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Assessment of the hydromorphological quality of streams in the Venta River Basin District, Latvia

Jolanta Jēkabsone✉ and Linda Uzule

University of Latvia, Faculty of Geography and Earth Sciences, Alberta St. 10, Riga, Latvia

✉ Corresponding author, jolanta.jekabs@gmail.com

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Abstract. Hydromorphological quality assessment is an important research topic, especially after the implementation of the EU Water Framework Directive. In this study the hydromorphological quality at 46 sites in 22 streams of the Venta River Basin District (RBD) in Latvia was investigated during the vegetation periods of 2011–2013. The UK River Habitat Survey method was used in the research. No significant differences in Habitat Quality Assessment (HQA) and Habitat Modification Scores (HMS) were found between stream types. We found that the most important factor affecting HQA scores in our research territory was instream vegetation, which coincides with results of other researchers. There was a significant negative correlation between HQA and HMS. Distance from the source had a negative correlation with HQA and a positive correlation with HMS. River type had a positive correlation with special features (beaver dams, fringing reed bank, wetlands, etc.).

Key words: hydromorphological assessment, River Habitat Survey, Venta RBD, Latvia.

INTRODUCTION

According to the EU Water Framework Directive (WFD), surface waters in Europe must achieve good ecological quality by 2015 (European Commission, 2000). The WFD requires ecological quality assessment of running waters based on various biotic (phytoplankton, macrophytes, phytobenthos, benthic invertebrates, and fish fauna), chemical, and hydromorphological elements (European Commission, 2000). When evaluating the quality status of water bodies, the predominant role used to be given to the assessment of biotic elements (Logan and Furse, 2002), with the support of hydromorphology and physico–chemical assessment (European Commission, 2000). Previous monitoring focused on chemical parameters and assessment of benthic invertebrates in running waters (O'Hare et al., 2006), but the new legislation of the WFD states that it is necessary to include hydromorphology in the assessment of ecological status. Assessment of river hydromorphology is needed not only for the implementation of the WFD but also for nature conservation purposes, such as the monitoring of the condition of Special Areas of Conservation under the EC Habitats Directive and helping the management and restoration of rivers (Boon et al., 2010).

Rivers have important functions in ecosystems, such as natural flood control, ecological refuge development, production, and species conservation. However, aquatic ecosystems are among the most severely affected habitats (Sala et al., 2000). Streams and their floodplains have been modified as a result of land drainage, floodplain urbanization, and flood defence (Sparks, 1995; Kronvang et al., 2007). More recently, physical disturbances such as damming, channelization, separation of channel and floodplain, and destruction of riparian vegetation have become more relevant in Europe and have therefore been included into the assessment methods (Feld, 2004; Lorenz et al., 2004; Timm et al., 2011). The morphology, longitudinal and lateral connectivity, as well as the discharge regime of running waters are severely disturbed in Central Europe. Only 10% of the river reaches in the alpine region can be classified as near natural (Muhar et al., 2000). In Latvia there are still streams with sites corresponding to 'conditions that are representative of a group of minimally disturbed sites, i.e. reference site, described by selected physical, chemical and biological characteristics' (Springe et al., 2010).

There is a long history of biological assessments in Europe but systems for the assessment of hydromorphological quality are far less developed (Erba et al., 2006). Various methods and indices (Muhar et al., 2000; Friberg et al., 2005; Kamp et al., 2007) are used in different countries to characterize hydromorphological quality. Characterization of the physical structure and assessment of the habitat quality of rivers are gaining importance in the context of environmental planning, appraisal, and impact assessment. Hydromorphological quality assessment plays a crucial role in the WFD because it is used to determine 'undisturbed' and 'heavily modified' conditions of rivers (Raven et al., 2002). In order to fulfil the demands of the WFD, stream and river assessment must be changed fundamentally from a single index system to a more holistic approach (Feld, 2004). Numerous researchers emphasize that the stream quality assessment requires knowledge about the hydrological regime, geological formation, and geomorphological processes of the stream, as well as about impacts of natural and anthropogenic origin both in the past and present (Riis and Biggs, 2003; Tremp, 2007). Several European countries have developed methodologies to identify the morphological character of rivers (Muhar and Jungwirth, 1998; Raven et al., 2000; Buffagni and Kemp, 2002; Rinaldi et al., 2013). The reason for the wide application of these methods is that they rely on well-established monitoring activities and simple classification criteria (Bizzi and Lerner, 2012). There are a few researches that refer to the hydromorphological and hydrological quality of Latvian streams (Grīnberga, 2010; Springe et al., 2010) but only one research was used to assess the hydromorphological quality of Latvian rivers using the River Habitat Survey method (Briede et al., 2005).

Water bodies have to be managed and protected according to the natural hydrological boundaries of river basins instead of administrative borders. A river basin is understood as the area from which all surface water flows into one river. In order to facilitate management of water and water bodies, the Latvian river basins were merged into the following four river basin districts (RBD): Venta, Daugava, Lielupe, and Gauja. The management plans shall present an overview of the current RBD status and the results of the analysis of impacts of human activity thereon, provide information on water protection objectives and their justification, and identify water bodies at risk of failing to achieve good status by 2015.

The aim of the study was to assess the hydromorphological quality of streams in the Venta RBD based on the River Habitat Survey method.

MATERIAL AND METHODS

Study area

A total of 46 sites in 22 rivers in the Venta River Basin District (RBD) were investigated. Data were collected during the vegetation season from August to October in 2011 and 2013. According to the Water Framework Directive 2000/60/EC System B typology, Latvian rivers can be divided into six types: small rhitral rivers (9 sites investigated), small potamal rivers (7 sites), medium-sized rhitral rivers (13 sites), medium-sized potamal rivers (13 sites), large rhitral rivers (2 sites), and large potamal rivers (2 sites).

The Venta River is a river in north-western Lithuania and western Latvia. Its total length is 343.3 km of which 178 km flows in Latvia. The total area of the Venta RBD in Latvia is 15 625 km^2 (Fig. 1), which makes up 24.5% of Latvia's territory (Ventas upju..., 2009). About 385 thousand inhabitants live in the RBD. Its population density (16 persons per km^2) is more than two times lower than the average in Latvia. The mean catchment size of the investigated rivers is 308 km^2 (varies from 20 km^2 of the Rumbulite Stream to 2016 km^2 of the Barta River basin). The mean altitude at stream source of the investigated sites is 60 m a.s.l., the highest point is 102 m a.s.l., and the lowest point near the sea is only 2 m a.s.l. All rivers belong to the Western Hydrological District and are characterized by

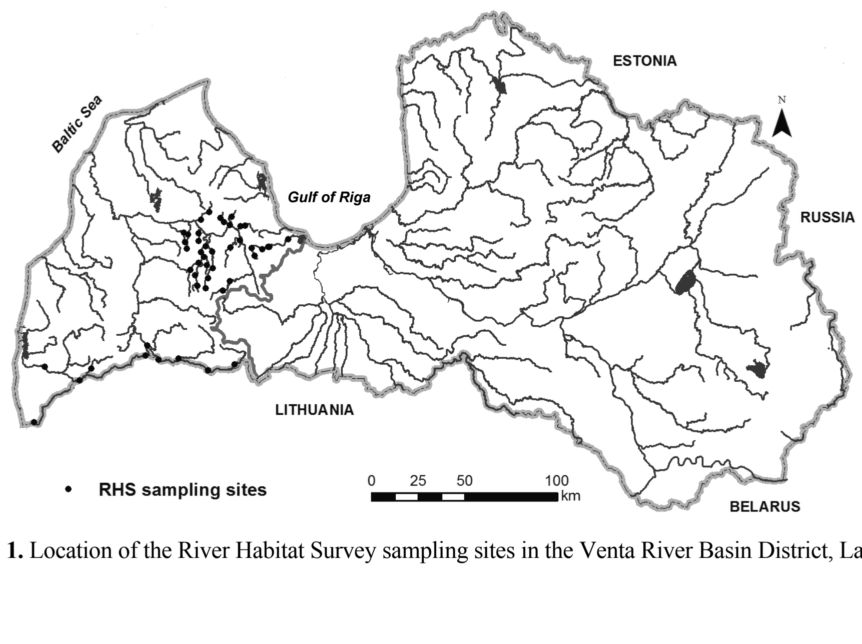

Fig. 1. Location of the River Habitat Survey sampling sites in the Venta River Basin District, Latvia.

two runoff peaks: autumn and spring flood, as well as a relatively short ice cover period (approximately 60 days) (Glazaceva, 1980). The mean runoff for the studied sites is relatively low – 0.126 m^3; it ranges from 0.015 m^3 (Valgale River) to 0.69 m^3 (Barta River). The mean channel slope is rather steep (2.1 m/km); it varies from 0.66 m/km (Vadakste River) to 6 m/km (Rumbulite Stream). The Rumbulite Stream has one of the highest slopes in Latvia.

The mean ratio of the average area of agricultural land and forests is very similar in the studied catchments (Table 1). However, there are significant variations between river basins, and coverage of agricultural land varies from 15% to 80%. Forest cover varies from 8.1% to 77.5%. The Abava River basin is characterized by mostly higher percentage of tilled land and pasture (central part of the area).

Hydromorphological site characteristics

To determine the hydromorphological quality of rivers, the UK River Habitat Survey (RHS) method (Raven et al., 1998) was used. According to this method, a river is divided into segments 500 m long and 50 m wide. Each segment is further divided into 50-m long stretches. Bed substrate; flow type; channel modification; bank material, modifications, and features; channel vegetation type (within 10 m); banktop land use (within 5 m); and vegetation structure (within 1 m) are recorded within each spot-check. We calculated two main indexes using RHS: Habitat Quality Assessment Index (HQA) and Habitat Modification Score (HMS) (Table 2).

Table 1. Proportion of agricultural land and forests in the studied stream basins

	Agricultural, %	Forests, %
Mean	43.8	48.1
Maximum	80.0	77.5
Minimum	15.0	8.1

Table 2. Scores and descriptive categories of Habitat Quality Assessment (HQA) and Habitat Modification Score (HMS) (Raven et al., 1998)

HQA		HMS	
Score	Descriptive category	Score	Descriptive category
>60	High quality	0	Pristine
45–60	Good quality	0–2	Semi-natural
30–45	Average quality	3–8	Predominantly unmodified
<30	Bad quality	9–20	Obviously modified
		21–44	Significantly modified
		>45	Severely modified

The HQA shows habitat diversity in relation to natural characteristics, such as tree roots, various shoals, vegetation structure, macrophyte diversity. The HMS characterizes human activity in the stretch (bank reinforcing, river straightening, deepening, drainage pipes, dams, bridges).

Data analysis

Pearson correlation coefficients calculated by Statistical Package for Social Science were used to obtain links between hydromorphological and hydrological parameters. All data were collected in the Microsoft Access database. The HQA and HMS values were calculated using the Rapid 2.1 database (Davy-Bowker et al., 2008). Land use in the catchments was estimated using the Corine Land Cover database. Other site-related information (altitude, slope, distance to source, etc.) was obtained from topographic maps M 1 : 10 000 and orthophotos.

RESULTS

The observed HQA values varied between 7 and 66 points (SD 16.6) with the mean value of 39 points. According to the HQA score, only 37% of the analysed stretches were of high or good quality, 30% of the stretches had average quality, and 33% were of bad quality.

The mean HMS for the assessed stretches was 13 points, ranging from 0 to 45 points (SD 13.4). Of all sites 37% belonged to pristine or semi-natural rivers, while 26% of the river stretches were significantly modified. Only one river site, Bebrupe at Karklini, which also had the lowest HQA value (7 points), was severely modified (HMS score 45) (see Fig. 2). Its poor quality was caused by the fact that the river is significantly affected by human activity. In 1963 the entire length of the 11-km-long river was regulated (Latvijas Republikas..., 2008). Another negative factor is that the lower part of the river has been reprofiled. These are the two main reasons why the hydromorphological quality of the Bebrupe was bad.

One of the most important attributes affecting HQA scores in the Venta RBD was stream vegetation structure, which accounted for 19.6% of the total HQA score (Table 3). Other important attributes were bank vegetation structure (18.5%), trees and associated features (15.6%), flow type (14.8%), and channel features (12.3%). These five attributes explained 80.9% of the total HQA score. River modifications were mostly caused by drainage activity (resectioned bank or bed, culverts) and urban activity (road bridge, flow control). Poached banks made by wild animals and reinforced banks (road) were the main types of modification in pristine or semi-natural rivers.

In all, six stream substrate types were observed. Sand, gravel/pebble, and silt were the predominant types observed in 94% of all stream substrates in spot-checks. Other three recorded substrates were cobble, boulder, and artificial.

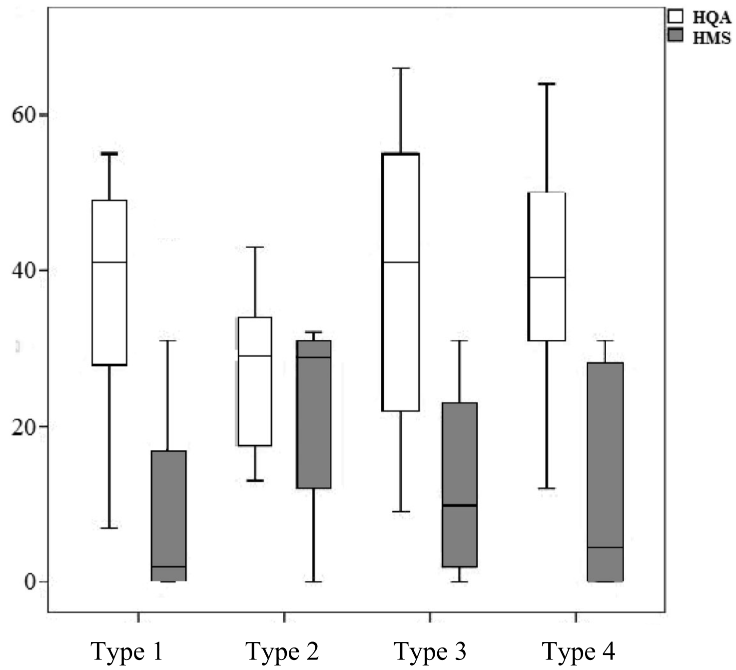

Fig. 2. Values of HMS and HQA for river types in Latvia. Box plot explanation: upper horizontal line of box, 75th centile; lower horizontal line, 25th centile; horizontal bar within box, median; upper horizontal bar outside box, 90th centile; lower bar outside box, 10th centile.

Table 3. Mean values of HQA and HMS scores and parameters in the Venta RBD

	Average score	Average score, %
HQA arising from flow type	4.7	14.8
HQA arising from channel substrate	4.1	12.3
HQA arising from channel features	1.7	3.9
HQA arising from bank features	3.9	7.6
HQA arising from bank vegetation	8	18.5
HQA arising from instream channel vegetation	6.1	19.6
HQA arising from land use in 50 m	1.6	3.8
HQA arising from trees & associated features	6.8	15.6
HQA arising from special features	1.8	3.8
HQA score	38.7	
HMS arising from modifications at spot checks	4.01	37.7
HMS arising from modifications not at spot checks	2	16.1
HMS arising from features of the site as a whole	3.7	29.8
HMS score	9.71	

Unperceptible (47% of all recorded flow types), smooth (35%), and rippled (14%) flow were the most dominant flow types. Chute flow occurred only in four rivers and chaotic flow in one river.

The structure of the bank face and top was simple at most of the rivers. Uniform bank vegetation structure was mostly observed in agricultural areas. The most common channel modifications were dams as well as resectioned and reinforced stretches. Beaver dams were observed on six rivers, mostly medium-sized ones.

The predominant bank material was earth, which occurred in 98.5% of the sites. Other observed bank materials were piled wood, concrete, clay, and gravel/sand. Marginal and bank features differed from one bank to another. In the whole, the left bank had 42 bars (vegetated and unvegetated) while the right bank had only 25. Reed was the most typical stream vegetation type, recorded in 41% of all spot-checks.

In general, no significant differences were observed in HMS and HQA scores between the river types. Still, medium-sized rhritral and potamal river stretches tended to have better habitat quality than small sites (Fig. 2).

The Pearson correlation coefficients identified most important hydromorphological factors that affected stream quality (Table 4). Distance to source had a negative correlation with HQA (–0.403), but a positive correlation with HMS (0.563). River type had a positive correlation with special features (0.406). Special features, such as debris dams, wetland, fringing reed bank, were most commonly observed for type 4 streams (medium-sized potamal rivers). A strong negative correlation was observed between HQA and HMS (–0.726; $p < 0.01$).

DISCUSSION

Since the adoption of the WFD, more than 22 hydromorphological assessment methods have been developed (Birk, 2003). So far the most comprehensive study of the hydromorphological state of Latvia's rivers was carried out within the STAR project, when 24 medium-sized lowland streams were investigated using the RHS method (Springe et al., 2010). Still, the existing data of hydromorphological conditions do not describe the whole territory of Latvia, and the amount of data is too limited to draw conclusions about the overall conditions. The shortage of data is the most pronounced in reference to the Lielupe River and Daugava River basins in the southern and eastern parts of Latvia where almost no hydromorphological assessments have been carried out. Latvian scientists have not developed their own method for hydromorphological assessment and in practice this parameter is not included in the national monitoring programme. So far, RHS has been the most commonly used method for the estimation of the hydromorphological state of Latvian rivers. Results of the current study show, that, overall, the method and scoring system for HMS and HQA indexes are appropriate also for rivers in Latvia. Findings of this research could be used to adapt the RHS method to Latvian conditions.

Table 4. Pearson linear correlation coefficients between hydrological and hydromorphological parameters of streams in the Venta RBD. ChanSub – channel substrate, ChanFea – channel features, BankFea – bank features, BankVeg – bank vegetation, ChanVeg – instream channel vegetation, Land50 – land use within 50 m, Type – river type, Dist – distance to the source

	Flow	ChanSub	ChanFea	BankFea	BankVeg	ChanVeg	Land50	Trees	Special	HQA	HMS	Type	Altitude	Slope	Width	Depth	Dist
Flow																	
ChanSub	0.448**																
ChanFea	0.309*	0.344**															
BankFea	0.412**	0.457**	0.497**														
BankVeg	0.350**	0.367**	0.417**	0.477**													
ChanVeg	0.247*	0.151	0.012	0.318*	0.273*												
Land50	−0.101	−0.147	0.029	−0.002	0.256*	0.007											
Trees	0.292*	0.241	0.474**	0.591	0.804**	0.185	0.417**										
Special	0.260*	0.110	0.281*	0.374**	0.313*	0.148	0.534**	0.485**									
HQA	0.505**	0.487**	0.586**	0.784**	0.839**	0.380**	0.348**	0.885**	0.585**								
HMS	−0.199	−0.327*	−0.543**	−0.489**	−0.647**	−0.077	−0.416**	−0.690**	−0.482**	−0.726**							
Type	0.081	0.086	−0.102	0.240	0.140	0.270	0.249	0.149	0.406**	−0.076	0.260						
Altitude	−0.186	−0.190	−0.105	−0.489**	−0.035	0.180	0.005	−0.178	−0.146	0.164	−0.238	−0.013					
Slope	−0.359	−0.162	−0.208	−0.245	−0.194	0.046	−0.175	−0.324*	−0.405**	0.237	−0.34*	−0.56**	0.197				
Width	0.360*	0.427**	0.235	0.467**	0.336*	0.260	0.077	0.289	0.356*	−0.381**	0.486**	0.558**	−0.284	−0.415**			
Depth	−0.058	−0.218	−0.032	−0.256	0.123	0.293	0.150	0.047	0.106	0.113	0.010	0.292	0.319*	−0.238	0.110		
Dist	0.414**	0.367*	0.322*	0.641**	0.317*	0.282	0.103	0.348*	0.423**	−0.403**	0.563**	0.581**	−0.46**	−0.502**	0.798**	0.008	1

According to a previous study in Latvia, HQA scores were between 55.9 for reference sites and 51.9 for anthropogenically impacted sites (Briede et al., 2005). In our study, the average HQA score was 38.7 points, which is significantly lower. The HMS scores in our research were 13.3 points, which is noticeably higher than in the previous study, where the HMS was 1.8 points in the reference sites and 4.2 points in anthropogenically impacted sites. One reason could be that the catchments of the Abava and Slocene rivers have a large proportion of agricultural land and so these rivers are heavily anthropogenically affected. Another reason might be river regulation. Intensive river regulation took place in the whole of Latvia from the 1960s until 1985 (Šķiņķis, 1992). Stream regulation increases annual flow amplitude, enhances base flow variation, and changes temperature, mass transport, and other important biophysical patterns and attributes. As a result, ecological connectivity between upstream and downstream reaches, ground waters, and floodplains may be interrupted. Native biodiversity and bioproduction are usually reduced or changed and non-native biota proliferated (Stanford et al., 1996). Our study analyses a large number of regulated stream stretches. The total length of the analysed rivers is 638 km of which approximately 179 km is regulated. There is only one river, the Sventāja, that is not regulated in any place throughout its length (Latvijas Republikas..., 2008).

The most important attributes affecting HQA scores in the Venta RBD were stream vegetation structure (19.6%), bank vegetation structure (18.5%), and trees and associated features (15.6%) (see Table 3). The contributions of flow type (14.8%) and channel substrate (12.3%) were also noticeable (Table 3). In European lowland rivers plant vegetation in stream is one of the most important factors, contributing 13.7% of the total HQA score, followed by channel substrate (10.9%) and bank vegetation structure (10.1–10.5%) (Szoszkiewicz et al., 2006). We can conclude that the HQA score in the Venta RBD depends markedly on five attributes while the impact of other attributes is significantly lower. The relationships were more pronounced in our study as compared with other studies (Briede et al., 2005; Szoszkiewicz et al., 2006; Urosev et al., 2009). Differences in results can be explained by the extent of research territory. Most of the researches cover wide geographic areas (Raven et al., 2000; Briede et al., 2005; Szoszkiewicz et al., 2006, 2010). Our study area was relatively small and compact covering the western part of Latvia and referring to approximately 24.5% of Latvia's area (Ventas upju..., 2009). Physiogeographic conditions are influenced by the size of the area: there is a wider variety of physiogeographic conditions in a larger territory.

The Pearson correlation coefficients revealed a negative correlation of distance to source with HQA (–0.403), but a positive correlation with HMS (0.563) in the Venta RBD (see Table 4). River type had a positive correlation with special features (0.406). This study also confirmed findings of other studies (Briede et al., 2005; Erba et al., 2006), namely, a negative correlation between HQA and QMS: if the degree of modification of a river increases, its natural characteristics will decrease. Special features (mostly beaver dams) had a positive correlation (0.534) with land use within 50 m. Distance to source had a positive correlation with stream width (0.798) but a negative correlation with altitude at stream source

(−0.46) and channel slope (−0.502). This is due to the fact that the width of the river has a direct correlation with the length of the river, and the altitude and slope tend to be lower closer to the river mouth than upstream. HQA had positive correlations with all RHS parameters, while HMS was negatively correlated with these parameters. The reason is that the HQA describes the diversity of natural characteristics. The more natural the characteristics, the lower the degree of modification. Special features, such as debris dams, wetland, fringing reed bank, were most commonly observed for type 4 streams (medium-sized potamal rivers). A strong negative correlation was observed between HQA and HMS (−0.726; $p < 0.01$).

To conclude, river hydromorphology is a new field of research in Latvia and several improvements are needed. Results of the current study show that, overall, the scoring system of the UK River Habitat Survey method is appropriate also for rivers in Latvia, but adaptation to local conditions should be done. In general, rhitral rivers will have higher scores than potamal rivers, although both river types are equally natural. For example, for naturally slow flowing potamal rivers with naturally monotonous and deep riverbeds covered with sand, the HQA index tends to lower the real habitat quality.

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