Conclusions

Vladimir A. Gritsenko, Vadim V. Sivkov, Artem V. Yurov, and Andrey G. Kostianoy

Abstract This concluding chapter briefly describes the results of the research presented in the book, which has 22 chapters including the present Conclusions and Introduction written by volume editors of the book. This book entitled "Terrestrial and Inland Water Environment of the Kaliningrad Region" is the first one in the series of four volumes which will be published in the coming years under the general title "Environmental Studies in the Kaliningrad Region." This first volume deals with physicogeographical and bio-geo-ecological conditions and environmental problems of the Kaliningrad Region focusing on terrestrial and inland water environment. This book is addressed to the specialists working in various fields of environmental problems and ecology, water resources and management, land reclamation and agriculture, and international cooperation in the Baltic Sea Region.

Keywords Bioecology, Geoecology, Inland water, Kaliningrad Region, Terrestrial environment, Southeastern Baltic Sea Region

V.A. Gritsenko (✉)
Shirshov Institute of Oceanology Russian Academy of Sciences, Immanuel Kant Baltic Federal University, Kaliningrad, Russia
e-mail: gritsenko_vl@mail.ru

V.V. Sivkov
Shirshov Institute of Oceanology Russian Academy of Sciences, Immanuel Kant Baltic Federal University, Moscow, Russia
e-mail: sivkov@kaliningrad.ru

A.V. Yurov
Immanuel Kant Baltic Federal University, Kaliningrad, Russia
e-mail: AIUrov@kantiana.ru

A.G. Kostianoy
Shirshov Institute of Oceanology Russian Academy of Sciences, Moscow, Russia
e-mail: kostianoy@gmail.com

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The chapters presented in this book are devoted to various aspects of the Kaliningrad Region environment, which allows readers to make their generalized opinion on environmental features and problems. Some chapters are compilations and generalizations of the works published mainly in Russian editions which are hardly accessible to western scientists, while others contain unpublished data and custom approaches, sometimes debatable.

The main results and aspects of the entire book are:

1. Two structural stages are distinguished in the geological section of the Kaliningrad Region: the lower one is composed of gneisses, crystalline schists, and amphibolites of the *Archaean-Proterozoic age* (platform basement), and the upper one is the *Phanerozoic platform* cover, represented by poorly dislocated and slightly metamorphosed sediments. The Kaliningrad Region is rich in diverse mineral resources. Actually all economic minerals discovered within Kaliningrad Region are spatially and genetically associated with the deposits of the platform cover. They are represented by oil, drinking and mineral underground water, amber, building materials, which are actively exploited [1]. Potassium-magnesium salts, numerous occurrences of which are known here, are of the greatest economic interest. The main treasure of the region is the Baltic amber, which has been the research object for almost 150 years. One might assume that after so many years of research, there are only a few unresolved issues of fundamental importance. Publications in recent years still prove the opposite. Fundamental issues, such as the resin source, the formation time of the Baltic amber, and the position and period of the legendary "amber forest," are still a matter of debate. The updated taxonomic composition of amber inclusions was published for the first time in English [2]. The data was obtained as a result of studying the primary material from the quarries of the Kaliningrad Amber Combine. Unfortunately, comprehensive studies of amber in Russia have not been carried out since the 1970s. The existence of the world's largest amber deposit still allows us to hope for such research [2].
2. The lithogenic basis of the Kaliningrad Region landscapes is the Quaternary deposits. The surface of pre-Quaternary deposits in the region is characterized by complex relief, including denudation uplands ("remnants"). Erosion-denudation pre-Quaternary relief was transformed by glacial and fluvioglacial processes. The incision system exists in the northern and western parts of the Sambia Peninsula, continuing on the bottom of the Baltic Sea. Along with the uplifts and depressions that have been inherited from the pre-Quaternary surface, there are inversion forms of the modern relief [3]. At the same time, there are some geological facts, proving the fact that the main strata of the Pleistocene sediments are not continental (glacial, water-glacial, and separating alluvial facies), but were accumulated in the sea with the participation of icebergs and fast ice. According to the author [4], the Pleistocene glacier was so thin and slow-moving that it produced virtually no damage, so the tectonic factor had much more significant effect on the relief than the glacier. Even

some doubts about the existence of a blanket Pleistocene glaciation within the Kaliningrad Region occurred.

3. The modern appearance of the Kaliningrad Region landscapes shares similarities with the flat European landscapes, which lies within the accumulation zone of the last Quaternary glaciation. Based on the features of Quaternary sediments and relief, various landscapes were distinguished: landscapes of glacial origin, landscapes of fluvial origin, and landscapes of marine and lagoon origin. They relatively are divided into plains of the main moraine, finely moraine elevations, lacustrine-glacial plains, seaside landscapes, ancient delta lowlands, valley landscapes, and ancient alluvial plains undergoing aeolian processing [5].

   The soil and vegetation cover, evolved in the postglacial period from tundra to forest, underwent significant changes in the last millennium due to active human activity. On the most part of the territory, the lithogenic base was formed in the Pleistocene period. Some of the younger landscape complexes (marsh landscapes, river terraces) were formed in the Holocene. The youngest dynamic landscapes – modern floodplains of rivers and seashores – are still in genesis; channel and marine accumulation and abrasion processes are in action. Soils and vegetation cover have passed several stages of development along with climatic trends [5].

   Conducted recently in the region, targeted palynological studies for the first time made it possible to clarify the main pattern of forest and peatland formation in the Kaliningrad Region during Holocene [6]. According to studied pollen spectra, the territory of the Kaliningrad Province doesn't form an entire palaeoenvironmental district and is to be divided, in this respect, onto two different parts, each of those could be united with the neighboring regions of Poland and Lithuania. A boundary between these two identified palynological districts is stretched along the rivers Deima, Pregolya, and Pissa. They are palynologically similar in the Early and the Middle Holocene. The differences between them appeared in the Late Holocene when conifers became dominating in the northeastern part of the region having gradually replaced communities of the "nemoral complex." The latter remained common in the south and especially in the southwestern parts of the Kaliningrad Region where they were key components of forest vegetation in the Late Holocene together with *Carpinus* and *Fagus*. Having been affected by human activity, vegetation structure suffered an essential change on the territory of Pregolya glaciolacustrine plain since the beginning of the seventeenth century (400 BP), while in Lower Neman Lowland, such alterations are recorded only since the middle of the eighteenth century (250 years BP), apparently due to its hard approachability that restricted human impact onto pristine forests in this area. Intensive land use and clear cutting resulted into a large reduction of broad-leaved and spruce-broad-leaved forests in the area and, simultaneously, caused an increase of agricultural areas and synanthropic habitats as well as secondary pine and birch stands in both study landscapes [6].

The analysis of the modern natural complexes stability on the Curonian and Vistula Spits has shown some similarities. In particular, the distribution of potential sustainability stages – the "weakly stable" landscapes – is about 1/3 in area expression. The remaining categories show a certain variability, which is primarily due to the structural features of natural complexes of spits. There are 19% more natural complexes classified as "stable" on the Curonian Spit than on the Vistula Spit, which is owing to the structure of the deflationary-accumulative plain. Unstable natural complexes are 18% more on the Vistula Spit, which can be mainly associated with a large number of complexly oriented dune ridges; highly unstable are about 11% more on the Curonian Spit, which is due, first of all, to the presence of not fixed or weakly fixed dune arrays. The main trend of the natural complexes digression of spits is the leading role of the first stage (55% and 52% of the Curonian and Vistula Spit areas, respectively). The highest level of digression is more common for coastal zone of the spits (beach, seaside dune ridge complex) [7].

4. The main factors of landscape genesis at the Kaliningrad Region are land use and settlement systems. The modern system of settlement is to a certain extent formed by landscape conditions, but also, in many cases, settlement system is associated with other factors – primarily political, socioeconomic, and demographic. The greatest contrast in the settlement structure in comparison with prewar time is possessed by three natural regions: the ancient Neman Delta, an array of ancient alluvial sands of the Neman and Sheshupe interfluvial areas, and end-moraine hills [5].

   At current time, the landscapes of the Kaliningrad Region represent a system of territorial complexes that vary in transformation degree and are at different stages of their development. The modern settlement system of the Kaliningrad Region is determined by their system before 1945, which was strongly connected with the hydrographic network and landscape structure of the territory. After World War II, the new administrative division occurred, and the transport network of the region has changed, resulting in railway network reduction. Now the region is less populated than before the war, and the vast majority of the present population is concentrated in the regional center and around it. After World War II and the restructuring in the 1990s, the modern land use of the Kaliningrad Region is characterized by agriculture development, which reflects use of previously abandoned lands for agricultural needs. At the same time, the restorative succession also takes place in the region. Many of such territories have become sort of "natural reserves," which affects the biodiversity of the territory. The main feature of the region is the landscape mosaic pattern. The state borders of the Kaliningrad Region are particularly important for modern landscape genesis [8].

   Cities of the Kaliningrad Region include two or more types of natural landscapes. Most of the cities in the region are located on the riverbanks: the Pregolya River and its tributaries. Features of inner landscapes define not only the planning features of cities but also the development of some negative processes. Thus, the coastal position of cities determines the restriction of their development by the seashore, as well as the risk of coast destruction. Cities in the lower course of the Pregolya River experience floods due to wind surges. The cities' transport system is the main factor determining the functionality of their modern spatial structure [9].

5. The river network is well developed and very dense [10]. The watercourses are classified as plain streams and belong to the Baltic Sea catchment area. Over 95% of watercourses are "small," characterized by a large short-term variability of hydrological and hydrochemical parameters comparable to the seasonal changes. Much of the Kaliningrad Region's territory is occupied by the Pregolya River basin, as well as by the basins of its several major tributaries.

   As a consequence of small slopes, the estuarine and adjacent parts of the rivers are in the backwater of the receiving water bodies and very dependent on the wind-driven surges. Most small rivers are channelized, and the water pumped out from the polder lands is dumped therein. Almost all the rivers in the Neman Delta and at the Curonian Lagoon coast are connected with channels and form the united drainage system. Hydrometric parameters fluctuate significantly and are closely associated with both the weather conditions and the aggregate natural peculiarities of the drained area. Ice conditions are very unstable, and the formation of two-layer ice is possible.

   According to the chemical composition of water, the studied streams belong to bicarbonate class, calcium group, mainly of the first water type [HCO_3- $<$ (Ca^{2+} + Mg^{2+})]. Pursuant to the total hardness value, the water is "moderately hard." Oxygen conditions, the content of organic matter, and nutrients in most watercourses do not comply with maximum concentration limits for fishery water bodies, especially during low-water periods.

   The Neman River enters the Kaliningrad Region already quite polluted, and the major watercourses in the delta plain (the Matrosovka Canal, the Nemonin River) determine the load on the Curonian Lagoon. The main source of nutrient load on the Vistula Lagoon is the Pregolya River. The Pregolya River is exposed to intensive pollution. The condition of some small rivers is indicative of their catastrophic contamination. Small rivers emptying directly into the Baltic Sea build up a load on the sea mostly only during wet periods.

   Transboundary rivers arrive in the Kaliningrad Region already quite polluted. The proportion of nutrient runoff received from the territory of the neighboring states ranges from 10 to 80% or more of the total nutrient runoff of the transboundary watercourses discharged from the Kaliningrad Region. The amount of nitrite nitrogen, mineral phosphorus, and total iron discharged into the Curonian Lagoon by the Neman River differs little from what is incoming from the adjacent territories [10].

6. The Pregolya River runoff from the area of its catchment is directed to two receiving reservoirs – the Vistula Lagoon and the Curonian Lagoon. The watershed of the Pregolya River was divided into 42 interconnected subbasins in the model installation, the allocation of which was carried out taking into account major tributaries, hydrological stations, as well as the existing state border between the segments of catchment areas in Poland and Russia. The

calculation of the volume of water flow rate from the Pregolya River catchment was made by tools of numerical simulation [11]. The flows to the Vistula and Curonian Lagoons constitute 1.96 and 1.2 km^3/year, respectively, which in total give 3.16 km^3/year from the Pregolya River catchment toward the Baltic Sea through both lagoons. In general, 1.46 km^3 of water per year comes to the Kaliningrad Region from the territory of watershed of the Pregolya River in the neighboring countries (Poland and Lithuania). In addition, next 1.26 km^3 more of water is formed in the catchment before the division of the Pregolya River into arms. Each individual subbasin of the Pregolya River major tributaries provides through outlet section at the confluence: the Lyna-Lava River, 1.37 km^3/year; the Wengorapa-Angrapa River, 0.69 km^3/year; the Instruch River, 0.3 km^3/year; and the Golubaya River, 0.14 km^3/year. Thus, out of the annual average of 760 mm of precipitation, 530 mm comes back to the atmosphere by means of evaporation and 230 mm flows with surface runoff [11].

7. More than 100 species of zooplankton are found only in the largest water bodies of region such as the Neman River and Lake Vishtynetskoe (Vištytis) [12]. In other water bodies, diversity of zooplankton is lower (60–80 species). Abundance and biomass of zooplankton in lakes are significantly higher than in rivers. Small lakes had the highest number of indicators and weights. In the Lake Vishtynetskoe, these indices are 2.5–3 times lower. With the increase in river flow, the quantity of zooplankton tends to be zero. The number and biomass in almost all the groups of water bodies are dominated by copepods. The exception is the Neman River, where this group is inferior in numbers to rotifers and in weight to Cladocera.

   In the zoobenthos there were identified 450 species [12]. The most diverse zoobenthos is of the Neman River and fleeting rivers. A smaller variety of zoobenthos is characteristic for small lakes. A large number of zoobenthos was observed at the Neman River, but 80% of it was shellfish. The high number of organism is also noted in slow rivers shorter at length. The highest biomass of zoobenthos is registered in the Neman River. This rate is significantly lower than in small rivers and Lake Vishtynetskoe. In general, with increasing flow rate of the river the biomass of benthos reduce on 15%. Zoobenthos biomass is also low in small lakes. The biomass basis in all groups of water bodies is consisted of shellfish.

8. Comparing the data for 1982–1998 shows a gradual depletion of the river plankton and benthos communities in the Pregolya River by 1995, which is explained by chemical pollution and anthropogenic eutrophication [13]. At the same time, since 1997, there has been a sharp increase in the quantitative characteristics and qualitative diversity of communities. Analysis of interannual changes in biodiversity, abundance, and biomass of components of the river biota in 2000–2011 shows improvement of environmental situation in comparison with the 1990s. The boundaries of biotic communities with the dominance of filter-feeding mollusk and rooted aquatic vegetation are gradually moved downstream, with the appearance of benthic species which did not occur in the lower reaches in the 1980s and 1990s. Currently, despite the fact that

contamination level of the Pregolya River is still high, the biota of the river in the lower reaches is in the best condition ever recorded in the scientific press [13].

9. During the vegetation period, the structure of phytoplankton of the small rivers of the Pregolya River system is mainly determined by diatoms—benthic forms and fouling species [14]. The phytoplankton structure in the Pissa and Angrapa rivers is largely determined by the fact that they flow from the Vyshtynetskoye and Mamry lakes, respectively. Phytocenosis of these rivers is characterized by higher taxonomic diversity, domination of cyanobacteria in terms of numbers and biomass, in some cases, and the highest phytoplankton productivity. The Pregolya River is more susceptible to the influence of the Angrapa River, whose water flow rate is noticeably higher than the second tributary—the Instruch River. In some watercourses of the second order, the mass development of *Euglenids* was noted, which indicated the contamination of waters with organic substances [14].

   In the river coasts, the dominant species of vegetation are *P. australis*, *S. fragilis*, *S. alba*, *A. glutinosa*, *S. sagittifolia*, *S. sylvaticus*, and *P. arundinacea*, and frequently occurring are *C. acuta*, *R. amphibia*, *S. erectum*, and *B. umbellatus*. Aquatic vegetation is represented predominantly by communities with *P. pectinatus*, *P. nodosus*, *S. emersus*, *N. lutea*, and *M. spicatum*. Data on the growth of rare sensitive algal species in the region (*H. rivularis*, *A. chalybaea*) and findings of *C. elegans*, *D. glomerata*, *V. frigida*, *V. bursata*, and *V. canalicularis* are published for the very first time [15]. In the Krasnaya River, *B. trichophyllum* was found, recorded in the Red Book of the Kaliningrad Region. A new habitat for *E. telmateia*, a vanishing species, also listed in the Red Book of the Kaliningrad Region, has been identified [15].

10. From the point of view of nature management and protection, underground waters, which are the main source of household and drinking water supply in the Kaliningrad Region, are essential [16]. Fresh underground waters of the Kaliningrad Region are the main source of the regional water supply: 53% of people in the cities and 99% in rural are supplied with water from underground sources. Water is provided from the Upper Cretaceous, Paleogene, and Quaternary aquifers: the Moscow-Valdai (formerly known as mid-Russian-Valdai) and Oka-Dnieper (previously Lithuanian-Central Russian) intermoraine aquifers. The quaternary aquifers with 63% of water consumption are of the aquifers with the highest operational importance. The highest anthropogenic burden falls on the upper intermoraine (the Moscow-Valdai, mid-Pleistocene) aquifer, which is widespread in the southern part of the region. The aquifer distribution area is more than 9,300 km^2 (70% of the regional territory).

    The study of the features of the geological structure, relief, and hydrogeological conditions allowed us to typify the conditions for the protection of groundwaters of the upper intermoraine horizon. Since the protection of groundwater is understood as the degree of their isolation from pollution sources, for the first classification level of protection conditions, the nature of the overlapping and underlying aquifer of sediments was adopted. The most dangerous is a combination of security conditions when the upper water-resistant horizon is absent and a hydraulically uniform aquifer of groundwater and pressure water is formed [16].

According to the data on the distribution of the upper aquiclude reduced capacity values, a map of isochrones of pollutant penetration from the surface to the Moscow-Valdai aquifer was designed [16]. It should be noted that this map does not display the exact time intervals, but their approximate values allow us to estimate the rate of pollutant infiltration. The disintegration time of pollutants varies widely. Such pollutants as solutions of some mineral salts (chlorides, sulfates, nitrates, etc.) or long-lived radioactive isotopes are very persistent and very slowly disintegrate. Other pollutants are also quite resistant but with a limited lifetime. A large group of pesticides is characterized with a large interval of disintegration time – from several months to 5–10 years.

The joint analysis of various environmental protection factors in relation to the Moscow-Valdai aquifer in the Kaliningrad Region identified three categories of protection of groundwater. The groundwater of an area of 1,700 km^2 (18% of the area of the aquifer) is considered unprotected. The territories which are characterized as partly protected occupy 3,500 km^2 (38% of the area of the aquifer). The 44% of the territory (4,100 km^2) of the Moscow-Valdai aquifer distribution is characterized as protected from contamination [16].

Potential hazards are located in the vicinity or directly on unprotected areas, on mineral deposit developments, municipal solid waste landfills, and stocks of mineral and organic fertilizers. The hydraulic connection between the rivers and the waters of the Moscow-Valdai aquifer is manifested particularly actively in the areas with weak protection, and it threatens with the penetration of pollutants from the rivers Pregolya, Lava, Instruch, Sheshupe, Neman, and Deima. Particular attention should be focused on the intakes which receive the water of the Moscow-Valdai aquifer and located in the areas characterized as unprotected or partly protected. The greatest potential hazard to the natural systems and groundwater in particular is created by the oil fields. One-third of the region's oil fields are located in the areas where the groundwater of the studied aquifer is not protected, and it increases the risk of contamination. Developments of construction material deposits are less dangerous compared to oil extraction, which is due to the relative geochemical inertness of these minerals. However, removing the overburden rock and subsequently operating the useful clay formation reduce the capacity of impermeable clays rocks overlying the aquifer [16].

11. The Lake Vishtynetskoe (Vištytis) is a unique transboundary reservoir in terms of origin, hydrological features, productivity of all trophic levels, and composition of the ichthyofaunal [17]. It is a deep pond of oligotrophic type with clear, transparent water. According to hydrochemical and hydrobiological indicators, the trophic status of the Lake Vishtynetskoe remains at a stable level. At the same time, for individual zones of the lake on both sides of the border, there are signs of mesotrophy, in some cases eutrophic. The fishery importance of the lake is determined by the existing traditional fish fishery and developed amateur fishing. The lake is also directly used for touristic purposes.

The main reasons for the catch decline after the 1980s are non-ecological and biological, and the general deterioration of socioeconomic conditions in the country and, in general, is typical for the fishing industry in Russia, as well as the acquisition of the status of a transboundary basin by Lake Vishtynetskoe. The conclusion is that the achieved level of recreational load should be fixed and not be increased in the future, and rational use of fish stocks in the lake should be coordinated with Lithuania [17].

The processes of beach disruption are connected with both natural phenomena (currents, high water level, intensive wave action) and human activities. The following kinds of influence can be identified on the part of tourism and recreation, placed in the order of decreasing degree of their impact on beach degradation and coast disruption: the construction of temporary objects (cafes, camp sites, etc.) immediately on the beach or within the dunes-palve; driving jeeps on the beach or within the dunes-palve, laying new paths through dunes; and also beach trampling. This requires additional shore protection. Neglecting abrasion processes can also cause shore sloughing which jeopardizes the buildings. Consequently, the natural carrying capacity of the available beaches should be considered when planning and constructing new tourism and recreation complexes. The good news are that the Government of the Russian Federation within the Federal Target Programme "The Development of Domestic and Inbound Tourism in the Russian Federation (2011–2018)" allocated money for shore protection works in Svetlogorsk. However, this will only cover 4.5 km out of the total 140 km of beaches. For over 40 km of sand beaches, which are very popular in the Kaliningrad Region especially during the summer season, the issue is still urgent and requires a comprehensive solution and joining efforts of federal and regional authorities [18].

Specially protected natural areas (SPNA) play an important role in biodiversity and landscape preserving in the Kaliningrad Region. However, further development of the SPNA in the region has to fight several problems. In particular, Kaliningrad should improve the regional environmental management and control, increase the level of supply and technical support for protected areas, and deepen the system of international and, above all, cross-border cooperation in the environmental sphere. International collaboration in the environmental sphere should be focused on sustainable development of the entire Baltic Region and the Kaliningrad Region in particular.

The Kaliningrad region is valuable for the whole Europe in many regards owing to its remarkable landscapes, cultural, historical, and recreational places of interest. Several specially protected natural areas in the Kaliningrad Region are located along the borders of Lithuania and Poland (the Curonian Spit National Park, the Vishtynetsky Nature Park, the Dyunny Partial Reserve); they play an important role in the system of long-term cross-border cooperation, especially the national park "Curonian Spit," which was included in the list of World Natural Heritage by UNESCO along with the Lithuanian National Park "Kurshu Neria." The cross-border SPNA compose a system of specially protected natural areas under different national jurisdictions that share the same ecosystem and are capable to ensure the preservation of ecological balance at a level that gives the maximum ecological and socio-economic effect. The cross-boundary specially protected natural areas are an integral part of the European strategy for the conservation of biological and landscape diversity.

The leading direction for the regional environmental compliance at the current time is improving SPNA system not only by involving new territories but also by improving the law protecting the status of existing areas. For example, it makes sense to give the status of specially protected nature areas to the Vistula (Baltic) Spit, the area around the Balga Castle with the Vistula Lagoon, to the unique intact bog in the Pravdinsky District, to the areas along the Curonian Lagoon in the Slavsky and Polessky Districts, and so on. At the same time, even more important is to improve the system of environmental protection activities and to make the control over economic entities within existing protected areas stronger in order to encourage initiatives with positive ecological effect [19].

And, finally, another proposal in the context of environmental activities in the region is based on the results of macrophyte study in the reservoirs of the region; nine species were proposed to be granted the status of "rare species," in particular *Batrachium eradicatum* (Laest.) Fries, *B. fluitans* (Lam.) Wimm., *B. trichophyllum* (Chaix) Bosch, *Callitriche hermaphroditica* L., *Ceratophyllum submersum* L., *Zannichellia palustris* L., *Z. major* Boenn. ex Reichenb., *Potamogeton acutifolius* Link, and *P. friesii* Rupr [20].

This book presents a brief systematization and description of the knowledge on the terrestrial environment and inland water resources in the Kaliningrad Region. The publication is based on observational data, scientific literature mainly published in Russian editions, and long-standing experience of authors of the chapters in the scientific research on the Kaliningrad Region environment. This book is addressed to the specialists working in various fields of environmental problems and ecology, water resources and management, land reclamation and agriculture, and international cooperation in the Baltic Sea Region. This is the first book in the series of four volumes, which will be published in the coming years under the general title "Environmental Studies in the Kaliningrad Region." The other three volumes will be devoted to physical oceanography, geoecology, and bioecology of the Southeastern Baltic Sea.

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