# 5. SUMMARY

The impact of anthropopressure on freshwater ecosystems is associated with the introduction of pollutants into rivers, hydromorphological transformations of riverbeds and changes in the land use in the catchment area. This activity has long been a threat to inland waters and deteriorates the quality of water in the rivers around the world. Upper Silesia (Upper Silesian Coal Basin), which is a historical and geographical area, is one of the most industrialised and urbanised regions in Europe. Hard coal has been mined in this area since 1740. Since then, about 65 underground hard coal mines have discharged salty mine waters (mainly with high concentrations of chlorides and sulphates) that originated from Carboniferous rocks into the waters in the Vistula and Odra catchments through the mine dewatering systems. This process caused the degradation of these rivers in the last decades of the 20$^{th}$ century. Currently, about 35 hard coal mines are still operating in the area of the Upper Silesian Coal Basin. Even after the mines are closed, in order to eliminate the flood risk to any adjacent workings, salty mine waters are pumped to the surface through the mine dewatering system, which is then discharged into surface waters including directly into rivers. Therefore, the degradation of the rivers in this region is primarily caused by anthropogenic salinisation.

The objectives of the doctoral dissertation were as follows:

- to analyse the structure of the invertebrate communities, water plants and their communities and diatom assemblages in rivers with various degrees of anthropogenic transformations with particular emphasis on the river, which currently has the highest secondary salinisation in the world caused by the discharge of underground waters by the hard coal mines;
- to determine the environmental factors that significantly affect the structure of the invertebrate communities, water plants and their communities and diatom assemblages in the studied rivers;
- to assess the impact of anthropopressure on the lotic habitats and the degradation of ecosystem services in the selected rivers;
- to compare the diatom assemblages in the selected rivers that have different degrees of anthropogenic transformations and to assess the quality of these waters based on the phytobenthos and diatom index.

The research was carried out in 2017-2018 in selected abiotic types of rivers in Upper Silesia and the adjacent areas. Eight rivers within the Vistula and Odra catchments with different degrees of anthropogenic transformations were selected for the study, which belong

to the following abiotic types: Type 5 (Bolina and Centuria), Type 6 (Mitręga and Mleczna), Type 12 (Dziechcinka and Wisła) and Type 17 (Korzenica and Wiercica). Depending on the degree of anthropopressure, two sampling sites were selected in each of the rivers – one in the upper course of the river (reference) and the other in the lower course. Biological samples of macroinvertebrates, rotifers, macrophytes and diatoms were collected in the field using quantitative methods. Samples of the water and bottom sediments were also collected for the laboratory analyses. The physical and chemical properties of the water were analysed as well. The hydromorphological assessment of the sampling sites was carried out based on the Hydromorphological Index for Rivers (HIR) and two indices, i.e., the Hydromorphological Diversity Index (WRH) and the Hydromorphological Transformation Index (WPH).

A total of 143 macroinvertebrate taxa, 76 macrophyte taxa and the 15 plant communities that they formed were identified in the selected rivers. Moreover, 214 taxa of diatoms and 11 taxa of rotifers (only in the Bolina River) were also recorded. The maximum salinity of 33.56 PSU was recorded in the Bolina River (higher than the salinity of the Baltic Sea and similar to the salinity in the North Sea). Canonical correspondence analysis (CCA) showed that, among the environmental factors, the electrical conductivity, degree of the natural features of the riverbed and the land use adjacent to the rivers as reflected by the value of the WRH index, some fractions and the content of organic matter in bottom sediments as well as the temperature of the water had a significant impact on the structure of invertebrate communities, diatom assemblages and the structure of water plants. Using the method for assessing the hydromorphological condition of rivers based on the Hydromorphological Index for Rivers (HIR) and calculating the two indices, i.e., WRH and WPH enabled the impact of human pressure on both water plants and macroinvertebrates to be assessed. They are essential tools that are used to assess the degree of any anthropogenic transformations in the catchments of Central European rivers. The WRH index not only reflects the degree of the natural features of a riverbed and the land use of the area adjacent to a river, but also the relationship between the features of the habitats and the structure of the macroinvertebrate and macrophyte communities. A decrease in the diversity of diatoms, macrophytes and aquatic invertebrates was recorded in the rivers with the highest levels of anthropogenically salinised rivers, i.e., in the Mleczna and Bolina rivers. These rivers have created suitable habitats and routes for the dispersion of alien and invasive alien species, including *Gammarus tigrinus*, *Potamopyrgus antipodarum*, *Physa acuta* and *Elodea canadensis*. Anthropogenically salinised rivers favour invasive alien species over native species. In anthropogenically salinsed rivers, only species with a wide range of tolerance to this factor are included in the communities of native macroinvertebrates and macrophytes, i.e., Diptera (especially

Chironomidae), Coleoptera, Odonata, Heteroptera, Oligochaeta and only some water plants such as *Potamogeton pectinatus* or *Phragmites australis.* It has been proven that salinity can not only promote the dispersion of alien species but can also reduce it. Secondary salinsed rivers are a unique habitat for salt-tolerant and marine species, including the diatoms *Ctenophora pulchella*, *Achnanthes brevipes* var. intermedia, *Halamphora luciae*, *H. coffeaeformis*, *Navicula salinarum* f. *minima*, *N. flandriae*, *Gyrosigma attenuatum*, *Pleurosigma salinarum*, *Pleurosira laevis* and *Tabularia fasciculata*. *N. flandriae*, which has a wide tolerance to salinity (Mleczna and Bolina rivers) was recorded for the first time in Poland. *Brachionus plicatilis*, a halophilic species that is rare in Poland, was recorded for the first time in the Bolina River. It has been shown that at the higher water temperature that is caused by the discharge of salty mine waters into a river, rotifers may also develop in winter. *Cymatia rogenhoferi*, a rare, halophilous species of bug and the marine oligochaete species *Paranais litoralis* occurred in the Bolina River. The Asian oligochaete species *Monopylephorus limosus* was recorded for the first time in Central Europe (the Bolina River). The occurrence of *P. litoralis* in one of the tributaries of the Upper Vistula is one of the few inland localities of this species that is known to date. It has been documented that the invasive alien species *P. antipodarum* can occur in watercourses with a salinity of up to 12.25 PSU, which is the highest salinity value for this species in flowing waters. Moreover, it has been shown that some macroinvertebrate taxa are more resistant to salinity than has been reported in the literature. A new species of diatoms, *Planothidium nanum*, was recorded in the source section of the Centuria River. Further studies confirmed the wider occurrence of this species. This result and the other results presented in the dissertation indicate that the rivers of Upper Silesia and the adjacent areas are still valuable environments for research on the occurrence of new species of aquatic organisms for science and for the country.

In the face of global climate change, which will exacerbate the observed adverse changes in the aquatic environment, and the environmental threats that result from the degradation of flowing waters, further detailed monitoring of rivers is necessary. On the other hand, some of the secondary salinised rivers can also be model rivers for research in the context of the impact of climate change on the ecosystems of flowing waters.