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Section: Water Engineering

Naturalization Processes in the Beds of Regulated Rivers

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Abstract

The article deals with the naturalization processes occurring in the regulated stream beds. It was found that naturalization processes are influenced mostly by the prevalence of herbaceous and woody vegetation in regulated streams. 34 species of woody vegetation were found in analyzed streams. The most common among found types were sallow (*Salix caprea* L.) and shrubs (*Salix Ciner* L.). The overall density of the woody vegetation, growing on the slopes of streams, reaches $T = 1.26 \pm 0.20$ pc./m^2. The strong dependence of the woody vegetation habitats density on the distance to the forest (correlation coefficient 0.70 to 0.90) was received. Both woody and grass vegetation seems to have the same impact in reducing the nitrate ion concentration in the water self-purification.

Keywords: regulated streams; naturalization; vegetation; nitrates.

1. Introduction

By regulating the beds of natural rivers and streams their natural meanders were removed as well as transverse profile of beds was artificially formed. Rivers have become straight ditches, intended to lead the excess water collected from the drainage system. It is estimated that the regulated river beds in Lithuania occupies 82.6% and natural river meanders – only 17.4% of the total river network [1].

Nitrogen and phosphorus compounds have the greatest impact on the eutrophication of coastal and marine waters. Because of these adverse effects algae start to bloom and there is the lack of oxygen in the Curonian Lagoon and the Baltic Sea. Coastal habitats are created on the interaction of water and land [2]. Water enters and flows out of the river flowing only through this coastal ecotone. The water falls into the river in five ways: with surface runoff, by infiltration, through shallow groundwater layer, through deep underground layer and flowing through the drainage systems. The unique physical and biochemical properties of coastal ecotones determine not only the flow of water but also the flow of nutrients.

During the analysis of the uptake of nitrogen compounds into water bodies it was noted that the highest concentration of biogens can occur not from anthropogenic activities and river run-off, but from other events having seasonal effects (vegetation and depth of soil freezing) [3]. Plant filtration zones along banks of streams are recognized as the most effective means of protecting the waters from the non-point agricultural pollution in many parts of the world [4–6]. It is argued that the vast majority of the nitrates and phosphates are retained in 10 meter wide protective zone. Studies carried out in Wisconsin [7] showed that the 4.6 and 9.1 m wide zones of grassy vegetation reduced nitrogen and nitrate uptake into nearby bodies of water by 90 and 96%, respectively. Mander [8] compared the wet meadow/gray alder buffer zones (11 and 20 m) and wet meadow/gray alder buffer zones (12.28 m) of nitrogen retention in Estonia. The first buffer zone seized 67% of the total nitrogen, while the second buffer zone seized even 96% of nitrogen. The destruction of protective bank zones of river valleys affect natural ecosystems, acting as a natural biogeochemical barriers, providing landscape with aesthetic view, protecting biodiversity as well as reducing pollution of surface waters.

Currently, naturalization processes are rapidly developing in regulated streams – with occur of various factors (accumulated deposits, deformed slopes), the designed stream bed changes, transverse and longitudinal deformations of beds occur, the bed bottom meandering features occur as well. The meandering stream bed consists of 59.1% of the analyzed stream beds [9].The grass species composition of the slopes of regulated streams is changing as well [10]. Plant communities, specific only for streams and ditches, start to form. During herbaceous vegetation change, woody plants begin to grow in ditches and slopes of regulated streams. The most common are deciduous trees and shrubs. Lamsodis [11] found

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that more than 36 plants of woody vegetation types grow in the ditches and regulated streams as well as in Nevėžis plain, of which 19 – trees and 17 – shrubs.

The goal of the work – to identify the prevalence of grassy and woody vegetation occurring during the naturalization processes in regulated streams and assess its impact on water quality.

2. Object and methodology

Researches have been carried out in Lithuania. Strips of the following streams were selected for the research: Alsa, Aluotis, Bezdonė, Dūkšta, Gveznianka, Juoda, Mažasis, N-2, Nemaitiškis, R-55, Riešė, Rudamina, Šešuvis, Vaišvilė, Vilnoja, Z-3 and Žalesa. The selection method of regulated streams was random. The essence of this method is that the number of the members of the analyzed group is randomly selected. The total number of analyzed measuring sections in regulated streams – 297, section length – 10 meters.

The river profile is divided into the slopes and bank protection zones. In each of the analyzed zones the prevalence of woody vegetation (which used to grow there) was determined according to quantitative and qualitative characteristics of habitats of different types, communities and their whole:

- number of types (R_{sk});
- frequency (D) – the prevalence of woody vegetation has been identified as the ratio of the bed slope or its parts (bank protection strips, the upper and the middle part of the foot), in which the types (habitats) were found, and the number of analyzed strips, %. Tree frequency (D_M) and shrub frequency (D_K) were isolated as well;
- density (T) – the density of woody vegetation in the habitats was determined as the total number of stems per 1 m^2 of the total area of the bed slope (measured by the number of stems per square meter, unit/m^2), highlighting the bank protection zone and the slope. Tree (T_M) density as well as shrub density (T_K) were analyzed separately.

In all analyzed zones the diameter of shrubs or trees stems was established for each type of woody vegetation. Diameter was measured 10 cm above the ground. The average stem diameter was calculated separately for each type of the trees, shrubs growing on the slope and in the bank protection zone. In the analyzed zones, besides the overgrowing with woody vegetation, the overgrowing with grassy vegetation was studied as well. The varietal composition of grass growing on the slope and in the bank protection zone was evaluated. Samples for water quality testing were taken at the beginning and the end of the analyzed zone of the Šešuvis and Alsa streams. Nitrate content in water is determined in accordance with ISO 7890-31998. Water quality [12].The data were processed by the methods of mathematical statistics [13].

3. Results

Studies carried out in Lithuanian regulated streams showed that all streams are affected by the process of naturalization. In regulated streams, beds begin to meander in places. Depending on the slope of the stream, shallowness starts forming in 65% of the analyzed zones or sludge starts to build-up in 35% of the analyzed zones. The bed of some regulated streams becomes comparable to that of natural, unregulated streams. Different types of grass vegetation grow on the regulated streams slopes due to different moisture conditions on the slopes of the ditch. In the upper part of the slope, vegetation is similar (by composition of types) to the one that grows in the bank protection zone. Due to the high moisture content the stream bank vegetation grows at the bottom of the slope.

In the analyzed Lithuanian streams a simple reed (*Phragmites australis* (Cav.) Trin.), meadowsweet (*Filipendula ulmaria* (L.) Maxim.), marsh sedge (*Carex acutiformis* L.) were found. Since the slopes of regulated streams are not mowed, and there are around cultivated fields, slopes of streams are overgrown with tall grassy vegetation, weeds (stinging nettle (*Urnica dioica* L.), hardness (*Artemiria vulgaris* L.) and the big burdock (*Arctium lappa* L.).

Especially a lot of weeds were found in the N-2 stream and in Vaišvilė regulated stream. Much of tall herbaceous vegetation, such as common reed (*Phragmites australis* (Cav.) Trin.) was found in Vaišvilė and Žalesa regulated streams. In the regulated streams slopes as well as in the bank protection zones many pharmacies plants, such as a simple raspberry (Rubus idaecus L.), common bramble (*Rubus Caesius* L.), St. John's wort (*Hypericum perforatum* L.), coltsfoot (*Tussilago farfara* L.) and hop (*Humulus lupulus* L.) can be found. In particular, many medicinal plants were found in Vilnoja regulated stream. Almost in all analyzed regulated streams one could find sections where the river bottom was also covered with grassy vegetation. In particular, much herbaceous vegetation was found in the R-55 stream and in Vaišvilė stream. At the bottom of the river beds of the Dūkšta and Gveznianka analyzed sections no grassy vegetation was found.

In the regulated streams of Lithuania other naturalization processes are going on as well. Some of the sections of regulated streams are overgrown (or start to overgrow) with woody vegetation, that is trees and bushes. While researching regulated streams of Lithuania 34 types of woody vegetation (16 trees, 18 shrubs) were found. In the bank protection zone 21 types of woody vegetation (12 trees and 8 shrubs) were found. In the slope sections of 297 analyzed regulated streams of Lithuania woody vegetation was found in 209 of them. In 134 sections of the slopes we found shrubs or their forms, and in 112 – the trees. The total number of the woody vegetation type frequency on the slopes of Lithuania's regulated streams reaches 70%.

The most common of the tree types in the research area were sallow (*Salix caprea* L.), brittle willow (*Salix fragilis* L.), alder (*Alnus incana* (L.) Moench) and alder (*Alnus glutinosa* (L.) Gaertn.) as well as beleric birch (*Betula pendula* Roth). The gray willow (*Salix cinerea* L.) needs to be kept as the most widespread bush, eared willow (*Salix aurita* L.), black

willow (*Salix myrsinifolia* Salisb.), osier willow (*Salix viminalis* L.) are often seen. The woody vegetation was found in 70 sections of the bank protective zones of the 297 analyzed regulated streams. The total number of the woody vegetation type frequency in Lithuania's bank protective zones of the regulated streams is 23%. The most common types found in the protective zone are gray alder (*Alnus incana* (L.) Moench), birch (*Betula pendula* Roth) and black alder (*Alnus glutinosa* (L.) Gaertn.). In order to assess abundance of woody vegetation, we calculated the overall woody vegetation density T = 1.39 ± 0.20 pc./m^2. Abundantly overgrown with woody vegetation are the Z-3 stream (4.94 pc./m^2) and Šešuvis stream (5.62 pc./m^2) (Fig. 1). No woody vegetation was found in Alsa regulated stream.

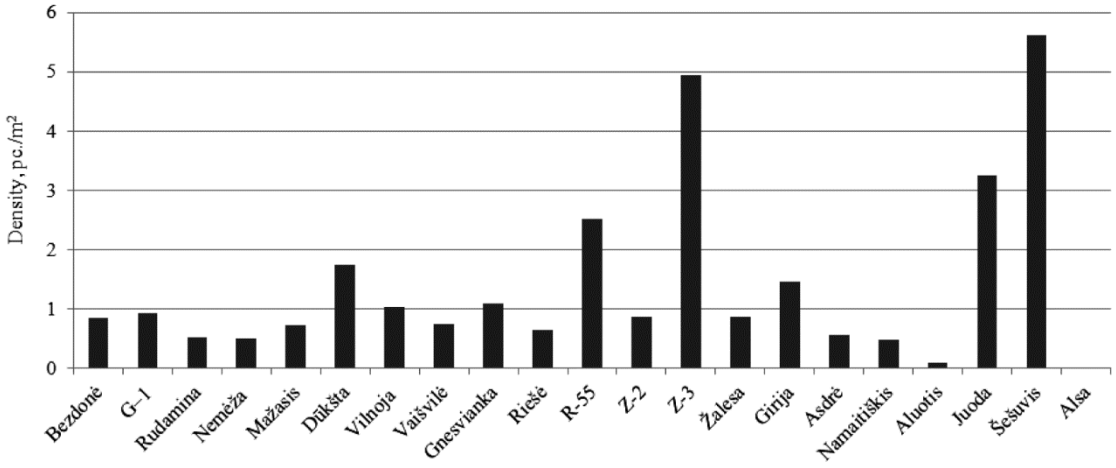

Fig. 1. Woody vegetation density distribution in the regulated streams of Lithuania

The density of woody vegetation can be estimated and in the bank protection zone. The overall vegetation density in the bank protection zone was T = 0.07 ± 0.02 pc./m^2. So it can be said that the regulated streams slopes in Lithuania are much more abundantly overgrown with woody vegetation than the bank protection zones. This may have resulted in the fact that some of the bank protection zones are mowed. It does not enable the growth of trees and shrubs. Meanwhile, 99% of the analyzed slopes of streams have not been mown.

The analysis of the purpose of the land adjacent to regulated streams showed that in 85% cases of the total sampling of study sections (N = 594), there were meadows and pastures as well as roads near regulated streams, in 9% cases – arable land and in 6% cases – the outskirts. The spread of woody vegetation on the slopes of regulated streams is strongly influenced by their location in relation to the forest (Fig. 2). The highest vegetation density and type diversity were found in those sections of regulated streams, which flow through the outskirts 50–300 m from it.

The increased vegetation density was observed in such regulated streams, which are flowing through the non-urbanized area overgrown with woody vegetation. In regulated streams, which flow near the settlements, the woody vegetation density of cultivated fields is much lower (Rudamina, Mažasis, Riešė). It is observed that vegetation density is low (Bezdonė; Nemaitiškis) in such regulated streams, which flow through the forest, because their slopes are covered with trees.

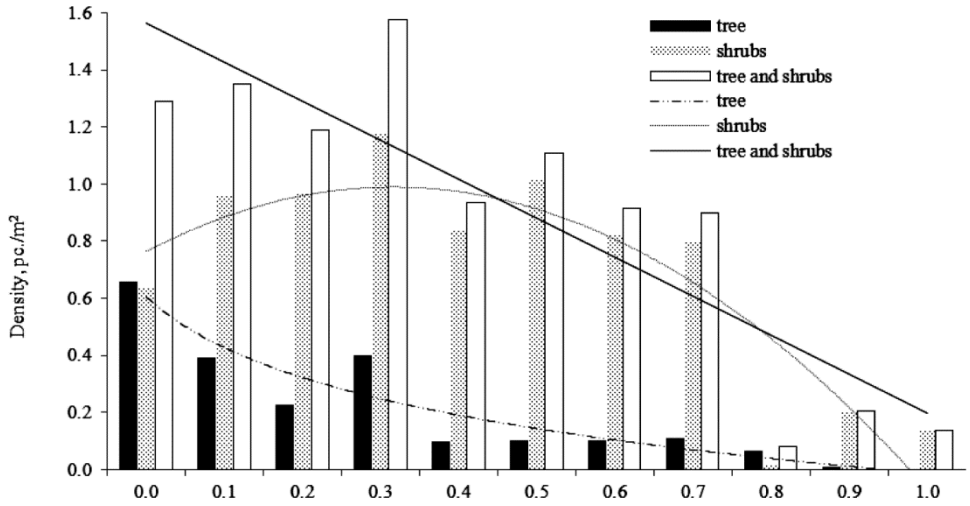

Fig. 2. Dependence of woody vegetation density on distance to the forest

So, while entire slope the regulated stream is covered with woody vegetation, the density is not high. In those regulated streams, where the slopes in the outskirts are overgrown not with trees but with shrubs, the different vegetation distribution is being noticed. Such is Aluotis stream (Fig. 3), flowing in the northern part of Lithuania.

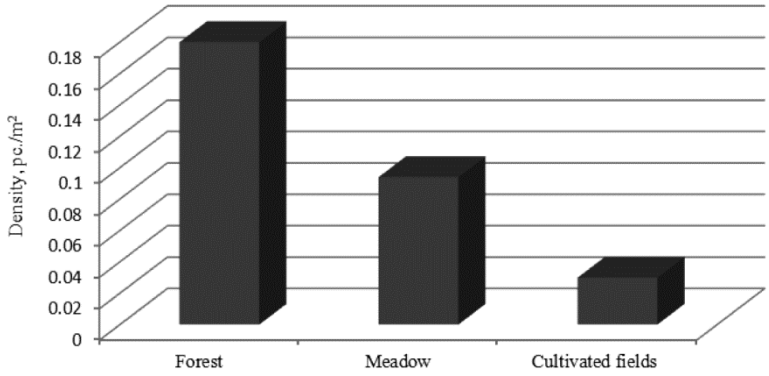

Fig. 3. Woody vegetation density when the stream of Aluotis is flowing through the land of different purpose

When performing research in Central Lithuania [11], the highest diversity of types was observed in those ditches and regulated streams, which are dug in the forest, on outskirts and close to the forest (<100 m). In more than 500 m from the forest, one could find only shrubs growing in the regulated streams of the fields of Nevėžis plain. According to Lamsodis (2002), dependence of the woody vegetation on the distance from ditch to the forest, is quite close $r = -0.82$, p>95%. Thus, forest and outskirts in the landscape are places, where drainage channels and regulated streams are most naturalized from dendrological point of view. It can be argued that in many cases the woody vegetation occurs primarily where conditions of the access to the slopes are most favorable. In the regulated streams of forests and outskirts, trees and shrubs begin to grow on the slopes when their seeds accidentally get in the ditches. However, the distribution of woody vegetation in the regulated streams of the outskirts and fields shows that they spread not only in the forest environment. Some of the seeds of woody vegetation could get on the slopes from the settlements, farmsteads and roadside planting strips.

The analysis of the mean of the bank protection zone width of regulated streams shows that in arable land it is 1.72 m, the coefficient of variation – 0.75, standard error of mean – S_x = 0.24 m. The mean error at the 95% confidence – S_{x95} = 0.48 m. In as many as 79% of all analyzed regulated streams the width of the protective zone of the regulated stream in arable land was less than 2.5 m, as it is required by the regulations. A much worse situation was fixed in the protective zone widths near cultivated fields (arable land). In Alsa stream the zone width mean is 0.69 m and in Mažasis stream – 0.77 m. The zone width mean of Alsa stream (beside arable land) – 0.69 m representing 13% of the necessary strip width, coefficient of variation – 0.84, the standard error of the mean, when reliability is 95%, S_x = 0.20 m. In the regulated Alsa stream only 25% were eligible, and 13% of the land was plowed up the river.

The studies of nitrate concentration, conducted in the regulated streams of Šešuvis and Alsa, have shown that both in the regulated zones of the stream Šešuvis, where the slopes are covered with abundant woody vegetation, and in Alsa stream, where grass vegetation predominates, the nitrate concentration varies very little and does not exceed permissible levels during vegetation period. Only at the end of the growing period of the plants nitrate concentrations in Šešuvis and Alsa rivers in December exceeded the amount 1.51 times (Fig. 4). The sharp increase of the nitrate content in water in the zones of Alsa and Šešuvis regulated streams may be associated with the expired period of vegetation and organic matter caching, which result from decomposition of plants.

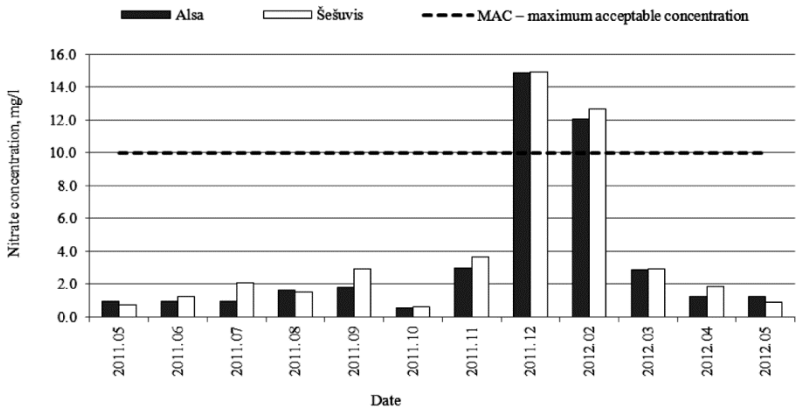

Fig. 4. Šešuvis and Alsa nitrate concentration in the period of research

The nitrate ion analysis in the zones of the Šešuvis and Alsa regulated streams showed that the nitrate ion concentration (when comparing the beginning and the end of the zone), declined. There was not found any significant difference between the reduction of nitrate concentration and the overgrowing of the stream with grassy or woody vegetation. We conclude that the grass and woody vegetation may be equally effectively intercept and remove nutrients. Trees and shrubs growing in the protection zone and stream slopes strongly reduce the concentration of nitrates in water coming from nearby cultivated fields, but unsupervised strips overgrow with lush vegetation and bushes and large amount of plant residues increases the amount of organic nutrients in the surface water.

4. Conclusions

34 species of woody vegetation were found in the regulated streams of Lithuania during the research. The most commonly found types wee sallow (*Salix caprea* L.) and shrubs (*Salix Ciner* L.). The overall average density of woody vegetation on the analyzed slopes of regulated streams $T = 1.26 \pm 0.20$ vnt./m^2.

The woody vegetation type diversity on the slopes of regulated streams depends on the situation of the streams in the territory (in the woods, on the outskirts or agricultural land). The strong common dependence of woody vegetation density on the distance from the habitats to the forest (correlation coefficient 0.70 to 0.90) was received.

It looks like woody and grass vegetation have the same impact on the water self-purification process, and the nitrate ion concentration in the stream water is directly dependent on plant vegetation.

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