University of Gdańsk – Department of Geography of Regional Development

C O A S T A L R E G I O N S 3

BALTIC EUROPE ON THE EVE OF THIRD MILLENIUM

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General characteristics of the natural environment of Baltic countries with special consideration to coastal zone

1. Introduction – Baltic Europe in a physical geographical aspect

The natural scope of Baltic Europe may be determined in various ways depending on the assumed delimitation criteria. Taking into account the deepest geological ground, the core of Baltic Europe are countries situated within the scope of the archaic Baltic shield (Finland, Sweden, north-western Russia) and partially within the area of the Precambrian Russian platform (Baltic States, Belarus, north-eastern Poland). Outside these structures, there is located the south-western Baltic coast (western Poland, Germany, Denmark) (Fig.1). In terms of landscape, the southern scope of Baltic Europe can be deemed to be the zone of maximal scope of the last glaciation, called the Baltic glaciation in Poland (Würm), indicated by the occurrence of young end moraines zones (Fig.2). Within this area, there prevails a young glacial landscape with a dominance of lakelands. These criteria are reflected in complex physical geographical divisions of Europe, in which the area round the Baltic is divided among several high rank units. And thus, for example, Kondracki (1981) divides it among three physical geographical territories: Northern Europe (the above mentioned Baltic shield), Eastern Europe (Eastern Europe Lowland) and Western Europe (so-called Off-Alpine Western Europe, and in south-eastern Poland, Alpine and Carpathian countries). Due to significant problems in an unequivocal delimitation of Baltic Europe on the basis of geological, geomorphological or climatic criteria, the most frequently used criterion is the hydrograhic (catchment) one. The area of Baltic Europe is thus assumed to be the Baltic drainage basin of a size of 1721 000 km^2 (Mikulski, 1985), which includes 13 countries. Countries wholly covered are Lithuania, Latvia, Estonia and the Kaliningrad district of the Russian Federation. Countries covered by the drainage in greatest part are Poland, Sweden and Finland. It also covers large parts of the Petersburg district of Russia, Belarus, northern Germany and Denmark, as well as small parts of the Czech Republic, Slovakia and Ukraine (in the catchments of the Odra and Wisła). The biggest in size of the Baltic countries is Sweden (450 000 km^2), the biggest population has Poland[1] (39 mln people). The Baltic is often divided into seven sea subregions, for whom partial drainage basins are respectively determined (Fig.3). The biggest of these regions is the Baltic Proper (half of the 415 000 km^2 of the whole Baltic), which has also the biggest drainage basin (569 000 km^2) (Mikulski, 1987).

The approach to Baltic Europe from the point of view of drainage basin has got also an important functional aspect. It is within this area that all the sources of pollution reaching the Baltic by water are located. It is worth noticing that the proportions of the size of the drainage basin and the very Baltic water area are 4:1, and the reservoir is a sea situated in a region of a relatively cool climate, quite shallow, non-tidal and epicontinental (closed), which contributes to a relatively slight water exchange. All these factors contribute to the relatively high pollution of the Baltic waters. Thus, it is so important

1 with reference to the number of people living in the Baltic drainage basin, as the countries with the biggest population are Germany and Ukraine

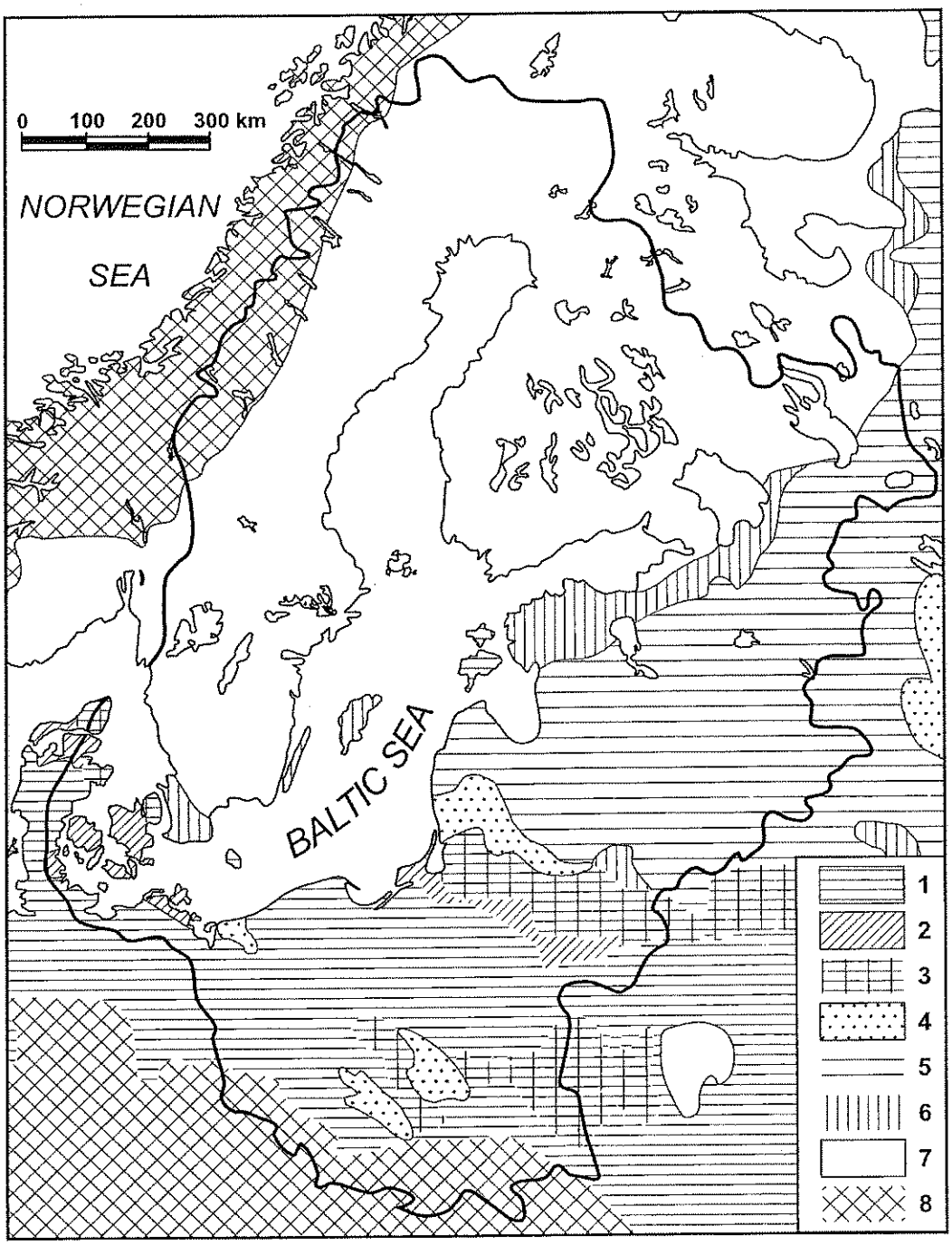

Fig. 1. Age of rocks of sub-Quaternary ground in the Baltic region (after Hĺkanson, 1993)

Age of rocks: 1-neogen, 2-paleogen, 3-upper Cretaceous, 4-lower Cretaceous, Jura, Triassic, 5-Permian, Carboniferous and Devonian, 6-Silurian, Ordovician, Cambrian, 7-igneous and metamorphic Precambrian rocks, 8-poligenetic rocks

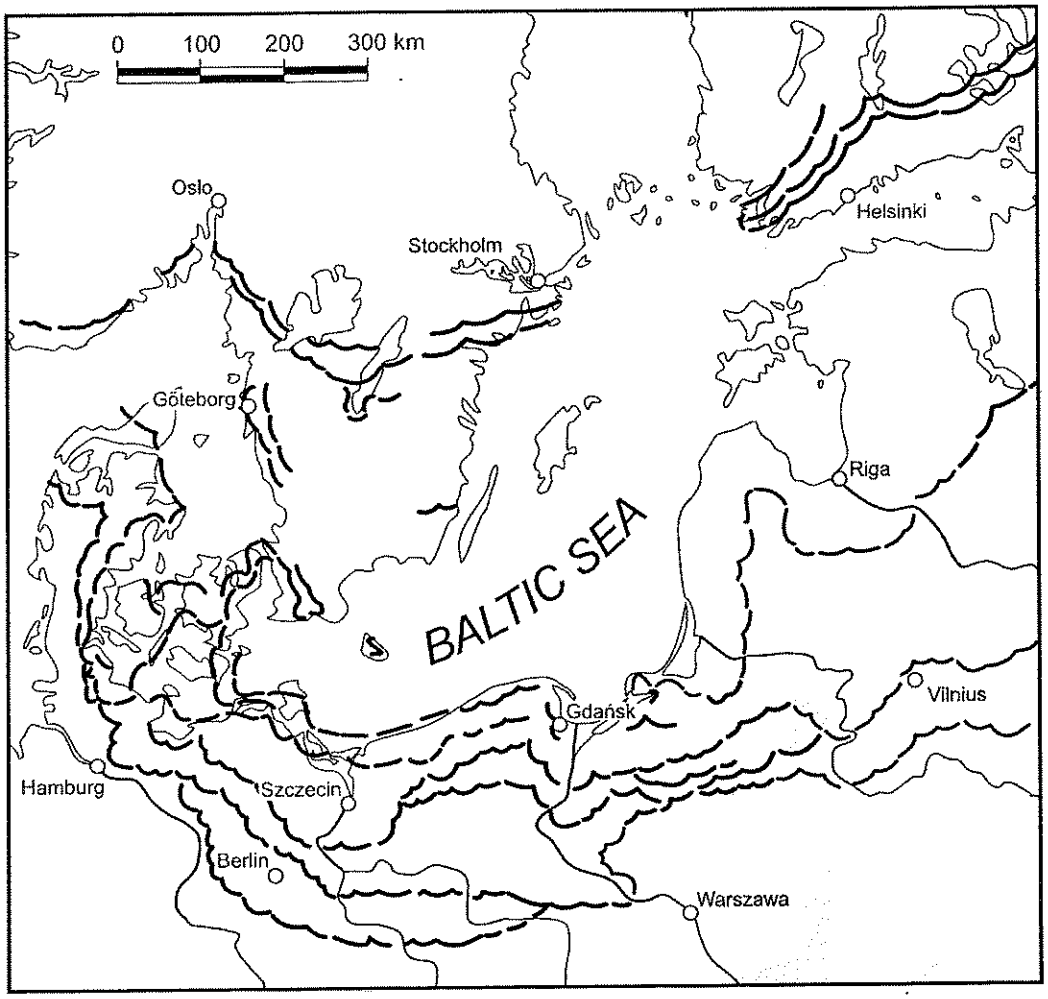

Fig. 2. Location of main end moraines zones formed during phases of Würm glaciation (after Woldstedt, 1955)

to analyse this part of Europe in terms of drainage and catchment systems, as, thanks to the diversified land relief and precipitation, water is here the basic carrier of matter including pollutants.

In this chapter, the author attempts to generally outline the main features of the environment of Baltic Europe within the scope of the Baltic drainage basin, and the second part of the study concentrates on the areas closer to the sea, i.e. in the coastal zone, for which there will be described main coast types shaped by a complex of sea, land and atmospheric factors in very diversified conditions of the natural land environment of the Baltic coastline.

2. Natural environment of Baltic Europe

Geological structure

Surface geological formations of the area of Baltic Europe are contemporarily made mainly of Quaternary sediments created due to processes related to glaciations taking place in the Pleistocene. The ground below Quaternary formations is very diversified. The oldest ones occur within the

Fig. 3. Baltic Europe – hydrographic division of the Baltic and its drainage basin against borders of states (after Mikulski, 1987)

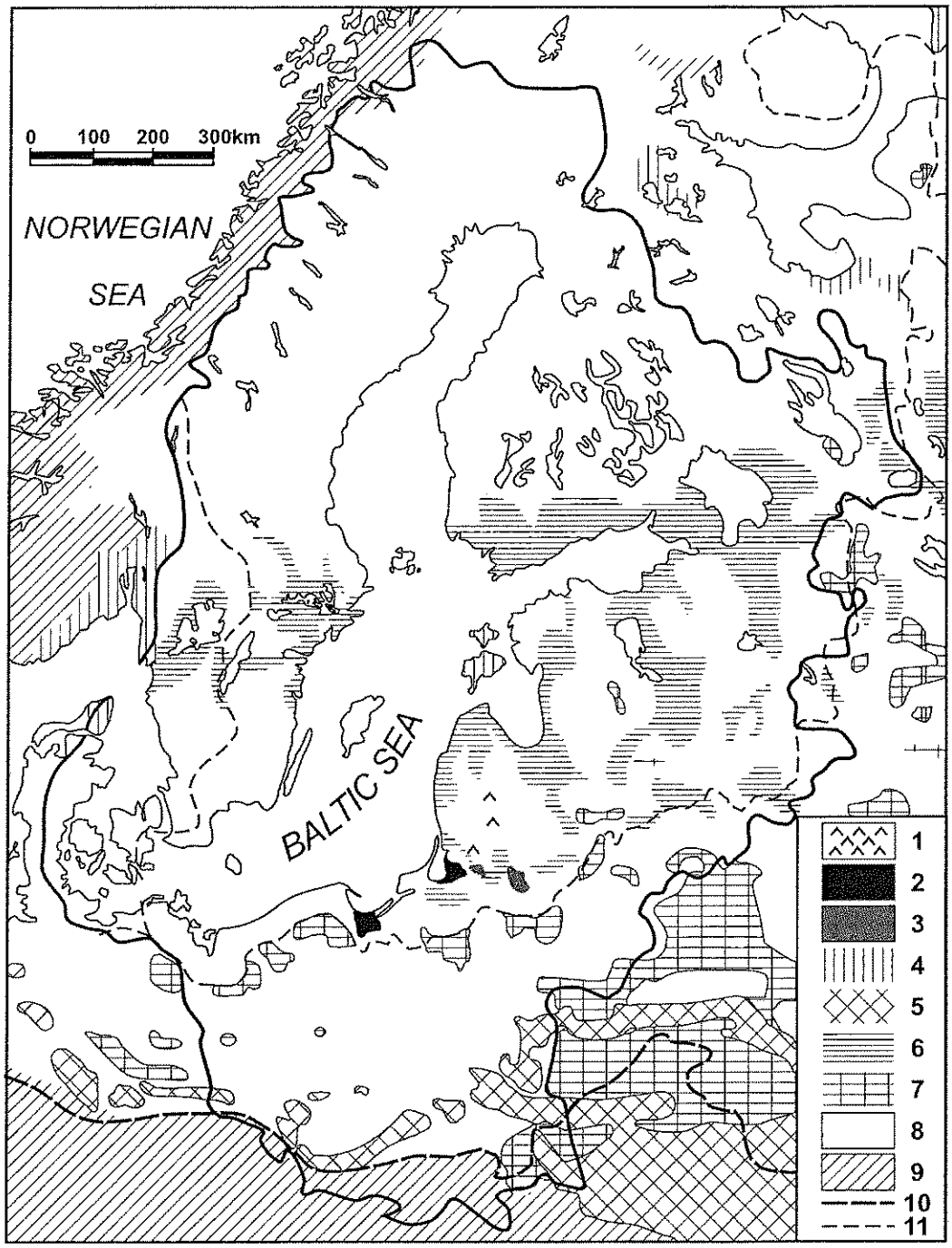

Fig. 4. Quaternary surface geological sediments in the Baltic region (after Hĺkanson, 1993)

1-peat deposits, 2-alluvian deposits, 3-eolian sands, 4-sea deposits, 5-loess deposits, 6-glaciolimnic deposits (clay, silt, sands), 7-fluvioglacial deposits (sands, gravel, boulders), 8-boulder clay (non-sorted clay with boulders), 9-ground rocks, 10-maximum scope of Pleistocene glaciations, 11– scope of Pomeranian substage of Wisła glaciation

Baltic shield. These are Precambrian igneous and plutonic rocks (e.g. granite) and metamorphic rocks (e.g. gneiss). Further to the south, in the territory of the Baltic States and Russia, in the Quaternary ground there prevail Palaeozoic rocks, mainly sandstone. Upper Cretaceous rocks are characteristic of Lithuania and north-eastern Poland, while in north-western Poland, Germany and Denmark, in the ground, there usually occur formations of younger Tertiary – Neogene. In mountain areas, as of the Scandinavian mountains, as well as Carpathians or Sudetes, the origin of the ground rocks is varied and they are generally not covered by a layer of Quaternary sediments. The mosaic character of Quaternary sediments is very strong, depending on the conditions and processes which formed them. In the whole Baltic drainage basin, however, there prevails the so-called till, sometimes with sand and gravel (Fig.4). Yet, there often occur also glaciolimnic deposits created in limnic conditions, mainly in southern Finland, the surroundings of lake Ladoga, in Estonia, Latvia and central Sweden, as well as fluvioglacial (of outwash plains) sand – gravel deposits, created on the foreland of end moraines zones, mainly in Poland, Belarus and Ukraine. In the south-eastern part of the drainage basin (Poland, Ukraine), there often occur loess covers too, on which there were formed the most fertile soils of the region and where the early civilisation centres developed (e.g. Sandomierz morainic plateau in Poland). Part of surface geological formations is also a result of processes taking place in the post-glacial period, the Holocene, during which inland and coastal eolian dune covers were created; numerous peat lands were formed in the processes of lake overgrowing; and in rivers' mouths (e.g. of the Niemen and Wisła) alluvial (river) sediments were accumulated.

Land relief

Apart from the border outskirts of Baltic Europe, constituted from the west and north by the Scandinavian mountains (with altitudes over 2000 m above the sea level), and from the south by the Sudetes (maximum altitude 1602 m above the sea level) and Carpathians (max. over 2600 m above the sea level), the majority of the area is dominated by lowland relief shaped under the influence of the operation of the Scandinavian continental glacier in the Pleistocene, and of the processes accompanying glaciation and deglaciation. The last million years is a period during which the Baltic area was iced at least three times. The last glaciation – the Baltic one (called also Wisła or Würm glaciation) lasted from about 120.000 to 10.000 years ago, reaching the maximal scope of the continental glacier about 15.000 years ago. Within the area covered by it, the relief is now most varied. However, it may be assumed that the morphogenetic operation of older glaciations (Mindel, Riss) was stronger, since they had a greater scope, and the ice thickness was then biggest and reached maximally 3000 m. Yet, older formations, situated south of the maximal scope of the Wisła glaciation, are today less distinct in landscape due to a longer erosion period which they have undergone. The most durable traces of glacial relief are clay morainic plateaux with series of end moraines (Fig.2), ground moraine plains and sandy outwash plains, as well as glacial channels mostly filled with lakes, and proglacial stream valleys. The most visible traces of the operation of the continental glacier are lakes, whose number and size increase to the north, reaching maximum in central Finland and Sweden. The Baltic area has undergone considerable geomorphological changes in the postglacial period. One of the basic processes from which they resulted is isostatic uplift, i.e. a gradual elevation of the Scandinavian shield. They started after the withdrawal of the continental glacier when the shield was relieved from huge ice masses. After the withdrawal of the continental glacier from the area of the Baltic Proper, Baltic Ice Lake was formed. After a subsequent period of cooling (younger Dryas), about 10,000 years ago, the ice lake obtained a link with the ocean through central Sweden and the Yoldia Sea was formed. Next, due to isostatic uplift, about 9400 BP, it again lost its link with the ocean (Ancylus Lake) only to regain it about 8000 years ago (Litorina Sea). Since then, a successive rising of Fennoscandia has been taking place. It is strongest in the Gulf of Bothnian (9 mm/year), on average around Stockholm and Turku (4-5 mm/year), falling to zero on the southern Baltic coast (Fig.5). In southern Germany, north-western

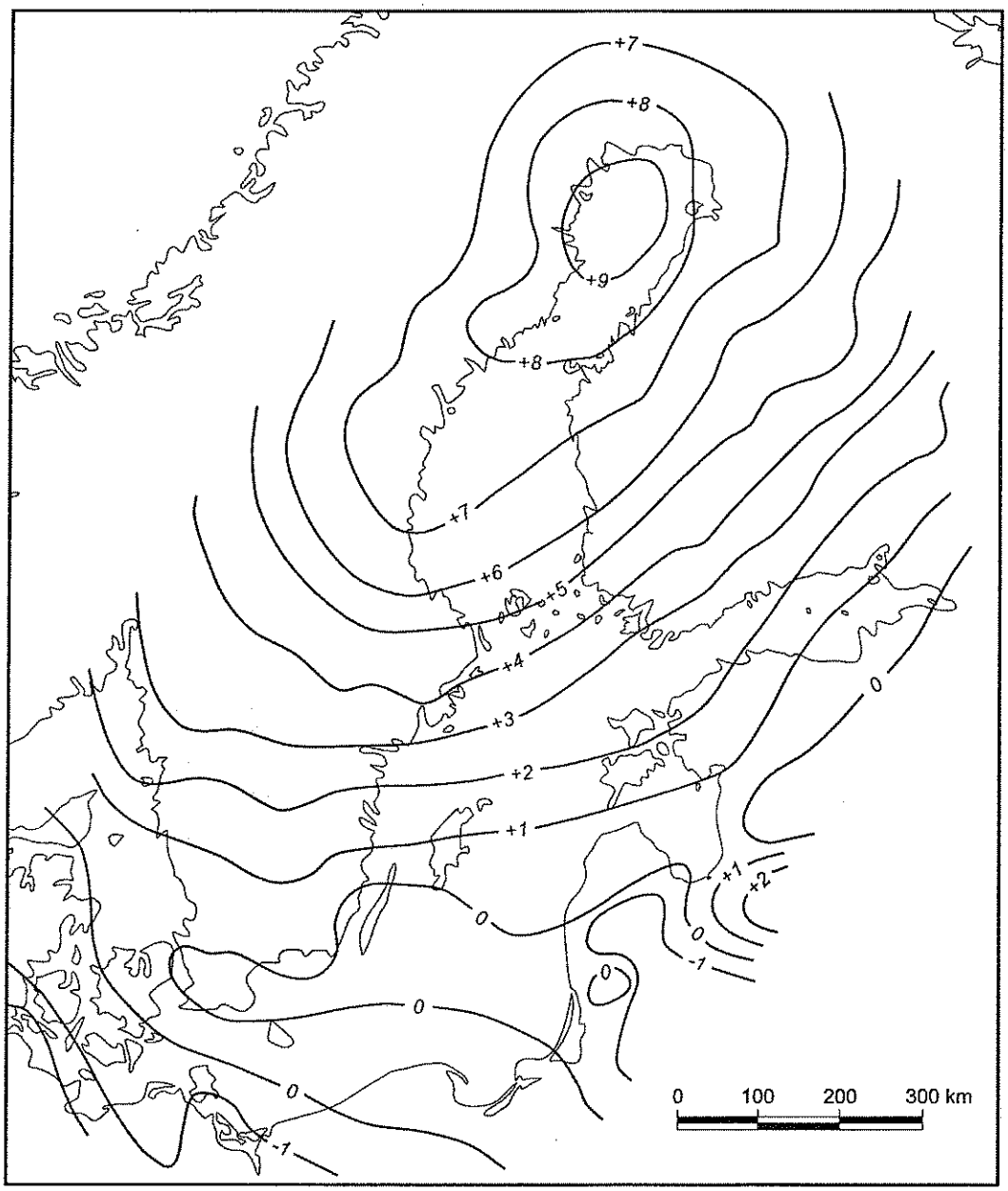

Fig. 5. Contemporary rate (mm/year) of isostatic uplift of land in the Baltic region (after Voipio, 1981)

Poland and eastern Latvia, these processes have even negative values (land is subsiding). Isostasy has a key significance for many present ecological and sedimentation processes taking place especially on the coasts. In the coastal zone, there are also intense holocene processes; eolian accumulation of dunes, abrasion of cliff shores, growth of river deltas.

Features of climate

The whole of Baltic Europe is situated within a temperate climatic zone. North-eastern Germany, Poland, the Baltic States and southern Sweden (south of Stockholm) are characterised by a temperate warm transitory climate. Only the westernmost past of the drainage basin (Denmark) has this type of climate in a marine variation, and easternmost part (Belarus) in a continental variation. Central and

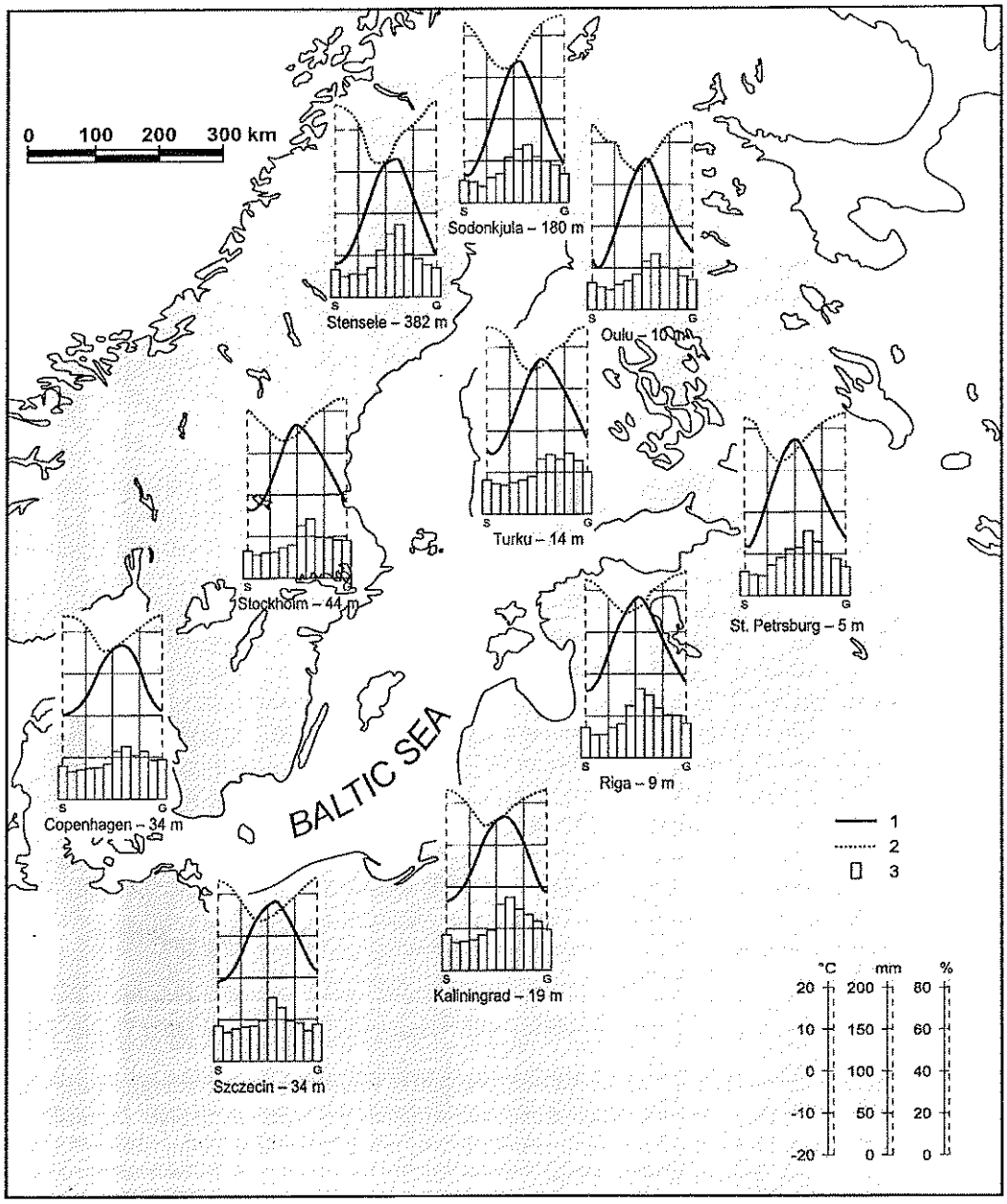

Fig. 6. Variability of mean monthly air temperatures, precipitation and relative humidity value in the Baltic region on the basis of data of 1881-1959 (after Fizykogieograficzeskoj Atlas Mira, 1964)

1– air temperatures, 2-relative humidity, 3-atmospheric precipitation

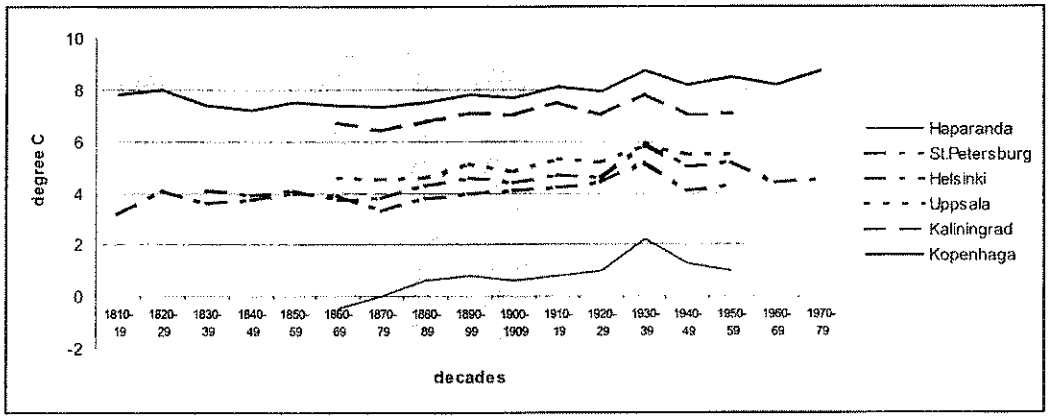

Fig.7. Mean annual decade air temperatures in chosen Baltic cities (after Kwiecień, 1987)

northern Sweden and Finland together with the surroundings of Ladoga and Onega lakes in Russia are characterised by a temperate cool climate – in the area of the Scandinavian Mountains, in a marine type but with more severe mountain conditions, and in central Sweden and southern and central Finland, in a transitory variation. The most severe climatic conditions characterise northern Sweden and Finland, where the cool temperate climate turns into subarctic, especially in the northern part of the Scandinavian Mountains. What is characteristic of climate round the Baltic is an occurrence of extreme mean monthly air temperatures in July (maximum), and in January or February (minimum) (Fig.6). Mean temperatures of July range between 17-18°C on the southern coast of the Baltic (e.g. in Copenhagen, Szczecin, Stockholm, Kaliningrad and Riga) and 15-17°C in the area of the coast of the central Baltic, and 13-15°C in the northern part of the drainage basin, especially in land interior. In the zone on both sides of the Arctic Circle, there are distinct big differences in temperatures between places located on the Baltic and in land interior. E.g. around 65° north latitude, in Stensele, Sweden, situated about 200 km from the seashore, the mean temperature of July is about 13°C, and in Oulu, Finland, situated on the Baltic, it is close to 17°C. Still bigger differences occur between temperatures of the coolest months. On the southern Baltic coast, air temperatures range between +1°C (Copenhagen) and -2°C (Kaliningrad).

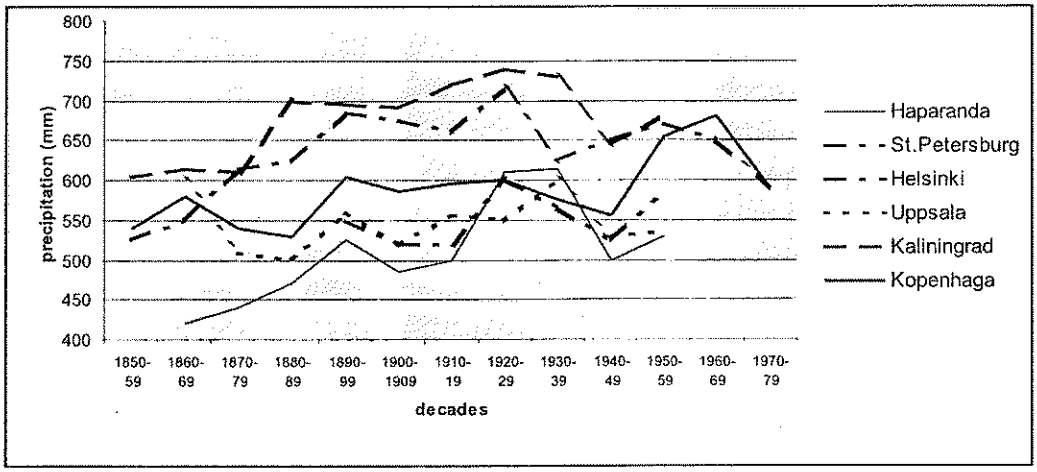

Fig.8. Mean annual decade sums of precipitation in chosen Baltic cities (after Kwiecień, 1987)

Table 1. Basic parameters of main rivers in the Baltic drainage basin

River name	River length (km)	Drainage basin area (km^2)	Mean annual discharge (m^3/s)	Unit runoff ($dm^3/s \cdot km^2$)
Neva	74*	281100	2600	9,25
Wisła	1047	193910	954	4,92
Odra	854	106200	580	5,24
Nemunas	937	98200	674	6,86
Daugava	1020	87900	688	7,83
Kemijoki	550	51400	581	11,3
Göta	720	50180	585	–

after: Vaipio (1981), Czaya (1987), supplemented
*below Ladoga Lake

On the central Baltic, they range between -3°C (Stockholm), through -4°C (Riga) to -5°C (Turku) and -8°C (St.Petersburg). In the case of January or February, they fall not only to the north but to the east as well together with an increase of a continental character of the climate. In Oulu, the mean temperature of February is -10°C, and further to the north in land interior, it falls to -13°C.

The differences in mean monthly temperatures of the coolest months are, thus, almost three times bigger (14°C) than of the hottest months (5°C). Mean annual air temperatures in Baltic Europe range between 0 and 8°C (Fig.7).

The variability of atmospheric precipitation volume is in Baltic Europe a bit smaller than of air temperatures. The precipitation volume ranges between about 450-500 mm in the northern part, where it is mostly in the form of snow, through 500-600 mm in the western and south-western part of the Baltic drainage basin (Copenhagen, Stockholm, Szczecin), to 600-700 mm in north-eastern Poland and the Baltic States (Kaliningrad, Riga, Helsinki). The distribution of precipitation is characterised, to a certain degree, by an „inversion" in relation to the increase in a continental character of climate, together with which precipitation rises as well. This phenomenon is caused partly by the situation of northern Sweden and Finland in a precipitation shadow of the Scandinavian Mountains. The spatial and temporal variability of precipitation in the Baltic drainage basin can be seen also in Fig.8. With regard to air humidity, its lowest values are noted between May and July, the highest ones in winter (November – January). The biggest differences in mean annual values of relative humidity are noted in the northern part of the Baltic drainage basin (65-90%), a bit smaller in the southern part (70-90%). These differences are, however, not very significant.

Inland surface waters

The Baltic drainage basin is well surface drained by a relatively highly developed river network. As a result of the Pleistocene glaciations, the territory has the biggest lake density in Europe, reaching 10% in a scale of states (Finland, Sweden). Due to the geomorphological structure of the area, being mainly a result of glacial operation, the southern and eastern parts of Baltic Europe are drained by relatively long rivers (Odra, Wisła, Nemunas, Daugava, Neva with tributaries), with large drainage basins of almost 100 000 km^2 of size or bigger (Tab.1). On the other hand, the northern and western parts of the drainage basin, on the territory of Sweden and Finland, are drained by shorter rivers with smaller drainage basins, having, however, especially in Sweden, big grades, thanks to which their hydroenergetic potential is high. Swedish territory is drained by the largest number of rivers in the whole Baltic region.

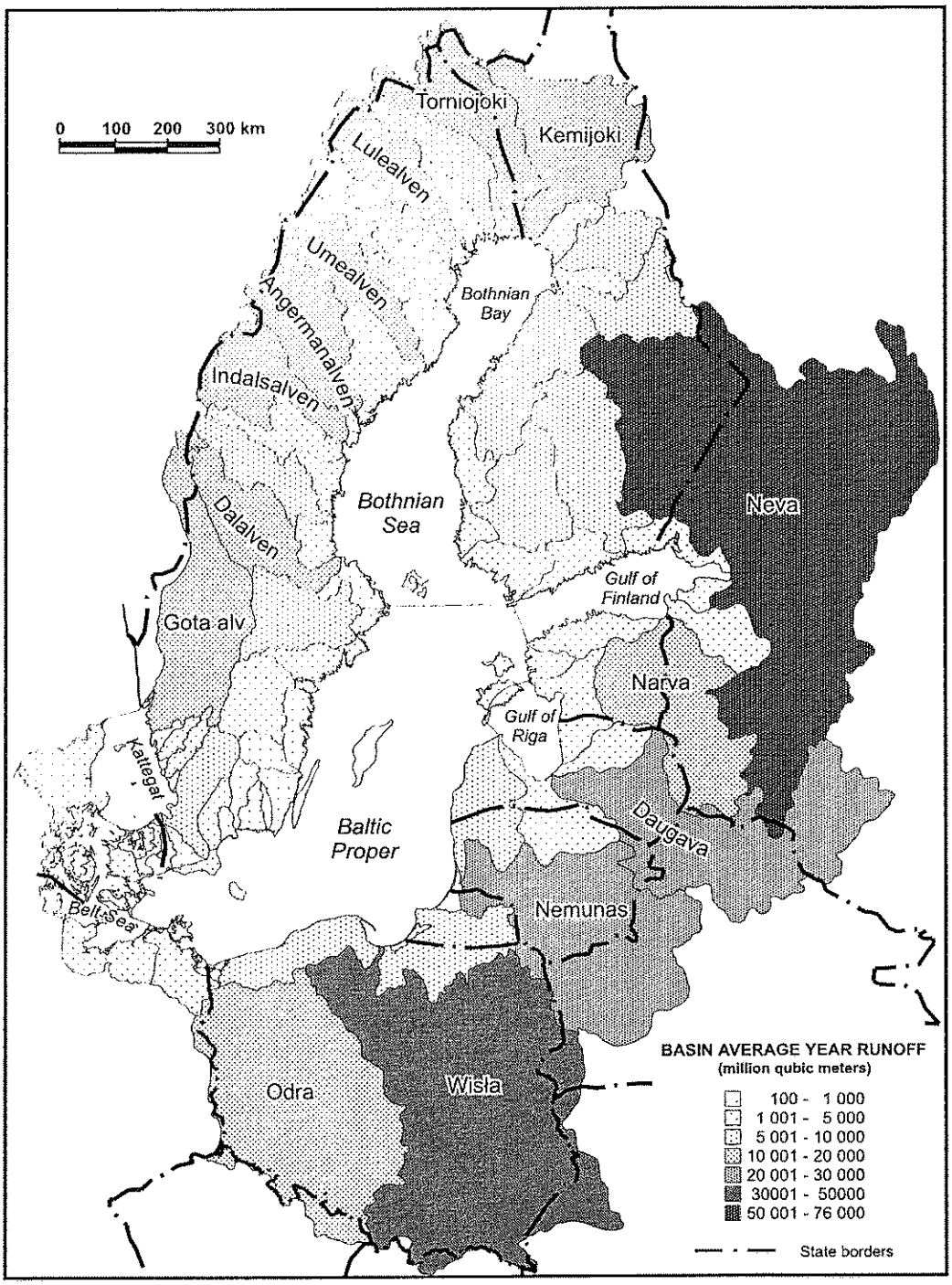

Fig. 9. Largest river catchments in the Baltic drainage basin and mean annual outflow from their area

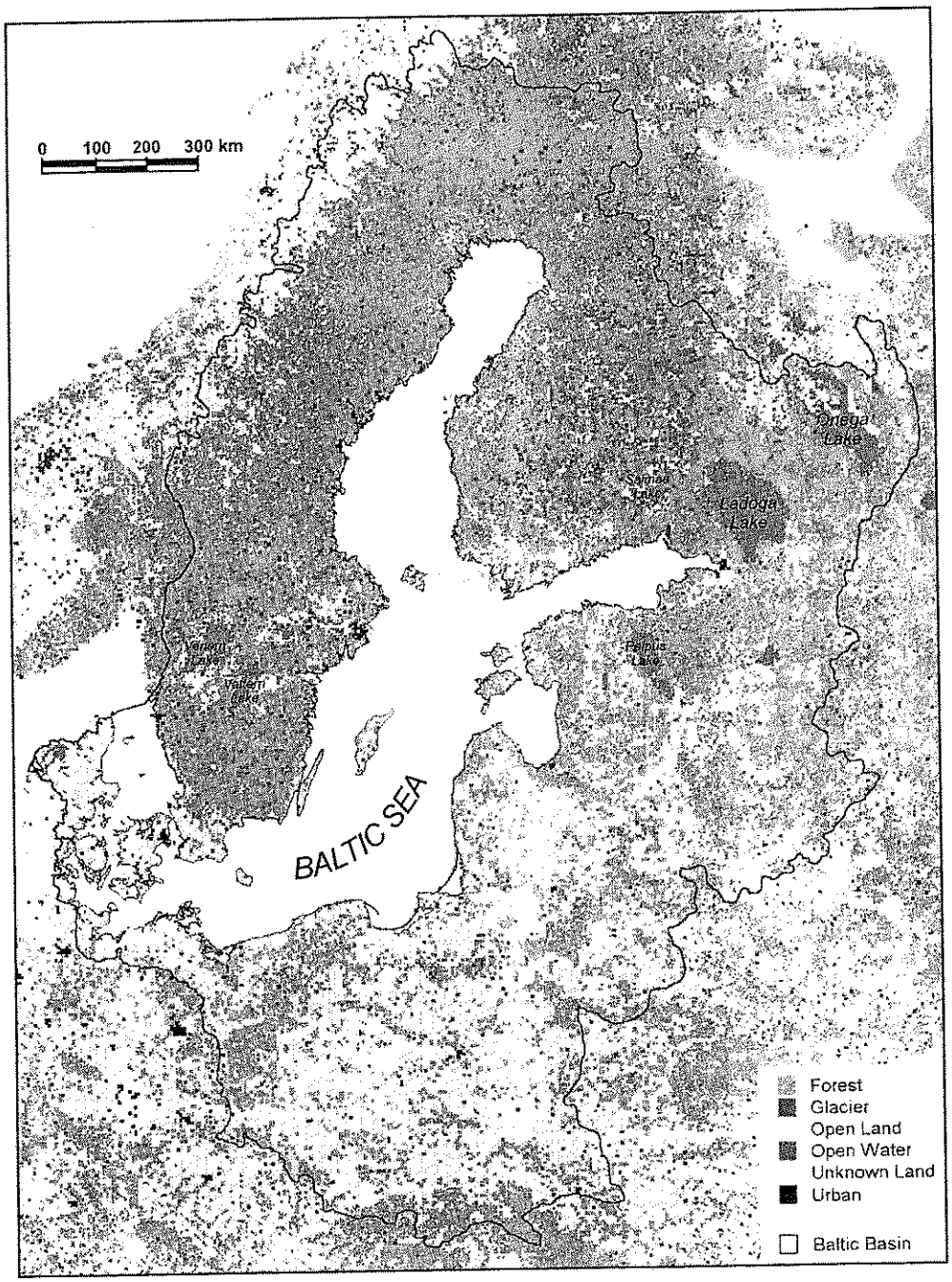

Fig. 10. Main categories of land cover in the Baltic region (addopted from GRID Arendal)

Table 2. Basic data on the biggest lakes of Baltic Europe

Lake name	Area (km^2)	Maximal depth (m)	Mean depth (m)	Volume (km^3)
Ladoga	18400	225	50	908
Onega	9610	124	29	285
Vänern	5546	98	33	153
Saimaa	4400	58	17	74,8
Peipus	3583	14,6	4,5	86,2
Vättern	1899	119	39	74

after: Geographical Dictionary of Europe (1976), Choiński (2000)

In the southern part of the drainage basin (including southern Sweden, Lithuania and Latvia), there dominates a mixed type of river alimentation, with a predominance of rain, in the central and eastern part – mixed with a predominance of snow, and in the northern part – snowy. The biggest outflow is noted in the catchment of the Neva and Wisła, also big of the Niemen and Daugava. A relatively big outflow occurs also in the catchments of Swedish rivers originating in the Scandinavian Mountains (Fig.9). The volume of outflow and character of the development and use of catchments are correlated with the volume of nutrients' supply, which significantly contribute to the pollution of the Baltic. The greatest load of nitrogen compounds is supplied from the catchments of the Wisła, Odra, Nemunas, Daugava and Neva, and of phosphorous compounds from the catchments of the Odra, Wisła, Neva, Polish Pomeranian rivers and Daugava. This indicates that a majority of the load of nutrient pollutants in the Baltic comes from the territory of Poland, Lithuania, Latvia and Russia.

In the landscape of Baltic Europe, lakes are a very significant feature. They are especially numerous in the central part of the region, in central Sweden and southern Finland, where they take up the largest areas. In Sweden, there are over 83000 lakes bigger than 1 ha. However, the biggest lakes of the region, of tectonic origin, Ladoga and Onega are situated on the territory of St.Petersburg district of the Russian Federation (Tab.2, Fig.10). Lakes, apart from an ecological function, play a very important economic role as water reservoirs, fishing and recreation areas, constituting, apart from seaside areas, the second most important recreation zone in Baltic Europe.

Soils and land use

The area of the Baltic drainage basin is characterised by a varied soil cover which was formed mainly in the conditions of a postglacial climate on postglacial formations. Local topographic conditions and character of ground rocks determined mainly the type and fertility of created soils. Most generally, it may be said that the Baltic region is dominated by podzolic soil, i.e. formed under coniferous forests dominant in this region. In the northern part, there prevails gley podzolic soil, in the southern part – turf podzolic soil. In northern Germany, Denmark and southern Poland, there prevails brown soil, and in south-eastern Poland – black-earth. Soils formed on Scandinavian clay on the ground of igneous and metamorphic rocks are usually not very fertile. Also soils produced on sandstone parent rock are poor in nutrients and poorly permeable, which still increases their rewashing. Bigger amounts of nutrients are found in soils produced on limestone and till grounds. They are also less permeable.

Despite the basic participation of inhabitants of the region in forming the plant cover of the terrain, especially in the southern and eastern part, it still depends, to a high degree, on natural factors, such as relief, type and fertility of soil ground. On the surface of igneous rocks of the

Scandinavian Mountains and stony clays, there are usually forests. On fluvioglacial formations – sand and gravel, where the most fertile fractions have been washed away – there usually occur forests and pastures. Whereas, much more fertile soils have been created on the clay of morainic plateaux, mainly south and east of the Baltic. Here usually occurs arable land. Glaciolimnic formations (deposited in limnic conditions of post-glacial marginal lakes) may be usable for agriculture, yet, sometimes they are too compact (silt). The situation is similar with peat deposits, which are often too strongly hydrated. Eolian sands and sand dunes, formed mainly in the Holocene, have low fertility.

The vegetation of the Baltic countries is highly diversified. In the northern part, there prevail forests, covering over 50% of the territory of Sweden, Finland and the Petersburg district (Fig.10). They mostly belong to the zone of coniferous forests (taiga). Relatively large forest territories occur in Estonia, Latvia and northern and western Poland. While, the highly deforested areas are Lithuania, north Germany and Denmark, which belongs to the least forested European countries (forestry degree 12%). The scope of cultivated areas constitutes a „negative" of the scope of forests. It is largest in Denmark (over 60% of the area of the country), northern Germany, Poland, Lithuania and Belarus. The main settlement centres of Baltic countries concentrate in the coastal zone (Copenhagen, Göteborg, Stockholm, Oulu, Turku, Helsinki, St.Petersburg, Tallinn, Riga, Klaipeda, Kalinigrad, Gdańsk, Szczecin, Rostock). Only in Poland and Germany, are the metropolitan centres of states located far from the Baltic coast, which results from historical as well as natural conditions (more favourable conditions for settlement prevailed in the interior than on the sea, in contrast to Scandinavian and Baltic States.

3. Coastal zone of Baltic Europe

Types of coasts

The types of Baltic coasts are extremely diversified. They depend, on the one hand, on their geological structure and processes taking place in the land part of a shore, and on the other hand, on the sea hydrodynamics in the littoral zone. Seashore is a „lens" in which many features and influences of sea and land environment cumulate. At the same time, it is a zone in which land and sea influences interact. Differences among coasts concern their topography and dynamics, morphological and biological processes (Fig.11). The basic type of Swedish and Finish coasts is a skerry composed of archipelagos of islands extending along coasts. For instance, the archipelago on which Stockholm is situated is composed of 25000 islands. Such coasts offer excellent conditions for water sports, e.g. sailing or angling. The remaining Scandinavian coasts are usually open shores, mostly sandy, more rarely cliffs. Only the shores between Sundsvall and Örnsköldsvik, in central Sweden, can be classified as fjords (HÍkanson, 1993). On the coasts of the southern and eastern Baltic, there prevail accumulation shores, dune shores with beaches, interwoven with erosive sections, mostly cliffs. Bodden low coasts occur in the areas of lagoons: Kuroński, Vistula, Szczecin Lagoon and in northern Germany, as well as in river mouths. They are most popular on the southern Baltic, however, in a scale of the whole area, relatively rare. The picture of the Baltic coasts is supplemented with cliffs abraded in sub-Quaternary rocks, limestone, occasionally crystalline rocks, characteristic of the shores of western Gothland, northern Bornholm and northern Estonia. Most of the beaches of the southern and eastern Baltic, especially connected with dune shores, offer very favourable conditions for summer recreation.

Characteristics of coastal zone and shores of the Baltic

The general description of the coasts of the region was made mainly on the basis of the study „Red List of Marine and Coastal Biotopes and Biotope Complexes of the Baltic Sea, Belt Sea and Kattegat" (1998). Shores will be characterised starting with Denmark and going east round

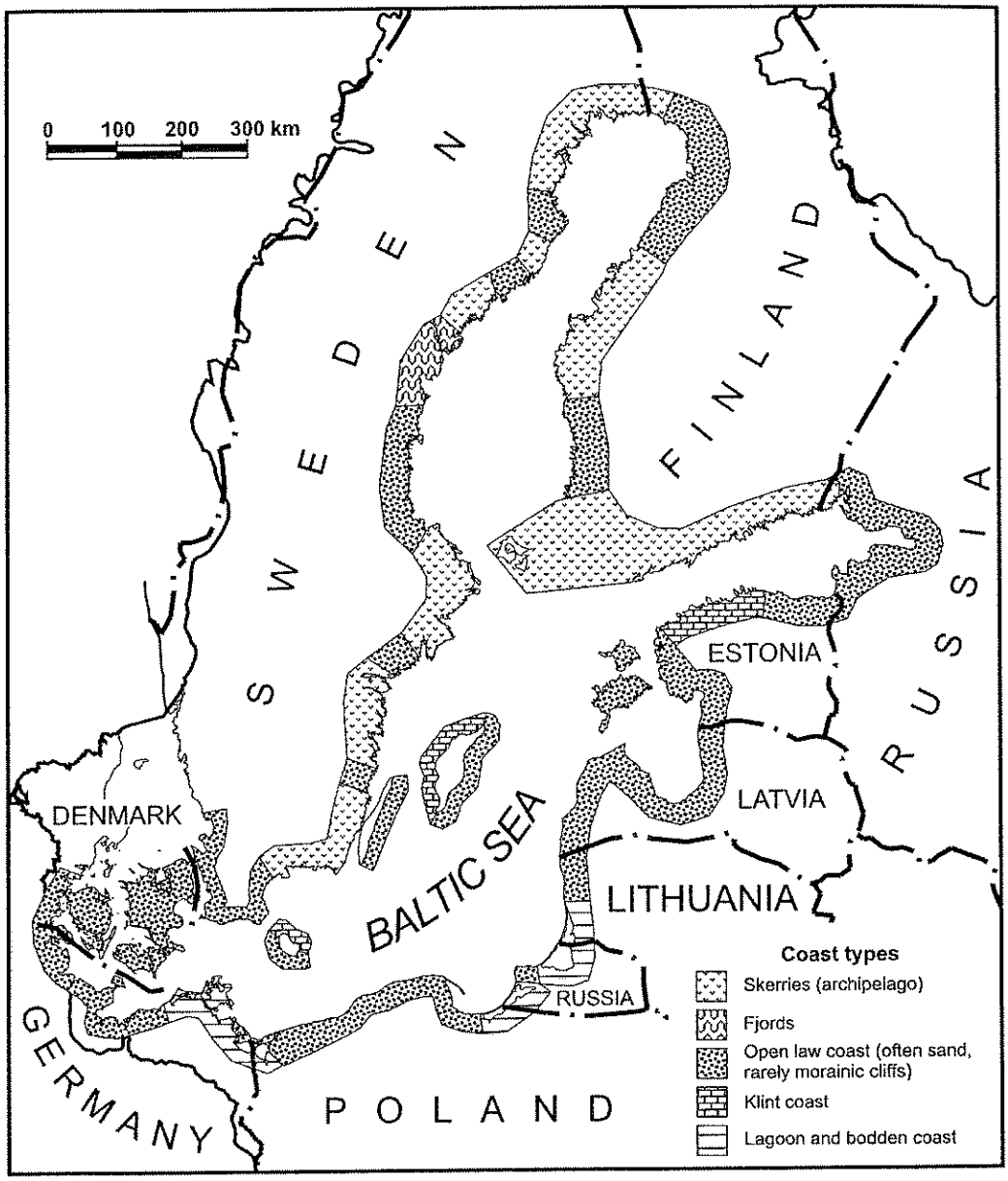

Fig. 11. Basic types of Baltic coasts (after Voipio, 1981)

the Baltic. Danish coasts were mostly shaped in the glacial and postglacial period. Initially a very irregular coastline was straightened by the sea operation. As a result, the diversification of coasts is high. They include cliffs, barrier coasts, low bodden coasts, sandy and gravel spits closing lagoons and bays. Rocky sub-Quaternary surfaces show in the coasts of Bornholm and on the cliffs of Djursland, Mön and Stevns. German coast is a mosaic of moraine cliffs, Holocene areas of eolian accumulation and coastal marches. In Schlezwig-Holstein, cliffs take up 90 km of the coast, of which 1/3 is abraded. In Mecklenburg, there are 128 km of cliffs (36% of coast), out of which 74 km

undergoes strong erosion. Those are morainic cliffs, apart from an 8-kilometre chalk cliff in Rugia. An average abrasion rate is 20-35 cm a year, and its maximal values of 2.1 m a year were noted in Rosenort near Rostock. The remaining shores are mostly dunes and sandbars, out of which the largest ones cover the Darss-Zingst peninsula. In Schlezwig-Holstein, the only dune area with a natural forest is found in the „Wooden Dunes near Noer" nature reserve. Behind sandbars, brackish lakes are formed, in time, evolving into boggy areas. Shores of lagoons in Front Pomerania are covered by salty marshes which developed to 70 cm above the sea level. They used to be intensively meliorated but, in the recent years, attempts have been made to return them natural conditions. Waterlogged coast with meadows occurs also in the Peene estuary into the Pomeranian Bay. It constitutes an excellent habitat for water birds.

Coasts on Polish territory constitute mainly a mosaic of dune and cliff areas with a small fraction of flat waterlogged coasts. Out of over 500 km of coast, over 100 km is taken up by cliff coasts, mainly of a morainic character, built mostly out of clay, sand and boulders. Most of Polish cliffs undergo abrasion of a varied rate ranging between several centimetres and over 1 metre a year. The highest cliffs, occurring on Wolin Island at the German border, have about 90 m of height. There are also numerous dead cliffs, due to natural reasons (rise of land, decrease in sea level) or human made shore development. Accumalation dune coasts cover about $^3/_4$ of the length of Polish coastline. What is especially characteristic are sandbars behind which there occur coastal lakes (e.g. Łebsko, Bukowno, Jamno) or waterlogged plains of organogenic (biogenic) accumulation. Coastal lakes are brackish due to inflows and infiltration of sea waters. In front of dunes, and sometimes under cliffs, there extend sandy beaches of between 10 and 50 m of breadth. Parts of Polish coastline are occupied by low waterlogged shores, sometimes flooded with sea waters (e.g. in the estuary of the Odra, or Reda into the Gdańsk Bay), where conditions are favourable for the development of halophilic vegetation. What is characteristic of the eastern part of Polish coastline are sandbars with lagoons (Pucka Bay and Vistula Lagoon).

Sandy Vistula Sandbar, of about 50 km of length, is continued on the territory of the Kaliningrad district of the Russian Federation, where, apart from that, there is situated half of the length of the 100-kilometre Curonian Sandbar. Within the district, Curonian Sandbar reaches its maximum breadth of 3.8 km, and the height of the dunes formed on it reaches 68 m. Apart from accumulation dune coasts, there occur also morainic cliffs of the Sambia Bay, reaching 55-60 m of height. Similar in character is also Lithuanian coast of about 250 km of length. The eastern shore of the Kuroński Sandbar is almost completely boggy and overgrown with reed. Curonian Sandbar, on the Lithuanian territory, reaches 400 – 2000 m of breadth and is characterised by an occurrence of a whole sequence of eolian accumulation forms, including open moving dunes. As much as 89% of the sandbar is covered by semi-natural forests. Russia is separated from Lithuania by the river Nemunas, in whose delta, there occurs a mosaic of meadow, marsh, lake and forest habitats. This area, covering 200 – 400 km^2 on both sides of the border, is flooded for 10 – 60 days a year. Despite a strong anthropisation of the delta (polders, canals, exploitation of peat), it constitutes an important natural area, through which 10 to 100 million of birds migrate every year. North of Klaipeda, the coastal plain turns into an accumulation dune coast with beaches reaching 100 m of breadth and dunes of 7 – 15 m of height. Among the dunes, there occurs also local bogginess as well as terraced coastal plains formed on a glacial clay ridge of a mean height of 6 – 10 m. A local morainic cliff occurs in Karkle. Near the border with Latvia, the coast is formed by a plain of marine origin composed of several litomorphological levels. Of over 500 km of Latvian coast, almost half are dune coasts, the remaining part are mostly cliffs. A unique coast ecosystem developed near the border with Lithuania, nearby the Nidas marshes, where marsh, beach and dune biotopes contact the sand and peat in the ground. About $^1/_4$ of the length of Latvian coast are abraded shores forming active cliffs of 6 – 15 m of height. Most of them are morainic cliffs, only on the eastern coast of the Riga Bay, there occur

sandstone cliffs. Foredunes and white dunes extend along the 230 km of Latvian coast. Beaches are highly diversified, with a greatest fraction of sandy ones (240 km), a smaller fraction of gravel and stony ones (150 – 180), and the smallest fraction of beaches with boulders which occur only on the Riga Bay (between Mçrsrags and Engure, and between Tuja and Ainaţi, near the border with Estonia). The breadth of beaches varies between 10 and 80 m, though, there occur 100-metre beaches. The degree of diversification of the Estonian coast, similarly to the Finnish and Swedish, is one of the highest on the baltic. The total length of the coastline (with islands) of this small country of 45 thousand square km, is almost 3800 km, of which $^{1}/_{3}$ is the coast of the mainland, and $^{2}/_{3}$ of islands. The length of coastline of the three biggest islands (Saaremaa, Hiiumaa, Muhu), constitutes half of all island shores, and, in terms of size, they take up 93% of the total area of islands. In Estonia, a total number of 1521 island has been counted, yet, 1116 of them is not bigger than 1 ha, hence they are rather complexes of rocks than typical islands. Most of Estonian shores fall steeply to the sea and only in few places, e.g. in western Saaremaa, do they have gentle slopes. On the coast, there occur outcrops of rocks: in the south-west of Devon sandstone, in the west of Silurian limestone, and in the north of clay, sandstone and limestone from Cambrian and Ordovician. At the foot of the Estonian rocky cliffs, there are often formed alluvial fans covered by leafy forests. On shallow bays, there are common boggy areas and coastal meadows, while low sandy dunes (to 2 m) occur sporadically. In some places, sandy and clay beaches are abraded and then clay terraces are formed. Along the coastline, there are also some shallow lakes, many of which have lost contact with the sea relatively recently, in the geological time scale. They are often already strongly bogged or totally transformed into marshes. Due to isostatic uplift of land, these lakes, as well as old beaches, „wander" into land and are successively overgrown by vegetation. In Estonia, they are called alvars. Typical of Estonian coastal zone is also frequent destruction of coastal forests and dunes by boulders and ice blocks of up to 10 m of height, transported by storm waves during spring thaw. This is connected with a small sea depth along these shores. These processes cause also an exchange of sediments on beaches.

The coast of Petersburg district of the Russian Federation has about 550 km of length. Most of these shores have an erosive character. The Southern shores of the Gulf of Finland within Russia have partially a sandbar character. Areas of eolian accumulation and glacier sediments occur here more frequently. On the northern coast and some islands of the gulf, rocks of the ground, mostly Precambrian, are exposed. Coasts of Finland are highly diversified. Southern coasts (on the Gulf of Finland) and western ones (Bothnian Sea) mostly consist of rocks and skerries, showing features typical of large archipelagos. The biggest of them are the Aland islands. On many fragments of the coastline, as a result of abrasion and isostatic uplift, Precambrian ground rocks have been uncovered. The vegetation of skerry coasts is usually poor, composed mainly of a mosaic of lichens and other pioneer species. Especially the shores of the Bothnian Bay (north-western Finland) are shaped under the influence of isostatic uplift, reaching here almost 1 cm a year. New fragments of the coast keep appearing here, constituting habitats for plants and animals. This part of Finnish coasts is more gentle; vast shallow waters eventually turn into meadows, and then overgrow with bushes and trees. The length of Baltic coastline of Sweden is (without islands) over 2200 km, however, including the length of island shores, this value increases about three times. Thus, Sweden has the longest coastline of all Baltic countries. The western coast of the Bothnian Bay is composed in the northern part of an archipelago of sandy and gravel islands, and in the south of a morainic coast with exposed rocks and gravel beaches. The area called Quark, between the Bothnian Bay and Sea, is also characterised by a rocky coast with archipelagos of islands. The coastline of the Bothnian Sea is constituted mainly by steep morainic cliffs falling into a deep coastal zone of the sea. Here occur also the only fjords on the Baltic (e.g. Ĺngermanfjord) and the highest Swedish island (Mjältön, 236 m over the sea level). In the south of this part of Swedish coast, the shore is lower and less steep, and islands and skerries

are less numerous. Gravel and stony beaches are common, while sandy ones are rare. On the coast of the so-called Archipelago Sea, situated in the area of the Aland islands, there occur fjord-like bays cutting into land, as well as lacustrines, rocky beaches, island and skerries. The coast of the Baltic Proper is characterised by a concentration of archipelagos in the northern part. There prevail here long fjord-like bays, while in the south, in Kalmarsund, there prevails morainic coast. In the south of Sweden, common are sandy beaches, now and again broken by morainic shores. On Oland and Gothland, there occur limestone cliffs. In Sund and Kattegat common are sandy beaches; in the south, there appear rocky cliffs; and on the island of Ven in central Sund, morainic cliffs. Swedish coast of Kattegatt is a mosaic of sandy and morainic beaches, broken by rocky cliffs. In the northern part of Kattegatt, there occur archipelagos extending into Skagerrak.

This cursory description of the coasts of the Baltic was intended to emphasise their extreme diversification. It shapes a high natural potential of the shores, which is, however, strongly endangered by a whole complex of human factors, of which the most important are: agriculture, industry and urbanisation, and what goes with them: eutrophication of waters, recreation, overfishing of fisheries and exploitation of the sea bed. As it was calculated, $^1/_4$ of land biotopes in the Baltic coastal zone and as much as 43% of biotopes of coastal lakes are highly endangered. Further 48 and 43% of biotopes of these types of environment respectively is endangered to a bit smaller degree but also significantly. Only near 1/5 of shores is not endangered (Red List of...., 1998). Hence, in order to save the coastal zone for the use of future generations, it is necessary to deeply understand its geographical environment, both in terms of resources and natural amenities, as well as of the sensitivity of the environment to various forms of man's pressure.

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