# BIOTOPE DETERMINANTS OF EPT ASSAMBLAGES STRUCTURE – TÂRNAVA WATERSHED (TRANSYLVANIA, ROMANIA) CASE STUDY

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**KEYWORDS**: mayfly communities, stonefly communities, caddisfly communities, Târnava Mare River, Târnava Mică River, Târnava River.

**ABSTRACT**

This study aims to analyze the biotopic factors affecting the EPT assemblage diversity in the rivers of the Târnava Watershed. Our research revealed that the high diversity of the Plecoptera communities is associated with river reaches with boulder and cobble lithological substrate, accentuated slope and natural bank dynamics, and also it is directly correlated with dissolved oxygen and inversely correlated with chemical and biochemical oxygen demand, total hardness, nitrates and total nitrogen in the water. The high diversity of the Trichoptera communities is associated with water which presents moderate quantities of nutrients (total phosphorus, phosphates) and with river reaches with heterogeneous structures (where runs and bends were present). The diversity of the Ephemeroptera communities is positively correlated with the multiannual average flow and riverbed width.

**RÉSUMÉ**: Déterminants du biotope sur les structures des communautés EPT – Etude de cas du bassin hydrographique de la Târnave (Transylvanie, Roumanie).

Cetta étude concerne l'analyse de l'influence des facteurs du biotope sur la diversité des communautés d'éphéméroptères, plécoptères et trichoptères des rivières des Târnava Bassin. Les résultats de l'étude relèvent que la grande diversité des associations de plécoptères est associée aux secteurs de rivière qui présentent les caractéristiques suivantes: fond dominant lithologique, pente accentuée et dynamique naturelle des berges, corrélation positive à la concentration d'oxygène dans l'eau et corrélation négative à la durite totale, à la concentration des nitrates, à la quantité d'azote total dans l'eau ainsi qu'aux valeurs CCO-Mn et CBO5. La grande diversité des trichoptères est associée aux eaux présentant des quantités modérées de nutriments (phosphore total et phosphates) ainsi qu'aux secteurs de rivière à structure hétérogène (présentant des rapides et des méandres). La diversité des communautés d'éphéméroptères est positivement corrélée aux débits liquides multi-annuels et à la largeur du lit mineur de la rivière.

**REZUMAT**: Determinanți de biotop asupra structurii comunităților EPT – Studiu de caz bazinul hidrografic Târnava (Transilvania, România).

Studiul analizează influența factorilor de biotop asupra diversității comunităților de efemeroptere, plecoptere și trihoptere în cazul râurilor din bazinul Târnava. Rezultatele studiului relevă faptul că diversitatea mare a comunităților de plecoptere este asociată sectoarelor de râu cu substrat dominant litologic, pantă accentuată și dinamică naturală a malurilor, de asemenea este corelată pozitiv cu gradul de oxigenare al apei și negativ cu duritatea totală, concentrația azotaților, cantitatea de azot total din apă și valorile CCO-Mn, CBO5. Diversitatea mare a trihopterelor este asociată cu apele care prezintă cantități moderate de nutrienți (fosfor total și fosfați) și cu sectoarele de râu cu structură heterogenă (în care sunt prezente repezișuri și meandre). Diversitatea comunităților de efemeroptere este corelată pozitiv cu debitele lichide multianuale și cu lățimea albiei minore.

## INTRODUCTION

Ephemeroptera, Plecoptera and Trichoptera larvae communities are key components for matter cycling in the lotic systems (Allan, 1995; Wallace and Webster, 1996; Rawer-Jost et al., 2000; Abdul-Aziz et al., 2010; Yates and Bailey, 2010; Jiang et al., 2011), and are good indicators of ecological status (Staicu et al., 1998; Kreatzweiser et al., 2005; Bonada et al., 2006; Diggins, Newman, 2009; Aura et al., 2011; Sedeño-Díaz et al., 2012; Narangarvuu et al., 2014; Turkmen and Kazanci, 2015).

This study aims to analyze the biotopic factors influencing EPT assamblage diversity in the Târnava rivers. The Târnava River basin was selected for this analysis due to its dimensions, high variability of biotopes and also high variability of human impact (Curtean-Bănăduc et al., 2001; Curtean-Bănăduc, 2005a). The Târnava Watershed (Târnava Mare, Târnava Mică and Târnava main rivers) is situated in the central part of the Romanian Carpathians and drains the southern part of the Transylvanian Depression. With a total surface area of the catchment of 6,157 km$^2$, a length of 249 km and a height difference of approximately 1,250 m, the Târnava River is the second main tributary of the Mureş River, representing 21% of this hydrographic basin. The Târnava River is formed by the junction of Târnava Mare River (3,606 km$^2$ basin surface and a length of 221 km) and Târnava Mică River (2,049 km$^2$ basin surface and a length of 191 km) (Roşu, 1980).

## MATERIAL AND METHODS

The results are based on the benthic macroinvertebrate quantitative samples of 24 stations in the reference area (Fig. 1, Tab. 1). The samples were taken from five different points, in each station (10 m length), in order to highlight the specific diversity of local microhabitats. The sampling was carried out with an 887 cm$^2$ surface Surber Sampler, with a 250 µm mesh net. The sampled biological material was fixed in 4% formaldehyde solution and was analyzed in the laboratory with an Olympus (150X) stereomicroscope. Ephemeroptera, Plecoptera and Trichoptera larvae were identified at the species level.

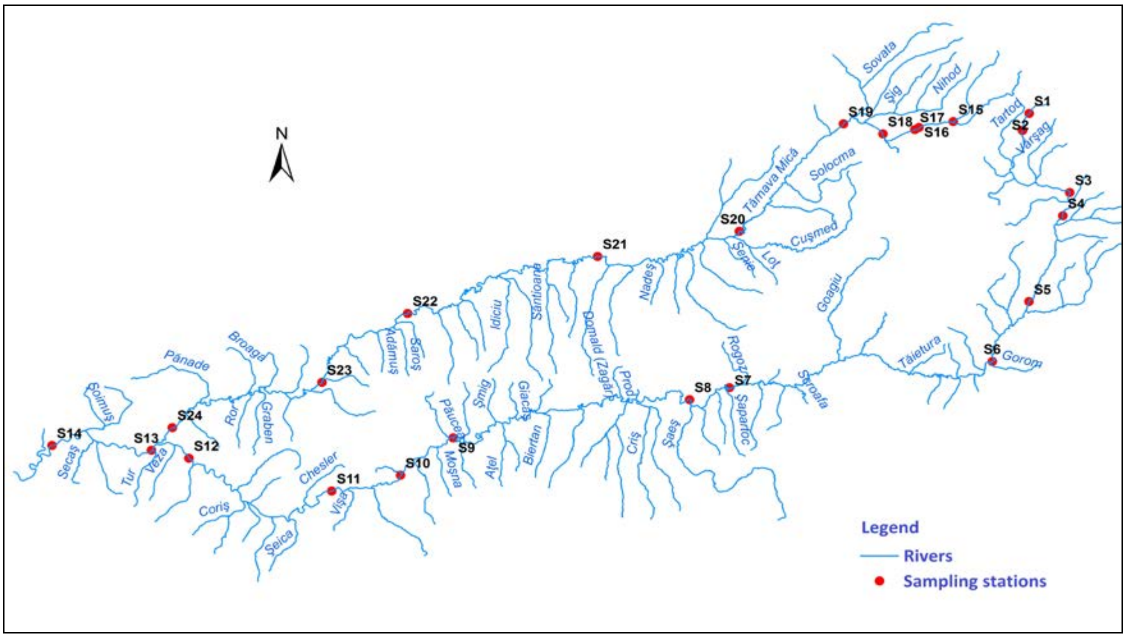


Figure 1: The sampling stations location on the studied rivers:
Târnava Mare (S1 – S12), Târnava (S13, S14), Târnava Mică (S15 – S24).

Table 1: The sampling stations location on the studied rivers.

| Sampling stations | GIS Stereo 70 POINTS X, Y | Position |
|---|---|---|
| S1 | 527322,580905<br>564610,161545 | Târnava Mare, five km upstream Vârşag locality |
| S2 | 526660,279367<br>562436,41699 | Târnava Mare, one km upstream Vârşag locality |
| S3 | 532115,38254<br>554014,135054 | Târnava Mare, one km upstream Zetea Dam lake |
| S4 | 531336,309742<br>550804,504496 | Târnava Mare, one km downstream Zetea Dam lake |
| S5 | 527069,455486<br>539095,109498 | Târnava Mare, between Zetea locality and Odorhei locality |
| S6 | 521937,932132<br>530838,859923 | Târnava Mare, four km downstream Odorhei locality |
| S7 | 488134,519504<br>527886,824765 | Târnava Mare, five km upstream Sighişoara locality |
| S8 | 482997,898116<br>526281,030128 | Târnava Mare, one km downstream Sighişoara locality |
| S9 | 452726,517213<br>520268,736478 | Târnava Mare, two km upstream Mediaş locality |
| S10 | 446241,702069<br>515269,513909 | Târnava Mare, four km downstream Mediaş locality |
| S11 | 437195,876026<br>512952,91462 | Târnava Mare three km downstream Copşa Mică locality |
| S12 | 414836,320828<br>519516,518406 | Târnava Mare two km upstream Blaj locality |
| S13 | 414195,720599<br>518752,386123 | Târnava, one km downstream confluence of Târnava Mare River and Târnava Mică River |
| S14 | 398239,794978<br>516402,326039 | Târnava, three km upstream confluence with Mureş River |
| S16 | 511901,508551<br>561665,936165 | Târnava Mică, one km upstream Praid locality |
| S17 | 510767,929206<br>561449,798245 | Târnava Mică, one km upstream Praid locality |
| S18 | 508252,478901<br>562076,51088 | Târnava Mică, one km downstream Praid locality |
| S19 | 503264,107128<br>563057,563364 | Târnava Mică, one km downstream Sovata locality |
| S20 | 489173,69412<br>549014,554564 | Târnava Mică, one km upstream Sângiorgiu de Pădure locality |
| S21 | 470935,991703<br>544743,681313 | Târnava Mică, one km upstream Coroisânmartin locality |
| S22 | 447012,116361<br>537362,929148 | Târnava Mică, one km upstream Târnăveni locality |
| S23 | 435624,085388<br>528247,747231 | Târnava Mică at Cetatea de Baltă locality |
| S24 | 416824,63681<br>521604,529235 | Târnava Mică, one km upstream Blaj locality |

The assessed biotopic variables were: slope, multiannual average flow, riverbed width, depth, substratum type, presence of pools, riffles, runs and bends, channel modification (expressed in percentages of natural state of the riverbed) and chemical characteristics of the water (total hardness – DT, dissolved oxygen – DO, biochemical oxygen demand – $BOD_5$, chemical oxygen demand – COD-Mn, $Cl^-$ $SO_4^{2-}$, $NO_3^-$, $PO_4^{3-}$, total nitrogen, total phosphorus). The substratum types (mud, sand, gravel, pebbles, cobbles, boulders, large boulders) were expressed as percentages of the transversal section surface (10 m length).

The community's diversity is expressed using the Menhinik (M) (Krebs, 1989) and Gini-Simpson (S) indices (Jost, 2007). Habitat factors – diversity of EPT assemblages conditionality were analyzed using Canonical Correspondence Analysis – CCA (ter Braak, 1986); ordinations were done using CANOCO v 4.5 (ter Braak, Smilauer, 2002). Were obtained regressions, which describe the variation of biodiversity indexes in relation with biotope conditions dynamic. For the statistical analysis and regressions the computer programme STATISTICA 7.0 was used. Statistical evaluations were performed using a level of significance probability (p) with 5% risk of error ($p \leq 0.05$).

**RESULTS AND DISCUSSION**

In the reference zone 12 mayfly species (belonging to seven genera and six families), (Bănăduc, 2013), eight stonefly species (belonging to five genera and five families) (Curtean-Bănăduc, 2005b) and 13 caddisfly species (belonging to nine genera and nine families) (Robert and Curtean-Bănăduc, 2005) were identified.

Ephemeropteran communities present a high specific diversity and heterogeneity in S1 (M = 0.802, S = 0.67), S3 (M = 0.718, S = 0.746), S7 (M = 1.336, S = 0.593), and S8 (M = 0.775, S = 0.705), in other sectors the Menhinik index values were between 0.4 (S11) and 0.77 (S5), and the Gini-Simpson index presented values between 0.153 (in S11) and 0.65 (in S5).

The plecopterans are present only in the upper courses of the Târnava Mare River (S1 – S4) and Târnava Mică Rivers (S15 – S17), in these sectors the communities of plecopterans present a relatively high specific diversity and heterogeneity (S2 M = 0.873, S = 0.76; S3 M = 1.376, S = 0.743; S4 M = 0.834, S = 0.641; S15 M = 0.804 S = 0.682; S16 M = 0.873, S = 0.705; S17 M = 0.87, S = 0.764) with the exception of the sector S1 (M = 0.767, S = 0.36) in which the heterogeneity is small.

The communities of trichopterans present a high heterogeneity in S3 (S = 0.8), S4 (S = 0.87), S6 (S = 0.762), S7 (S = 0.711), S16 (S = 0.8) and S17 (S = 0.868). In other lotic sectors the Gini-Simpson index values vary between 0 (in S11) and 0.605 (in S19); in all the analyzed sectors the Menhinik index values are small, ranging between 0.131 (S11) and 0.451 (S4).

The CCA which relates EPT biodiversity to the environmental variables, showed that the first two axes (eigenvalues $\lambda1 = 0.402$, $\lambda2 = 0.145$) explained 90% of the total variance (Fig. 2). The slope, presence of large boulders, boulders and cobbles were positively correlated with the first axis, whilst the presence of pools and pebbles were negatively correlated with the first axis. Menhinik and Gini-Simpson indices for Plecoptera were positively correlated with the first axis, which meant that the slope, presence of large boulders, boulders and cobbles are favorable for Plecoptera diversity. The presence of runs and bends were positively correlated with the second axis; maximum and average riverbed widths were negatively correlated with the second axis. Multiannual average flow, channel modification and the sand type of the substrate loaded equally on both axes, being negatively correlated with both of them. The diversity of Trichoptera communities expressed through Mehinik and Gini-Simpson indices were positively correlated with the presence of runs and bends; the Menhinik index for Ephemeroptera was positively correlated with the multiannual average flow and Gini-Simpson indices for Ephemeroptera were positively correlated with average and maximum riverbed width.

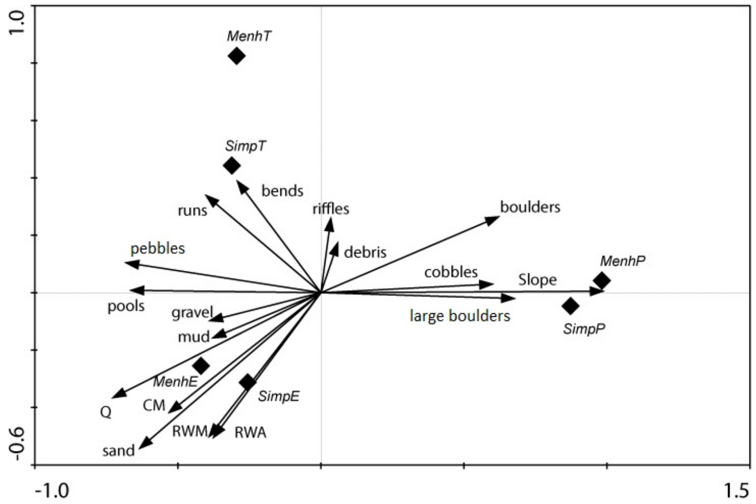


Figure 2: CCA biplot of EPT biodiversity and environmental variables. Abbreviations: MenhE – Menhinik index for Ephemeroptere, MenhP – Menhinik index for Plecoptera, MenhT – Menhinik index for Trichoptera, SimpE – Gini-Simpson index for Ephemeroptera, SimpP – Gini-Simpson index for Plecoptera, SimpT – Gini-Simpson index for Trichoptera, Q – multiannual average flow, CM – channel modification, RWM – maximum riverbed width, RWA – average riverbed width.

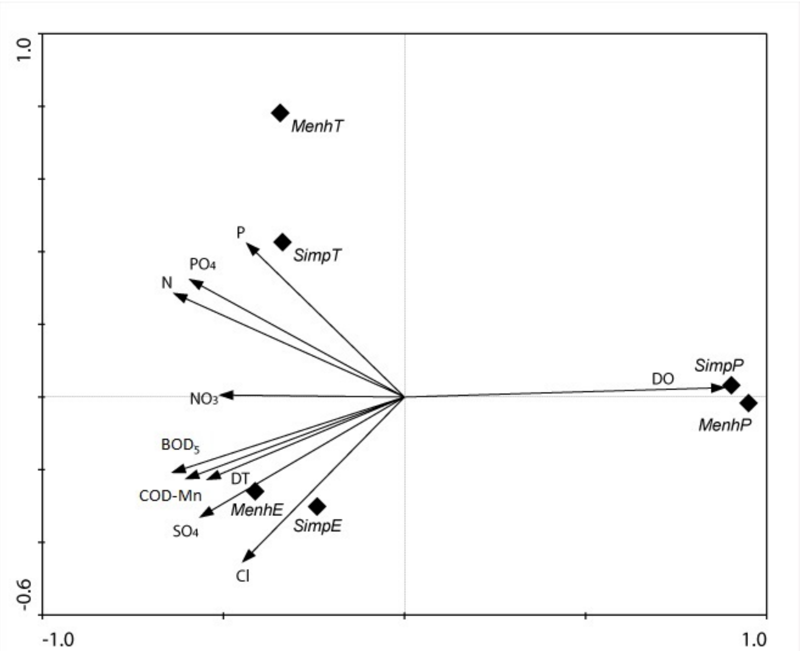


Figure 3: CCA biplot of EPT biodiversity and water chemical characteristics. Abbreviations: MenhE – Menhinik index for Ephemeroptera, MenhP – Menhinik index for Plecoptera, MenhT – Menhinik index for Trichoptera, SimpE – Gini-Simpson index for Ephemeroptera, SimpP – Gini-Simpson index for Plecoptera, SimpT – Gini-Simpson index for Trichoptera, DO – dissolved oxygen, COD – chemical oxygen demand, $BOD_5$ – biochemical oxygen demand, DT – total hardness.

The results of the CCA, which relates to EPT biodiversity values and water chemical characteristics, showed that the first two axes (eigenvalues λ1 = 0.406, λ2 = 0.162) cumulatively explained 89.3% of the total variance (Fig. 3). DO was strongly positively correlated with the first axis, while the nitrates concentration, total nitrogen, $BOD_5$, COD-Mn and total hardness were negatively correlated with this first axis. The biodiversity indices for Plecoptera were determined by the first axis, being positively correlated with dissolved oxygen and negatively correlated with nitrates concentration, total nitrogen, $BOD_5$, COD-Mn and total hardness. Total phosphorus was positively correlated with the second axis, while chloride concentration was negatively correlated with the second axis. The Gini-Simpson indices for Trichoptera were determined by the second axis, being positively correlated with moderate quantities of total phosphorus.

In the studied sectors, the concentration of nitrates ranged between 1.2 mg/l (S4) and 52.75 mg/l (S7), with an average of 9.268 mg/l. The concentration of phosphates was relatively low in all of the analyzed sectors and ranged between 0.0 mg/l and 0.167 mg/l. The concentration of sulphates varied between 5.71 mg/l (S4) and 291.12 mg/l (S11), with the highest values (> 165 mg/l) recorded in the lower part of the Târnava Mare River (S10 – S13) and the Târnava Mică River (S24) and in the Târnava River (S14). The chloride concentration varied between 7.1 mg/l (S4) and 415.35 mg/l (S21). The COD-Mn values, as an indicator of oxidable matter in the water, ranged between 4.1 mg/l (S16) and 31.04 mg/l (S8), with an average of 12.446 mg/l; $BOD_5$ values varied between 1.5 mg/l (S1) and 13.66 mg/l (S8) with an average of 4.971 mg/l. The total nitrogen shows moderate quantities, ranging between 0.317 mg/l (S3) and 3.280 mg/l (S6), with an average of 1.524 mg/l; the total phosphorus shows small amounts, ranging between 0 mg/l and 0.17 mg/l (S19), with an average of 0.029 mg/l (Tab. 2).

Analysis of correlations indicates that there exist significant correlations between diverse Ephemeroptera communities expressed by the Gini-Simpson and the following physico-chemical water parameters of the water: total hardness – DT (Fig. 4), dissolved oxygen – DO (Fig. 5), sulphates (Fig. 6), nitrates (Fig. 7), phosphates (Fig. 8), total nitrogen (Fig. 9) and total phosphorus (Fig. 10).

Table 2: Water chemical characteristics of the Târnave rivers.

| Chemical variables | Minimum | Maximum | Median | Mean | Standard deviation |
|---|---|---|---|---|---|
| DO (%) | 55.600 | 99.000 | 79.940 | 82.945 | 13.346 |
| COD-Mn (mg/l) | 4.100 | 31.040 | 10.290 | 12.446 | 7.819 |
| $BOD_5$ (mg/l) | 1.500 | 13.660 | 4.745 | 4.971 | 3.074 |
| TH (german degrees) | 3.080 | 20.940 | 7.840 | 9.626 | 5.834 |
| $NO_3^-$ (mg/l) | 1.200 | 52.750 | 5.935 | 9.268 | 12.263 |
| $PO_4^{3-}$ (mg/l) | 0.000 | 0.167 | 0.028 | 0.058 | 0.064 |
| $SO_4^{2-}$ (mg/l) | 5.710 | 291.120 | 58.715 | 100.784 | 93.167 |
| $Cl^-$ (mg/l) | 7.100 | 415.350 | 95.700 | 132.701 | 121.712 |
| N total (mg/l) | 0.317 | 3.280 | 1.113 | 1.524 | 1.041 |
| P total (mg/l) | 0.000 | 0.170 | 0.010 | 0.029 | 0.044 |

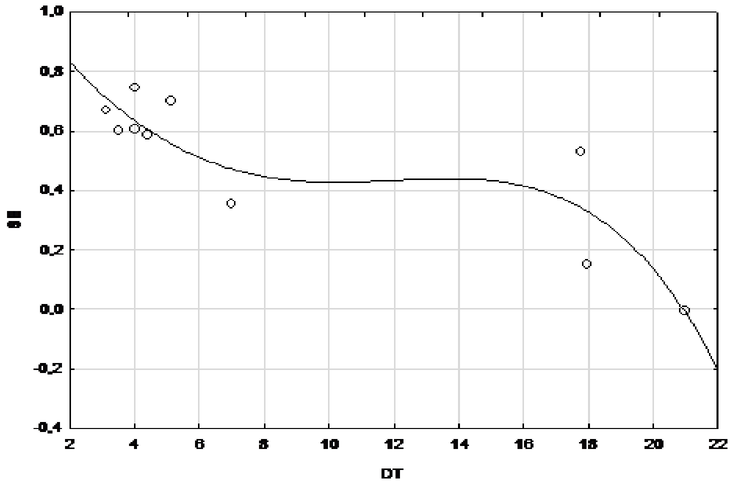


Figure 4: Ephemeroptera diversity variation, expresed by Gini-Simpson – SE index depending on the total water hardness – DT SE = 1.10738 – 0,15828*DT + 0.010215*$DT^2$ – 0.00001181*$DT^4$, $r^2$ = 0.881, p = 0

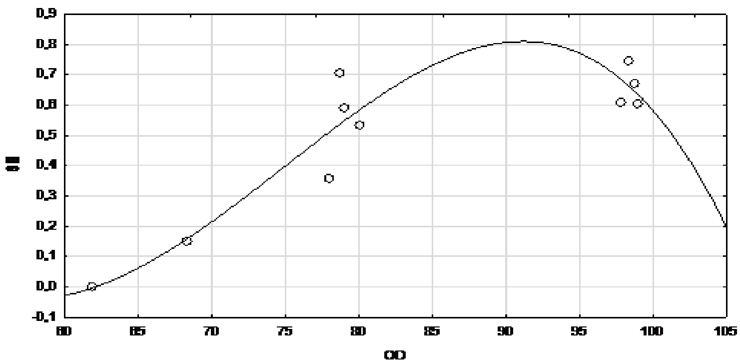

Figure 5: Ephemeroptera diversity, expressed by Gini-Simpson index – SE depending on the concentration of oxygen in water – DO.
SE = 11.7197 – 0.46603*DO + 0.005043*$DO^2$ – 0.000000149*$DO^4$, $r^2$ = 0.933, p = 0

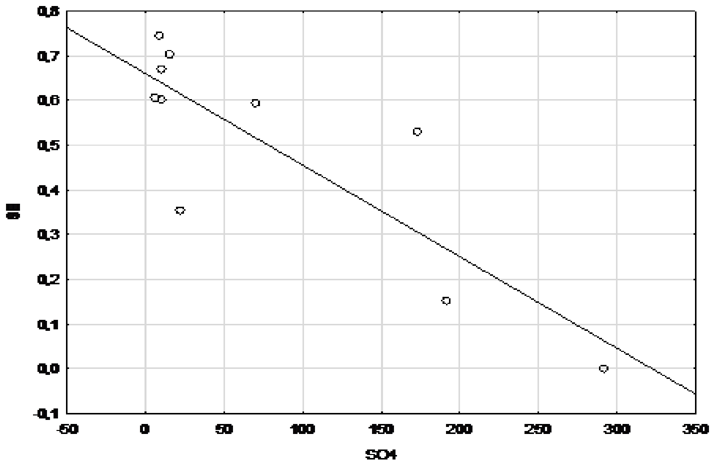


Figure 6: Ephemeroptera diversity variation, expressed by the Gini-Simpson index – SE depending on the concentration of sulphates in the water – SO4. SE = 0.660039 – 0.00205*SO4, $r^2$ = 0,841, p = 0

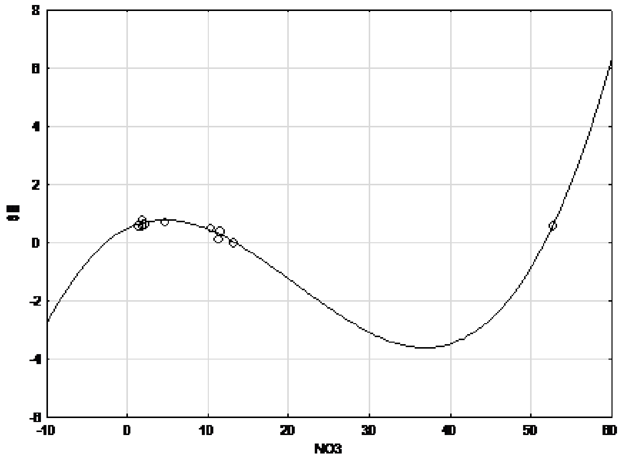


Figure 7: Ephemeroptera communities diversity variation, expressed by the Gini-Simpson index – SE depending on the concentration of nitrates in water – $NO_3$.

$SE = 0.467943 + 0.135536*NO_3 – 0,01635*NO_3^2 + 0.000262*NO_3^3$, $r^2 = 0,947$, $p < 0,05$

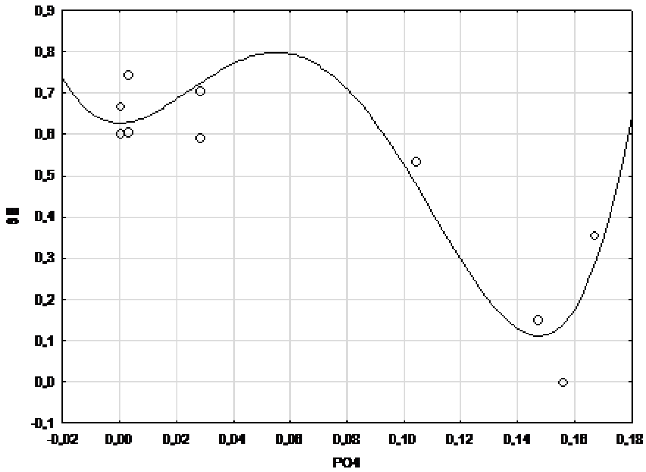


Figure 8: Ephemeroptera communities diversity variation, expressed by the Gini-Simpson index – SE depending on the concentration of phosphates in water – PO4.

$SE = 0.626602 + 208.757*PO_4^2 – 3478.7*PO_4^3 + 12901.2*PO_4^4$, $r^2 = 0,941$, $p < 0,01$

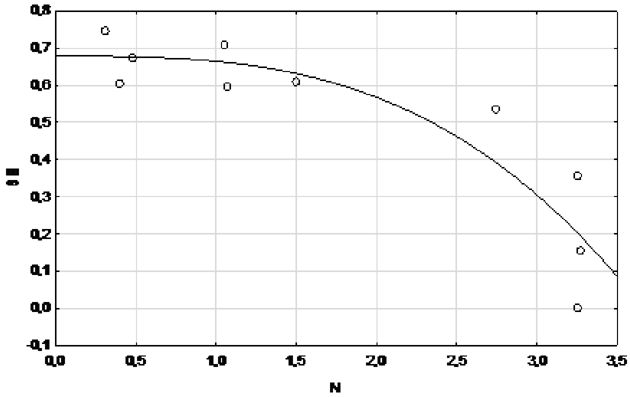


Figure 9: Ephemeroptera communities diversity variation, expressed by the Gini-Simpson index – SE depending on the concentration of total nitrogen in water – N.

$SE = 0.678297 – 0.01381*N^3$, $r^2 = 0.902$, $p = 0$

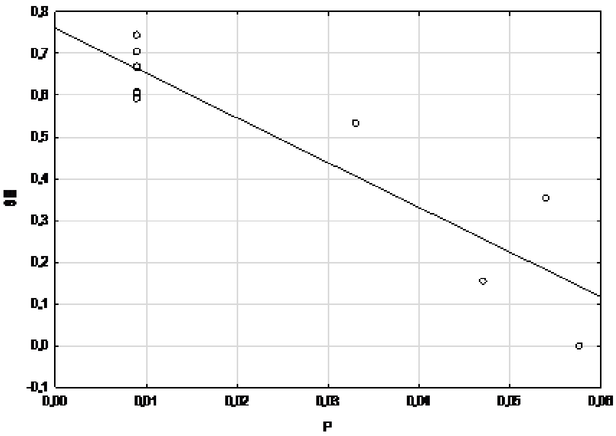


Figure 10: Ephemeroptera communities diversity variation, expressed by the Gini- Simpson index – SE depending on the total phosphorus concentration in water – P. SE = 0.759763 – 10.707*P, $r^2 = 0.908$, p = 0

## CONCLUSIONS

High Plecoptera community diversity is associated with river sectors with a lithological substrate comprising boulders and cobbles, accentuated slope and with natural banks, and also is positively correlated with dissolved oxygen and negatively correlated with chemical and biochemical oxygen demand, total hardness, nitrates and total nitrogen in the water. The high diversity of the Trichoptera communities is associated with water which presents moderate quantities of nutrients (total phosphorus, phosphates) and with river sectors with heterogeneous structures (where runs and bends were present). The diversity of the Ephemeroptera communities is positively correlated with the multiannual average flow and riverbed width. Regression analysis can be used to forecast the biodiversity dynamic – as indicator of homeostasis of the analyzed lotic systems, in case of water physico-chemical parameters, in various management scenarios of the studied rivers.

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