

# River Re-naturalisation in the Tisza River Basin after Forest Cutting Activities

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**Abstract:** Forest cutting is a typical kind of economic activity in the Ukrainian Carpathians. Forest cutting within a river basin and especially timber transportation downstream the rivers leads to almost complete destruction of the river habitats. River re-naturalisation actions, taken by the authors included clearing of timber remains, restoration of natural conditions by means of building rapids, spits and capes from local stones, and creation of depth drops and areas with different flow velocity and turbulence in the Skorodnyi stream. These works were followed by stocking the stream with invertebrates and fish. The hydrobionts for stocking were collected in an undisturbed river, similar to the Skorodnyi stream by its size, underlying rock and altitude.

Mechanical destruction of habitats and excessive amount of timber residues lead to the condition when rivers, influenced by intensive forest exploitation, face replacement of litorheophilic fauna by xylophytous and perophilic species. After wide development of xylophytous shredders (Amphipoda), some eurybiontic predators (Hirudinea) appear, then come gatherers (larvae of Chironomidae), etc. Under conditions where the whole riverbed suffers, such “defective” communities can exist for years. In such cases, the general abundance rates, biodiversity and the functional activity of bottom fauna remain rather low, while even little efforts for re-naturalisation may lead to fast restoration of the river biota.

**Keywords:** Re-naturalisation, macroinvertebrates, forest cutting, small rivers

## Introduction

The intensive forest cutting is a typical kind of economic activity in the small river basins in the Carpathian Mountains in Ukraine. Active works within the river catchment and especially timber transportation downstream rivers lead to almost total destruction of the river habitats. Biotic groups in the riverbed also suffer because most species of hydrobionts are not able to survive in the severe conditions of mechanic and hydrodynamic impacts, as well as high turbidity together with considerable changes in chemical water composition. It is worth mentioning that the natural restoration of both biotic structure and ecological status after the negative pressures and impacts caused by forest exploitation takes quite a long period of time, while the consequences of this

activity can be traced during several years and when no measures are taken to restore the habitats, these consequences can be observed during several decades. Today billions of dollars are spent all around the world to restore streams and rivers, but attention is often not paid to direct restoration of river communities' biological structures, while the attention is usually drawn to restoration of flora and sometimes fish populations (PALMER *et al.* 2005).

## Material and Methods

The research took place from August, 2008 till August, 2012 and covered three small tributaries of the Tisza River (the Danube River basin): the tribu-

taries Dovgorunya and Loschansky streams, and the tributary Skorodniy stream. The material in all examined rivers was collected in August 2008, September 2009, May 2010, and August 2012. The selection of a particular sampling site and samples was done using AQEM monitoring scheme (<http://www.aqem.de/>). In each sample, 20 “replicates” were taken from all major habitat types. For all the examined rivers, the detailed description of biotopes was done, and the following parameters were measured: concentration of dissolved oxygen (using an oxygen indicator Oxi 315i), pH, and water temperature (using of pH meter devices – millivoltmeter pH-150MA and portable pH meter pHep-2). The measurement of average water flow velocity in the stream was carried out using microcomputer flow meter and speedometer MKRS YUAKS 407262.001 PS. The Soerensen index (IS) was used as an index for similarity of communities according to qualitative data (SOERENSEN 1948).

The Skorodniy stream, where forest cutting activities had been finished completely before research, was selected for re-naturalisation. The geographic location of the area designated for the stream re-naturalisation is as follows: stream outlet – N 47°55'39.3" E 024°13'27.6", altitude of 451 m a.s.l., and the timber raft area – N 47°55'55.2" E 024°13'34.4", altitude of 549 m a.s.l. In general, the river length is about 4.5 km. The length of the riverbed damaged by timber rafting, was 1.5 km. This part of the stream was littered with large amounts of timber, notably logs of various lengths and to a lesser extent with wood chips. In some areas, full of rapids, the riverbed was covered with wooden beams to enable the movement of heavy machinery.

The whole process of stream re-naturalisation consisted of five stages. The first stage included collection of wooden residues in the riverbed. During the second stage, the morphological and biotopical structure of the river was restored on the basis of the proportion of bottom substrata areas, which was earlier determined for this case (AFANASYEV 2006), and remainder of natural bends, rapids and hollows. Due to the fact that eight weirs, seven half-weirs and 5 artificial rapids were constructed of local stones, the riverbed tortuosity was restored, and drops of depths and zones with different stream speeds and turbulisation were created.

The third stage included a selection of an undisturbed (reference) river and examination of the area

which would meet the requirements for reference conditions of the habitats, being similar to the river in question by its size and geological structure of the riverbed, and situated at the same height above the sea level. The authors selected the Pykhy River, located within the territory of the Carpathian National Park at an altitude of more than 600 m a.s.l., and which has a similar biotopical structure that is typical for the small rivers in this region. After general examination of the bottom communities within different biotopes of the pilot area by means of standard selection method – “kick and sweep” (this method of investigation of aquatic macroinvertebrates in the littoral areas is the most effective), the integrated sample was taken for quantitative assessment of the bottom fauna. Furthermore, some hydrobionts were captured for the purpose of their reintroduction into the restored Skorodniy stream. The invertebrates for relocation were captured in the pilot area with the help of drift catchers by exhausting the bottom and outwashing the surface soil into special nets. The mesh of capturing nets was 25 micrometers in diameter and 25x25 cm in size. The enumeration and primary identification of the invertebrates were carried out at the field. Besides, some indigenous species of fish was caught. The whole material collected was placed into thermocontainers, specially prepared and protected from heat, and delivered under constant aeration to the Skorodniy stream upper reaches in September, 2009.

The introduction of invertebrates was carried out at five sites of the riverbed at a distance of 150-200 m from each other. The following invertebrates were released: approximately 5000 specimens of Ephemeroptera naides, most of which were: *Baetis digitatus* (Bengtsson, 1912), *B. vernus* (Curtis, 1834), *B. rhodani* (Pictet, 1843), *Epeorus assimilis* (Eaton, 1885), *Paraleptophlebia wernerii* (Ulmer, 1920), *Ecdyonurus venosus* (Fabricius, 1775), etc.; approximately 3000 specimens of Trichoptera larvae, most of which were: *Rhyacophila dorsalis dorsalis* (Curtis, 1834), *Hydropsyche instabilis* (Curtis, 1834), *Cheumatopsyche lepida* (Pictet, 1834); approximately 1500 specimens of Plecoptera naides, most numerous of which were: *Leuctra albidula* (Kempfy, 1899), *Nemurella pictetii* (Klapalek, 1900), *Protonemura intricata intricata* (Ris, 1902); among the biggest species were: *Dinocras cephalotes* (Curtis, 1827), *Perla marginata* (Panzer, 1799)

and *Perla burmeisteriana* (Claassen, 1936). In addition, approximately 12 000 specimens of other aquatic invertebrates were released.

Nine stream trouts *Salmo trutta morpha fario* (Linnaeus, 1758), five gobies *Cotlus poecilopus* (Heckel, 1837), and four minnows *Phoxinus phoxinus* (Linnaeus, 1758) were also released directly into the Skorodniy stream upper reaches. All these fish species are typical representatives of the mountain rivers in this region.

The fourth stage included supervision of performed works. A test capturing of bottom fauna, aimed at determining the success of the performed works in the Skorodniy stream, was carried out in May, 2010 at three sites: upstream the introduction place, in the middle of the stream and downstream.

The final stage included control of effectiveness of the conducted measures in the long-term perspective. In August 2012, some material was collected in all examined rivers and a comparison was made between the obtained data from the Skorodniy stream and those from the reference river, as well as the results from previous years.

## Results

The examination of the rivers that were subject to considerable anthropogenic pressure of forest exploitation activities, showed, in general, a poor ecological status of these rivers, destruction of their biotopical structure, defectiveness or absence of hydrobiontic communities, high turbidity, presence of scum in the water, musty smell, etc.

At the Dovgorunya River, which had been subject to pressure of forest exploitation activity for quite a long period of time, the rapid biotopes disappeared and were littered heavily with wood chips, bark, conifer needles and branches. There were no living organisms in the riverbed. In summer (August 2008), the water pH level was shifted to the "acid" side with indices of 4.5-5, and the level of dissolved oxygen in water varied from 40 to 60%. In autumn (September 2009), in spite of partial cleaning owing to summer and autumn high water and seasonal improvement of water quality, pH level varied within the limits of 5.5-6, while the oxygen saturation level was 80%. Usually, the oxygen saturation level in rivers of the Tisza basin reaches 120% and goes even higher, while the pH level varies from 7.5 to

8.1 (AFANASYEV 2006). In August 2012, *Gammarus balcanicus* (Schaferna, 1922) (230 ind.m<sup>-2</sup>) and Herpobdellidae (50 ind.m<sup>-2</sup>) were recorded in the bottom communities.

Research showed that the Loschansky stream was heavily littered with timber, wood chips, and needles remaining in the riverbed and the floodplain. Along the whole river, the natural channel was damaged, tortuosity of river was changed and the hydrological regime was disturbed. There were no hydrobiological elements except for the water-plant component and bacterial deposit. The chemical parameters indicated high level of contamination (taking into consideration the wintertime): pH – 5.5, NH<sub>4</sub> – 0.358 mg.dm<sup>-3</sup>, NO<sub>3</sub> – 0.021 mg.dm<sup>-3</sup>, and NO<sub>2</sub> – 0.008 mg.dm<sup>-3</sup>. The oxygen saturation level was 85%. High concentrations of phenols (>20 mg.dm<sup>-3</sup>) were registered. In spring 2009, it was determined that the ecological status of the river had considerably improved, after the spring floods and the performed preventive works for timber removal. Much attention was paid to the first steps of the stream macro-fauna restoration, which involved larvae of some trivial species of insects of first age groups (Ephemeroptera, Chironomidae, Simuliidae and other Diptera) and single oligochaetes belonging to the genus *Limnodrilus*. By 2012, the bottom community consisted mainly of *G. balcanicus*, which accounted for 75% of the abundance and 60% of the biomass. Herpobdellidae accounted for between 20% to 30% of the abundance, and a few larvae of Chironomidae, juvenile Ephemeroptera, Simuliidae and *Limnodrilus* sp. were observed.

The Skorodniy stream was characterised by almost total degradation of natural biotopes due to straightening of the riverbed, disappearance of small rapids, pools and backwaters. In addition, almost 1 km of the river was described as heavily littered and loaded with timber, in particular logs of various sizes, and to a lesser extent with wood chips, needles and conifer branches. Moreover, judging by scale (surface) of the bottom substratum, timber was not inferior to stones and sometimes even dominated over them. The natural riverbed consisted mainly of marble and calciferous bedrock (50%), boulders (25%), stones of different size (15%), pebbles (5%), and detritus (up to 5%). The stream depth varied from 0.10 to 0.25 m, in some places – 0.5-0.7 m. Flow velocity was 1-3 m.s<sup>-1</sup>. Water temperature was

13°C. Despite the fact that timber logging works downstream of the watercourse had been stopped more than a year ago, the chemical parameters of the aquatic environment indicated water contamination: concentration of dissolved oxygen was rather low (7.9 mg.l<sup>-1</sup>). The level of oxygen saturation of water was 95%, while pH level was shifted to the “acid” side – 6.2. High concentration of phenols (< 7 µg.dm<sup>-3</sup>) was registered. The river population consisted only of thin fouling of water plants and a small number of macro-fauna representatives, such as Herpobdellidae and some Chironomidae larvae. Only amphipods of the *G. balcanicus*, were widely spread, while the other fauna typical for this region was absent. The abundance of bottom animals was low and varied from 150 to 200 ind.m<sup>-2</sup>.

The proportion of the population and biomass of bottom invertebrates in the material prepared for reintroduction generally corresponded to the structure of the bottom communities from the reference site of the Pykhy River and consisted of more than 60 species of macroinvertebrates, which belonged to 11 taxonomic groups. This material included representatives of: Oligochaeta, Gastropoda, Amphipoda, Arachnida, Collembola, Ephemeroptera, Plecoptera, Trichoptera, Diptera, Coleoptera, Simuliidae, and Chironomidae.

Yet in eight months after the introduction, the structure of the bottom population in the Skorodniy stream included species composition of bottom communities similar to those in the reference river IS=0.78. The abundance of the bottom community was still low (200 ind.m<sup>-2</sup>). However, the community dominance/ diversity curve differed from the typical of the reference conditions (AFANASYEV 2006) as far as high domination of one species was observed (Fig. 1). As in August 2008, the dominant species in the stream was *G. balcanicus*.

The research conducted three years later showed that in the rivers Dovgorunya and Loschansky, 3-3.5 years after completion of the forest cutting activities, a structure of the bottom communities, similar to that found in the Skorodniy stream in 2009, was established. With an average number of 280 and 350 ind.m<sup>-2</sup> respectively, the share of *G. balcanicus* was from 60 to 75%. There was a large number of Herpobdellidae accounting for 20-25% of the total number and up to 30% of the biomass of macroinvertebrates. The samples also contained larvae of

Chironomidae and few Ephemeroptera, Simuliidae, *Limnodrilus* sp.

The structure of the community of bottom invertebrates in the Skorodniy River in August 2012 appeared as fully completed by quantitative parameters – 1356 ind.m<sup>-2</sup> and 14 g.m<sup>-2</sup>, as well as by taxonomic richness – 67 species of macroinvertebrates from ten taxonomic groups. The most widely present groups included: Ephemeroptera (20 species), Trichoptera (15), and Plecoptera (nine). The community dominance/ diversity curves became straighter (Fig. 2). At the same time, juvenile larvae of Chironomidae and green drake *Baetis* sp. dominated by number, while Plecoptera (*P. burmeisteriana*) and Ephemeroptera (*E. assimilis* and *Baetis* sp.) by biomass. Specimens of *G. balcanicus* and Herpobdellidae were rarely found. Similarity of the species composition with that of the reference river was quite high, with IS=0.58. In addition, there was a local population of trout, as well as other fish in the river, typical of this region. This allowed us to conclude that restoration of the ecological state of the Skorodniy River was successful.

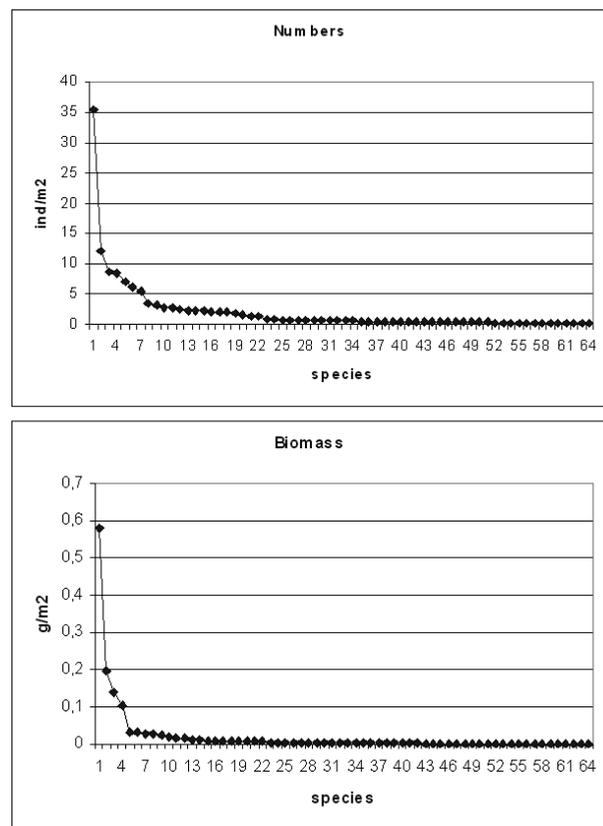


Fig. 1. Benthic macroinvertebrate community dominance/ diversity curves in the Skorodniy stream, eight months after recovery (May 2009)

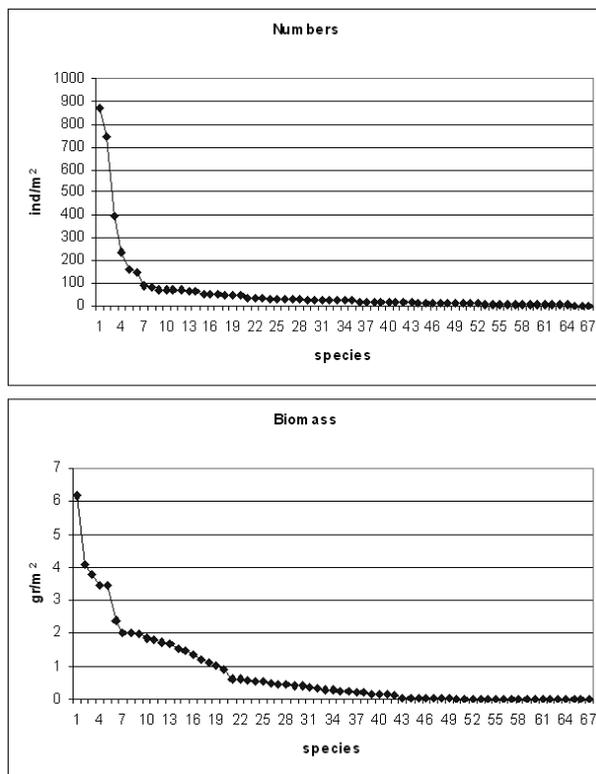


Fig. 2. Benthic macroinvertebrate community dominance/diversity curves in the Skorodniy stream, three years after recovery (August 2012)

## Discussion

One of the most considerable reasons for physical destruction of river habitats is forest exploitation within the river catchments and timber logging directly in the riverbeds (WALLACE *et al.* 1995). Since the active works within the catchments and especially timber logging along small rivers are a widely spread phenomenon in the Ukrainian Carpathians, the situations, in which the biotopical structure of mountain rivers is destroyed, are rather typical. Except for the factor of mechanical intrusion into the biotopic structure of the river, an important factor that influences both the general state of the river and the structure of biotopic communities is the accumulation of logs, subquality timber, wood chips, bark, needles and other forestry waste in the riverbeds (FAUSTINIA, JONES 2003, DANILIK *et al.* 1987). On the one hand, this leads to physical pollution of the rivers, and, on the other hand, to changes in chemical composition of water (DANILIK *et al.* 1987, YERSHOVA 1987). Sometimes quite big timber remains stimulate the accumulation of organic compounds in the mountain rivers with hard rocks and lead to morphological changes of the riverbed (FAUSTINIA, JONES

2003). Excessive amounts of organic substances cause considerable decrease in the level of oxygen, dissolved in water, especially during the periods of water temperature increase in spring and in autumn. In such cases the organisms that demand high contents of oxygen die. Sedimentation of hard remains of fine timber downstream of the watercourse causes siltation in the spawning areas. Constant ingress of suspensions and silt sedimentation within the spawning areas interferes with the self-cleaning of soils. Thus the areas, suitable for spawning, shrink very fast (SPIVAK 1994).

Research carried out within a small river catchment showed that the restoration of the flow qualitative characteristics happens not earlier than 14 years after the tree cutting. However, in case of such intensive forest exploitation, even the mentioned time is not sufficient for the complete restoration of the damaged conditions and high-quality riverbed formation (TEUNOVA 2004). It should be noted that decomposition of conifer timber also takes a long time and is accompanied by release of phenolic organic compounds that influence perniciously the river biota. Results of more than ten year monitoring of consequences of forest cutting on invertebrate communities in mountain rivers were reported by SWANK *et al.* (2001) and STONE, WALLACE (1998).

Excessive amounts of timber as a substratum for bottom invertebrates facilitate the development of xylophytous animals. In general, the lithophilic fauna, which is typical for the mountain rivers, is replaced by xylophytes and perophilic species. Formation of xylophytous and perophilic communities is reasonable from the evolutionary point of view, being aimed at restoration of river biocenoses in habitats, which are locally polluted by timber in natural conditions. After wide development of xylophytous shredders (Amphipoda), some eurybiontic predators (Hirudinea) appear, then come gatherers (larvae of Chironomidae), etc. However, under conditions where the whole riverbed or large areas of it are polluted, such a situation is not normal.

Even if, several years after finishing of forest exploitation and several floods and high waters, the riverbed is cleared from needles, wood chips and small fragments of timber, the communities of xylophytous chippers and eurybiontic predators may exist for ages. In this case, together with defective biotopic structure of the river, the general quantitative

level and functional activity of bottom fauna would remain rather low. The general level of biodiversity also becomes lower, both because of the low diversity of species and the mono-dominant structure of communities. In addition, the sites located downstream of the watercourse may face “biological pollution” by species that are not typical of the natural conditions. Under conditions where the whole riverbed suffers, such “defective” communities can exist for years. In such cases, the general abundance rates,

biodiversity and the functional activity of bottom fauna remain rather low. Thus, it is worth concluding that even little efforts for re-naturalisation may lead to fast and considerable improvement and restoration of the river biota and ecological state in general.

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