Features of the restoration of biological communities after the technogenic transformation of the estuary area of the Pregolya River (the Baltic Sea basin)

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Abstract. The structural parameters of plankton, benthos and macrophytes after large-scale technogenic transformation of the mouth area of the river were studied. Pregolya. A decrease in the species richness and area of growth of macrophytes, a simplification of the structure of communities was noted. The renewal of plant communities in the places of their origin was recorded, primarily due to the species resistant to biogenic pollution. A decrease in the abundance of submerged species with wide leaves was revealed, which is an indicator of an increase in water turbidity. The species were found in the phyto- and zooplankton community, living in conditions of an increased content of nutrients and suspended matter. There was no significant decrease in the species diversity of summer plankton and benthos, and the quantitative indicators are comparable with the data before the work. A feature of the restoration of the zooplankton and benthic community was the appearance of brackish-water species in the river branches, which were not previously recorded there, incl. alien species of mollusks and polychaetes.

1. Introduction
The Pregolya River flows through almost the entire Kaliningrad region. Estuarine water system, including the mouth of the river Pregolya and a partially isolated part of the Vistula Lagoon - the Kaliningrad Sea Canal, is characterized by mixing of fresh and sea waters, vertical and horizontal salinity gradients, and surges [1]. The mouth area of the river, where the port city of Kaliningrad is located, is subject to technogenic transformation and is under constant anthropogenic pressure. Work is regularly carried out to deepen the bottom, and the coastal zone along its considerable length has been transformed into industrial zones.

In the period from 2014-2018 a large-scale technogenic transformation of the coastal zone and river bed in Kaliningrad was carried out. Between the branches of the Novaya and Staraya Pregolya rivers on the swampy floodplain Oktyabr'skij Island (figure 1), the consolidation of water-saturated soils was carried out, the reconstruction and construction of bridges, embankments, filling and concreting of the river banks were carried out. The profile of the channels on the branches of the river was significantly deepened and changed, which changed the configuration of the bottom and the granulometric composition of the soil lining it, especially in the medial of the river. The areas of the coastal biotope have decreased, and coastal aquatic vegetation has been destroyed. The coastal zones of the branches of the Pregolya River were subjected to the greatest transformation.
The aim of this work is to assess the current state and identify the features of the restoration of communities of plankton, benthos, and macrophytes in the mouth area of the Pregolya River after the technogenic transformation of its channel.

2. Materials and methods

The material was sampled in the mouth area of the Pregolya river, about 17 km long at 10 sections (20 stations) located on the Novaya (N. Pregolya) and Staraya Pregolya (S. Pregolya) branches, after the confluence of the branches and at the mouth (figure 1) during June 25-26 and partially on August 12 and 19, 2019.

The selection of hydro chemical and hydro biological samples, their office processing were carried out by standard methods [1-5]. Phytoplankton were sampled from the surface horizon; zooplankton - in the medial part of the river with a Jedi net (d = 14 cm, mesh 100 μm) totally from the bottom to the surface, in the coastal part (ripali) 50 liters of water were filtered through the Apstein net (mesh 100 μm). To take samples of zoo benthos, a Van Veen bottom grab was used (S = 0.023 m²). Macrophytes were studied in more detail in 2013-2014, 2018-2020 method of trial plots. In total, 40 geobotanical sites have been laid, more than 76 descriptions have been completed in accordance with the methods [4-5]. To assess the trophic status of a water body, we used the indices of river macrophytes: MIR [6-7], IBMR [8-9], MTR [10].

3. Results

In June 2019, the water temperature varied in the surface horizon in the range of 24.5-26.0 °С, in the bottom - 20.1-24.0 °С. The water transparency varied from 1.0 to 1.8 m. The bottom salinity in the branches did not exceed 1.5 PSU, and in the area closer to the mouth it reached 5.6 PSU (figure 2). The reason for this was the surge phenomena that occur during westerly winds, which occur not only in autumn, but also in summer. The values of nitrate nitrogen in the surface horizon, which affects the development of aquatic flora, ranged from 0.045 to 0.38 mg/dm³.

Some changes in the composition and structure of communities of plankton, benthos, and aquatic vegetation were noted in comparison with the period before the start of large-scale construction, which we described earlier [1].

Phytoplankton S. and N. Pregolya comprised 66 taxa of microalgae with a rank lower than the genus, the greatest species richness were distinguished by green ones with conjugates (41%) and diatoms (29% of the total number of taxa). The contribution of each of the groups - cyan bacteria, cryptophytic, dinophytic, golden, yellow-green and euglena - did not exceed 7%.

In both branches in the ripal along the course, an increase in the α-diversity of phytoplankton was noted due to an increase in the number of species of diatoms and green algae, which, in turn, was influenced by the weak current and the presence of aquatic plant communities in the coastal zone.

June 2019 compared to June of the late 1990s, in phytoplankton r. N. Pregolya revealed a decrease in the average α-diversity by 1.7 times [1]. Cryptophyte algae dominated in phytoplankton in S.
Pregolya, and green algae in N. Pregolya. The biomass was mainly formed by the same groups, as well as dinoflagellates and diatoms.

The total number of phytoplankton was higher in N. Pregolya, and the biomass in S. Pregolya due to the vegetation of cryptophyte rivers. Cryptomonas (table 1). Similar differences were observed in June at the end of the 1990s [1].

### Table 1. The quantitative characteristics of phytoplankton of the Pregolya River, June 2019.

| Indicator                        | Old Pregolya Minimum - Maximum | New Pregolya Minimum - Maximum |
|----------------------------------|--------------------------------|--------------------------------|
| Number of taxa/sample            | 32 ± 5                         | 27 ± 4                         |
| Minimum                         | 27 - 37                        | 20 - 35                        |
| Number, mln. cells/l            | 3.61 ± 0.55                    | 4.83 ± 1.16                    |
| Maximum                         | 3.06 - 4.15                    | 2.54 - 6.33                    |
| Biomass, g/m³                   | 1.65 ± 0.01                    | 0.60 ± 0.04                    |
|                                 | 1.64 - 1.66                    | 0.56 - 0.67                    |

Note:* Mean ± standard error.

Zooplankton was represented by 65 species and taxa of a larger order: Rotifera - 25, Copepoda - 12, Cladocera - 28. Bivalvia larvae were abundant in the meroplankton. The total number of zooplankton in the ripal varied from 17.6 to 762, and in the medial from 34 to 292 thousand individuals * m⁻³. The biomass of zooplankton in the riparian zone was 278-1870, and in the medial it was 254-5647 mg * m⁻³. Euryhaline planktonic crustaceans Eurythemora affinis, which live in large quantities in the Vistula Lagoon, were recorded in N. Pregolya (figure 2), where they had not previously been found in summer [1]. During the study period, a statistically significant positive relationship between the biomass of E. affinis and the bottom water salinity was found (Spearman’s R = 0.95, p = 0.000).

![Figure 2](image-url) Distribution of Eurythemora affinis biomass (blue columns, mg*m⁻³) and bottom salinity (red numbers, PSU) according to the longitudinal profile of the Pregolya River, June 2019.

The species composition of macrophytes within the city along the concrete embankments was 49 plant species. It was noted that filamentous algae (r. Cladophora, Oedogonium, Rhizoclonium riparium) and duckweed (Lemna minor, L. gibba, Spirodella polyrhiza) significantly increased their participation in communities. The projective cover of duckweed at different stations was 30-60%. Reed and egg-lily communities, as well as broadleaf pondweed (Potamogeton lucens, P. perfoliatus) in the city center, according to 2019 data, have disappeared or their projective cover has decreased. P. lucens in 2020 was mainly recorded closer to the river channel, where it develops more successfully due to the lower abundance of duckweed. The frequency of occurrence of the species in urban areas is 23.6%, the average projective cover in communities is only 9%. The process of restoration of
abundance has been noted for *Sagittaria sagittifolia* and *Nuphar lutea*, the latter blooming and bearing fruit. The abundance of arrowheads in communities in 2020 ranged from 1 to 5%, the frequency of occurrence was 27.7%. Plants are mostly in a vegetative state, do not bloom. Communities with the participation of *Nymphaea candida* recovered to a lesser extent. In both cases, in 2020, not only the number of flowering individuals and their projective cover increased, but also juvenile plants appeared. *Scirpus lacustris* is the slowest to recover. The highest occurrence within the city is in two species - *Ceratophyllum demersum* (65.3%) and *N. lutea* (70.8%), which indicates the eutrophic nature of the watercourse.

Calculation of various macrophyte indices for rivers (MIR, IBMR MTR) confirms this observation. Compared to the data before the hydro technical works, the trophicity of water in the river within the city limits increased slightly (MTR, IBMR), and according to the MIR index, there is a small degree of degradation of river vegetation for the affected area from the hydraulic works carried out along the Oktyabr'skij and Kant islands (Table 2).

| Year       | MIR 2013-2014 | IBMR 2013-2014 | MTR 2013-2014 | IBMR 2020 | MTR 2020 |
|------------|---------------|----------------|---------------|-----------|----------|
| Oktyabrskij Island | 35.8         | 33.9           | 7.6           | 7.05      | 26.6     | 24       |
| Kant Island | 35.4          | 31.5           | 6.5           | 6.6       | 29.8     | 28.6     |

In the community of benthic invertebrates of the river, noticeable structural changes associated with the constant or episodic presence of brackish-water invading species - the mollusk *Rangia cuneata* (Bivalvia: Mactridae) and the polychaetes *Marenzeleria neglecta* and *Laonome cf. calida*. The general spatial patterns of distribution of benthic organisms in the river channel remained the same: quantitative indicators increase from the mouth upstream, the largest number of species and high quantitative indicators are characteristic of coastal biotopes, the type of benthic communities changes from oligochaete-chironomid to zebra mussel or unionid in the direction from the mouth upwards with the flow. Basically, the quantitative indicators of zoobenthos are comparable to those before the period of large-scale construction. However, in the sections of the branches of the S. and N. Pregolya where the most radical transformation of the channel and the coast took place - in the area of st. 28о and 28, macrozoobenthos was characterized by a very high level of development in Riparian zone: the number reached 27-30 thousand individuals/m², biomass - 2-6 kg/m². High numbers of one third were provided by the development of small non-selectively ingesting detritivores - oligochaetes, which is an indisputable sign of an excess of easily hydrolysable organic matter on the bottom surface and its siltation. The total average biomass of benthos here reached 2170 g/m² due to bivalve and gastropod mollusks. Both the abundance and biomass of benthos were an order of magnitude higher than before the anthropogenic transformation of the channel. On the contrary, the abundance and biomass of benthic invertebrates in the medial decreased by an order of magnitude; the species composition and quantitative representation of benthos were the smallest in this biotope. The presence of three species of large mollusks with high filtration activity indicates a large amount of organic suspension, both in the water column (*Dreissena polymorpha*) and in the bottom layer (*Unio spp, R. cuneata*) - it turns out to be enough to ensure the development of mollusk biomass at the level 0.8-6.0 kg/m².

4. Discussion

A significant decrease in the species diversity of summer plankton, in comparison with the data of previous studies in 1996-2007 [1], has not been revealed. In the community of phyto-and zooplankton, species have been found that live in conditions of an increased content of nutrients and suspended matter.

A distinctive feature of 2019 was the appearance among the dominantes in the June phytocenoses of N. Pregolya of the green *Spermatozopsis exsultans*, typical of nitrogen-enriched waters of small or
low-flowing water bodies [11]. Mass vegetation of this species (about 3 million cells/l) is noted in the phytocenosis of st. 29, while in the other parts of the branches its number was 4.5 (station 28, N. Pregolya) and 11-20 times less (S. Pregolya). One of the factors that influenced the increase in the abundance of this species was the high concentration of nitrate nitrogen in N. Pregolya (0.38 ± 0.12 mg/dm³), relative to other sections of the river. The presence of euryhaline *E. affinis* in the N. Pregolya branch was not previously noted, which indicates the passage of brackish water from the bay up the river and along the N. Pregolya branch. The average abundance and biomass of zooplankton (135 thousand individuals/m³, 1525 mg/m³) in June 2019 was higher than the average long-term indicators of zooplankton (71 thousand individuals/m³ and 664 mg/m³) in the period 1996-2007 [1]. In general, the quantitative indicators of plankton were not lower than similar data before the channel transformation.

The construction works had the greatest impact on the plant and animal communities associated with the bottom biotope.

The number of species in the aquatic flora decreased by 12.5% compared to the previous study period before the technogenic transformation (2013–2014), when there were 56 plant species from 31 families and 43 genera [1]. However, the general characteristics of the river according to the MIR, IBMR MTR indices remain unchanged - the share of species with a high level of trophicity is high. The extinction and decline in the abundance of submerged broad-leaved species is an indicator of increased turbidity. At the same time, there is a renewal of plant communities in the places where they converge, which demonstrates the high plasticity of river vegetation and its ability to fairly quickly recover after exposure.

An increase in the biomass and abundance of benthic invertebrates in the coastal zone, in particular, filter feeding mollusks, was noted. This is due to two factors:

- Creation of an artificial concrete substrate and stone fillings during the construction of embankments for several kilometers, which is favorable for the sedimentation of the zebra mussel;
- The presence of runoffs that increase the trophic and saprobological status of the considered section of the river.

Fully consolidated during excavation, these communities formed very quickly due to river drift. At the same time, drift did not provide restoration of benthic communities in the medial part of the river in the impact area. This suggests that the granulometric composition of the bottom substrate in the medial, changed as a result of dredging, does not allow for the restoration of the previously existing communities.

In the Pregolya branches (15-17 km from the mouth), for the first time in summer, brackish-water species of zooplankton and benthos were recorded, which were not previously recorded there, while the salinity of bottom waters reached 1.5 PSU.

5. Conclusion

Thus, the technogenic transformation of the coastal zone and the river channel significantly influenced the simplification of the composition and structure of aquatic plant communities, and their projective cover changed. At the same time, the processes of renewal of perennial plants were noted where they were destroyed.

A significant decrease in the species diversity of summer plankton, in comparison with the data before the transformation of the river, was not revealed. The species found inhabiting conditions of high nutrient and suspended matter content. The quantitative indicators of plankton were comparable with similar data before the transformation of the channel.

A feature of the restoration of the zooplankton and benthic community was the appearance of brackish-water species in the river branches, which were not previously recorded there. Probably, the
reduction of plant communities and concreting of embankments along the river branches facilitated the unimpeded passage of surge water from the bay upstream of the river.

The results obtained are significant for further planning and optimization of the reduction of technogenic loads on the river ecosystem during the development of coastal territories, and can also become the basis for monitoring the spread of alien invasive species and rare and protected species of plants and invertebrates in river estuaries in the river.

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