the river, were the indicators of a high saprobity level. The saprobity index (S) varied from 1.4 to 2.0 and gradually decreased downstream. According to the "Classes of water quality in dependence on saprobity indices" (Guseva et al., 1999) the Lava River water is characterized as "pure enough", and falls to a "β-mesosaprobic" zone at both months. There were only two exceptions in October: the water can be characterized as "pure" at st. 2.

Generally, the upper segment of the river, from st. 1 to st. 3, where the highest values of saprobity index (1.68–2.05) were recorded, contained more organic than the lower reach area (S=1.59–1.68).

Near the city of Pravdinsk the index was the highest (2.05–1.77), it testified to increased organic pollution there. The second leap of the index (1.59–1.65) was recorded in the area of Znamensk.

5. Benthos

Species composition

Thirty two groups and species were recorded in October 2002, e.g *Hydra* sp., Oligochaetes and leeches (*Glossiphonia* sp., *Helobdella stagnalis)*. Mollusks were presented by eight species (Gastropoda—*Valvata pulchella, Valvata cristata, Bithynia tentaculata, Planorbarius* sp., Bivalvia—*Pisidium amnicum, Euglesa personata*, *Dreissena polymorpha* and *Unio pictorum)*. The sufficient role in benthic community belonged to insect larvae, and Diptera was the most diverse among them (*Chaoborus* sp., *Serromyia* sp. and Chironomidae, Tipulidae, Ceratopogonidae, Psychodidae groups). Moreover, Odonata, Plecoptera, water bugs and mites were found. Isopoda (*Asellus aguaticus*), Anisopoda (Corophiidae), and Ostracoda crustaceans also inhabited the Lava River (Chepurina, 2004). The largest number of species (21) was found in the Pravdinskie water reservoirs.

Eighty six taxa of benthic invertebrates were found in June 2003: Hydrozoa, Turbellaria (2 species), Oligochatea (more than 3 species), Hirudinea (5 species), Gastropoda (19 species), Bivalvia (17 species), Crustacea (4 taxa), Arachnida (1 species). Insects were also diverse: Odonata (3 species), Ephemeroptera (9 species), Heteroptera (1 species), Trichoptera (6 species), Plecoptera (1 species), Megaloptera (1 species), Coleoptera (2 species) and Diptera (11 taxa). Thus, the benthic fauna of the Lava River can be characterized as rich enough.

Density of the benthic community in the coastal zone was larger than in the streambed part of the river at the sts. 1–3, but at sts. 4–6, on the contrary, the largest abundance was recorded in the streambed part of the river. A lot of easily-consumed organic matter accumulated in the sediments were found at the sts. 1–3. Thus, there were favorable conditions for development of special psammon communities (oligochaetes and chironomids is the basic part of it). In the segment of sts. 4–6, where river hydrodynamic is different, small Pisidiids predominated. So, the benthos distribution in the river is heterogeneous.

Benthic communities

In the Pravdinsk water reservoirs (st. 1), both in the streambed and coastal part, Oligochaeta dominated in the community, and Chironomidae was subdominant. About 19 taxa occurred there.

In the streambed part, just below the dam of the Pravdinsk reservoir (st. 2) *Valvata* community with 19 taxa was recorded. The Chironomidae community existed near the river bank. In the streambed part as well as near the river bank Oligochaeta subdominated in the communities.

In the streambed part of the st. 3 the Hirudinea community was recordered. The number of taxa was the lowest there, it was seven. But near the bank there was the *Dreissena polymorpha* community with 16 taxa.

Chironomids and Oligochaets were the permanent component of each community.

The largest number of taxa (about 40) was observed in the sts. 4–6 area, where the Unionidae community (consists from 29 taxa) was observed near the river bank. On the bank of st. 5 the *Viviparus viviparous* community existed.

Distribution of the benthic community (Figs. 3a, 3b) depends on the nature of the river-bed, features of hydrological regimen, and the degree of river pollution.

An increase of benthos biomass and density was reordered at st. 4 (Fig. 3) that stipulated by small bivalves or oligochaetes.

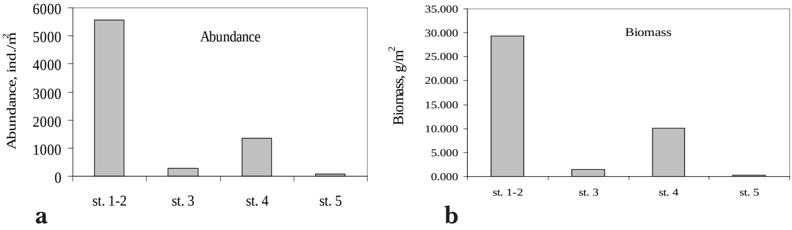

Fig. 3. Distribution of benthic biomass and abundance in October 2002.

The number of taxa decreased downstream, benthos was of β-mesosaprobic character there, i.e. organisms preferred polluted water (Chepurina, 2004). Moreover, biomass and density decreases. For example, the abundance at st. 5 dropped 83 times in comparison with sts. 1–2, and total biomass dropped 100 times. It testified that the degree of river pollution was increasing downstream.

6. Hydrochemical Conditions

As a result of the investigaions, it was established that total and organic nitrogen content in the water of the Lava River in October 2002 didn't exceed the limit value of 10 mg/l (MPC, Maximum Permissible Concentration for waterbodies valuable for fishery). The decrease of total and organic nitrogen concentrations downstream was observed. This tendency was well pronounced in the surface layer (maximum observed concentration of total nitorigen amounted to 6.9 mg/l at the st. 1, minimum one amounted to 3.4 mg/l at the st. 5.), but much less expressed in the near-bottom layer. It may be caused by the nitrogen release from degradation of organic matter on the riverbed, as well as nitrification and denitrification processes.

The concentration of total and organic phosphorus did not exceed the limit value for natural surface waters (Guseva et al., 1999) and varied along the river (the average concentration was 16.0 mg/l). In the surface layer the concentration of phosphorus slightly increased downstream: the total phosphorus content increased by 23 percent and organic one by 12 percent. On the contrary, in the near-bottom layer the concentration decreased along the river: the organic phosphorus content decreased four times and total phosphorus decreased by 12 percent only.

The water was saturated with oxygen at every station: the concentration varied from 10.0 to 13.3 mg/l, the saturation rate varied from

82 to 110 percent. Redox-potential and pH values amounted 136.0–97 mV and 7.9–9.0 respectively. Hence, according to these values the river waters are regarded as alkalescent and alkaline; but geochemical conditions are oxidizing.

The values of suspeded matter were above 26 mg/l in the surface layer and above 36 mg/l in the near-bottom one. Such hightened values was connected with augmentation of water content downstream by the end of November and increase of water velocity that caused increase in suspended matter content.

In general, the content of organic component of suspended matter in the near-bottom layer was higher than in the surface layer (on average by 50 and 42 percent respectively) at every monitoring point. Suspended matter belonged to organic and terrigenous-organic types.

The concentration of mineral component rose towards the mouth, which was appropriate to rivers. But as a whole, the concentration of suspended matter decreased downstream.

The additional results of the ensuing investigation in June 2003 allowed to estimate the ecological state of the river. Thus, the river belonged to II and III contamination classes ("pure" and "pure enough") according to the values of BOD, dissolved oxygen and ammonia nitrogen that were obtained (Guseva et al., 1999). The concentration of other chemical elements significant for enviromental assessment did not exceed the limit values (MPC) (Guseva et al., 1999). Only the amount of nitrite nitrogen did not meet the requirements to waterbodies of fishery significance, but simultaneously it did not exceed the MPC for waterbodies that are used for drinking water supply. The heightened content of nitrites might be connected with a strengthening of organic matter decay in summer.

The spatial distribution of the parameters investigated was mosaic in summer, and the stable tendency of parameters distribution along the river was not elicited. The trend of decreasing of nutrients content downstream the river, recorded in autumn 2002, was weakly seen in summer 2003.

The investigations of the years of 2002 and 2003 showed seasonal and yearly changes in the values and distribution of the hydrochemical elements. The comparable values were analysed and it was discovered that they ranged within the following limits: dissolved oxygen ranged from 6.8 to 13.31 mg/l, BOD—from 1.6 to 2.9 mg/l, pH—from 7.53 to 9.02, carbon dioxide—from 6.6 to 9.15 mg/l, chlorides—from 15.6 to 22 mg/l, sulphates—from 28.3 to 30.3 mg/l, calcium—from 60.9 to 64.9 mg/l, hydrocarbonates—from 250.2 to 271.5 mg/l, ammonia nitrogen—from 0.14 to 0.29 mg/l, nitrite nitrogen—from 0.04 to 0.076 mg/l, nitrate nitrogen—from 0.381 to 0.577 mg/l, phosphates—from 0.131 to 0.179 mg/l, silicium—from 5.12 to 6.23 mg/l, and iron—from 0.071 to 0.074 mg/l.

7. Discussion

The first investigation of the Lava River biota (zooplankton, benthos) had been carrying out since March till October 1979 in the two Pravdinsk water reservoirs, after cessation of the two hydroelectric power stations. Locations of two sampling station of 1979 and our st. 1 and st. 2 (2002, 2003) coincided. In 1979 sixty-five and fifty-one zooplankton species were found at st. 1 and st. 2 respectively (Tsybaleva, 1981) while only 35 species were found in 2002–03. Only a few species, marked in that previous investigation, were recorded in our samples: *Brachionus calyciflorus, Filinia longiseta, Keratella quadrata, Alona* sp., *Bosmina longirostris, Chydorus* sp., *Diaphanosoma brachyurum, Leptodora kindtii, Peracantha* sp., *Polyphemus pediculus* and *Mesocyclops leuckarti*. Thus, during three decades the species composition of zooplankton changed gradually.

During investigation of the Lava River 50 benthic species from 11 groups were found in 1979 (Tsybaleva, 1981), while in our investigation we have found 32 groups and species and 86 taxa in October 2002 and June 2003 respectively. It testifies to increasing of the species diversity of benthos. It is important that dominant groups (Oligochaeta and Chironomidae) have not changed since that time at these two stations.

Comparing our data with the data of previous investigation (Tsybaleva, 1981) we can conclude that principal changes of zooplankton and benthos composition did not happen. But, it is impossible to make conclusion about quantitative changes of biota during the period of 1979–2003 as (a) in 1979 zooplankton and benthos were investigated during the longer period (March–October), (b) it were studied in more number of different biotopes and, (c) other samplers were used.

We recorded the decrease of zooplankton species diversity and abundance downstream, from st. 1 to st. 5. It can be connected with the rise of river flow velocity, especially below the dam of the Pravdinsk reservoir, located below st. 2 area. Broad width, low depths and low velocities of the river stipulates the development of the reach zooplankton fauna at sts. 1, 2 area. Exactly this factor may be responsible for enrichment of the water by organic substances at the upstream segment of the Lava River (sts. 1–2). It confirmed by relatively high saprobity index at mentioned above sts. 1–2. Zimmermann found (Zimmermann, 1961) that drop of the flow velocity causes a shift of zooplankton community composition to polysaprobity zone. Our observations confirm this tendency: the values of saprobity index were the highest at the stations with the lowest flow velocities.

Moreover, along-river the spatial variations of saprobity index were similar to the organic phosphorus variations in the surface layer (Fig. 5). Cities of Znamensk and Pravdinsk may also bring a considerable part of organic pollution into the river that proved by the leap saprobity index at st. 2 and st. 5 respectively.

Distribution of nutrients along the river proved that most of them come from the upper part of the Lyna-Lava River basin. The concentration of nutrients decreases downstream in a result of hydrodynamical dilution and lesser unit load of nutrients from Russian part of the basin.

Thus, a main contradiction discovered during the investigations is that species composition of plankton and benthos organisms testifies to increase of trophic pollution of the river towards the mouth. It display in decrease of species composition, abundance and biomass of organisms that prefer clear water. The changes of nutrients along the river testify to opposite. An increase of concentrations downstream was recorded only for total and organic phosphorus. The concentration of nitrogen varied not widely along the river. Such difference may be related to biological communities that are integral feature of the river while the chemical ones reflect ecological state only at the time of investigation; besides, the chemical elements vary with time sharper.

Proposal for monitoring

As it was mentioned above, the nutrients concentration decreased along the Russian segment of the Lyna-Lava River. It means that they are mostly coming from the Polish upper part of the basin. The considerable decrease of biodiversity, biomass and abundance of plankton and benthic organisms was found towards the lower river stream. In this connection and due to trans-boundary status of the Lava basin it is necessary to arrange a joint regular inspection together with Polish partners for more precise assessment of ecological state of the river. The monitoring program must be later on mutually coordinated regarding the same terms and ecological parameters and cover both the Russian and the Polish parts of the river (Directive 2000/60/EC, 2000; Schagina, 2005). The proper spatial scheme of monitoring stations (Fig. 4) and optimal temporal schedule of surveys are worked out for the Russian part of the river (Igoshina et al., 2003; Chubarenko et al., 2003):

Station No. 1 is to be located 0.3 km below the city of Znamensk or 0.2 km upwards the river's mouth. This station belongs to Kaliningrad Center For Hydrometeorology and Environmental Monitoring, and it will inflowing waters to the Pregolya River.

Station No. 2 is to be situated just above the city of Znamensk to collect the data on quality of the water coming to the city.

During the investigations in 2002 and 2003 a reduction of plankton and benthos species diversity and biomass was recorded between the city of Znamensk and Rodniki settlement. Location of Station No. 3 must be defined later in consequence of detailed survey on estimation of pollution sources there.

Site of Station No. 4 will coincide with the station "Rodniki" of Kaliningrad Center's for Hydrometeorology and Environmental Monitoring network of standard stationary monitoring points. This Station will serve as a reference point and be used for distributed load estimation.

Station No. 5 (a check point for the city of Pravdinsk) must serve for evaluation of the impact of Pravdinsk waste water on the river quality.

Station No. 6 is supposed to be in a lower part of the Pravdinskoe water reservoir and will serve for evaluation of quality of reservoir's water which discharges into the river.

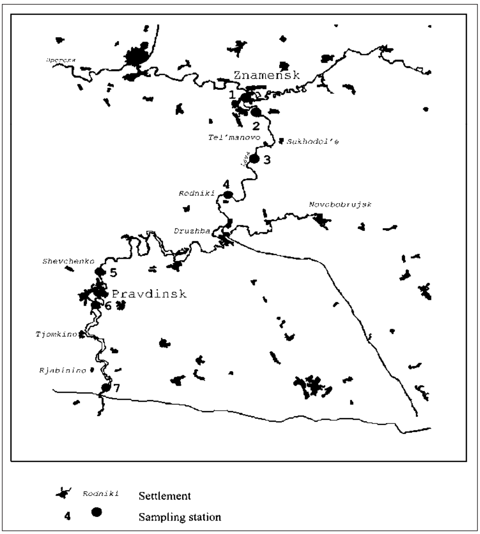

Fig. 4. The proposed monitoring scheme for the Russian part of the Lyna-Lava River basin.

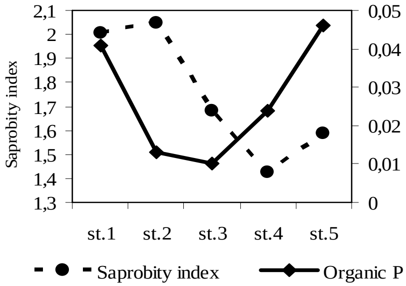

Fig. 5. The dynamics of saprobity index and organic phosphorus in the Lava River in October 2002.

Station No. 7 is to be situated close to the Russian-Polish border and used for measuring-in of transboundary transfer of components being investigated.

Suggested parameters for monitoring are the following: total and organic nitrogen and phosphorus, ammonia nitrogen, nitrite, nitrate, phosphate, dissolved and relative dissolved oxygen, pH, Eh, temperature, salinity, suspended matter (organic and inorganic), water clarity, chlorophyll-a, species composition, abundance and biomass of zooplankton and benthos.

Monitoring is supposed to be carried out three times a year with regard to the biorhythm of ecosystem: (1) in spring, after the spring tide (end of April–beginning of May), (2) at the time of summer low water, when the water vegetation is full-blown and organisms are abundant (end of July) and (3) in late fall, until freeze-up (beginning of November).

Conclusion

The investigation proved the range of values of water quality parameters that were typical for the Lava River in summer and autumn, and their variability along the river. The results of the investigation allowed estimating the ecological state of the river via the values of BOD, dissolved oxygen and ammonia nitrogen. The river belongs to II and III contamination classes ("pure" and "pure enough"). Nutrients concentration decreased along the Russian segment of Lyna-Lava. It was evident that nutrients were coming mostly from the Polish upper part of the basin.

Some hydrochemical and biota parameters testify to probable influence of the cities of Pravdinsk and Znamensk upon the zooplankton resulting in species number increase, and organic enrichment of the water.

As for biological communities, 35 species of holoplankton were recorded in zooplankton; some of them were meroplanktic larvae and bottom dwellers. The most species were typical inhabitants of aquatic and semi-aquatic brash of rooted vegetation. The species composition was typical for the corresponding sampling season (autumn, summer) in general. The decrease of the most zooplankton parameters (number of species, abundance, biomass, similarity index, saprobity index) was recorded from upstream to downstream segments of the river that was mainly connected with peculiarities of the river hydrology.

In October 2002 thirty-two groups and species were found in benthos. In June 2003 eighty-six taxa of benthic invertebrates were also recordered. Benthic organisms mainly belonged to β-mesosaprobic species.

On the basis of investigation a scheme of transboundary Russian-Polish monitoring was elaborated. The scope of these data will serve as a background for further assessment of water quality under international monitoring of the whole Lyna-Lava River basin. Joint monitoring also must be aimed at eliciting a tendency of distribution of biota, pollutants and data storage for further forecasting and modelling.

Acknowledgement

The results of this study were obtained during the local project "Development of the monitoring scheme for the Russian part of the Lyna-Lava river basin" (scientific supervisor—Dr. B. Chubarenko), that was implemented by the Laboratory for Coastal System Study of the P.P. Shirshov Institute of Oceanology in 2002–03 under the contract with Department of Land Use and Natural Resources (Head, A.I. Akinin) of the Administration of the Kaliningrad Oblast. The authors appreciate the help of Kaliningrad Center for Hydrometeorology and Environmental Monitoring for treating water samples. The authors thank Mr. Vladimir Chechko for sediment sample analysis, and Mr. Sergey Zotov and Mrs. Elena Ezhova who passed valuable remarks.

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Transboundary influence of potential oil spill sources on the Curonian Spit area (South-East Baltic)

Boris V. Chubarenko, Artem I. Shibin, Natalia V. Reznichenko

Introduction

Threat of oil pollution for South-East Baltic coastline has been increasing recently because of intensification of oil transportation in the region. The number of oil stranding incidents of unidentified origin at Kaliningrad sea coast has increased during last few years (Chubarenko, 2004).

In order to protect efficiently the Baltic Sea coastline it is necessary to conduct an integrative activity, which includes both satellite, aero-, and situ-monitoring, and on-line forecast of the oil spill drifts, and ecological risk estimate in the areas of possible oil spills. The purpose of present paper is to comparatively analyse a probable oil spill sources in the South-East Baltic taking the Curonian Spit as target area of potential oil pollution.

The Curonian Spit, a unique natural and cultural complex of both natural and human creation, was chosen as a focus object. In 2000, the whole Curonian Spit, which is separated by Russian/Lithuanian border in two parts, was enlisted in the UNESCO World Heritage List (Mukiene, 2003). Both Lithuanian and Russian parts of the spit have a status

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of National Park. This status permits organization of special protection of this unique and vulnarable area as well as benefiting from its large potential for science, education and recreation.

The large oil field "Kravtsovskoe" (D6), discovered in 1983 in the southeastern Baltic Sea, is located at a distance of 22.5 km from the coastline of the Curonian Spit. Coastal area pollution is possible if emergency conditions will happen on the sleetproof platform or pipeline. According to estimations of Luckoil Company and technological description of the field-development program, the accident risk is very small, and the investor provides every arrangement of prevention, localization and liquidation of oil pollution (Lukoil doc., 2004). Even though the accident risk during oil production on the D6 platform is minimal (Lukoil doc., 2004), the oil field "Kravtsovskoe" (D6) was taken into consideration as one of the potential source of oil spill, which might threat to the Curonian Spit ecosystem.

Besides the D6 oil platform, ship accidents, oil traffic and oil handling in harbors might have a negative impact on the Curonian Spit coastline. Closely located branch of the ship traffic route to Klaipeda is an obvious potential threat for the Curonian Spit (Fig. 1). There are other potential sources of oil pollution—the ship traffic routes to Baltiysk—Kaliningrad and Gdansk. Taking into account that, according to the world statistics, more than 90 percent of oil spills are resulted from the tanker accidents (Monina, 1991), the oil traffic ways from Klaipeda

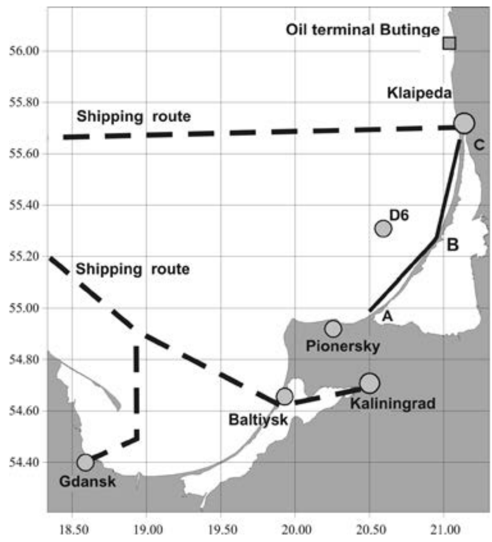


Fig. 1. Location of potential sources of oil pollution in the South-East Baltic. AB and BC are the Russian and Lithuanian segments of the Curonian Spit coastline.

and Baltiysk were also considered as potential sources of oil spills in the region.

The harbors of Baltiysk and Pionersky were taken as the third potential oil spill source (Orlyonok, 2004). The discharges from them could develop a threat to the Curonian Spit under certain hydro-meteorological conditions as well.

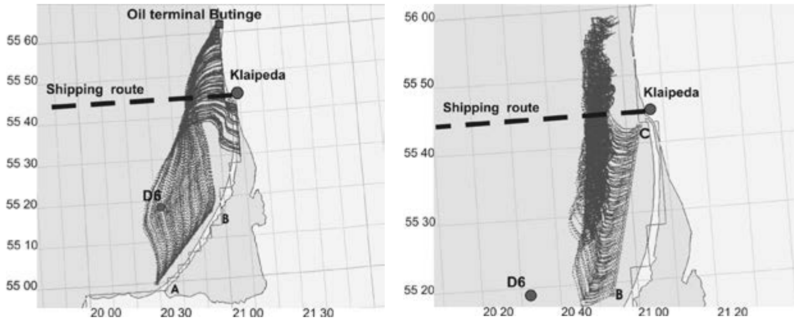
Methods

Forecasts of emergency conditions in the Baltic Sea are monitored by operational numerical methods, which are an effective tool for analysis and prediction of marine environment. In the present paper, we have used the model Seatrack Web (Ambjörn. 2004), to analyze the oil drift toward shoreline of the National Park "Curonian Spit". The system Seatrack Web, applied for the oil drift and for other chemicals, is based on an operational ocean model HIROMB (High Resolution Operational Model for the Baltic Sea) and operational weather model HIRLAM (High Resolution Limited Area Model) (Funkquist, 2003). This operational modeling system has been developed by German and Swedish experts at the Swedish meteorological and hydrological institute (SMHI) in close co-operation with the Danish authorities. The HIROMB system calculates daily forecasts of sea water level, current field, salinity, temperature, as well as the ice thickness, concentration and drift for the Baltic Sea area, using data from operational Danish, German, Swedish and Finnish hydro-meteorological services.

The program Seatrack Web today is extensively used in Sweden, Denmark, Finland, Poland, Estonia, Latvia, Lithuania and Russia. This model allows forecasting a drift of oil under an influence of wind and currents, taking into account temperature depending oil evaporation, sinking and change in buoyancy. The model helps to optimize the oil combating and coast protection activities. Moreover, a hindcasting can be carried out within the Seatrack Web, and probable location of the sources of actually detected oil patches can be recognized (Ambjörn, 2004).

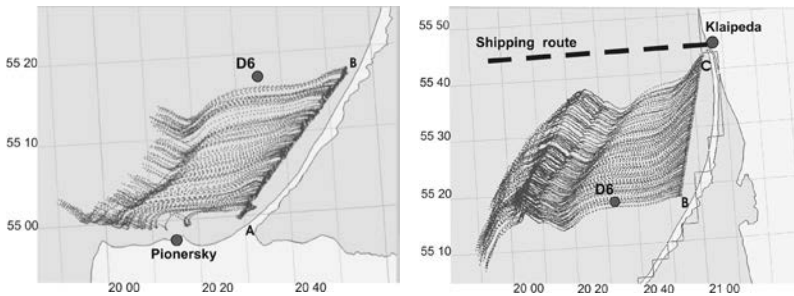
The Baltic Sea area along the coast of the National Park "Curonian Spit" was chosen as a potential subject of oil pollution in our case (Shibin, 2005). The tool "backtrack" of the operational program Seatrack Web was used primarily for analyzing different scenarios of oil drift in this area. As the result, the oil drift trace corridor from the targeted Curonian Spit coastline toward the potential sources was reconstructed (Fig. 2). The time-continuous data file of the backtracking calculations was collected from 22.02.2005 to 9.05.2005 for analysis of different hydro- and weather conditions. Backtracking calculations were run for the Russian and Lithuanian segments of the Curonian Spit practically each day during this period (Fig. 3). Apart from hindcast simulations, the direct oil drift calculations were made for the same conditions for controlling the backtracking calculations and getting supplementary data.

Variety of scenarios directly resulted from the set of hydro-meteorological situations during the study period. The duration of the scenar-



a **b**

Fig. 2. Examples of the "backtrack" simulation results made by Seatrack Web for the Russian (a) and Lithuanian (b) segments of coastline for the periods of 09–02.03.05 and 07–27.05.05 respectively. The stretch AB along the Russian and BC along the Lithuanian segments of coastline were taken as potentially polluted area. The lines of the oil spill back traces cover a probable area where a location of initial oil spill would be.



a **b**

Fig. 3. Example of the "backtrack" simulation results made by Seatrack Web on 12–07.04.05 for the Russian (a) and Lithuanian (b) segments of Curonian Spit coastline.

io simulation was usually about 13 days. The direct drift calculations were made to analyze temporal dynamics of oil patch characteristics like evaporation, emulsification, sinking, stranding and dispersion. All of them were identified every 3 hours as well as the length of pass of the center point of oil patch and amount of oil-water compound. The possible trace and oil patch propagation velocity were calculated separately for the cases when Russian and Lithuanian segments of coastline were impacted.

Analysis of probability of meteorological conditions, which were used in simulations, showed that collected scenarios covered a majority (96 percent of probability in a whole) of probable combinations of wind speed and directions (Table 1). It evidences statistical representation of the collected scenarios.

Table 1.

Statistical repetitiveness (in %) of wind situations for the Curonian Spit by data for Nida (Gidrometeorologicheskie Usloviya [Hydrometeorological State], 1985). Gray shading marks the situations taken into account for Seatrack Web scenario simulations.

Wind directions	Gradations of the wind speed, m/sec								
	0–1	2–5	6–9	10–13	14–17	18–20	21–24	25–28	29–34
N	1.35	7.24	2.90	0.63	0.28	–	–	–	–
NE	1.20	6.83	3.36	0.30	–	–	–	–	–
E	0.83	5.03	4.22	0.80	–	–	–	–	–
SE	1.12	5.34	5.17	1.50	0.11	–	–	–	–
S	0.80	6.06	2.78	0.45	0.17	–	–	–	–
SW	0.63	5.52	4.51	0.70	0.11	–	–	–	–
W	1.06	8.27	4.85	0.70	0.28	0.02	–	–	–
NW	1.18	9.17	4.13	0.60	0.22	–	–	–	–

$\sum = 96.44\%$

Results

Twenty of 56 scenarios of backtrack simulations for Russian segment of the Curonian Spit (e.g. Figs. 2a and 3a) were the cases, when the back-trace of the oil pollution traversed one or several of potential oil spill sources (Fig. 1). There were 33 cases in total when back-trace traversed one of them. Simulated back trace of the oil pollution traversed the Klaipeda harbor two times (6 percent of the above mentioned 33 cases), the oil terminal Butinge—four times (12%), Klaipeda's branch of the route of oil transportation on the length of 70 km from Klaipeda—13 times (39%), the D6 offshore oil platform—13 times (39%) and the Pionersky harbor—1 time (3%).

Sixty-seven scenarios of backtrack simulations for Lithuanian coastline for the period of 22.02.05–09.05.05 brought 82 cases, when backtrace traversed one or several of potential sources and 20 cases when pollution didn't touch any source. Simulated back trace of the oil pollution traversed the Klaipeda harbor 19 times (23 percent of the above mentioned 82 cases), the oil terminal Butinge—6 times (7%), Klaipeda's branch of the routes of oil transportation on the length of 35 km from Klaipeda—40 times (49%), the D-6 oil platform—17 times (21 %).

The generalized statistics is presented in Fig. 4, where each of the potential sources is characterized by percentage of probability to pollute both national segments of the Curonian Spit (AB and BC) under current hydro-meteorological conditions for the period of 78 days (22.02.05–09.05.05). The higher percentage of pollution for the Lithuanian segment in comparison with the Russian one is prescribed by its closer exposition to the main three oil spill potential sources: Klaipeda branch of the routes of oil transportation, the Klaipeda harbor and platform D-6. For Russian segment of Curonian Spit coast, as well as

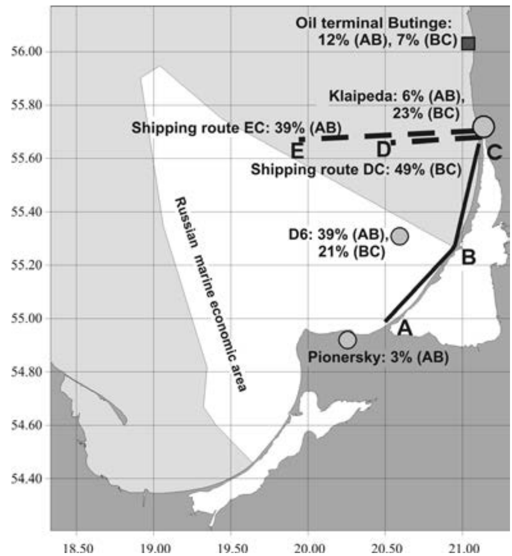


Fig. 4. Each potential source is characterized by probability to pollute either Russian (AB) or Lithuanian (BC) segment of the spit. The probability was estimated according to repetitiveness of situation when back trace traversed a source for the period of 22.02.05–09.05.05.

for Lithuanian one, there are two potential sources which are characterized by maximum of probability: Klaipeda branch of the ship traffic route (the roadstead near the entrance to Klaipeda Harbor may be considered as a part of it) and oil platform D-6.

Thus, there is a considerable possibility of the pollution of the Curonian spit coastline from different sources in the region. Total time of the drift and instant velocity of propagation depend on the hydrometeorological conditions. The amount of spilled oil and duration of a spill are not important for the propagation velocity, but they influence upon the width of polluted section at the targeted coast.

The extreme values of the oil drift time (*min* and *max*) were defined for all considered potential pollution sources by direct Seatrack Web simulations. The time of oil drift towards the Russian segment of coastline (Fig. 5a) is of order of 60–80 hours from the entrance into Klaipeda harbor, of 36–220 hours—from the segment EC (70 km) of the Klaipeda branch of the routes of oil transportation, of 15–174 hours—from the D-6 oil platform and of an order of 65 hours—from the Pionersky harbor. The oil drift time to the Lithuanian coastline (Fig. 5b) is of order of 2–84 hours from the entrance into the Klaipeda harbor, of 2–246 hours—from the segment DC (35 km) of the Klaipeda's branch of the routes of oil transportation, of 18–105 hours—from the D-6 oil platform, and of 25–60 hours—from the oil terminal Butinge.

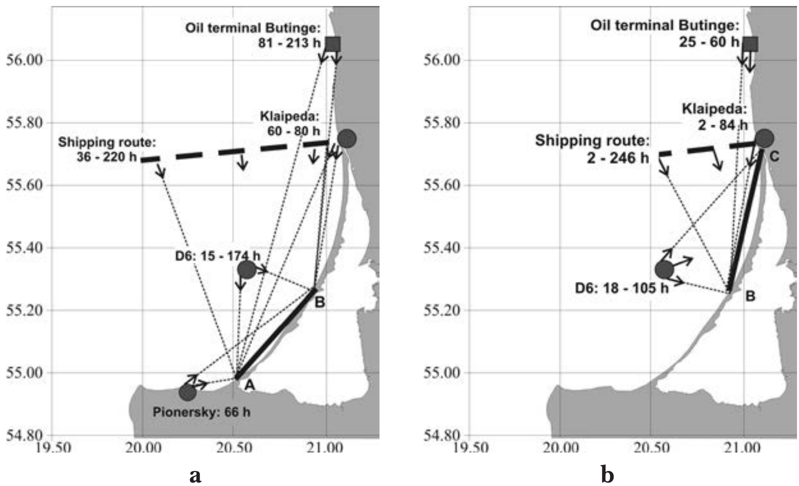


Fig. 5. Estimated time of the oil drift ("drifting" or "reaching" time) from different sources towards the Russian segment (a) and Lithuanian segment (b) of the Curonian Spit.

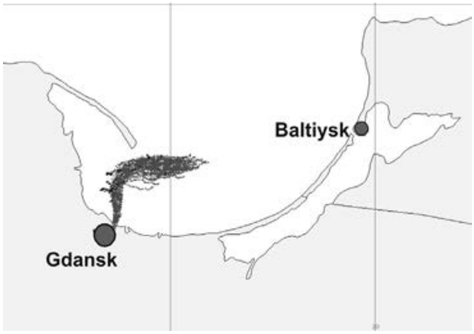


Fig. 6. Example of Seatrack Web simulation results for hypothetic oil drift from Gdansk harbor at 10–14.02.05.

It was defined during the investigation that the potential oil spill sources on the Polish coastline can cause the pollution of the Kaliningrad Oblast (Fig. 6), as well as potential Russian oil spill sources can impact both Lithuanian and Polish coastlines.

The specific numerical experiments were performed to analyze an evolution of oil spill for different types of oil. Simulations indicated that the evaporated part of the oil, for any oil type, reaches its maximum (10–40%) in 36–42 hours after the oil blowout. The parts of the oil at the surface and the dispersed oil are transforming one into another. The dispersed part of oil is usually within a limit of 25 percent of spilled amount, and the portion of the oil at the surface never decreases below of 44 percent. Oil-water saturation happens within the first 12 hours and reaches its maximum in the first day, and an increase of this saturation during next days is not significant. It has been revealed that if the temperature of the sea water increases, the evaporation oil rate will increase, too. The evaporated part of the oil increases or decreases by 1 percent at the expense of the part of the oil at the surface, and in general these changes are not significant.

Conclusions

All the selected probable sources of oil spill (the entrance into Klaipeda harbor, segment of the Klaipeda branch of the routes of oil transportation, D-6 oil platform, Pionersky harbor and oil terminal Butinge) are potentially dangerous for the Curonian Spit. Even in the case of the longest time of oil drift (80 and more hours), the oil patch contains significant amount of the oil in the form harmful for targeted coastline.

According to analysis of probability of the pollution from different potential sources, the Klaipeda branch of the ship traffic route together with the roadstead near the entrance to Klaipeda Harbor make up the highest threat to the Lithuanian coast of the Curonian Spit. The next danger is the oil platform D-6. For the Russian coastline, besides the branch of the oil transport way to Klaipeda, the D-6 oil platform is also the most dangerous potential pollution source.

The probability of the oil spill as a consequence of ships accidents (11.6%), or both oil blowout from vessels and loss during loading of the fuel (30.5%) is finally higher than that of the oil escaping during shelf drilling (1.4%) (Monina, 1991). Therefore, the branch of the ship traffic way to Klaipeda, the area of roadstead and entrance to Klaipeda harbor are supposed to be the most harmful among other possible potential sources of oil pollution for the Curonian Spit coastline; the D-6 oil platform or the Kaliningrad Oblast coastal sources pose some threat as well.

Direct oil drift simulations show that the width of polluted coastal sector is never less than 12 km when the oil spill happens at the platform D-6 and the oil drifts directly towards the coast. If an accident happens on the transport route and the oil drifts directly to the coastline, the width of polluted coastal segment is not less than 17 km. In case of oil drift from the Butinge terminal, it is bigger than 23 km; and from the Pionersky harbor—about 20 km. These particular values of oil pollution zones should be taken as the basic minimal ones for planning of oil combating measures.

The width of the polluted coastal section and all the characteristics of oil patch depend on the oil drift time from the potential source. The characteristic time of oil drift towards the coast of Curonian Spit from the platform D-6 is of about 15–18 hours. In general, the patch reaches the Russian and Lithuanian segments of the coast approximately at the same time if weather conditions are equally "favorable". The fastest arrival is for the cases of the oil spill in the vicinity of entrance to Klaipeda harbor under for northern and north-western winds.

The calculations provided the rate of patch widening with time. In 50 hours after the beginning of the oil spill, the transverse width can be up to 20 km. It was found that transversal oil dispersion develops slower than by the linear dependence on time.

The current investigation had been performed for the Curonian Spit as an example, clearly represents the real threat of oil spills in South-East Baltic as a whole. It is obvious that each of considered potential sources of possible oil pollution (regardless of their prioritization by risk probability) required equal attention and undertakings in order to prevent the consequences of possible emergency situations in case of oil spill. There is a constant threat of an accident in the South-East Baltic from any of the potential sources. Therefore it is important to join activities of the appropriative administrations and institutions from the Kaliningrad Oblast, Lithuania and Poland in order to create and efficiently work with the system of the prevention, discovery, forecast and liquidation of oil spills in the region. This cooperation can be achieved through an increase of readiness of special services for join measures, mutual development of forecasting and early warning systems, mutual trainings and join efforts in enhancing of an availability of oil spill combating facilities.

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Large-scale transport of coastal waters into the Gulf of Gdansk due to seasonal mixing mechanisms

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Abstract

Water exchange between shallow coastal zone and deeper part of the Gulf of Gdansk arising due to seasonal coastal cooling in littoral area is described. Analysis of annual circle of sea-surface heat budget, water temperature and buoyancy flux for coastal area of the Baltic allowed to reveal the time periods when cold down-slope water cascades transport water masses from shoals into deeper parts of the Gulf of Gdansk. Structure of the flow and its flow-rate are considered on the basis of available field data obtained in the Baltic Sea.

Keywords
Horizontal water exchange, littoral-pelagial water exchange, seasonal coastal cooling/heating, heat budget, coastal zone, Gulf of Gdansk

1. Introduction

Transport and mixing in upper layers of large water bodies is a question of utmost importance for basin-scale dynamics and ecosystem functioning. Specific coastally-related mixing mechanisms, arising in autumn, are particularly important for ecological consequences and trans-border fluxes as well: they lead to the formation of permanent

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littoral water sinking along the bottom slope and its intrusion into the main water body below the upper mixed layer (Brooks et al., 1972; Garrett, 1991; Imboden & Wüest, 1995; Zhmur & Yakubenko, 2001). This way in autumn, when the thickness of the upper mixed layer increases with time, the polluted waters from the coastal region are transported directly into the deeper and deeper sea layers, being only slightly mixed with surrounding water masses (*see* Fig. 1).

This mechanism was described initially by limnologists (Forel, 1880; Mortimer, 1974). In oceanography its has obvious consequences like following: an existence of intermediate water layer of the Arctic origin in the Ocean (Ivanov & Shapiro, 2003; McPhee-Shaw & Kunze, 2002; Johnson & Teague, 2002) or a cold freshened water layer in the Southern Baltic generated in the Gulf of Bothnia. However, the very process of generation of these cold water cascades near the coast is still not well known. Since the intrusions are driven by small density differences, it was generally supposed that they contribute mainly to mixing in littoral area (Browand et al., 1987; Ellison & Turner, 1959). Nevertheless, it was pointed out (Bennett, 1971; Carmack, 1979) that thermally induced seasonal horizontal mixing can be a very important mechanism of matter and energy transport in lakes and inland seas with large shoals, like the Baltic, for example. It has been proved already

Fig. 1. Schematic of the generation of cold-water cascades during autumn–winter cooling period in shallow coastal areas, and the map of the Baltic, showing in white the areas, where seasonal vertical convection reaches the bottom, and in grey the regions, receiving the cascades.

by field measurements in oceans and seas that intermediate layers are formed by waters cooled at the surface in polar regions or over shelves in winter time (Foster & Carmack, 1976; Killworth, 1977; Meincke, 1978; Thorpe & White, 1988; Leaman & Schott, 1991; Thomsen et al., 2001).

2. Physical background

The main physical reason for horizontal water exchange is the time lag between the responses of shallow and deep waters to seasonal change of heating/cooling conditions: being shallower, coastal waters respond faster than deeper once (Chubarenko & Hutter, 2005). In order to identify more exactly the period, when the conditions for horizontal exchange occur in the Gulf of Gdansk area, let us consider it in some more detail. The curves on Fig. 2 present a principal seasonal course of water temperature T_w and heat budget H at the sea surface for the given region (Gidrometeorologicheskie Usloviya… [Hydrometeorological Conditions…], 1992). It is on the Figure that the temperature of water surface has a maximum at the middle of August; this very time, the curve of the heat budget crosses zero. Immediately with the beginning of surface cooling, shallower coastal waters start to be colder than deeper ones, thus, at the end of August. Starting from this time, *in deep water* one observes the formation of growing down upper mixed layer (UML), maintained by thermal vertical convection due to surface cooling. Where the depth of the basin is smaller than the

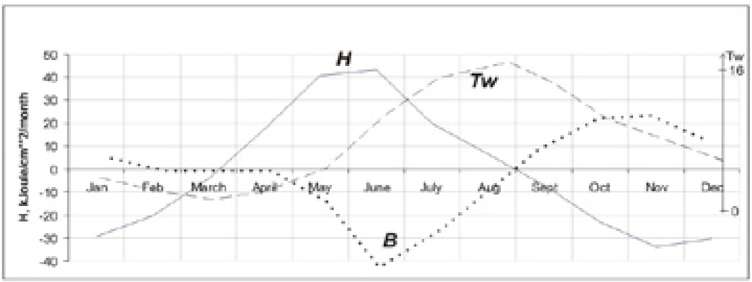

Fig. 2. Water temperature T_w (in °C), heat budget H (in kJoule/cm²/month) at the water surface and the resulting buoyancy flux B (in relative units) for the conditions of the Gulf of Gdansk. Positive B means here that surface water becomes heavier with time, whilst during period of negative B it becomes lighter. Plotted on the base of data for T_w and H taken from (Gidrometeorologicheskie Usloviya… [Hydro-meteorological Conditions…], 1992), B was calculated.

UML, the convection reaches the bottom (*see* Fig. 1), and the resulting water temperature becomes lower above smaller depths. This way, the horizontal temperature gradients are formed in coastal zones, leading directly to the formation of cold-water cascades down slope.

This process of cold water cascading is physically driven not by the heat flux H itself, but by *the buoyancy flux* $B=\frac{g\alpha H}{\rho_0 C_p}$ into the surface water layer. Here, g is acceleration due to gravity, α is thermal expansion coefficient, ρ_0 is (reference) water density and C_p is the specific heat of water. The third curve in Fig. 2 gives the principal behaviour of the buoyancy flux, calculated for the mean monthly water temperature and salinity values (not to scale in the Fig. 1). The negative values of B correspond to periods of stabilising heat flux, whilst positive values correspond to destabilizing heat exchange. This way, positive values of B mark almost half-a-year long period of formation of cold down-slope cascades.

As it is typical at mid-latitudes, the Baltic water in its seasonal cooling reaches the temperature of maximum density, where the thermal expansion coefficient α becomes zero (about 2.8–2.4 °C for the Gulf of Gdansk waters). The buoyancy flux at this moment becomes zero as well, and with further cooling water becomes lighter. Since the buoyancy flux is proportional to the product of the heat flux and the expansion coefficient, and both are now negative, the resulting buoyancy flux becomes positive—and one observes now the stabilizing effect of heat loss on the water column, and the formation of stable inverse winter stratification in the upper layer. Again, the reaction of shallow coastal waters comes faster, and, exactly near the coast, the growing with time stably stratified region arises, which is separated from the deep area (still involved in vertical surface-induced convection) by the autumnal thermal bar front. With further cooling, the entire basin becomes inversely stratified—and remains so until the spring heating starts. Positive vernal heat flux together with still negative expansion coefficient α produces again mixing from the surface, resulting in the homogeneous UML in deep part and *warm* (below the T_{md} however!) spring cascades from the coastal slope into the basin pelagial. This period of vernal formation of the UML is rather short (2–3 weeks in March for the Gulf of Gdansk) and cannot be demonstrated on monthly-averaged data in Fig. 2. Being shallower, the coastal waters are now heated faster, they are first to cross the T_{md}, and once again the stably (directly) stratified region arises over the shoals, bounded by the (vernal now) thermal bar front, moving with time off-shore. So, physically the same mechanism of the down-slope flow formation arises during spring heating, if the water in the basin has a temperature below the temperature of maximum density.

Thus, large-scale seasonal coastally-induced horizontal water-exchange between shallows and deep waters exists at any season due to different rate of their response to heating/cooling (Fig. 3):

- under stabilising buoyancy flux, the driving off-shore flow is formed in upper layer, coupled with the on-shore return flow in deeper layers;
- under destabilising buoyancy flux, the down-slope (off-shore) slow gravity cascade is the driving flow for horizontal water-exchange; it is accompanied with the return on-shore flow in the upper layer.

The transfer from one type of circulation to the other goes through the formation of the thermal bar, which intensifies vertical mixing, but restricts the horizontal one.

3. Application to the Gulf of Gdansk

Evaluation of the seasonal horizontal water exchange in the Gulf of Gdansk can be performed on the basis of data presented on Fig. 2. Analysis of the curves shows, that the basin should experience in its annual circle all the stages of the described above process (Fig. 3). In this paper, we shall concentrate on the process of down-slope cascading, so, it is important to point out here that the driving force for the cascad-

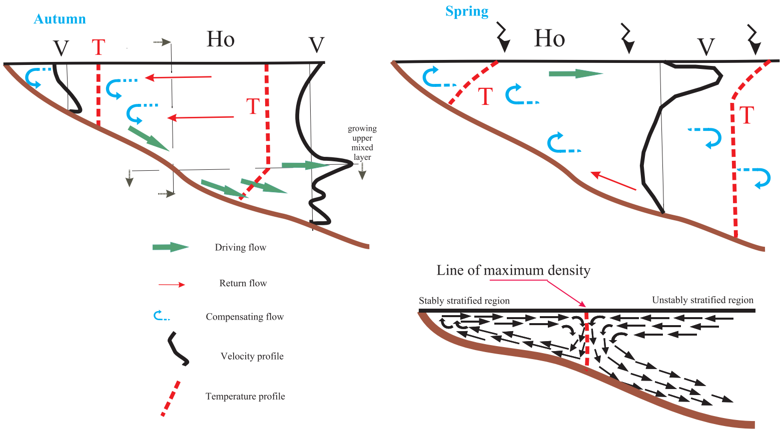

Fig. 3. Horizontal water exchange when temperature of water is above the TMD and the thermal bar front in coastal area.

ing—the buoyancy flux—has a maximum in October–November, with mean monthly values of $2.7-3*10^{-8} Wt/m^2$. The thermal expansion coefficient is recalculated from the curve of the surface temperature (for corresponding water salinities). Bottom slope down to isobaths of 50–80 m is of 0.0001–0.001. We ignore here the contribution of additional negative buoyancy fluxes due to surface water salinization during evaporation and ice formation, which can principally be estimated from the published data as well.

Flows down slope. Not many analytical results are available nowadays to evaluate the amount of water exchanged in the process of horizontal convection (see also Chubarenko et al., 2005). The most informative is the paper of Sturman et al. (1999), where the authors compare numerical results, their own field experiment results, data of field investigations of Adams & Wells (1984) and Monismith et al. (1990), and laboratory experiments. The range of analyzed bottom slopes was of $0.4° \leq \beta \leq 22°$, and discharges range over three orders of magnitude.

Both the thickness of the gravity current sinking along the constant bottom slope and its velocity scale for the steady state can be found from the momentum balance for the flow down the slope, which equates a turbulent friction and buoyancy (Turner, 1977), what is most convenient for the field cases. That gives for the scale of the mean steady state velocity, u, of the gravity current parallel to the slope, and for the thickness of the gravity current, h_g, the following expressions:

$$u \sim \left(\frac{Bl \sin\beta}{C_D} \right)^{1/3}$$

$$h_g \sim \left(C_D / \sin\beta \right)^{1/3} \left(\frac{\tan\beta}{1+\tan\beta} \right)^{4/3} l$$

where B is the buoyancy flux through the surface, l is the (horizontal) length of the littoral area, β is the bottom slope, and C_D is a drag coefficient. The flushing time scale, τ, is the measure of the time taken by the discussed above mechanism to flush the region above the slope

$$\tau_g \sim l^{2/3} \frac{(1+\tan\beta)^{4/3}}{(B\tan\beta)^{1/3}}$$

The discharge per unit width of the shore by gravity current is given by

$$Q = 0.24 B^{1/3} (l \tan\beta / (1+\tan\beta))^{4/3}$$

The equations above (Sturman et al., 1999) show that steady state discharge has a weak, but essential, dependency on the buoyancy flux. Discharge is more sensitive to variations of angles of slope, particularly for small angles. How it is evident from Fig. 1. $l\tan\beta = D_{mixed}$, where D_{mixed} is the depth of the upper convectively mixed layer, or the depth of the basin, if the convection reaches the bottom. Since the bottom slopes in the Gulf of Gdansk are very small, about 0.0001–0.001, the assumption of $\sin\beta \sim \tan\beta \sim \beta$ works very well, and in our case $l\sin\beta \sim \sim l\tan\beta \sim D_{mixed}$. Thus, the above presented formulae can be re-written as

$$u \sim \left(\frac{BD_{mixed}}{C_D}\right)^{1/3}$$ for the scale of induced down-slope flow,

$$h_g \sim (C_D)^{1/3} D_{mixed}$$ for the scale of the thickness of the flow,

$$\tau_g \sim \left(\frac{D^2_{mixed}}{\beta^3 B}\right)^{1/3}$$ for the flushing time scale, and

$$Q = 0.24 B^{1/3} D^{4/3}_{mixed}$$ for the discharge per unit width of the shore.

For estimative reasons, we can choose some typical for the Gulf of Gdansk values: D_{mixed}~50 m for late autumn, β~0.001, $B \sim 3*10^{-8}\ m^2s^{-3}$ and typical field value of $C_D \sim O(10^{-3})$ (see Turner, 1977). For the scale of the thickness of down-slope flow one obtains then h_g~5 m, for the down-slope current velocity u~8–12 cm s^{-1}, flushing timescale of O (50 days), and flow-rate per unit shore length $Q \sim 0.14\ m^3$ (from 1 m of shore line per second). For the lengths of the shore of about 200 km, this makes up ca. $3\cdot10^4\ m^2s^{-3}$, what is 30 times mean annual inflow of the Vistula River into the bay. The time for such flow required to move from the shore to the bay center (~50 km) is then less than 1 week (6 days only). Using for the estimations another friction coefficient C_D does not change the values principally: even if to take this coefficient ten times bigger $C_D \sim O(10^{-2})$ one obtains twice smaller velocity value (4–6 cm s^{-1}), but twice bigger thickness of the flow, with the same flashing time and discharge. Wide shoals (like that around Hel peninsula may significantly increase the rate of cold-water generation. Thus, *cooling-induced water-exchange in fall/winter is powerful mechanism of basin-wide mixing*.

Fig. 4 displays the resulting flows how they are arranged in the South-East corner of the Baltic Sea. Vertical convection in fall and win-

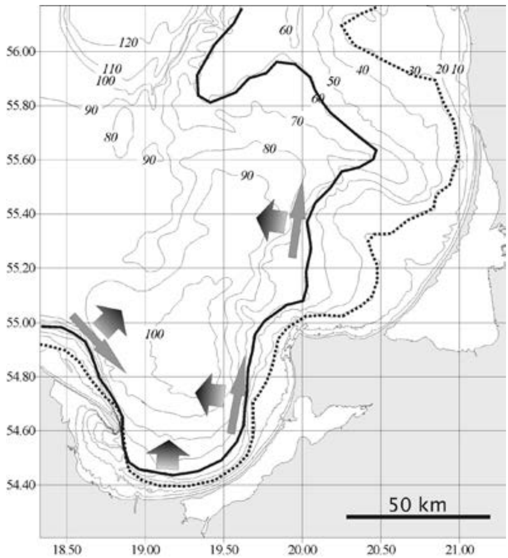

Fig. 4. Off-shore flows induced by seasonal cooling in South-East part of the Baltic Sea.

ter reaches here the depths down to 30–60 m, so, the bottom slope from the coastline to the corresponding depth is the source of cold-water cascades for deeper areas. Since the motions are very slow, the Earth rotation becomes important, which tends to turn the flows to the right. This phenomenon is well known as the thermal wind (Gill, 1986). Thus, almost half a year (from the beginning of September till end of February, *see* Fig. 2), general water circulation is favorable for transport of coastal polluted waters towards deeper Baltic layers and along the shore, how it is presented in Fig. 4.

4. Concluding remarks

During fall and spring transitional periods, horizontal water temperature gradients are developed between shallow and deep parts of large water bodies: shoals respond faster to seasonal changes in sun radiation and air temperature. Even though the generated water circulation is very weak (an order of magnitude of the induced current is units to tens of $mm\ s^{-1}$), it works throughout the whole year and establishes an additional transport mechanism with evident seasonal variations. The most intense horizontal water exchange develops in the Gulf of Gdansk to the end of November, when both the buoyancy flux is large and gravity helps to accelerate down-slope cold cascades.

For typical seasonal heat fluxes, aspect ratios, bottom slopes and bathymetric structures the discharge of near bottom cascade is estimated in $3 \cdot 10^4\ m^2 s^{-3}$, what is much larger than the Vistula River inflow. The induced horizontal motions embrace the whole entire of the Gulf of Gdansk, not just narrow coastal zone. Thus, the mechanism contributes a lot to basin-wide horizontal mixing, oxygen and nutrient transport, spreading of polluted coastal waters across the national boundaries.

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The role of coastal lagoons in land-sea transport of water and substances in the South-East Baltic

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Loading by various pollutants is the significant external factor, which determines the behaviour of the Baltic Sea ecosystem. Traditionally a load function is determined as a sum of multiplication between discharges and concentration of pollutants for artificial sources and rivers:

$$\mathbf{Q(i)(t) = \sum qj(s) – C(si)\, j + \sum qj\ (r) – C(ri)j}; \qquad (1)$$

where **Q(i) (t)** is a time dependent flux of i-th substance into the Baltic (kg s^{-1} or ton a^{-1}),
q(s)(t) and **q(r)(t)** is time dependent water discharges for point artificial sources and rivers respectively (m^3 s^{-1} or km^3 a^{-1}),
C(si) and **C(ri)** is concentration for i-th substance at a point source or a river mouth (mg l^{-1} or kg m^{-3} or ton km^{-3}).

Variations of water discharge and concentration of substance contribute equally to time variations of mass discharge of this substance.

Kaliningrad Amber Mining Plant located on the western coast of the Sambian Peninsula (Kaliningrad Oblast, Russia), is a typical example of a point source. It discharges pulp produced after amber extracting to the surf zone, or directly dumps it on the beach. The volume of sediments discharged by this plant into the Baltic Sea had reached 100 mln

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tons during the period of 1880–1973 (Sivkov & Chubarenko, 1997). Two marine damping sites located on the western and northern coasts of the Sambian Peninsula, are also examples of point sources. The average total rate of damping for these sites equals 500–600 thousand tons of sediments per year, while the Amber Mining Plant discharges of 10–25 thousand tons per year (Kurchenko & Reznichenko, 2006).

None of the main rivers of the Kaliningrad Oblast discharges directly into the South-East Baltic. River sediments are collected first by the Vistula Lagoon, and then lagoon water is discharged to the Baltic Sea. Total discharge of sediments from the Vistula Lagoon is of 230–320 thousand tons a year (Chubarenko & Chubarenko, 2001; Kurchenko & Reznichenko, 2006).

The main part of fresh water runoff of the South-East Baltic (except the Vistula River) is directed not to the Baltic but to the coastal lagoons and estuaries. The Neman River is opened into the Curonian Lagoon, whose catchment area covers about 100 thousand km^2 in Lithuania, Belorussia and the Kaliningrad Oblast. The Vistula Lagoon has a drainage basin of the area of about 24 thousand km^2, which covers the area of the Kaliningrad Oblast and northern Polish municipalities. The Szczecin Lagoon (Odra Estuary) accepts discharge of the Oder River, which has the watershed in Poland and Germany.

When sediments and nutrients reach a lagoon, they become a subject of natural transformation. Organic and inorganic matters are

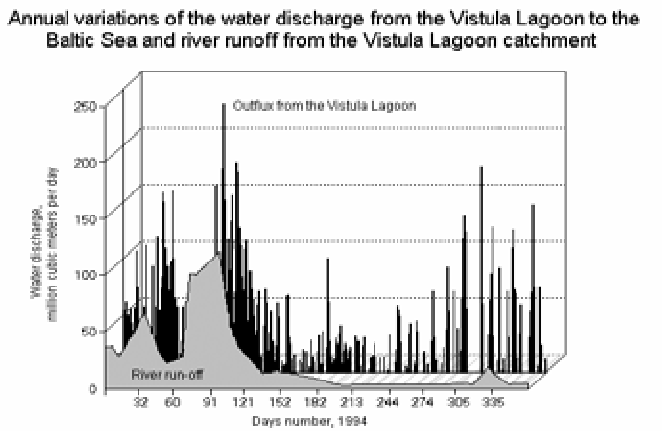

Fig. 1. Outflow of water from the Vistula Lagoon into the South-East Baltic due to water exchange process; fresh water runoff into the Vistula Lagoon from the lagoon catchment.

discharged into the Baltic Sea during water exchange between a lagoon and marine coastal zone only after some residence time (or "living time") in the reservoir of a lagoon. Remarkably, that this water exchange is determined by three main external factors, namely, level variation in adjacent marine area, local wind surge and rivers' runoff.

The example of the Vistula Lagoon, the shallow water reservoir with the average depth of 3.5 m and the total annual fresh water runoff of 3.67 $km^3\ a^{-1}$, shows the significant difference between time variations of river discharge (Fig. 1) and the outflow flux from the Vistula Lagoon. Since water exchange processes depend on atmospheric and hydrological influence, the flux of water from the lagoon is impulsive and has higher amplitude. This outflow of water washes organic and inorganic matter out of the lagoon, and forms impulsive load towards the marine coastal zone.

Concentration of sediments and nutrients in the lagoon is less in comparison with river mouths. Fig. 2 shows the diagram of spatial distributions of nitrates and nitrites in the Vistula Lagoon and the Pregolya River mouth, the main river in the Vistula Lagoon drainage basin. Remarkable decrease of nutrient concentration is caused by both direct dilution of nutrients when mixing with marine water and natural assimilation of nutrients by the lagoon ecosystem.

Thus, presence of lagoons determines specific time variations of water discharge and concentrations of discharged matter. Therefore, the

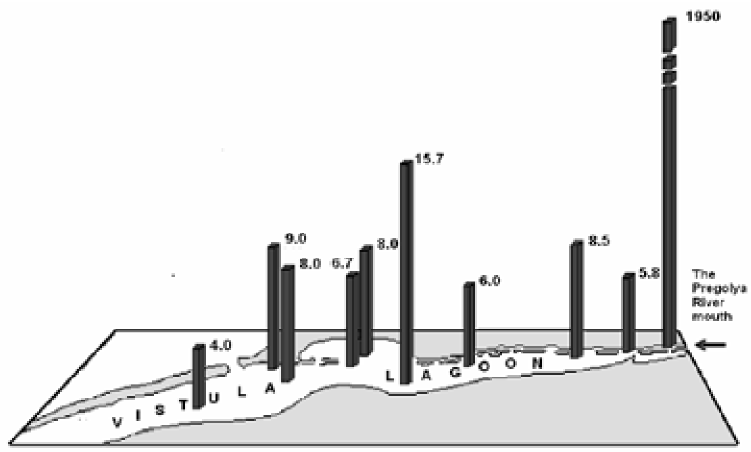

Fig. 2. NO2+NO3 concentration (mg l^{-1}) in the Pregolya River mouth and the Russian part of the Vistula Lagoon at the beginning of June 1995.

final function of a load from a catchment to a marine coastal zone differs from river load in terms of time variations and amplitude. In the case of the South-East Baltic the buffer role of lagoons is to be considered for correct formulation of the boundary condition for ecological modelling of the Baltic ecosystem and elaboration of a management strategy for coastal ecosystems as well.

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