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Hydromorphological and physicochemical conditions of the Parsęta River

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Abstract. Rivers are hydromorphologically assessed in line with the Water Framework Directive. In order to assess the quality of the Parsęta River environment, the River Habitat Survey method was applied. The research studies, conducted in June 2016, provided an overview of hydromorphological issues, and also covered measurements and laboratory analyses on the quality of its waters. There were 24 measuring sections selected along the whole river. The selection of these sections took into account the representativeness of genetically various types of river valley, its size and discharge, and the variability of anthropogenic pressure. The assessment showed that the Parsęta River varies in natural quality (its HQA index ranged from 17 to 61) and that the modification of its valley is variable but generally low (its HMS index ranged from 0 to 33). Seventy-nine percent of the analysed sections were classified to the second (II) and third (III) hydromorphological classes, 8% to the first (I), and 13% to the fourth (IV). The central section of the Parsęta River has the highest degree of naturalness and the lowest degree of transformation. The river valley sections of kettle-hole origin are more transformed than those of fluvial origin. The quality of the Parsęta River waters assessed on the grounds of their physicochemical parameters indicates that the river is in good condition. The individual river water parameters are most often within the first (I) and second (II) classes. Any instances of the quality of waters being below the "good" level are due to phosphate concentrations exceeding the second (II) class and are contained within a 15-km stretch of the river below Białogard. A river section with a high degree of hydromorphological naturalness has the worst quality of waters.

Key words:
Upper Parsęta River catchment,
River Habitat Survey,
Habitat Modification Score and
Habitat Quality Assessment,
river hydromorphology,
water quality,
Western Pomerania

Introduction

The European Parliament's adoption of the Water Framework Directive (2000/60/EC) as the chief document regulating the principles of surface water quality assessment has necessitated the introduction of new measurement methods. They are based on the ecological assessment of an individual watercourse on the grounds of a set of biological indicators supported by physicochemical parameters and hydromorphological conditions. The British River Habitat Survey (RHS) is one of the methods developed to assess the condition of an individual river, the transformation of its environment and the occurrence of natural morphological elements in its channel and corridor. This method introduces reference conditions which allow rivers to be assessed and classified in relation to their environmental quality (Davy-Bowker and

Futse 2006; Gebler and Jusik 2012). The RHS system was adapted to Polish conditions (Szoszkiewicz and Gebler 2011). This method makes it possible not only to assess the current state of rivers, but also, by means of repetitive research studies (monitoring), to identify tendencies in emerging changes and on their basis to suggest and introduce re-naturalisation measures in their watercourses (Szoszkiewicz et al. 2009; Osowska and Kalisz 2011). Thanks to the universality and precision of the research method, a lot of Polish rivers characterized in terms of their varying degrees of transformation and location within various landscape areas, have been assessed according to the RHS principles (Czerniawska-Kusza and Szoszkiewicz 2007; Trząski and Mana 2008; Szoszkiewicz et al. 2009; Frankowski 2011; Kijowska and Wiejaczka 2011; Lewandowski 2012; Raczyńska et al. 2013; Spieczyński et al. 2013; Szpikowski and Domańska 2014).

The RHS method predominantly aims to assess the nature of a river channel and, to a lesser extent, to assess the whole valley of the river. Research is carried out on selected 500-metre-long sections of river. It consist in a diagnosis of the river channel, a determination of its natural morphological elements and an evaluation of its transformation level. Moreover, it describes the immediate vicinity of the watercourse and its adjacent area within a distance of 50 m. The comprehensiveness of this assessment is due to it taking the following elements into consideration: land use, valuable habitat elements and anthropogenic activities. Standardised evaluation sheets and bonitation developed as part of the method allow for quantitative evaluation of the level of an individual river channel's natural quality (by its HQA index) and transformation degree (by its HMS index) (Szoszkiewicz et al. 2012). The final stage of this assessment aims to assign a hydromorphological class to each river section under this assessment on the basis of a set of calculated indices. The detailed RHS method instructions objectify assessment, while the selection of test sections is largely considered to be a subjective testing factor, although this subjectivity can be somewhat limited by identifying a sufficient number of test sections per river. The virtue of this method is its comprehensiveness in assessing river surroundings. On the other hand, the lack of reference to the geomorphology of its valley as a component of a larger landscape unit may make it difficult to take appropriate measures to improve the quality of such river surroundings (Bielak et al. 2012). The disadvantage of the RHS method is its disregarding of water quality. The RHQ method, which includes the physicochemical properties of river waters in the hydromorphological evaluation, is also used in Poland (Hajdukiewicz et al. 2017).

The hydromorphological assessment of river channels was entered into the basic Integrated Environmental Monitoring programme at all Base Stations in 2015. At the Geoecological Station in Storkowo (Adam Mickiewicz University), the hydromorphological assessment was conducted by a team of specialist under the direction of Prof. Krzysztof Szoszkiewicz at four sections of the upper Parsęta River, i.e. within the river's first 13 km from its sources. There were also research studies conducted into the impact of geomorphological conditions on the hydromorphology of the upper Parsęta River at 9 test sections (Szpikowski and Domańska 2014). Upon these grounds, it was concluded that there was a lowering of hydromorphological class at the river valley sections of kettle-hole origin where human intervention in the valley and river channel was significant due to channel regulation works. Conversely, the hydromorphological status of the Parsęta River is much better in the sections of fluvial origin which have mostly preserved their natural character and where the river dynamically shapes various forms of channel.

The most important goal of the conducted research is to determine to what extent the results of the hydromorphological assessment of the river correspond with the water quality. Potential contamination delivered to the river channel from point or area sources can migrate with water, reducing its quality over considerable distances, which are also assessed to be natural by the RHS method. Appropriate research studies of the physicochemical properties of an individual river and its waters should therefore be treated as a supplement to the assessment of their hydromorphological conditions as part of such a comprehensive assessment.

Research methods

The research studies conducted in June in 2016 aimed to assess the hydromorphological state of the Parsęta River together with the physicochemical properties of its waters. These studies were conducted under stable hydrological conditions: at average-level waters, with no raised waters. Twenty-four measuring sections were selected, taking into account the influence of the following types of determinants: geomorphology (valley sections of fluvioglacial and fluvial origin), hydrology (varying flows and spatial distribution of tributaries) and anthropopressure (hydrotechnical facilities, river channel transformations, supply of pollutants, urbanised areas) (Fig. 1). Apart from the standard RHS assessment, some physicochemical properties of waters in the river were also identified. For the 24 measurement sections at the longitudinal profile of the Parsęta River, there were measurements conducted on specific electrical conductivity (SEC), pH, dissolved oxygen and water temperature, all by means of a multiparameter field meter (Hanna Instruments). At the same locations some water samples were taken with the purpose of determining ionic components. All chemical analyses were performed in the laboratory at the Geoecological Station in Storkowo where analytical methods were in line with the Polish Standard. The results of these chemical analyses provided the grounds for determining the water quality classes of the Parsęta River.

Study area

The Parsęta River catchment is located within the following physiographic subprovinces: the Southern Baltic Coastland, and the Southern Baltic Lake District (Kondracki 2000). It covers an area of 3,086 km^2. The length of the Parsęta River is 152 km and has a channel development index at 177% (according to the measurements made on a 1:10,000 topographic map). The whole river basin is within the range of the Pomeranian phase of the Vistulian glaciation on the northern side of the so-called "lake-district hump". The terrain and lithology primarily result from the areal deglaciation of the continental glacier, which led to its formation with dominant undulated and flat morainic plateaus, kame and kettle-hole forms, local outwash plains and meltwater trails (Bartkowski 1969; Karczewski 1989). The majority of the Parsęta River catchment is located within successive morphological levels of the northern slope part of the Pomerania region, which gradually decrease towards the Baltic Coast (Karczewski 1988). Today's system of surface runoff was formed during the Pomeranian continental glacier recession under the Pomeranian phase and was further modified by fluvial processes in the Holocene period. The areal disappearance of the continental glacier led to the formation of a complex network of meltwaters. At some sections, they formed the main outflow routes of such waters towards the west, forming what is referred to as the Pomeranian Pro-glacial Valley (Rachlewicz 1998). In the post-glacial formation stage of this network of rivers and lakes, kettle-hole depressions (which become combined through erosive stretches of river valleys) played a significant role. This is how the polygenetic system of the today's network of river valleys within the Parsęta River catchment (which is characteristic of young-glacial Polish areas) was created (Mazurek 2000). Its rivers have uneven longitudinal profiles, while the transverse profiles of its valleys have diversified morphology, witch conditions the course of hydromorphological processes at their river channels, leading to the occurrence of riparian zones which play a role in protecting the quality of river waters (Michalska 2001; Zalewski et al. 2001; Szpikowska 2009), and in slope-channel coupling. Therefore, rivers within the Parsęta catchment make use of various stretches of river valleys: those derived from kettle-holes; and those generated by meltwater trails, incl. stretches with pro-glacial and fluvial features and, sometimes, with deep-cut valleys. In some valleys, there are terraces made of Pleistocene sands, gravels and river muds (Geological Map of Poland 1974). Floodplain terraces are mainly composed of vari-grained sands with gravel and mud inserts (Zwoliński 1985). The valleys of smaller watercourses are filled with river silts mixed with fine-grained sands and organic material. Kettle-hole depressions under the system of river valleys are filled with fine-grained sands, silt, peat and gyttjas (Jasnowska and Markowski 1998).

The Parsęta River catchment is an area dominated by agro-forestry land use. According to Corine Land Cover 2012, up to 52.8% of the Parsęta River catchment is occupied by agricultural areas dominated by arable lands. A large part of the catchment area is covered by forests (43.9%) with coniferous stands dominating. Its remainder is made up of built-up and anthropogenic areas (2.9%) and waters (0.5%). The largest dense forest areas are located along the Radew River – the largest tributary of the Parsęta River – from Białogard through Tychowo up to Bobolice and from Połczyn Zdrój up to Barwice. Large complexes of arable lands are concentrated within the area from Białogard down to Kołobrzeg, west of Połczyn Zdrój and in the vicinity of Grzmiąca.

Results and discussion

The conducted research studies showed that the Parsęta River has quite variable values of the HQA index (Table 1, Fig. 2). Within individual sections, this index changes from a minimum of 17 up to a maximum of 61. The average HQA for the whole river is 40.4. The lowest value of HQA was found in the upper part of the river (3.6 km from its source), in section 2, at the bottom of an extensive kettle-hole depression. Low Habitat Quality Assessment values were also recorded in the estuary section of the Parsęta River (at km 148) in Budzistowo (HQA 25). The HMS index is highly varied (Table 1, Fig. 2). Within the analysed sections of the Parsęta River, it ranges from 0 to 33, with the average value of 4.6. In the Polish perspective, this value is low, and indicates a small degree of anthropogenic transformation of the Parsęta River channel. There

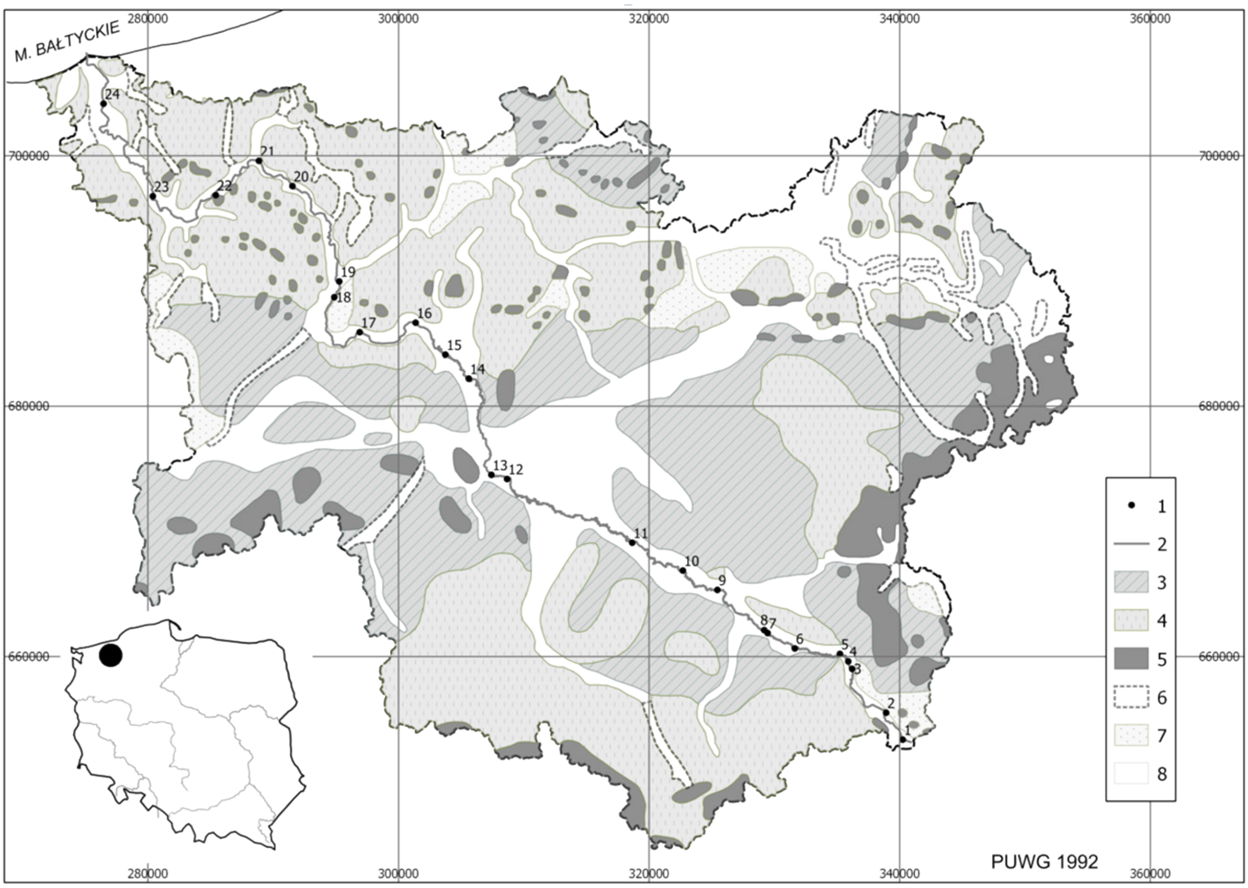

Fig. 1. Location of the RHS measurement sections at the Parsęta River at the background of the Polish Geomorphological Review Map (ed. 1 – RHS measurement sections, 2 – Parsęta River, 3 – undulating moraine plateaus, 4 – flat moraine plateaus, 5 – accumulative moraine, 6 – lake troughs, 7 – outwash plains, 8 – valleys

are no transformations within the 13 sections or their HMS index amounts to 1. The highest value of the HMS index (33) was found at the section located at the estuary of the Pysznica River (a right tributary of the Parsęta River) to the Parsęta River (section 21 at km 122 of the river) which is an artificial ditch of a meander (its neck) with debris dam at the bottom of the river. A high degree of transformation of the river was also found in the upper Parseta River, at km 22 of its course (section 8) situated below some breeding ponds in Żarnowo. The high level in its HMS index is influenced by channel regulation works which occur, among others, at the kettle-hole sections 1, 2 and 16. The river channel takes the form of a rectilinear drainage ditch cut into the valley bottom.

The hydromorphological class of the Parsęta River, calculated on the basis of the HQA and HMS indices, ranges from the first (I) class (HMS – natural and HQA – very natural) down to the fourth (IV) class (HMS – fairly modified, moderately modified or significantly modified and HQA – fairly natural or low natural). Its hydromorphological class tends to increase within the river sections of fluvial origin of this valley (e.g. at sections 3, 10, 12, 20). Within the river sections of kettle-hole origin, the hydromorphological class of the river deteriorates (e.g. sections 1, 2, 5, 7, 8), resulting mainly from the transformation of its river by channel regulation works and the presence of the aforementioned breeding ponds. Among the analysed sections of the Parsęta River, there are also a few located within kettle-holes but with their river channel undercutting the moraine plateau (e.g. section 13, north of Tychówko) or within the

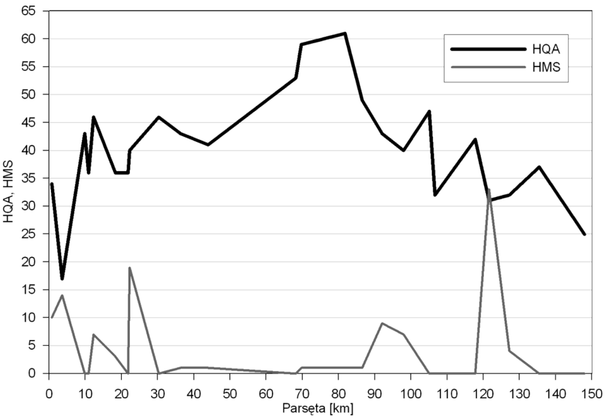

Fig. 2. HQA and HMS for the Parsęta River

pro-glacial valley section where the channel cuts terraces (at section 14, near Rzyszczewo). Among the sections of the Parsęta river, the studies also covered those located within the melt, but with the channel of the watercourse leading to the moraine plateau (e.g. section 13, north of Tychówko) or in the pradolin section with the trough undercutting the terrace (section 14, near Rzyszczewo). Under these conditions, there were numerous river channel forms, which significantly increased the naturalness of the habitat as well as the hydromorphological class of the river.

The values of physico-chemical properties of waters at the longitudinal profile of the Parsęta River indicate good water quality. The assessment includes 14 parameters listed in the Regulation of the Minister of the Environment dated 22 October 2014 as the group of physico-chemical parameters supporting the assessment of biological parameters. Most of the parameters within all or almost all of the Parsęta River are in the first (I) class. At the channel-head section, the waters in the Parsęta River show a low concentration of dissolved oxygen, increased concentration levels of NO^{3-}, PO_4^{3-}, Ca^{2+}, and increased alkalinity and overall hardness. These parameters are in the second (II) class, and hence the water status at this section can be assessed as good. Generally speaking, the water quality of the Parsęta River is lowered by the two following elements: alkalinity and concentration of phosphates. Alkalinity along the whole river profile is in the second (II) class, but this is a factor which can be considered to be natural due to the presence of calcium carbonate in sediments within young glacial areas (Kostrzewski et al. 1994; Paczyński and Sadurski 2007; Mazurek 2008). The concentration of phosphates was in the first (I) class in the upper part of the Parsęta waters (at sections 2–8), and in the second (II) class at most of the sections. The second (II) class was exceeded for PO_4^{3-} at the five sections: 12 and 16–19. These river sections, totalling ca. 15 km in length, should be classified as waters with below-good conditions. It should be stressed that the excessive phosphate concentration in the Parsęta River is not significant – no more than 60% above the standard for the second (II) class.

As for the profile variability in concentration of ion components in the Parsęta River (Fig. 3), high concentrations of some ions are observed in the

Table 1. Habitat Quality Assessment (HQA), Habitat Modification Score (HMS), hydromorphological class of the analysed sections within the Parsęta River against the genetic type of its river valley

Segment number	Kilometer of the river	HQA	HMS	Hydromorphological class	Genetic type of river valley
1	0.7	34	10	IV	W
2	3.6	17	14	IV	W
3	9.8	43	0	II	F
4	10.9	36	0	III	F
5	12.3	46	7	III	W
6	18.3	36	3	III	F
7	21.8	36	0	III	W
8	22.2	40	19	III	W
9	30.3	46	0	II	W
10	36.3	43	1	II	F
11	43.9	41	1	II	W
12	68.2	53	0	II	F
13	69.7	59	1	I	W
14	81.7	61	1	I	PR
15	86.5	49	1	II	W
16	92.0	43	9	III	W
17	98.0	40	7	III	F
18	105.1	47	0	II	PR
19	106.6	32	0	III	PR
20	117.8	42	0	II	F
21	121.6	31	33	IV	PR
22	127.2	32	4	III	PR
23	135.5	37	0	II	PR
24	147.9	25	0	III	PR

type of valley: W - kettle-hole, F - fluvial, PR - melting water trail, pro-glacial valley

upper river section. The supply sources of dissolved material are natural in this case; they originated from the leaching of sediments accumulated in an extensive kettle-hole depression drained by a drainage ditch which was the starting point of the Parsęta River. This is the area of the former lake with sediments of the carbonate gyttja lying under the peat (Kostrzewski et al. 1994; Jasnowska and Markowski 1998). Excluding those originating from peat leaching, the high concentrations of nitrates, sulphates and potassium in river waters may be caused by the area being polluted with contaminants from the fields surrounding the river headwaters area and from the village of Parsęcko. There is one distinguishing section in the river profile, i.e. section 17 at km 98 of the river, at the level of Białogard, which has increased concentrations of Na^+, Cl^-, and PO_4^{3-} up to the maximum values for the whole profile. Its deteriorated water quality is anthropogenic and is caused by the supply of sewage from the treatment plant in Białogard.

When assessing the hydromorphological condition of the Parsęta River, it should be kept in mind that it is characterised by natural diversity resulting from the river's considerable length and, therefore, from the increasing discharge and varying width and depth of its channel. The HQA index, especially in the upper part of the river, is lowered by the small amount of water plants, which in turn is due to the shading of its narrow river channel along the forest sections. This is an example of how using the RHS method for an objective assessment of the hydromorphological conditions of a river may be limited. The HMS index indicates that the Parsęta River is generally transformed to a low degree if compared with other coastal rivers (Florek 2008; Szpikowski 2011; Szpikowski et al. 2015); however, there are numerous hydrotechnical structures and

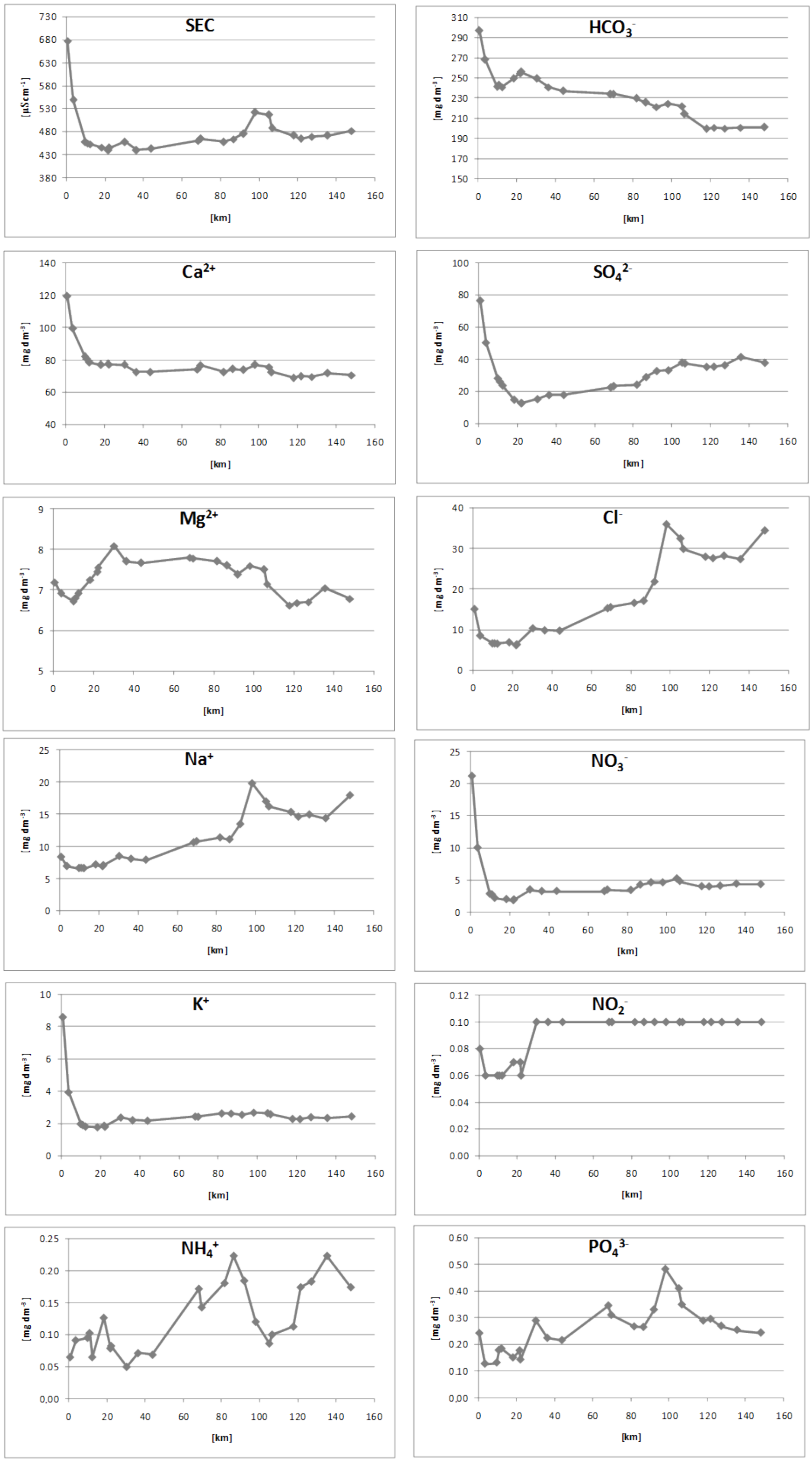

Fig. 3. Variation of physico-chemical parameters of the Parsęta River at the longitudinal profile of the river (SEC – specific electrical conductivity)

systems currently in use, as well as remnants of, for example, debris dams, weirs, culverts, bridges and fixed river banks, especially within the urban sections of Białogard and Karlino. The degree of the river channel transformation obtained by means of the HMS index is therefore determined by the research sections and their locations.

The good status of the Parsęta waters is indicated by their physico-chemical parameters. Most of the analysed quality indicators were classified in the first (I) class. The deterioration of its quality to the below-good level, which derived from anthropogenic supply, occurs only at an approximately 15-km-long section. The level of diversity in the hydrogeochemical type within the longitudinal profile of the Parsęta River may be an indicator of anthropopressure contributing to shaping the water chemistry of its waters. Along nearly 90 km (from the river sources to section 15, inclusive) the Parsęta River waters show a simple double- or triple-component type (according to the Altowski and Szwiec classification), including ions at various configurations (HCO_3^-, SO_4^{2-}, Ca^{2+}, Mg^{2+}) within the individual sections. From section 16 (Białogard) to the estuary of the Baltic Sea, the Parsęta waters are multi-component hydrogeochemical type waters (of four, five or six components, taking into account sodium and chloride ions). This fact confirms the influence of anthropopressure on its water quality.

Conclusions

Among all the 24 sections assessed by the RHS method, 2 obtained the first (I) class (natural HMS index, very natural HQA), 9 the second (II) class (natural HMS, natural and moderately natural HQA), 10 the third (III) class (natural, fairly modified and moderately modified HMS; moderately natural, fairly natural and little natural HQA) and 3 were deemed to be fourth (IV) class (moderately modified and significantly modified HMS; fairly natural and little natural HQA). There were no sections with a heavily modified channel modification score.

Upon the division of the Parsęta River into the following four sections: headwater section (sections 1–6), upper (sections 7–12), central (sections 13–18) and lower (sections 19–24), the average hydromorphological condition is as follows:

- headwater section: third (III) class, fairly modified HMS and fairly natural HQA,
- upper section: third (III) class, fairly modified HMS and moderately natural HQA,
- central section: second (II) class, fairly modified HMS and natural HQA,
- lower section: third (III) class, fairly modified HMS and fairly natural HQA.

This means that the Parsęta has the best hydromorphological condition in its central section stretching from Tychówko to Karlino.

The analysed sections in the fluvial (antecedent) valley, reached – on average – the second (II) class with moderately natural HQA and natural HMS. The river valley sections of kettle-hole origin and situated within the area of the pro-glacial drainage systems reached – on average – the third (III) class with moderately natural HQA and fairly modified HMS. Therefore, the fluvial sections were anthropogenically transformed to a low degree, and retained their natural character.

The hydromorphological status of the Parsęta River does not correspond to the quality of its waters. Within the sections of fairly or moderately natural character, the parameters of the Parsęta waters are in the first (I) water quality class or, much less frequently, in the second (II) water quality class, while the central section, rated natural, shows largely below-good water conditions. The differences in the hydromorphological and physico-chemical assessment of the river are related to a varied level of human impact on the environment: even the fairly anthropogenically transformed sections may show a low level of water quality due to the supply of area or point pollution into the river waters.

The assessment of the hydromorphological and chemical conditions will be repeated in subsequent years, thus making it possible to determine the direction of changes taking place within the Parsęta River environment.

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