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Classification of chemical status of rivers for water management planning in Lake Võrtsjärv catchment area, Estonia

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Abstract

The EU Water Framework Directive devotes close attention to the ecological assessment of surface waters and the measure of achievement of implementation programmes. Based on long-time monitoring data that consisted in gathering water quality information from rivers in the Lake Võrtsjärv catchment area in Estonia, classes of rivers with regard to water quality were devised. Secondly, a priority map at a river basin level for integrated water management planning was developed. The purpose of this study was to analyse trends in the water quality of medium-sized (from 108 to 1270 km^2), predominantly rural river basins in southern Estonia. Chemical monitoring data from 1980-2000 were used in this study. The total current ecological value of river water quality in the Lake Võrtsjärv catchment area assessed by chemical parameters as a whole is relatively low (quality class III). In order to analyse the temporal changes in the studied trends, the whole research period was divided into 2 equal parts: (1) 1981–1990 and (2) 1991–2000. The results from this study showed that the Summary Index for the water quality of the whole Lake Võrtsjärv catchment area, calculated by the saturation of dissolved oxygen, BOD_7, NH_4–N^+, N_{tot} and P_{tot}, decreased from 3.5 in the 1980s to 2.6 in the 1990s. The most remarkable trend is found for NH_4–N^+ and total N concentrations: the water quality improved by index values of 44 and 40% respectively. For water protection and river restoration programmes, catchments areas with higher priority for water management planning can be selected. The water quality index is preferred for this purpose.

Key words: classification of rivers, water management planning, water quality

1 Introduction

Implementation of the EU Water Framework Directive (WFD) will induce changes in both legislative and institutional water management systems. As a pre-accession country of the EU, Estonia must be ready for such policy, and river basin management planning is one of the first steps towards it. Estonian water policy has been and continues to be, directed mainly towards investment measures. It does not always take into account the needs of the ecosystems of rivers and lakes, and does not apply an ecosystem approach to water management.

There is a well-established practice in Estonia for the development of river basin management plans. Since the 1970s, several unsuccessful attempts have been made to introduce norms for water flow in riverbeds, based on the minimum flow, instead of on the assessed water needs of river ecosystems. Management measures regulated by the regional environmental authorities were not efficiently implemented, and mainly concerned permitted levels of pollutants. The biological classification of river systems is under elaboration. One can say that physico-chemical parameters are more effectively monitored than the hydromorphology and biological features of rivers.

The EU WFD introduces a new approach in water management. The main aims of this policy are:

- to develop a water management system based on hydrographic units instead of the present system based on administrative boundaries;
- to expand the scope of water interests (protection) to all waters;
- to set water quality objectives and criteria;
- to elaborate management plan and a program of measures for each river basin.

Phase I of the L. Võrtsjärv catchment area management plan is oriented towards a description of surface and groundwater status, including an analysis of human impact on the quality of water and water bodies. One of the most important and also problematic issues for river basin management planning is the designation of water bodies and establishment of relevant water quality objectives (Fig. 1). This is very closely connected with the improvement of monitoring programmes. The Water Directive describes in detail how ecological assessment should be performed, including which quality elements must be used. In this paper we address the questions of how the water quality parameters have been changed during the last two decades, and how these changes have influenced the water management planning process.

Under the guidelines of the EU WFD, an integrated catchment management is adopted as an important aspect in water policy for achieving a good status of water. The Directive established the general objectives of achieving good water status as a minimum goal. It also requires specially detailed measures for rivers of worse quality. Good status means the ecological status achieved conditions in which human activity did not have a significant effect on balanced and sustainable ecosystem. The status "good" that should be reached can be defined

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through numerical and biological criteria. Numerical criteria are the statistical averages of certain chemical or other values.

The boundaries between classes can be quite wide. In many cases the final decision about the boundaries of classes is influenced by financial consideration: the availability of funds for improving the ecological condition of water bodies. The boundary between the good and moderate levels also appears to be a political issue, because reaching them requires a certain amount of investment. However, the reference conditions and water quality may not be a political decision, but the criteria have to be based on ecological criteria. The river basin management plan for the improvement of water quality should be developed for those water bodies that do not corresponding to the requirements for **good status**.

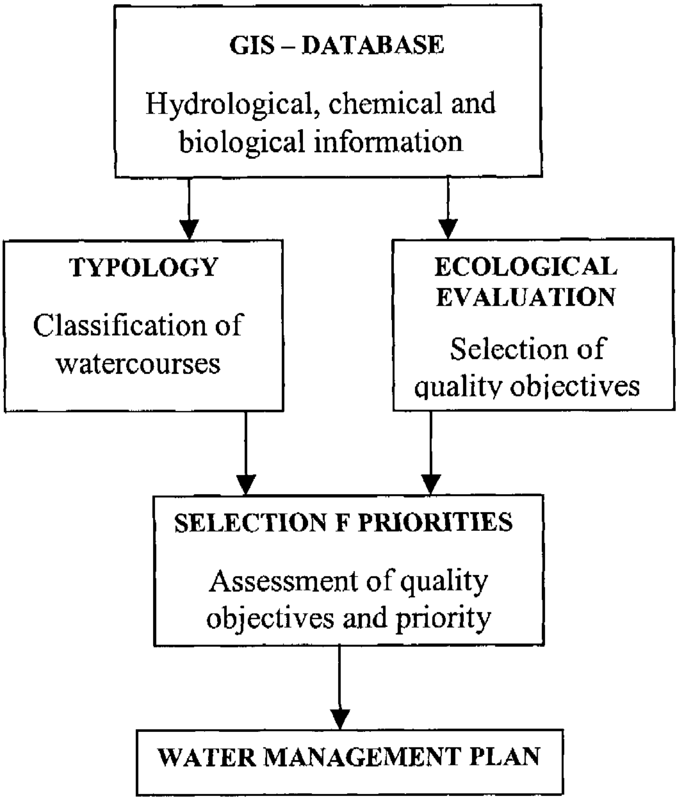

Figure 1: Steps in the methodology for assessment of water quality for water management planning.

2 Materials and methods

During the last decade much research has been devoted to the ecological quality of catchments and watercourses [1, 2, 3, 4]. The evaluation of water quality was based on physico-chemical monitoring data. Each parameter was compared with the quality criteria. More informative for water management planning is an integrated method using different water quality indicators. As a quality score, the summarised Chemical Index (C.I.) was used. The C.I. gives a score on five parameters, that is: saturation of dissolved oxygen, BOD_7, NH_4–N^+, N_{tot} and P_{tot}. It has been used to describe the state and changes of water quality by chemical classification. The chemical classification divides rivers into five classes (Table 1) and C.I. ranging from 1 (higher quality) to 5 (bad quality) for each parameter. For all rivers studied, the quality assessment was made along the whole length (Fig. 2).

Table 1: Water quality classification of rivers in Estonia.

Quality parameter	Class I High	Class II Good	Class III Fair	Class IV Poor	Class V Bad
pH	6–9	6–9	6–9	6–9	<6 or 9>
Dissolved oxygen, %	>70	70–60	60–50	50–40	<40
BOD_7, mg O_2 l^{-1}	<3.0	3.0–5.0	5.1–8.0	8.1–10.0	>10.0
NH_4–N, mg l^{-1}	<0.10	0.10–0.30	0.31–0.45	0.46–0.60	>0.60
N_{tot}, mg l^{-1}	<2.0	2.1–3.0	3.1–4.0	4.1–5.0	>5.0
P_{tot}, mg l^{-1}	<0.05	0.05–0.08	0.09–0.12	0.13–0.16	>0.16

The water with higher quality parameters is typical of Estonian natural waters that are not directly influenced by human activity. For the second class (II), a certain anthropogenic impact is allowed, but quality is still good and suitable for the river ecosystem [5]. Rivers that are moderately, significantly or strongly influenced by human activities correspond to a quality situation belonging to classes III, IV or V classes respectively. The goals for the five classes were linked to different quality requirements.

3 Site description

The study area is situated in the watershed of L. Võrtsjärv, the second-largest lake in Estonia. This watershed (3,104 km^2) belongs to the basin of L. Peipsi (47,800 km^2). The studied catchment mainly represents a moraine plain landscape type typical of southern Estonia [6]. The population density is relatively low, 22.5 inhabitants km^{-2} and towns, settlements and roads cover a small part of the drainage basin. About 30–40% of the studied catchments may potentially be used as arable land. However, during the 1990s arable land has decreased from 41 to 34%. In wooded areas, the forest covers 66% of the land and consists of coniferous and mixed forests. At the same time, one could observe no significant trends in water discharge – annual mean specific runoff in the whole catchment area by calculated linear trend demonstrated a diminishing trend, namely only 0.08 l s^{-1} km^{-2} from 1981 to 2000.

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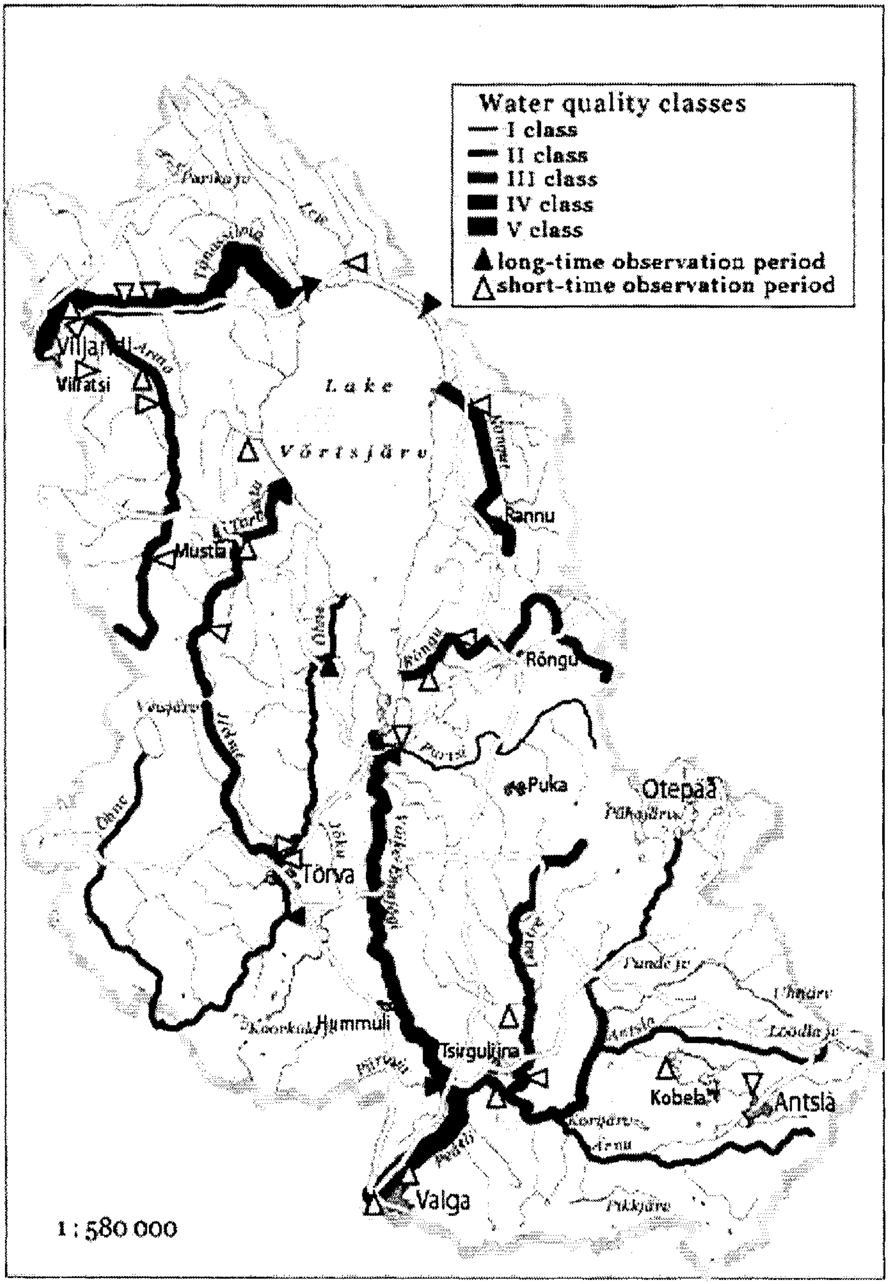

Figure 2: Monitoring sites and water quality classes of rivers in the Lake Võrtsjärv catchment area.

Many river courses have been regulated and/or canalised to some extent. The most intensive regulation of rivers took place during Soviet times (particularly in the 1950s and at the beginning of the 1960s), when large-scale amelioration programmes were in practice. Also, the creation of small water reservoirs was actively pursued in the 1980s. To drain wetlands, many rivers are dredged or cut, and the water level of some lakes has been reduced. At the beginning of the 20th century, water energy was used by 36 water mills and small hydroelectric energy stations. At present, 4 of these still function. These artificial lakes were usually of a small regulating volume and did not significantly influence rivers' runoff regime.

For the purposes of dredging and land amelioration, the unsatisfactory conditions of small streams can be caused by hydromorphological features in relation to the accumulation of suspended matter and the intensive growth of macrophytes in riverbeds. Some of the wetlands are directly drained through the construction of agricultural drainage systems and open ditches.

The Lake Võrtsjärv catchment area water management project has resulted from long-term collaboration between scientific institutions and environmental authorities, including Estonian-Finnish collaborative research studies. Joint Estonian–Finnish work in the field for better water management began already in the mid-1990s. Later increasing attention was paid to legislative and water management issues. During last two years the main activity was devoted to gaining experience in water management in compliance with the EU WFD.

4 Changes in the water quality classes of rivers

One of the main issues in Estonian water protection is the eutrophication of surface waters caused by the increased load of nutrients of anthropogenic origin. The critical content of total nitrogen, above which the eutrophication of rivers begins, is 2.8 mg N l^{-1}. In the rivers of the L. Võrtsjärv catchment area are considered to be background rivers. On the basis of 95% of all samples, TN concentration in the Õhne River was lower than the critical value, the mean concentration being 1.5 mg N l^{-1}. The nitrogen level in the other rivers was still quite high, although it has decreased in most rivers in recent years due to a reduction in the agricultural pollution load. The concentration of inorganic nitrogen, both NH_4–N and NO_3–N was highest in 1985–1987, when the use of fertilisers was very intensive and most of it was leached into the surface water [6]. The level of agricultural production and also nitrate concentration was highest in 1984–1988, whereas by the end of the 1990s, a period of low agricultural production, the concentration of nitrogen compounds in rivers has decreased remarkably.

The rivers discharging into L. Võrtsjärv are quite nutrient-rich. In the 1980s, the riverine discharge of nutrients increased drastically. Due to the intensive agriculture, in the 1980s the ecological quality of river water fell considerably. In the early 1990s a sharp decrease occurred, first of all in the area of nitrogen loading. With respect to the level at the end of the 1980s, only 5–10% of N, P and K mineral fertilisers and 30% of manure were applied in the agricultural lands of the catchment area at the end of the 1990s [6]. As nitrogen loading decreased faster than phosphorus loading, the N/P ratio in the loadings also decreased.

Table 2: Water quality classes by main rivers in the Lake Võrtsjärv catchment area, 1981–2000

River, period	O_2	BOD_7	NH_4	N_{tot}	P_{tot}	SUMMARY INDEX
Väike Emajõgi						
1981–1990	1.5	1.3	3.3	2.6	2.3	3.6
1991–2000	1.3	1.2	2.0	1.5	2.3	2.6
Difference	-0.2	-0.1	-1.3	-1.1	-0.0	-1.0
Õhne						
1981–1990	1.1	1.3	3.2	2.5	1.9	2.5
1991–2000	1.1	1.1	1.7	1.7	1.8	1.5
Difference	-0.1	-0.2	-1.5	-0.8	-0.1	-1.0
Tarvastu						
1981–1990	1.8	1.8	3.4	3.8	2.7	3.8
1991–2000	1.1	1.2	1.8	2.6	2.1	3.0
Difference	-0.7	-0.6	-1.6	-1.1	-0.6	-0.9
Tänassilma						
1981–1990	2.1	1.6	3.7	3.3	3.5	4.2
1991–2000	1.8	1.2	2.2	1.7	2.9	3.4
Difference	-0.4	-0.5	-1.6	-1.6	-0.6	-0.8

The present level of biological oxygen demand (BOD_7) in most of the rivers of the L. Võrtsjärv basin is quite low in comparison with the 1980s [7], when the amounts of wastewater discharged into the rivers reached the highest levels. The BOD of natural river water that is not directly influenced by human activity is generally less than 3.0 mg O_2 l^{-1}. BOD_7 3–5 mg O_2 l^{-1} indicates moderate human impact, and the values continuously above 5 mgO_2/l indicate obvious pollution. During the last decade, the BOD_7 level in the rivers of the L. Võrtsjärv basin has generally been classified as good (class II) or moderate (class III) (Fig. 3). The fluctuation of annual 90% values is also quite low, which shows the high efficiency of wastewater treatment in the towns and large villages of the basin.

The rather high BOD_7 in the Tarvastu and Tänassilma rivers, especially upstream of the Tänassilma River, was caused by a large amount of wastewater from the town of Viljandi [8]. Additionally, the upper reaches of Tänassilma River run through agricultural areas characterised by large amounts of slurry spreading in the fields, even in winter. The self-purification processes in the Tänassilma River (mineralization of organic matter) cause this high eutrophication level by inorganic nitrogen, especially by NH_4–N and very low O_2 concentration. This explains that the high level of NH_4–N at the mouth of the Tänassilma River does not indicate direct local nutrient pollution.

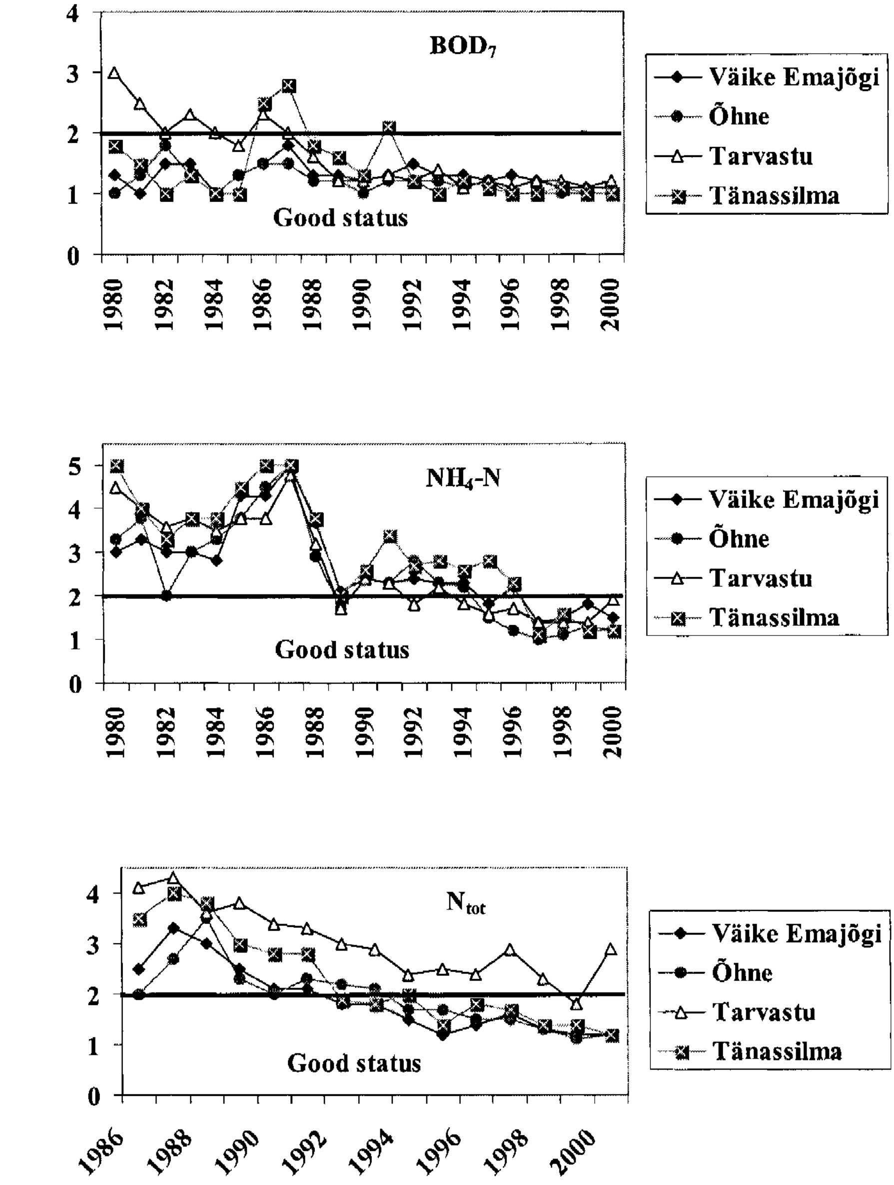

Figure 3: Dynamic of water quality classes in 1980–2000 by chemical parameters of rivers in the Lake Võrtsjärv catchment area.

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Intensive slurry spreading cannot guarantee better water quality as a class III in the long term. Within the protection programme, the construction of buffer stripes and the restoration of small wetland areas alongside creeks should be analysed.

In comparison with other rivers, the water quality score of the Õhne River was high: in the 1980s the annual mean C.I. was 2.5 and in the 1990s C.I. was 1.5. In general, the water quality class moved from **fair** to **good**. The ecological quality of the Väike Emajõgi River falls quickly after receiving incoming water from the Pedeli River (Fig. 2), which is a recipient of insufficiently treated wastewater from the town of Valga (14,300 inhabitants). Therefore the downstream section has poor water quality – class IV. In comparing two periods, 1981–1990 and 1991–2000, one can see a significant difference in the river's water quality (Table 2, Fig. 4). In terms of the two periods' mean water quality index, the improvement of dissolved oxygen, BOD_7, NH_4–N^+, N_{tot} and P_{tot} was 0.3, 0.4, 1.3, 1.1 and 0.4 unit values respectively.

To improve the river's water quality, in the mid-1990s the environmental authorities initiated wastewater treatment programmes. Recently extensive reconstruction of wastewater treatment plants remained important locally to reach the basic quality standards for water bodies.

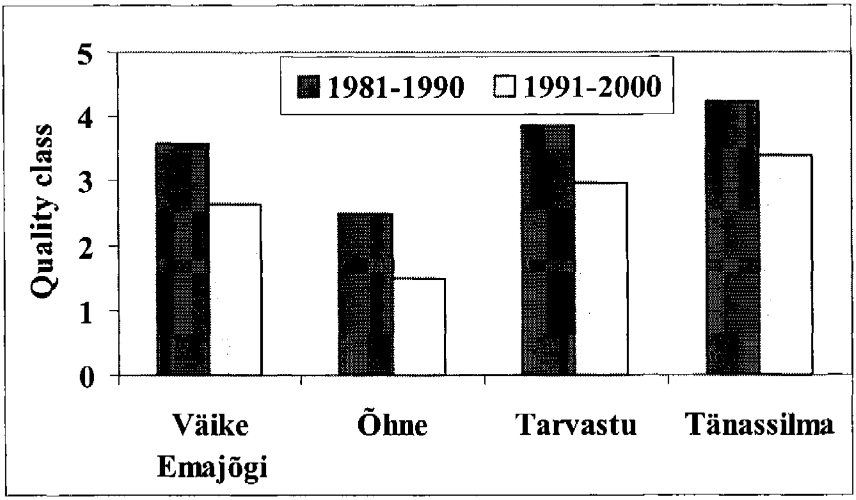

Figure 4: A comparison of annual mean water quality index of sub-periods 1981–1990 and 1991–2000.

Conclusion

The total current ecological value of river water quality in the L. Võrtsjärv catchment area as assessed by overall chemical parameters is relatively low, and belonging to the quality class III. The Õhne River and some smaller brooks in the eastern part of the catchment area have a good water quality. For the

Tänassilma River, class III will be the maximum attainable level in the near future. Despite chemical quality, the overall water quality should guarantee the migration of fishes from Lake Võrtsjärv to the upper reaches of main rivers (excluding the Tänassilma River), which have been established as important spawning sites. The long-term possibilities for water protection and river restoration could be considered. For this purpose catchment areas with higher priority for river restoration programmes will be selected in respect to water management planning. The assessment of quality elements could be transformed into a policy map for river water quality improvement programmes.

Water quality and ecological data could be transformed into policy maps for river restoration programmes. Based on the ecological value to the fishery, the highest priority in integrated management is held by rivers with water quality classified by the Chemical Index as <2.5. The upper reaches of the Väike Emajõgi River are in urgent need of restoration of their natural variety, focused primarily on small fragments of valuable habitats. These fragments can be designated as ecologically core areas of the river valley. It is typical that in countries with lower population density and large uncultivated areas, restoration programmes are primarily oriented towards degraded sites.

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