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TRANSYLVANIAN REVIEW OF SYSTEMATICAL AND ECOLOGICAL RESEARCH

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Angela Curtean-Bănăduc, Doru Bănăduc & Ioan Sîrbu

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„Lucian Blaga” University of Sibiu,
Faculty of Sciences,
Department of Ecology and Environment Protection

Apuseni Nature Park

“Lucian Blaga” University of Sibiu

Ecotur Sibiu N. G. O.

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Editorial Office:

"Lucian Blaga" University of Sibiu, Faculty of Sciences, Department of Ecology and Environment Protection, Dr. Ion Raţiu Street 5-7, Sibiu, Sibiu County, Romania, RO - 550012, Angela Curtean-Bănăduc (banaduc@yahoo.com, angela.banaduc@ulbsibiu.ro)

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IN MEMORIAM

Dimitrie Grecescu
(1841 - 1909)

Dimitrie Grecescu was a Romanian botanist and also a doctor.

Descendant of a family of slaves tied to the boyar Sferendache. He was born in the village Cerneşti, in the present Mehedinţi County in the south of Romania. His parents died early. He attended primary school in his village.

A remarkable draughtsman, he began to make a living immediately after finishing primary school by sign-writing and painting icons. He was discovered in a shop in Turnu Severin by Carol Davila, under whose protection he completed his studies in Bucharest. He obtained the Bacalaureat (1860) and then a degree in medicine (1863) at the School of Medicine and Pharmacy. He completed his doctorate in Paris with a thesis on medical botany (1868). He was appointed Professor of Medical Botany at Bucharest (1880). He became Correspondent Member of the Romanian Academy (1902), Member of the Romanian Academy (1906), Member of the International Academy of Geographical Botany in France and of several national and foreign scientific societies (Society of Pharmacists of Romania, Geographical Society of Romania, Imperial Society of Naturalists of Moscow, Society of Mathematical and Natural Sciences of Cerbourg).

He participated more than honourable as a medical officer (Major) in the Romanian War of Independence against the Turkish, taking part too in the siege of Plevna.

He was a proponent of the concept of Darwinism.

As Director of the Botanic Garden of Bucharest, between 1864 and 1874, he re-organized this institution and enriched it with many new species. He carried out floristic and phytogeographical research on the whole Romanian territory and also in other neibouring Balkans countries. He also proposed a new systematic classification for plants. He established the foundations of Romanian phytogeography, introducing into the description of vegetation geographical factors with an important role in species distribution. With native plants he collected, he created the Flora herbarium of Romania, and through the exchange of floristic material with botanic gardens abroad he created an European herbarium. Both herbaria, donated to the Botanical Institute of Bucharest, were destroyed in the bombing of 4 April 1944. He published important works among which are “Conspectul florei României” (Survey of Romanian flora) (1898) which lists 2450 species and varieties of plants accompanied by short ecological and phytogenetic descriptions, and “Flora medicală a României” (Medical Flora of Romania) (1892) with a linguistic study of medical properties and of indigenous medical geography.

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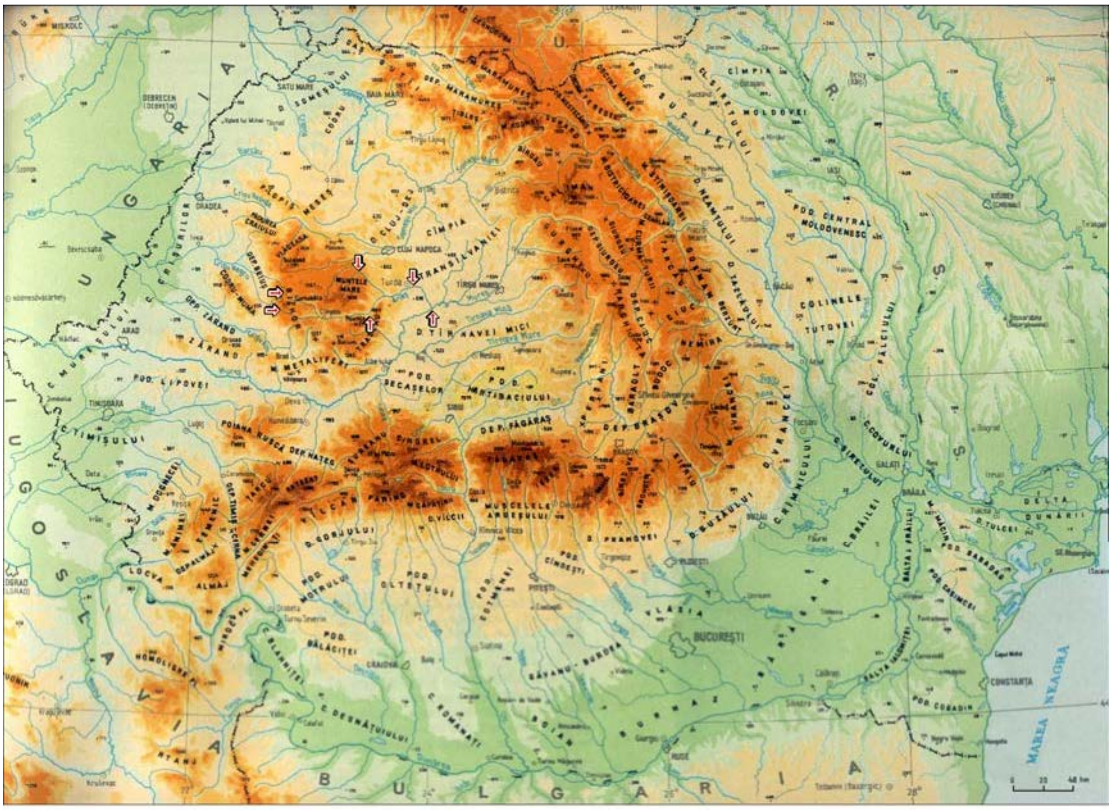
Preface

Located in the Western part of Romania, the Arieş River, called “Aurarus” in the past, is the largest right tributary of the Mureş River, with a catchment’s area of 2970 km^2 and a total length of 164 km. It represents one of the limits of the Apuseni Nature Park and its source lay East from the main ridge of the Bihor Mountains.

The Arieş can be divided in three main areas: the upper Arieş, also called the Arieşul Mare, from the river source to the locality Câmpeni, the middle Arieş, up to the locality Corneşti, and the lower Arieş, that stretches until the junction with the Mureş River. The Arieşul Mare collects its tributaries from the Scărişoara Plateau. They collect the waters coming from the Padiş limestone plateau. The junction of the Arieşul Mare and Arieşul Mic rivers forms the main Arieş River. In the locality Câmpeni, the Abrud River flows into the Arieş. It gathers many watercourses coming from several mining sites (Bucium-Izbita or Roşia Montană). Downstream of Câmpeni, the Arieş River records a strong left asymmetry: its tributaries come from the South-Eastern Bihor and Muntele Mare mountains. For example, the Hăşdate River crosses the famous Turzii Gorge. Other smaller tributaries come from the Feleacu Ridge.

This short presentation of the Arieş Watershed area reflects the importance of the region, which stretches on a large surface, including mountains, sub mountainous regions, depressions and plains. This diverse relief supports an increased biodiversity as regards the flora and fauna of the region. Moreover, the karstic relief of this region is one of the most spectacular in Romania.



The Arieş River basin localization
(Badea et al., 1983 - modified).

Thus, it's only normal that several natural reserves and natural monuments were declared in the area, to protect the unique landscape. Among the most famous nature reserves we can include the following: The Vidolm Forest, Scăriţa Belioara (botanical reserves); Dealul cu Melci (paleological reserve) and Cheile Turzii - The Turzii Gorge (mixed reserve). The following natural monuments are located in the Arieş catchment area: Detunata Goală, Detunata Flocoasă (geological and geomorphological monuments); Huda lui Papară, Gheţarul de la Scărişoara and Gheţarul de la Vârtop (all speleological monuments). Moreover, the upper reaches of the Arieş Watershed area (from the river source until the Albac locality) are included in the "Apuseni Mountains" Nature Park.

The Arieş Valley area has also an important cultural heritage. A long time ago, the Transylvanian regions were called "countries": Bârsa, Făgăraş or Zarand countries, because of their mountains, plains or rivers' names. There is only one exception: the Moţilor Country, named after the special Romanian type of people living there. The Moţilor Country includes a broad region from the upper reaches of the Arieş River, beginning with the locality Bistra. "*Moţ*" is a name that has its origin probably in the Latin word "motus", meaning „motion, exciting, agitation", thus reflecting the life style of the local over 2000 years old human population: motion, agitation and revolt. Another ancient population - called *mocani*- live in the villages located towards the locality Turda along the Arieş River (Lupşa, Sălciua, etc.). The area has an old Romanian tradition of resistance and fighting for political, economical and social rights and independence.

But the history of the Arieş Valley is mainly related to the mining industry. The locality Roşia Montană (whose Roman name was "Alburnus Maior") is perhaps the most authentic and important "document" regarding the mining activities from the Roman times all over Europe until the present. The controversy related to the exploitation projects from the Roşia Montană region represents another argument related to the importance of the Arieş Watershed area.

The fact that the river's drainage basin includes clean, unaffected regions but also strongly polluted ones represents another important characteristic of the area. Tourism represents the main impact on the Arieş River upper course, due to the location of the skiing track and numerous pensions. Pasture exploitation and deforestation are another human impacts throughout the Arieş Basin and they have serious negative effects, causing landslides and floods. Wood processing industry has also bad influences, by means of the sawdust accumulated in the riverbed. But the main pollutant factor in the Arieş region is the mining industry, with the slag dumps and the decantation ponds necessary for metal extraction. Last but not least, the general pollution factor is represented along the Arieş Valley and all its tributaries by the waste dumps located near the water courses.

Thus, this region combines unique landscapes with old industrial tradition, with actual problems and controversies and, most of all, with an acute need to study its biodiversity. This complex area requires a thorough research that should include the results of numerous scientists that had the curiosity and the knowledge to study it.

Hence, this scientific publication editors believes that it is mandatory to include all the scientific researches in one volume that might represent the starting point of a new perception of this special area, its ecology and its future development.

Acknowledgements

The editors of this volume would like to express their gratitude to the authors and the scientific reviewers whose work made the appearance of this publication possible.

The Editors

MORPHO-HYDROGRAPHICAL AND MODELING FEATURES OF THE ARIEŞ RIVER BASIN (TRANSYLVANIA, ROMANIA)

Marioara COSTEA *

* "Lucian Blaga" University of Sibiu, Faculty of Sciences, Department of Ecology and Environment Protection, Raţiu Street 5 - 7, Sibiu, Sibiu County, Romania, RO - 550337, marioara_costea@yahoo.com

KEYWORDS: Romania, Transylvania, Arieş River basin, geomorphology, zonation, modelling processes.

ABSTRACT

This paper presents an analysis of the relief of the Arieş River basin and also presents morphostructural conditions and morpholitology affecting the genesis and the evolution of the relief. The analyse following the correlations and interdependence among the internal and external factors, but also the actual conditionings of the environmental components. The corroboration of data makes possible a qualitative evaluation and zoning of current geomorphologic processes on the basin surfaces. Its will help identify the tendency of the disequilibrium in the morpho-hidrographical system of the Arieş River.

ZUSAMMENFASSUNG: Morpho-hydrographische und Modellierungskennzeichen im Einzugsgebiet des Arieş (Transylvanien, Rumänien).

Die Arbeit umfasst eine Analyse des Reliefs im Einzugsgebiet des Arieş-Flusses und der morphologisch-lithologischen und morphologisch-strukturellen Gegebenheiten, die seine Entstehung und Entwicklung beeinflusst haben. Die Analyse verfolgt die Wechselbeziehungen und Abhängigkeiten zwischen den internen und externen Faktoren, aber auch die gegenwärtigen, Umwelt bedingten Gegebenheiten. Das in Beziehung setzen der Daten erlaubt eine qualitative Evaluierung und eine regionale Gliederung der aktuellen geomorphologischen Prozesse, die die Oberflächendynamik des Einzugsgebietes bestimmen. Diese ermöglichen uns, die Tendenzen der Gleichgewichtsstörungen im morpho-hydrographischen System des Arieş-Flusses festzustellen.

REZUMAT: Trăsături morfohidrografice şi ale modelării în bazinul Arieşului (Transilvania, România).

Lucrarea prezintă o analiză a reliefului din bazinul Arieşului şi a condiţiilor morfolitologice şi morfostructurale, care influenţează geneza şi evoluţia acestuia. Analiza urmăreşte corelaţiile şi interdependenţa dintre factorii interni şi externi, dar şi condiţionările actuale, impuse de componente de mediu. Coroborarea datelor face posibilă o evaluare calitativă şi o regionare a proceselor geomorfologice actuale, care condiţionează dinamica suprafeţei bazinului. Acestea ne ajută să identificăm tendinţa dezechilibrelor în sistemul morfohidrografic al Arieşului.

MATERIAL AND METHODS

The methodology was based on the knowledge level of specific information and on the geological, geomorphological and hydrological data and procedures. The data needed were derived from topographic and geologic maps (scale 1:200,000) and field surveys. The hydrological method is based on the analysis of river basin surface, length and flow parameters. Geomorphological interpretation is based on cartographic material and field observations. The research was made for investigating the geographic aspects regarding the status of natural or anthropic components that are or may become significant factors of geomprphological changes, emphasising specially the geomorphological and hydrographical aspects, climatic aspects and land use. The results were used to achieve a distinct cartographic material. Geomorphological analysis follows some significant issues: location of the river basin, presentation of regional characteristics of geomorphological framework, summary data on petrography and superficial deposits, some summary data on basin and landform morphometry, especially on the levelling erosion surface (smoothing), terraces and meadows, forms description and comment on the distribution and typology of the relief and current gemorphological processes. Geomorphological zoning was the basis for mapping of synthetic cartographic material.

RESULTS AND DISCUSSIONS

The discussions are based on the interpreting of tables and cartographic material used.

Hydrographic relevant aspects. The Arieş River is the largest right tributary of the Mureş River. Its catchment covers an area of 2,970 km^2 and a length of 164 km (Tab. 1; Ujvari, 1972). Overall configuration of the basin and network features are the result of fluvial modelling superposed to distinct geomorphological units. Drainage density and hydrological parameter values belonging to the two major betray relief units: Romanian Western Carpathians and the Transylvanian Depression. A particularly important component of the geographical landscape of the Arieş River basin, with active role in shaping the relief and its dynamics, is the surface hydrographic network (***, 1971).

Table 1: Morphometric and flows data on the main streams of the Arieş River basin (***, 1971 with completions from Ujvari, 1972).

River	Station	Distance from source	Altitude of station	F basin (km^2)	H med basin (m)	Q med (m^3/s)
Arieş	Source	0	1,195	-	-	-
Arieş	Scărişoara	21	692	195	1,150	5.45
Arieş	Arieşul Mic confluence	43	550	579	1,042	-
Arieş	Câmpeni	47	544	631	1,023	11.7
Arieş	Abrud confluence	49	538	881	972	-
Abrud	Source	0	950	-	-	-
Abrud	Abrud	12	600	100	901	-
Abrud	Arieş confluence	22	538	229	844	-
Arieş	Baia de Arieş	74	468	1,195	975	-
Arieş	Iara confluence	115	390	2,003	958	-
Iara	Source	0	1,175	-	-	-
Iara	Iara	43	405	273	1,082	3.16
Iara	Arieş confluence	51	390	321	1,004	-
Arieş	Hăşdate confluence	124	340	2,309	911	-
Arieş	Turda	130	317	2,399	892	23.5
Arieş	Mureş confluence	164	263	2,970	804	-

Striking asymmetry of the basin is given primarily by the Arieş mountainous tributaries, more numerous and with larger basin area from mountain units to the east and north-east and fewer and shorter in the southern mountain units. Secondly, the tributaries of the plateau are more numerous and longer to left than right. The most representative tributaries of the Arieş River (Tab. 1) have a permanent drainage system, but first-order talweg in the mountain area and the first and second order talweg in the submontane hills and plateau have a temporary drainage system required by regime of precipitation and snowmelt. All hydrographic network is directly or indirectly influenced by Arieş and then by Mureş rivers. The Arieş River length is 164 km from source to its confluence with the Mureş River and the basin shape is elongated in the direction of flow from west to east (Fig. 1).

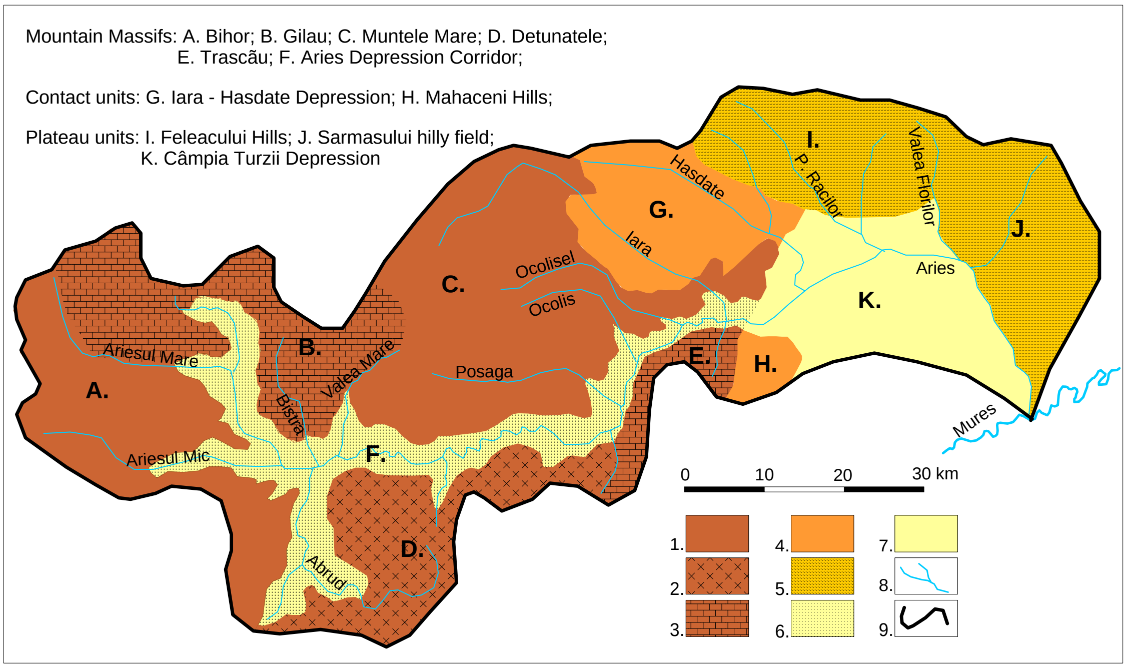


Figure 1: Geomorphological map of the Arieş Basin. 1. massifs developed mainly on crystalline schist, with or without sedimentary layer, with active crionival processes and relative streaming balance; 2. massifs developed on volcanic rocks with high fragmentation, active slope processes mainly due to the mining; 3. massifs developed on limestone with active karstic processes due to heavy rainfalls regime; 4. the hills contact area and tectonic-erosive depressions, with torrential modelling, high instability and regressive retreats of spring areas, due to rainfall and to land use changes; 5. plateau hills and hilly fields with high and very high frequency to landslides, with high instability due the geological conditions and anthropogenic activities; 6. valley corridor and intramontaneous depressions with fluvial modelling, moderate to high intensity and frequency of floods and landslides due to association of climatic and anthropic factors; 7. depressionary areas, stable but with high susceptibility to dampness, due to water stagnations or to freatic level lifting, area with high susceptibility to flooding due to overflowing or to torrential flows; 8. minor riverbeds with moderate susceptibility to riverbed processes: accumulation, meandering and erosion and banks undermining; 9. river basin limit.

The supply and the discharge conditions in the Sebeş Basin depend on the morphoclimatic conditions. Their altitudinal variation reflects the tight, direct correlation between the rainfall quantity and the average specific discharge. For the Carpathian Basin we signal the importance of forest fund in the achievement of the medium discharging whereas the low values from the inferior basin are conditioned by the pluvial supply in reduced quantities and by temporarily leaving out from the discharge process important water quantities in storage lakes or decantation ponds, through infiltration and evaporation (Ştef, 1998).

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The human activity has influenced the hydrographic network and the hydrological system in the Arieş Basin, blocking the water flows, storages, derivations, regulation and draining off systems put into practice as a result of the mineral resources mining exploitation, all of these accomplished also in order to reduce the hydrological risks and the associated risks. Thus, we mention the storage lakes on the Abrud Basin, the ponds of Bucium - Izbiţa mine and Roşia Montană mining area, that function as water storage, decanting and purification structures: Corna, Brazi, Anghel, Tăul cel Mare, Ţarina, Găuri. These artificial elements have been absorbed in time by the natural environment, generating specific landscape units.

Geomorphologic assessments of the Arieş Basin

In physical-geographic terms the hydrographic basin of the Arieş River covers the central part of the Apuseni Mountains and the central-east part of the Transylvanian Depression. The Arieş River basin is bordered on three sides by the most representative massifs of the Apuseni Mountains: the Gilău - Muntele Mare Mountains to the north side, the Detunatele Mountains (north subdivision of the Metaliferi Mountains) and the Trascău Mountains to the south, and also the Bihorului Mountains to the west. Since the Transylvanian Depression is developed to the east periphery of the Apuseni Mountains, the investigated area resembles a quasi-linear amphitheatre, widely open to the east. The geomorphologic evolution has subordinated to the major Carpathian units "as a coordination element in the correlation and classification of phenomena" (Velcea and Savu, 1982). Altitudes decrease from west to east and from the principal watersheds to the centre, as the axis of drainage. We present in this connection the following sequence of relief steps, with different morpho-hydrographic characteristics.

The **mountain basin** includes parts of the second order subunits of the Apuseni Mountains. The main petrographic differences between the crystalline and the sedimentary rocks are mirrored in the relief morphology by total landscape prevalence in its spatial layouts. The great rock hardness of the crystalline - Mesozoic zone of the Apuseni Mountains and their resistance to erosion have produced a massive relief displaying blunt and round summit with peaks exceeding 1600 - 1800 m, with erosion outliers and with a representative development of the Carpathian erosion levelling, which confer a distinctive aspect of the Carpathian Basin of the Arieş. In contrast with summits and interfluvial surfaces, the Arieş Valley and the valleys of its tributaries are very deep (relief energy is different, with value between 300 - 500 - 600 m), with steep slopes of the thalweg and numerous slope creases in longitudinal profile, which are as many disequilibrium points along the minor riverbed. The versants have steep slopes, which make the valleys look like gorges, with vertical position and slope creases in transversal profile (vally' shoulders level), which show the widening of the Arieş Valley on the same route. The prominent tectonic and morphologic fragmentation, varying surfaces and altitudes of the mountain sector, as well as their connection to the hydrographical network which limit them have led to an obvious territorial differentiation (Badea et. al., 2006; ***, 1987).

Thus, mention the **Bihor Massif,** which is the most representative unit of the Apuseni Mountains, located in the west extremity of the Arieş Basin with altitudes of 1500 - 1800 m (Curcurbăta Mare, 1849 m). This unit correspond to the crystalline - Mesozoic zone and formed the upper basin of the Arieş River. Geological constitution is complex. It consists of metamorphic rocks of Biharia series: gneisses, paragneisses, micaschists, amphibolites, quartzites with granite intrusions. The layer of sedimentary rocks consists in carstificabile (Jurassic limestone, Triassic limestones and dolomites). The latter are well-known for the exo and endocarstic relief, well represented to north of Arieşul Mare, in the karst plateau Padiş - Scărişoara. Polycyclic evolution of the relief in the Bihor Mountains highlighted differences of surface erosion levelling from north to south. Modelling complex Fărcaş - Cârligaţi occurs at altitudes of 1,550 - 1,650 m to the north (Bătrâna Mountains) and 1600 - 1800 m in the central massif of Bihor. The levelling erosion surface Măgura - Mărişel has two different altitudinal levels: one of 1350 - 1500 m and another of 1150 - 1300 m. This area is well represented to the north of Arieşul Mare, considered to be a "carstoplena" (Cocean, 2000), and less well represented in the south (Biharia - Găina Mountains) where is below approximatively 200 m. Feneş - Deva erosion surfaces has a peripheral position to the massif, is poorly developed at altitudes of 700 to 900 m and make connection to depressionary corridor of Arieş (Fisheux, 1999).

To the north of the Arieş Basin is extending to southern part of **Gilău - Muntele Mare Mountains**. Maximum altitude record on the northern watershed of the Arieş in the Muntele Mare Peak (1,825 m), from where radial summit going down to the Arieş: Neteda Peak (1,784 m), Dumitreasa (1,636 m), and to the west of Valea Mare - the Smidelor Peak (1,649 m). The relief energy of the summits is relative low (50 - 100 - 200 m), these have flat or smooth aspect, and peaks have aspect of domes being separated by shallow saddles. These mountains are built on crystalline structure of crystalline rocks belonging to mesozonal and epizonal schists of Bihor autochthonous and which have been pierced into central part by the granite batholithic of Muntele Mare composed of granite perfiroide, granite gneiss, pegmatite and quartz veins. There are also trapped crystalline formations in the recumbent fold structure of Codru and Bihor Nappe. Heights can identify the smoothing surface Fărcaş (1600 - 1800 m) a result of sdimentation in the tropical climate (wet and dry) of upper Cretaceous-Oligocene and Mărişel surface (1000 - 1300 m) moulded in the superior Sarmatian - Meotian. To the southern periphery of the massif is found poorly represented the Feneş - Deva erosion surfaces that make the transition to the Arieş Depression (***, 1983; ***, 1987, Posea, 2002).

Except for several crystalline strips, the Cretaceous deposits of Drocea Folds prevail to the south of Arieş in the **Detunatele Mountains**, between the Abrud Valley and Trascău Mountains. These deposits belonging to the Mureş geosynclines, where the Metaliferi Mountains were formed. The sedimentary - volcanic deposits of this area consist of Mesozoic sedimentary rocks (limestone, marls, sandstones, conglomerates, etc.) and Neogene volcanic rocks (basalts, andesites, pyroclastic rocks), which forms the Detunata and Geamăna peaks. (Posea, 2002; Posea et al., 1974) Against this geological background Detunatele Mountains have modest altitudes (800 - 1300 m), which preserve all the three erosion surfaces (Fărcaş - Cârligaţi at 1,200 - 1,300 m; Măgura - Mărişel at 900 - 950 m and 1000 - 1100 m, very well represented through local place name "Platforma (platform) Moţilor", and Feneş - Deva surfaces at 800 - 850 m) and some structural outliers above 1200 - 1,300 m: Detunata (1,258 m) and Vâlcoi (1348 m) - Geamăna (1,366 m) - Poeniţa (1,437 m); this last alignment forms the southern watershed of the Arieş Basin in the Detunatele Mountains.

The position of the **Arieş Corridor** is almost central in the upper sector of the studied river basin (upstream Câmpeni) (Popescu-Argeşel, 1984). Symmetry of the river basin is kept also in the middle sector between Câmpeni and Lupşa, but the basin is clearly asymmetrical in the same middle sector between Lupşa and Corneşti. This configuration of the river basin and position of Arieş depressionary corridor causes the convergence of the mountain ridges to the valley axis. Arieş Valley enhanced in the mid-Carpathian erosion level of inferior Miocene age (Posea, 2002). Remains of this level appear marginal to the Arieş Corridor, at altitudes of 750 - 800 - 900 m, and connecting the depressionary passageway with neighbouring mountain masses (Fig. 1). The lower part of the Arieş Corridor consists of a succession of river landforms: terraces and meadows of collector or his tributaries, alluvial funs of them etc. The Arieş Valley have narrows, some of them are gorges and have epigenetic character: the gorge of Albac - Vadu Moţilor, narrowing of the Frumoasa - Rogoz sector, Piţigaia, Muncelu, Baia de Arieş - Sălciua sector, Vidolm - Buru Gorge, narrowing of the Furduieşti on Abrud Valley and Drăgoieşti on Arieşul Mic Valley. Intense rate of differential erosion has led to concentration of drainage and shape erosion and hydrographic convergence depressions along the Arieş Corridor: Albac Depression with the two branches Gârda de Sus - Arieşeni to the west and Horea to the north, Câmpeni - Bistra Depression, Lupşa and Poşaga Depression on the Arieşul Mare, Vidra Depression on the Arieşul Mic Valley and the Abrud Depression.

The **lower, depressionary basin** of the Arieş River, between Corneşti and Gura Arieşului, overlap entirely to the Transylvanian Depression. The step plateau of the basin recorded a decreased altitude from west to east and an increased fragmentation, with structural and pseudo-structural forms generated by monocline and by a strong modelling on small basins (first, second and third order). Modelling exercised by river network in the mountainous region was transmitted by contact with the Transylvanian Depression, where are developed Aiudului Hills to south and Feleacului Hills to north of Arieş River. Peaks are slowly, longitudinally oriented towards the Apuseni Mountains and convergent to the Arieş Valley. Slopes have gradients between 15 and 45^o and different exhibitions, mainly to north and to north-east in the Aiudului Hills and predominantly southern, south - western and south - eastern in the Feleacului Hills.

The Apuseni Mountains contact with Feleacului Hill is achieved by the passage **depression Iara - Hăşdate**, where the accumulative forms are well represented. It consists of two asymmetrical depressionary passageways developed along the Arieş tributaries - Iara and Hăşdate valleys. These are separated by a hillock - Agrişului Hill (800 m) developed on the hardest rocks. Petrographic base, consists of Cretaceous and Paleogene and Neogene sedimentary rocks (red clays, marls, limestones, sandstones, tufa, sands, gravels etc.), favoured preservation of three levels of erosion: 700 - 800 m in the Agrişului Hill, 600 - 650 m erosion level met in all the peaks to the north of Arieş and 450 - 500 m erosion level along the valleys.

The **Feleacului Hills** covers a part of the Arieş north basin between Hăşdate and Florilor valleys. The north watershed of the Arieş River basin follows the main peak of this hill oriented from west to east: Măgura Sălicei (824 m) - Peana (832 m) - Cioltu Mare (718 m). Detached from the main ridge, secondary peaks orientated from north to south, are separated by tributaries of the right side of the Arieş River: Micuş, Valea Racilor, Calda Mare. The geological substrate is composed of: Eocene - Oligocene deposits in the west part (with marls, clays, gypsum, limestone - Sălicea karst-plateau), Sarmatian deposits in the central and eastern part (clays, sandstone, sand, gravel, containing the known "Feleac concretions") (Schreiber, 1990). The main peak retains traces of the Sarmatiene modelling, representative to the west part to the level of 700 to 800 m altitude, known as "Feleacului level" (***, 1987). At the east of the Racilor Valley this level is underrepresented, in turn are more developed the erosion levels of 550 - 650 m and 450 - 500 m. In the Arieş Basin limit the Aiudului Hills are represented by the highest and northern part of them - **Măhăcenilor Hills** (556 m). These made the contact between Trascău Mountains and depressionary area of the Mureş Corridor, with maximum development as an extended promontory between Aiud River and Arieş River to Călăraşi and Unirea (***, 1987; Badea et. al., 2006).

Also, the inferior Arieş Basin is extending partially on the **Câmpia Turzii Depression** (part of the Mureşului Corridor). Câmpia Turzii Depression, known as Inferior Arieş Depression too (Savu, 1987), was moulded by the Arieş fluvial action, relative to erosion level base of the Mureş River. The meadow takes up a large surface, having an asymmetric character, growing on the right side of the Arieş (500 m - 2 km) upstream the Câmpia Turzii, or on the left side between Câmpia Turzii and Gura Arieşului. The meadow stretches out to the terrace complex, with a differentiated potential of land-use; to the north is in direct contact with the upper terrace (75 - 85 m relative altitude) and to the south the meadow is continued by lower (8 - 12 m) and middle terraces (18 - 22 m, 30 - 40 m). In the petrographical composition are predominant the Pleistocene gravel and sands on the terraces bridges and Holocene in meadows. They are superposed on sedimentary deposits consist of marls, clays and Sarmatian sands, which are highlighted on cuesta or terraces slopes.

To the east the Arieş meadow comes in direct contact with **Ludoşului hilly plain**. This last sector is the western part of the **Sărmaşului Plain**, characterized by drowned valleys in slope deposits (mainly landslides) and low relief energy. The relief is represented by a complex of low altitude hilly plain. The relief energy is 50 - 100 m; the valleys are wide and meandering due to the dome structure and the elevation of riverbed, which confers them a high bogging potential. In the morphology can be identified lower summits which extend north-south: Stârcului Hilly (448 m) - Coasta Grindului (466 m) to west and Comorilor Hill (491 m) - Ţigla Fântânenilor (583 m) to east - forming the watershed of the Arieş Basin. Predominate clays, marls, sands with intersperse of sandstones, conglomerates and Sarmatian tufa.

Geomorphologic processes

Layered structure resulting from the altimetric succession determines a differentiation depending on the type of agent, the extent of processes, the occurrence rate and intensity. Other important elements to be considered in modelling are the structure, lithology, declivity degree, exposure and bio-climatic conditions (Velcea and Savu, 1982; ***, 1987).

In the mountain basin relief the modeling are subordinated to the predominantly crionival processes, to the gravitational and torrential processes, all of them being conditioned by the geological constitution and mountain climate conditions (2 - 7^{o}C, frost interval > 220 days, > 1,000 mm/year precipitations). Thus, the carpathic region of the Arieş Basin display a combination of crionival processes, pluvial denudation and sheet erosion, especially at altitudes exceeding 1,700 m. Crionival processes result from freezing cycles that take place regularly, from snow cover staying for approximatively six months/year and from solid precipitation prevalence. They are maintained by a low consistency of vegetal covers (subalpine pastures and bushes). The effects of crionival modeling are insignificant at slope level (600 - 1,600 m) since afforestation degree is consistent. At interfluves level erosion processes of low to medium intensity prevail, with torrential and ravening processes on the lower erosion surfaces (700 - 800 m). The mountainous basin is individualized by predominant forest vegetation and a stable balance originating in the high afforestation degree and balanced streaming (Fig. 1). Imbalances are subject to heavy rainfalls, made by the water equivalent of snow layer and by the association of them with uncontrolled forest exploitation and operated mining in the Roşia Montana area.

The geological substrate of the lower basin rich in clay and the climatic conditions (8 - 9^{o}C, 190 - 200 days with frost, 600 - 700 mm/year precipitations) favour the mass movement (landslides, collapse) and the torrential processes, which bring about quantitative and qualitative changes in the hills landscape. The hilly, depression and plateau basin are characterized by mixed erosion, transport and accumulation processes in a relative unstable balance. The environmental imbalances are due to hydro-climatic and anthropic stress in a favorable geological background (marls, clays and salt). Accelerated modeling processes are associated to pluvial denudation (splash erosion, rill erosion, ravening, torrential erosion) and mass movement (creep, solifluxion and landslides), which confer to the relief a specific morphodynamic potential. There is a high degrading potential conditioned by the salt deposits at Turda, as well as a high imbalance because of ground water, surfaces humidity and land improvement work. Slope processes in the plateau area facilitate the regression of sprigs area and degrading of small basin (***, 1987).

The valley corridors are subjected to water and sediment discharge transit which leads to intense alleviation and clogging processes or to floods. The riverbeds of the Arieş River and its tributaries are affected by linear processes in the mountain area and predominantly by lateral erosion in the plateau area. Also the accumulation of material is predominant in the depressionary passageway of Arieş in the mountain and in the inferior basin, generating specially at the confluence alluvial forms like: isles, sands, alluvial cones. Evolution of these forms is permanently controlled by the climatic patterns and by transport capacity of Arieş and its tributaries (Ştef and Costea, 2006). The instability of the riverbanks and the meander dynamic must be observed, especially in the plateau area, where the torrential phenomena are frequent. To this end the figure 1 displays a zoning of the relief units and predominant geomorphologic processes.

CONCLUSIONS

Due to its quality, as contact interface between geographical units, more or less similar in structure of the geosystem, the Arieş hydrographic basin has a series of distinct aspects. They derive from its central position in Romania, from the territorial features which are significant for the mountain units of the Apuseni group, along whose eastern mountainside lies the Carpathian Basin, from the specific features of the Transylvanian Plain unit but also of the contact area of mountain-depression, from the ranging in tiers of the physical - geographical conditions and of geomorphologic processes required by the altitudinal display of the basin from 263 m at its confluence with the Mureş River up to 1849 m in the Cucurbăta Peak. In the mentioned geomorphologic context, the current modelling manifest in a wide agents range: rainfalls, snow, temperature and processes (frost, thaw, erosion, transport and accumulation), leads to the formation of specific relief and to a continuous dynamic of slopes and river beds.

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BACTERIAL AND ENZYMATIC ACTIVITIES EVOLUTION IN WATER AND SEDIMENTS OF THE ARIEŞ RIVER (TRANSYLVANIA, ROMANIA)

Vasile MUNTEAN *, *Anca LIVIA* * and *Rahela CARPA* *

* "Babeş-Bolyai" University, Faculty of Biology and Geology, Kogălniceanu Street 1, Cluj-Napoca, Cluj County, Romania, RO-400084, vamutiro@yahoo.co.uk, alkeul@yahoo.com, k_hella@yahoo.com

KEYWORDS: Romania, Transylvania, Mureş River basin, Arieş River, pollution, sediments, water, enzymes, bacteria, indicators of quality.

ABSTRACT

Eleven water and sediment samples from the Arieş River were studied physico-chemically, microbiologically and enzymologically. The sampling sites were established along a distance of about 100 km of the river. The analyses were carried out in September 2007, and the results were compared with those obtained one year ago. The physico-chemical parameters of water analyzed were: pH, Eh, conductivity and O_2 concentration. The following four ecophysiological bacterial groups have been studied: aerobic mesophilic heterotrophs, ammonifiers, denitrifiers and iron-reducers. The following four enzymatic activities have been measured: phosphatase, catalase, actual and potential dehydrogenase. The presence of all the four ecophysiological bacterial groups was registered in all the studied sediments. The descending ranking of their abundance was: aerobic mesophilic heterotrophs > ammonifiers > denitrifiers > iron-reducers. The number of bacteria in sediments exceeds by approximately one order of magnitude the number of the corresponding group in water. Based on the bacteria number of each ecophysiological group, the bacterial indicators of sediment (BISQ) and water (BIWQ) quality were calculated. The four enzymatic activities were noticed in all the studied samples. On the base of the analytical data, the enzymatic indicators of sediment quality (EISQ) were calculated. As in the case of the microbiological analyses, the enzymatic potential of sediments increases downstream the river. Positive correlations, statistically very significant, have been established between the bacterial and enzymatic indicators. Unlike in the previous year, the pH and Eh of water in the P11 point registered values close to those registered in the other sampling sites, due to the diminution of the activities at the mining enterprises in Roşia Poieni and Roşia Montană, which carry the wastes into the Abrud River, a tributary of the Arieş River. The lowest level of both bacterial and enzymatic potential registered in the P11 sampling site in 2007, at the same level as in 2006, show the long-term polluting effect of wastes from mining entreprises on water and sediment quality.

RÉSUMÉ: Evolution des activités bactériennes et enzymatiques dans l'eau et les sédiments de la rivière d'Arieş (Transylvanie, Romanie).

Onze échantillons d'eau et de sédiment de la rivière d'Arieş ont été étudiés de point de vue physico-chimique, microbiologique et enzymologique. Les endroits propices pour l'échantillonnage ont été choisis à partir de 100 km de rivière. Les analyses ont été effectuées pendant le mois de septembre de l'année 2007 et les résultats ont été compares avec ceux obtenus une année avant. Les paramètres physico-chimiques analyses ont été: le pH, le Eh, la conductivité et la concentration de l'oxygène. Quatre groupes ecophysiologiques de bactéries ont été étudiés: aérobies mésophiles hétérotrophiques, ammonifiantes, dénitrifiantes et fer-réductrices. Quatre activités enzymatiques ont été étudiées: phosphatasique, catalasique, deshydrogenasique actuelle et potentielle. L'étude a mis en évidence la présence de tous les quatre groupes ecophysiologiques bactériennes dans tous les sédiments étudiés. L'ordre décroissant de leur abondance a été le suivant: bactéries aérobies mésophiles hétérotrophes > bactéries ammonifiantes > bactéries dénitrifiantes > bactéries fer-réductrices. Basé sur le nombre de bactéries des sédiments de chaque groupe ecophysiologique, ont été calculés les indices bactériens de qualité du sédiment (BISQ) et de l'eau (BIWQ). Les quatre activités enzymatiques ont été mises en évidence dans tous les échantillons étudiés. À partir des donnes analytiques, les indicateurs enzymatiques de qualité du sédiment (EISQ) ont été calculés. Comme dans le cas des analyses microbiologiques, le potentiel enzymatique du sédiment s'accroit vers l'aval. Des corrélations positives, très significatives de point de vue statistique, ont été établies, entre les indices bactériens et les indices enzymatiques. À différence de la situation de l'année précédente, le pH et le Eh de l'eau au point de prélèvement P11 ont enregistré des valeurs proches à ceux des autres points de prélèvement, ce résultat étant la conséquence de la diminution de l'activité des entreprises minières de Roşia Poieni et Roşia Montană, qui déversent leur résidus dans la rivière Abrud, un affluent de la rivière Arieş. Le plus bas potentiel, bactérien ainsi qu'enzymatique, enregistrés au point P11 en 2007, comme dans le cas de l'année 2006, indique une pollution à long terme de l'eau et du sédiment produite par les résidus des entreprises minières.

REZUMAT: Evoluţia activităţilor bacteriene şi enzimatice în apa şi sedimentele râului Arieş (Transilvania, România).

Unsprezece probe de apă şi sediment din râul Arieş au fost studiate fizico-chimic, microbiologic şi enzimologic. Locurile de prelevare a probelor au fost alese pe o lungime de 100 km a râului. Analizele au fost efectuate în luna septembrie 2007, iar rezultatele au fost comparate cu cele obţinute cu un an în urmă. Parametrii fizico-chimici ai apei analizate au fost: pH-ul, Eh-ul, conductivitatea şi concentraţia în O_2. Au fost studiate patru grupuri ecofiziologice de bacterii: aerobe mezofile heterotrofe, amonificatoare, denitrificatoare şi fier-reducătoare. S-au măsurat următoarele patru activităţi enzimatice: fosfatazică, catalazică, dehidrogenazică actuală şi potenţială. Studiul a relevat prezenţa tuturor celor patru grupuri ecofiziologice bacteriene în toate sedimentele studiate. Ordinea descrescătoare a abundenţei lor a fost: bacterii aerobe mezofile heterotrofe > bacterii amonificatoare > bacterii denitrificatoare > bacterii fier-reducătoare. Numărul de bacterii din sedimente a depăşit cu aproximativ un ordin de magnitudine numărul aceluiaşi grup de bacterii din apă. Pe baza numărului de bacterii al fiecărui grup ecofiziologic, au fost calculaţi indicatorii bacterieni de calitate ai sedimentului (BISQ) şi ai apei (BIWQ). Cele patru activităţi enzimatice au fost observate în toate probele studiate. Pe baza datelor analitice, au fost calculaţi indicatorii enzimatici de calitate ai sedimentului (EISQ). Ca şi în cazul analizelor microbiologice, potenţialul enzimatic al sedimentelor creşte, pe cursul râului, în aval. S-au stabilit corelaţii pozitive, foarte semnificative din punct de vedere statistic, între indicatorii bacterieni şi cei enzimatici. Spre deosebire de situaţia din anul anterior, pH-ul şi Eh-ul apei din punctul de recoltare P11 a înregistrat valori apropiate de cele înregistrate în alte puncte de prelevare, acest rezultat fiind consecinţa diminuării activităţii intreprinderilor miniere de la Roşia Poieni şi Roşia Montană, care îşi deversează reziduurile în râul Abrud, un afluent al Arieşului. Cel mai scăzut potenţial, atât bacterian cât şi enzimatic, înregistrat în punctul P11 în 2007, la acelaşi nivel ca şi în anul anterior, indică o poluare pe termen lung a apei şi sedimentului cauzată de deşeurile provenite de la intreprinderile miniere.

INTRODUCTION

Water resources management according to legal provisions regarding fresh water protection or improvement proves to be a very difficult task (Maloş et al., 2008), and there can not be any successful conservation of natural resources without a good knowledge about what is the present state and what is to be conserved (Hey et al., 2003; Mace, 2004; Nowak et al., 2008). The presence of many non-native species (Gavriloaie, 2008), high levels of heavy metals (Popek et al., 2008), and organic matter pollution (Berkesy et al., 2008) create serious environmental problems and consequently these ones are the main challenges for management or improvement of aquatic resources.

The present paper continues the study carried out on water and sediment of the Arieş River started in 2006. The results obtained in the first year of study revealed the existence of some polluting sources upstream the river, which strongly influenced the microbial and enzymatic activities in water and sediment, as well as some physico-chemical parameter of water, especially the pH and the redox potential (Muntean, 2007). The P11 sampling site, at the point where Abrud River flows in Arieş River, was seriously affected by pollution. Here we registered the only one acid value of water pH (4.5), the only one positive value of the redox potential of water (Eh = +145 mV), and the lowest bacterial and enzymatic potential of water and sediment, illustrated by the lowest values of the bacterial indicators of water and sediment quality, as well as the lowest values of the enzymatic indicators o sediment quality. The values of quality indicators were much lower as compared to all the other ten sampling points. We supposed that sources of pollution were the mining enterprises in Roşia Montană and Roşia Poieni, which carry the wastes into the Abrud River.

In 2007, we tried to pursue the evolution of the main parameters analyzed one year ago, in order to evaluate the persistence of the polluting effect of wastes from the mining enterprises on the bacterial and enzymatic potential in water and sediments of the Arieş River. We present here the results obtained in November 2007, compared with those obtained one year ago. The research was supported by the Romanian Ministry of Education and Research, under the framework of the National Research Programme CEEX.

MATERIALS AND METHODS

The physico-chemical, microbiological and enzymological analyses were carried out in September 2007, on water and sediments samples collected from the same eleven sites analyzed in 2006 (Muntean, 2007), as follows (odd number - upstream; even number - downstream): P1, 2 - Câmpeni; P3, 4 - Baia de Arieş; P5, 6 - Sălciua; P7, 8 - Turda; P9, 10 - Câmpia Turzii; P11 - site where the Abrud River flows into the Arieş River.

The following physico-chemical parameters of water were analyzed in situ, using a portable multiparameter: pH, Eh (redox potential), conductivity and O_2 concentration.

The following four ecophysiological bacterial groups have been studied: aerobic mesophilic heterotrophs (agar plates), ammonifiers (peptone medium; Atlas, 2004), denitrifiers (Pochon, 1954), and iron-reducers (Pârvu et al., 1977). The most probable number of bacteria was calculated according to the statistical table of Alexander (1965), except for the aerobic mesophilic heterotrophs, where the method of successive dilutions, was used.

The following four enzymatic activities in sediments were studied: phosphatase (Krámer and Erdei, 1959), catalase (Kappen, 1913), actual and potential dehydrogenase (Casida et al., 1964).

RESULTS AND DISCUTIONS

Results of the physico-chemical analyses of water are presented (Tab. 1). In all sites, the pH is alkaline. The lowest pH value was noticed in the P11 point (7.12) and the most alkaline (8.10) in the P8 and P9 sampling sites. The redox potential was always negative (between -35 (P2) and -70 (P8 and P9)), indicating a slight reducing capacity of water.

Table 1: Results of the physico-chemical analyses carried out in water.

Sampling site	pH	Eh (mV)	Coductivity ($\mu S\ cm^{-1}$)	O_2 ($mg\ l^{-1}$)	Temperature (°C)
P1	7.50	-40	180	11.30	12.5
P2	7.40	-35	169	11.00	12.7
P3	7.70	-48	198	10.60	12.5
P4	7.51	-62	194	10.75	12.6
P5	7.95	-62	258	10.20	12.6
P6	7.91	-63	264	10.30	13.5
P7	8.08	-69	320	10.75	13.9
P8	8.10	-70	381	10.08	13.9
P9	8.10	-70	392	10.15	14.1
P10	8.02	-65	502	9.45	14.0
P11	7.12	-19	580	10.30	12.0

We notice the great difference as regard the values of these two parameters, compared with the analyses carried out one year ago, when in the P11 sampling site was registered the only one positive value of Eh (+145 mV) and the only one acid value of the pH (4.45). The increase of the pH and Eh might be correlated with the strong diminution till cessation of the activities at the enterprises in Roşia Poieni and Roşia Montană, which carry the wastes into the Abrud River, a tributary of the Arieş River.

A negative correlation with very high statistical significance was established between the pH and the redox potential: $r = -0.922$, $p < 0.001$. Between the Eh and the temperature it was as well established a negative correlation, with good statistical significance ($r = +0.804$; $p < 0.01$). A positive correlation with high statistical significance ($p < 0.001$) was calculated between the temperature and the pH ($r = +0.868$). The temperature negatively correlated with the O_2 concentration, without statistical significance ($r = -0.516$; $p > 0.05$). The O_2 concentration was high (12.5 - 13.5 $mg\ l^{-1}$), in negative correlation with the conductivity ($r = -0.718$; $p < 0.05$), which registered values of the order of $10^2\ \mu S \cdot cm^{-1}$.

As in the analyses carried out in 2006, we noticed the presence of all the four ecophysiological bacterial groups, in all the studied samples. As well, the same descending ranking of their abundance was registered: aerobic mesophilic heterotrophs > ammonifiers > denitrifiers > iron-reducers, both in sediments, and in water. In sediments, the number of bacteria ranges as follows: mesophilic aerobes between $< 5 \cdot 10^5 \cdot g^{-1}$ dry matter and $> 10^7 \cdot g^{-1}$ dry matter; ammonifiers between $< 1.4 \cdot 10^4 \cdot g^{-1}$ dry matter and $> 3.9 \cdot 10^5 \cdot g^{-1}$ dry matter; denitrifiers between $< 1.6 \cdot 10^3 \cdot g^{-1}$ dry matter and $> 10^4 \cdot g^{-1}$ dry matter; iron-reducers between $130 \cdot g^{-1}$ dry matter and $> 2.4 \cdot 10^4 \cdot g^{-1}$ dry matter. In water, the number of bacteria belonging to each bacterial group was lower by approximately one order of magnitude than the number of the corresponding group in the sediments. The highest number of bacteria was always registered in the P10 sampling point, and the lowest one in the P11 sampling site.

Based on the bacteria number of each ecophysiological group, the bacterial indicators of sediment (BISQ) and water (BIWQ) quality were calculated, according to Muntean formula (1995 - 1996). The bacterial indicators values follow the same curve, as in the last year: lower upstream and higher downstream the river, both in water, and in sediments (Figs. 1 and 2). With one exception, the values of the BISQs values ranges from 4.459 (P1) to 5.297 (P10). The only one exception is that of the P11 point, where the value of the BISQ was only 3.778, significantly lower than he values registered in the other sampling sites. However, the value is also higher than those registered in the previous year (3.658). This indicates an increase of the bacterial potential of sediments, as compared with the previous year, but the level of this potential remains much lower than in the other sampling sites.

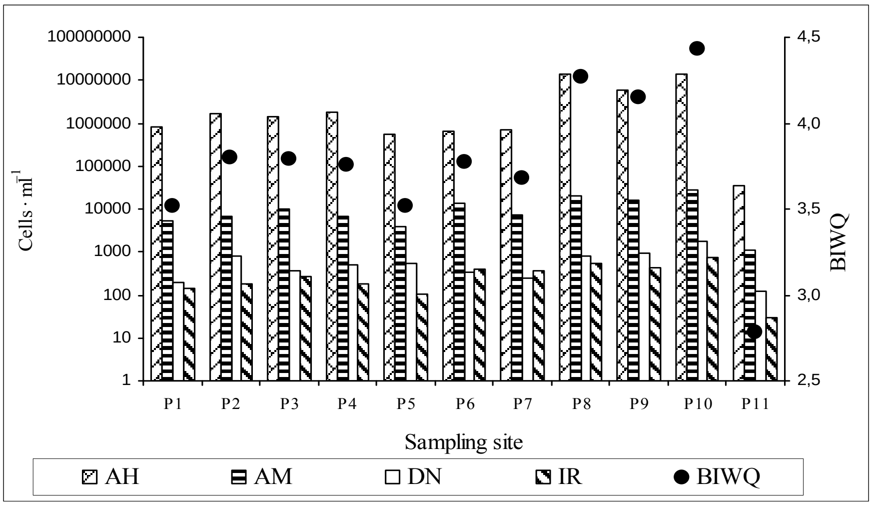

Figure 1: Results of the microbiological analyses carried out on water. AH = aerobic heterotrophs; AM = ammonifiers; DN = denitrifiers; IR = iron-reducers; BIWQ = bacterial indicator of water quality.

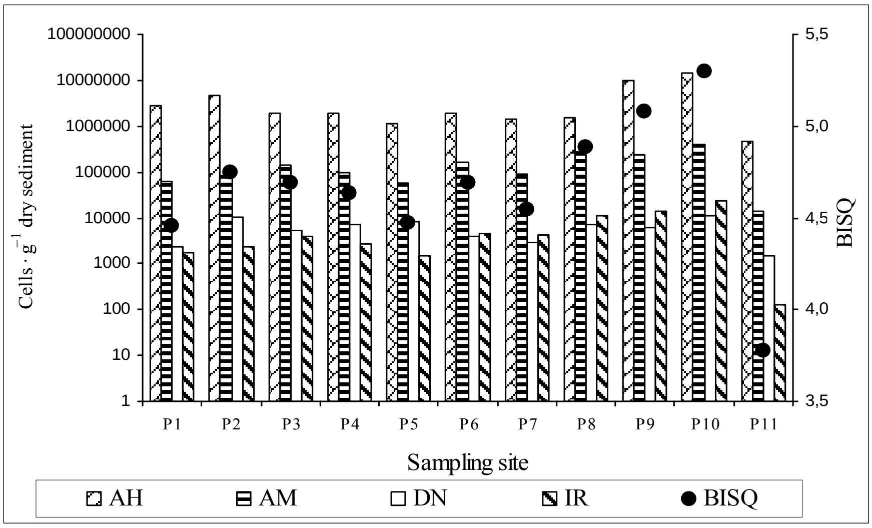

Figure 2: Results of the microbiological analyses carried out on sediments. Explanations: see the figure 1. BISQ = bacterial indicator of sediment quality.

The same is valid as regard the BIWQs, whose values ranges between 2.780 (P11) and 4.430 (P10), lower by approximately 1 as compared with the BISQs in each sampling point. Actually, the level of bacterial potential increased in each sampling sites, as compared with the previous year, with only one, insignificant, exception: the P8 point, where the BISQ decreased with 0.36% (Tab. 2). The increase might be partially explain by the fact that in 2007, the analyses were carried out in September, two months earlier than in the previous year; the temperature of the water was higher by approximately 3°C and, consecutively the intensity of biological activities were more intense.

Table 2: Evolution of bacterial and enzymatic indicators of quality in water and sediments. EISQ = enzymatic indicator of sediment quality; BISQ = bacterial indicator of sediment quality; BIWQ = bacterial indicator of water quality.

	Increase in 2007 as compared to 2006 (%)		
Sampling site	EISQ	BISQ	BIWQ
P1	34.27	5.84	11.4
P2	27.70	8.31	14.79
P3	34.99	8.68	17.54
P4	16.81	7.47	16.67
P5	11.13	3.72	4.39
P6	30.09	4.82	7.09
P7	8.76	2.09	3.94
P8	-5.60	-0.36	10.73
P9	-11.20	2.85	7.70
P10	-0.72	4.83	11.25
P11	1.54	3.17	8.99

The four enzymatic activities studied have been registered in all the sediments (Fig. 3), at a level higher than in the previous year in the sampling sites upstream the river (P1 - P7). The intensity of the catalase and phosphatase activities, and at less extent, the dehydrogenase activities, was quite high, as compared with similar researches (Ştef et al., 2004; Muntean and Grozav, 2007; Curticăpean and Drăgan-Bularda, 2007), and also as compared with the previous year.

The enzymatic potential of sediment is appreciated by enzymatic indicator of sediment quality (EISQ; values between 0 and 1), calculated according with Muntean et al. (1996). As in the previous year, the sediments show a very good enzymatic potential (EISQ > 0.500) only downstream the Turda city (Fig. 4). Upstream Turda locality, the EISQ values ranges from 0.290 (P1) and 0.393 (P3). As in case of bacterial indicators of sediment quality, in the P11 sampling site was registered the minimum value (0.124).

The enzymatic potential of sediment registered an even more obvious increase than the bacterial potential, but only upstream the river (P1 - P7). In the P8 - P10 sites, where we registered the highest values of the EISQs in both years, the enzymatic potential slightly decreased in the second year of research (Tab. 2).

We also notice that, as in BISQ and BIWQ case, EISQ remain at the same decreased level in the P11 point, indicating that the wastes from Roşia Poieni and Roşia Montană have a long time polluting effect, mainly on sediments. This assertion is sustained taking into account the diminution of the activity in the mining enterprises during the 2007 year, illustrated by the modification of the pH and Eh of the water in P11 point. As we have already noticed, these two parameters came close to those registered in the other sampling sites.

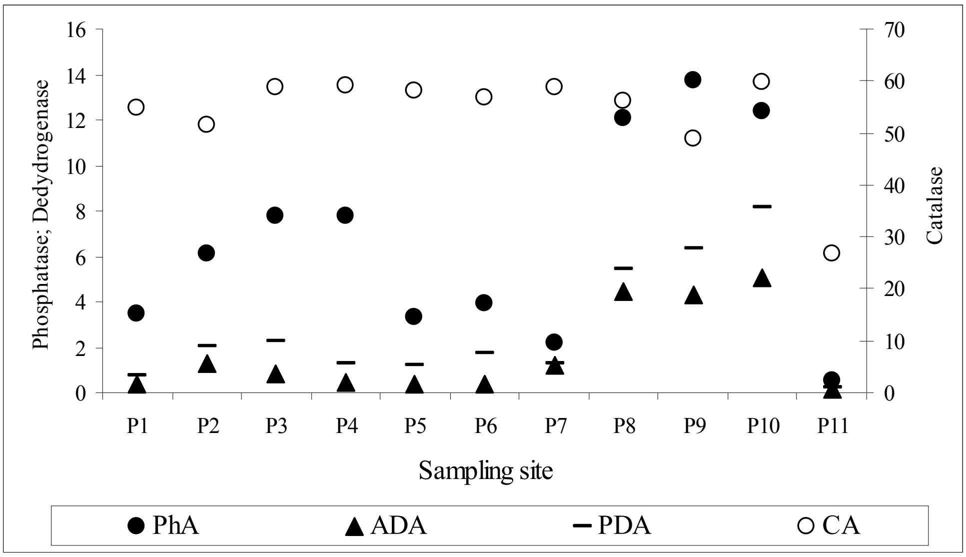

Figure 3: Enzymatic activity in sediments. PhA = phosphatase activity (mg phenol g^{-1}); CA = catalase activity (split H_2O_2 g^{-1}); ADA = actual dehydrogenase activity; PDA = potential dehydrogenase activity (mg formazan g^{-1} dry matter).

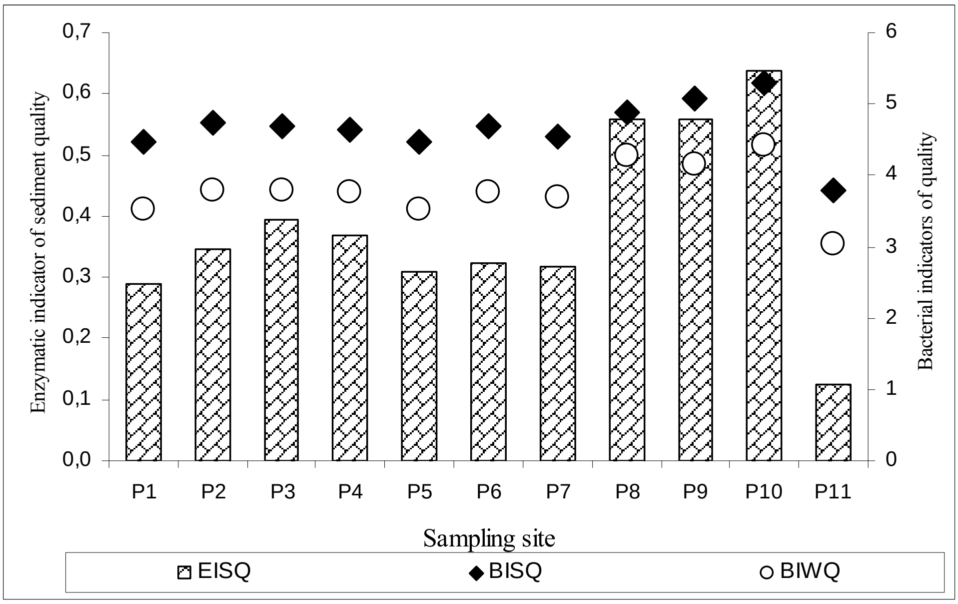

Figure 4: Comparison of microbial and enzymatic potential of the Arieş River in 2007. BISQ = bacterial indicator of sediment quality; BIWQ = bacterial indicator of water quality; EISQ = enzymatic indicators of sediment quality.

As in the previous year, positive correlations with very high statistical significance ($p < 0.001$) have been established between all the bacterial and enzymatic indicators: EISQ - BISQ ($r = + 0.943$); BISQ - BIWQ ($r = + 0.965$); EISQ - BIWQ ($r = + 0.980$).

CONCLUSIONS The physico-chemical analyses of water showed an alkaline pH and a redox potential negative in all the sampling sites, indicating a slight reducing capacity of water. However, the two parameters followed an obvious increase, as compared with the analyses carried out one year ago, coming close to those registered in the other sampling sites. The evolution was probably correlated with the strong diminution till cessation of the activities at the enterprises in Roşia Poieni and Roşia Montană, which carry the wastes in Abrud River.

The presence of the four ecophysiological bacterial groups, in all samples was noticed, at superior level than in the previous year. The values of the bacterial indicators follow the same curve: lower upstream and higher downstream the river, in water and in sediments. The four studied enzymatic activities have also been registered in all the analyzed sediments. The enzymatic potential of sediment registered an even more obvious increase than the bacterial potential, but only upstream the river (P1 - P7). As last year, the lowest level of both bacterial and enzymatic potential, showed by the BIWQ, BISQ and EISQ values, was registered in the P11 site, indicating that the wastes from Roşia Poieni and Roşia Montană have a long-term polluting effect, especialy on sediments. The conclusion can be drawn taking into account the diminution of the activity in the polluting mining enterprises during the interval since the last analyses.

The results certify the usefulness of the enzymatic and bacterial indicators as good tools for estimating the effect of the polluting factors on the habitats. Positive correlations with very high statistical significance have been established between the bacterial and enzymatic quality indicators.

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LABORATORY TESTS REGARDING THE REDUCTION OF METALLIC IONS CONTENT OF SOME SURFACE WATERS BY BIOREMEDIATION (ARIEŞ BASIN, TRANSYLVANIA, ROMANIA)

*Anca VOICU *, Mugur ŞTEFĂNESCU ** and *Ioan LAZĂR **

* Romanian Academy, Bucharest Institute of Biology, Splaiul Independenţei 296, sector 6, Bucharest, Romania, RO-060031, anca.voicu@ibiol.ro, mugur.stefanescu@ibiol.ro, ioan.lazar@ibiol.ro

KEYWORDS: Romania, Transylvania, Arieş River basin, mining, waste waters, metallic ions, acid pH, bioremediation.

ABSTRACT

Processing of copper containing ores in the mining area of Roşia Poieni generates huge quantities of effluents which contain high levels of heavy metals and acid pH, becoming thus a permanent pollution source for the environment. These effluents are collected in a decantation pond in Valea Şesei, where from the water is evacuated towards Arieş River, an affluent of the Mureş River.

The performed investigations aimed at several aspects, mainly: the physico-chemical and microbiologic characterization of water samples collected from various sites of Valea Şesei decantation pond, including upstream, downstream and within the pond points, laboratory tests performed in percolator columns in order to reduce the metal ions burden of the waste water from the pond, by using bioremediation technologies, i.e. biosorption, bioaccumulation and bioprecipitation.

ZUSAMMENFASSUNG: Labortests betreffend die Reduzierung des Gehalts an Metalljonen einiger Oberflächengewässer durch biologischen Verbesserungsmaßnahmen (das Becken des Arieş, Transylvanien, Rumänien).

Die Aufbereitungsarbeiten einiger Kupfererze im Bergbaugebiet Roşia Poieni haben bedeutende Mengen an auslaufenden Reststoffen mit einem erhöhten Gehalt an Schwermetallen und saure pH-Werte erzeugt, die eine fortwährende Belastungsquelle für die Umwelt darstellen. Diese Reststoffe werden in einem Absatzbecken im Şesa-Tal /Valea Şesei gesammelt, von wo das Abwasser in den Arieş, einen Nebenfluss des Mureş gelangt.

Mit den durchgeführten Untersuchungen wurden unterschiedliche Aspekte verfolgt und zwar: die physikalisch-chemische und mikrobiologische Kennzeichnung der in verschiedenen Teilen entnommenen Wasserproben, deren Probestellen oberhalb des Absatzbeckens Valea Sesei, im Becken selbst und unterhalb liegen; Labortests in Perkolationskolonnen mit dem Ziel der Reduzierung des Metalljonengehalts der Abwasser aus dem Auffangbecken unter Verwendung von Methoden biologischer Verbesserung, bzw. der Biosorption, Bioakkumulation und Biopräzipitation.

REZUMAT: Teste de laborator privind reducerea conținutului în ioni metalici a unor ape de suprafață prin bioremediere (Bazinul Arieş, Transilvania, România).

Activitățile de procesare a minereurilor cuprifere în zona minieră Roşia Poieni au generat importante cantități de efluenți cu conținut crescut de metale grele şi pH acid, surse permanente de poluare a mediului. Aceşti efluenți sunt colectați într-un iaz de decantare de la Valea Şesei, de unde apa este evacuată ulterior spre râul Arieş, un afluent al râului Mureş.

În investigațiile efectuate s-au urmărit mai multe aspecte şi anume: caracterizarea fizico-chimică şi microbiologică a probelor de apă colectate din diferite zone ale iazului de decantare Valea Şesei, incluzând puncte din amonte, interiorul iazului şi aval; teste de laborator realizate în coloane percolator în scopul reducerii conținutului în ioni metalici a apei reziduale din iazul de decantare folosind tehnologii de bioremediere, respectiv biosorpție, bioacumulare şi bioprecipitare.

INTRODUCTION

The environment is continuously contaminated with high quantities of residues, polluting elements that exert a negative influence upon people's life and environment.

Heavy metals polluting the environment have mainly an anthropogenic origin. The mining activities, both in underground or on surface, produced and are still producing huge quantities of processed metalliferic ores wastes. After processing of ores important quantities of effluents with high concentrations of metallic ions, mainly heavy metals, are generated. Such wastes are accumulated in decantation ponds, which finally became dumps of million tons tailings located on wide surface of land.

Such is the case in Roşia Poieni, Alba County, a vast mining area in the West Romanian Carpathian Mountains. The copper ore deposit from Roşia Poieni represents one of the most important copper deposits in the world (Dumitrescu, 2007). As a result of mining activities over a period of 30 years for processing of sulphide ores, a large decantation pond, called Valea Şesei, of about 30 ha in surface was formed. From this pond, waste waters are evacuated through a small river into the Arieş River, a main water stream, which is flowing to the Mureş River in the Tisa River basin.

The presence of heavy metals in aquatic environments is known to cause severe damage to aquatic life. Most of the heavy metal salts are soluble in water and form aqueous solutions and consequently can not be separated by ordinary physical means of separation (Hussein et al., 2004). Physico-chemical methods, such as chemical precipitation, oxidation or reduction, electrochemical treatment, evaporative recovery, filtration, ion exchange and membrane technologies have been widely used to remove heavy metal ions from industrial waste waters. But these processes may be ineffective or expensive, especially when the heavy metal ions are in solutions containing amounts in the order of 1 - 100 mg dissolved heavy metals ions/L (Volesky, 1999).

The bioremediation, obtained by biological methods such as biosorption, bioaccumulation or bioprecipitation of heavy metal ions from wastes, may provide an attractive alternative to physico-chemical methods (Kapoor and Viraraghavan, 1995; Kratochvil and Volesky, 1998; Sag and Kutsal, 1999; Volesky, 1987, 2001; Diels et al., 1999; Petrişor et al., 2002).

In this paper, the results concerning two aspects are presented: the physico-chemical and microbiological characterization of waste waters collected from several sites of Valea Şesei decantation pond, as well as from its effluents both upstream and downstream and some biosorption, bioaccumulation and bioprecipitation laboratory tests intended for removal of metallic ions from this waste water.

MATERIALS AND METHODS

Samples of waste waters with acid pH and high content of metallic ions (Tab. 1) have been collected in aseptic conditions from different sites, both from Valea Şesei decantation pond and from its upstream and downstream effluents.

Microbiological analyses had in view the isolation of several physiological groups of microorganisms presented in water samples, using selective culture media (Tab. 1). The density of studied microorganisms has been established by MPN method (Rodina, 1972).

Laboratory biosorption and bioaccumulation tests for metallic ions removal from waste water were carried out in 200 mm high and 35 mm diameter glass percolator columns (Fig. 1).

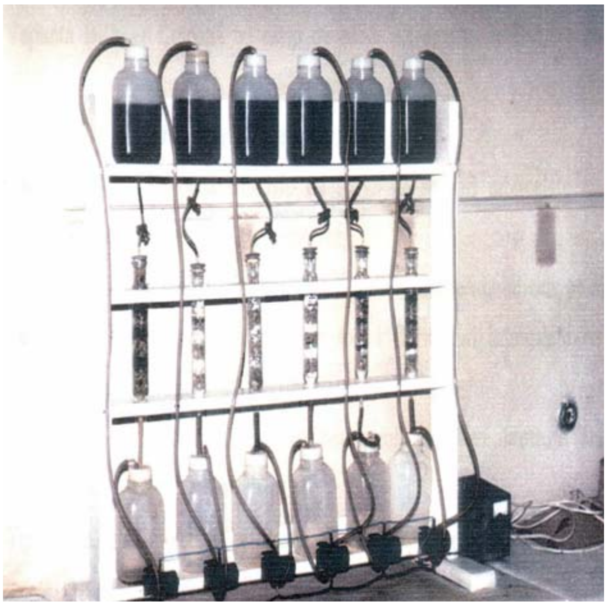

Figure 1: The glass percolator columns.

The percolator columns were filled with coarse sand in which were inserted two layers (10 mm size) of different porous natural (volcanic tuff, shell sand, bentonite, caoline, kisselgur) or artificial (molecular sieve, activated charcoal) materials. These adsorbent materials were previously washed with 0.1 NHCl solution, distilled water and dried at 105°C. On these adsorbent materials, different living microbial systems have been immobilized. The used microorganisms were namely: acidophilic heterotrophic bacteria consortium, mixed culture of yeasts of *Rhodotorula* and *Candida* genera, mixed culture of fungus, culture of cyanobacteria *Spirulina platensis*, mixed culture of *Pseudomonas* bacteria producing exopolysaccharides. The acidic waste water sample was recirculated through the percolator columns up to 8 times at 28°C, using adequate pumps.

Laboratory bioprecipitation tests of Cu ions from the acid effluent collected from Roşia Poieni with 300 ppm Cu concentration was performed using sulphate-reducing bacteria.

The experiments were performed at the natural acid pH of the effluent (2.0) and adjusted to slightly acid pH (5.0), both in the absence or in the presence of Postgate B medium components (Postgate, 1984) for bacterial growth optimization (medium used for cultivation of sulfate-reducing bacteria).

The concentration of metallic ions was determined in this study case using specific Merck kits.

RESULTS AND DISCUSSIONS

The heavy metals pollution sources from the Roşia Poieni quarry (Fig. 2) are the following: the local processing plant, the settling ponds and the sterile dumps.

In settling Valea Şesei pond the flotation sterile sludge consisting of water and sterile highly contaminated by heavy metal ions is stored.

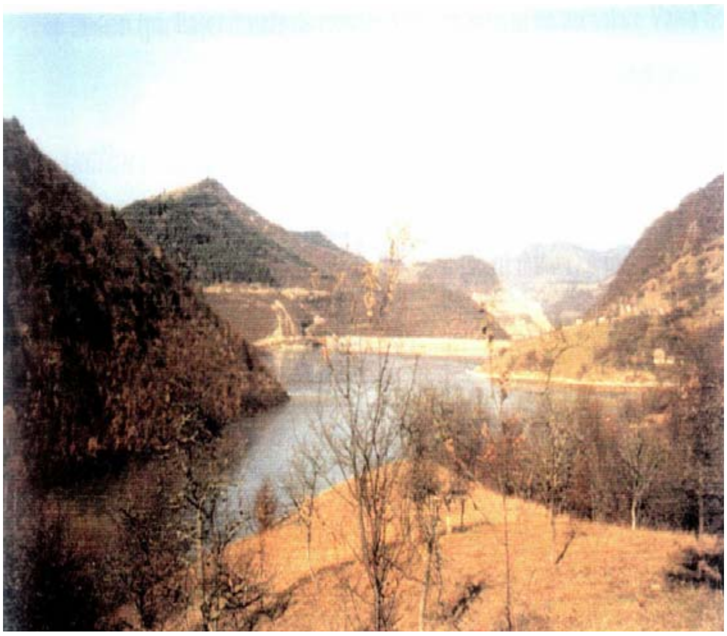

Figure 2: Valea Şesei decantation pond.

In the table 1 the metallic ions and sulphates concentrations and the pH values in different studied sites of the Şesei Valley decantation pond area (upstream of it, inside and downstream of it) were presented.

The low pH values of waters (1.86 - 3.50) indicates an intense solubilization process of metals from ore suspended particles, mainly for Fe, Cu, Zn, Al, Mn and Mg (53.0-6.705 mg/l).

Table 1: Metallic ions and sulphates concentrations and pH values in Şesei Valley decantation pond.

Metallic ions, sulphates	Concentrations in water (mg/l) collected from:			Limit values for surface waters (mg/l)
	Upstream	Inside	Downstream	
Total Fe	2,230 - 6,705	4,000 - 4,400	49.0	5.0
Cu	501.0 - 941.18	200.0	27.08	0.1
Zn	139.2 - 288.4	94.0 - 270.0	7.84	0.5
Al	938.06 - 2619.85	930.0	90.0	
Pb	0.91 - 1.0	0.10 - 0.12	0.05	0.2
Mn	53.0 - 85.0	53.0	35.0	2.0
Cd	0.93 - 1.87	0.243 - 0.500	0.027	0.1
As	1.66 - 8.63	< 1.0	-	0.01
Ni	2.7 - 6.7	0.340	0.021	0.5
Mg	156.1 - 465.5	500.0	-	
Ca	30.34 - 544.0	134.0	-	200.0
Co	2.09 - 5.56	-	-	
SO_4^{2-}	1,3240 - 1,7320	25,200 - 40,000	1,200.0	
water pH	1.86 - 2.43	1.97 - 2.0	2.89 - 3.50	

The acid waste water samples from several sites of Roşia Poieni mining area, before the evacuation in Arieş, are populated by rich microbial communities (Tab. 2). Important for the solubilization of metals contained in suspended ores particles are the sulfoxidizing bacteria (density of 10^6 ufc/ml), generating low level pH and high concentration of heavy metals. The physiological groups of microorganisms naturally occurring could be considered adapted to acidophilic conditions and resistant to heavy metals concentrations. Genetic studies on some bacterial isolates showed that metal resistance is encoded in plasmids (Jain, 1990). In yeasts, the synthesis of metallothioneine, an enzyme mediating the tolerance to metals, is encoded in chromosomal genes (Butt and Eckert, 1987). In the case of cyanobacteria, the intracellular fixation of metals is due to a specific protein metallothioneine also (El-Enany and Issa, 1999).

This microbial diversity represented an ideal source for isolation of microorganisms already adapted to acidophilic environments with high metallic ions concentrations, such as acidophilic heterotrophic bacteria, sulphate-reducing bacteria, yeasts, fungi. These microorganisms were selected and used in bioremediation processes such as biosorption, bioaccumulation and bioprecipitation of metals. For increasing the efficiency of these biological processes, immobilized microbial biomass can be used (Veglio et al., 1998).

Table 2: Several physiological groups of identified microorganisms' occurrence in different sampling sites of upstream, inside and downstream of Valea Şesei decantation pond.

Physiological groups of microorganisms	Density of microorganisms (no. ufc/ml)			Predominant types
	Upstream	Inside	Downstream	
Heterotrophic aerobic bacteria	2.5×10^2 - 4.5×10^5	2.5×10 - 4.5×10^2	1.5×10^2 - 3.5×10^3	*Bacillus* sp. *Pseudomonas* sp. *Arthrobacter* sp. *Micrococcus* sp. *Sarcina* sp.
Heterotrophic anaerobic bacteria	2.5×10^2 - 7.5×10^5	3.5×10^2 - 2.0×10^4	1.4×10^2 - 2.5×10^5	*Clostridium* sp.
Heterotrophic acidophilic bacteria	2.5×10 - 2.5×10^6	2.5×10^2 - 4.5×10^2	2.5×10^2 - 9.5×10^5	*Sulfobacillus* sp. *Sulfidobacillus* sp. *Acetobacter acidophilum* *Alcaligenes eutrophus*
Coliform bacteria	0-3.0×10	0	2.0×10 - 1.0×10^2	*Escherichia coli* *Klebsiella* sp.
- Nitrit bacteria - Nitrat bacteria	4.5×10 - 4.5×10^4 3.5×10^4 - 1.4×10^5	1.6×10^3 - 3.0×10^4 2.5×10^2 - 1.2×10^5	1.5×10^3 - 1.6×10^4 3.5×10^4 - 1.4×10^5	*Nitrosomonas* sp. *Nitrobacter* sp.
Iron oxidizing bacteria	2.5×10^2 - 9.5×10^2	2.5×10 - 9.5×10^2	2.0×10^2 - 2.5×10^2	*Sphaerotillus* sp. *Gallionella* sp.
Sulfoxidizing bacteria	2.5×10^3 - 4.5×10^6	2.5×10^2 - 7.5×10^6	1.1×10^2 - 1.1×10^6	*Thiobacillus thiooxidans* *Thiobacillus ferooxidans* *Thiobacillus thioparus* *Thiobacillus neapolitanus* *Thiobacillus denitrificans*
Sulfate-reducing bacteria	0 - 2.5×10^2	2.0×10 - 1.1×10^2	9.5×10 - 1.1×10^2	*Desulfovibrio* sp. *Desulfobacter* sp.
Yeasts	0 - 6.0×10	0	4.0×10 - 7.6×10^3	*Rhodotorula* sp. *Candida* sp.
Filamentous microscopic fungi	3.0×10^2 - 6.4×10^6	0-5.0×10	5.2×10^2 - 1.1×10^3	*Penicillium* sp. *Aspergillus* sp. *Alternaria* sp. *Paecilomyces* sp. *Fusarium* sp.

Previous to the biosorption tests, a screening of several adsorbent materials in the percolator columns was carried out (Fig. 2).

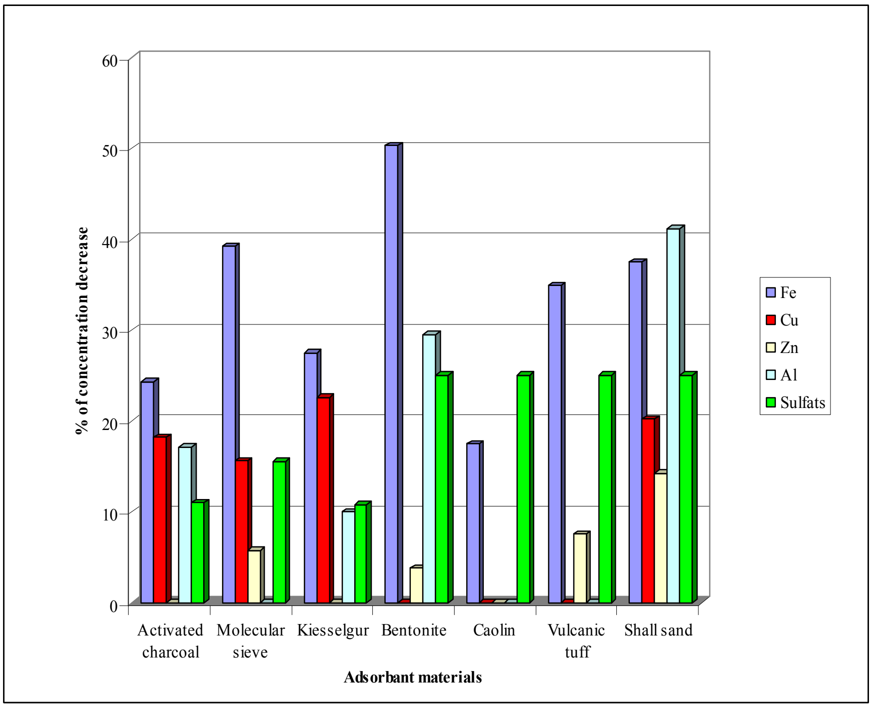

Figure 2: The removal of metallic ions and SO_4^{2-} from waste water collected from Valea Şesei decantation pond, using different adsorbent materials.

Regarding the removal efficiency of the used adsorbent materials, it was found the fact that the best ones in the decrease of metallic ions and SO_4^{2-} concentrations are the following: the activated charcoal, the molecular sieve and the shell sand. These founded materials were used like supports for immobilization of microbial systems (Tab. 3). By immobilization of the microorganisms, an increase of the removal efficiency of the adsorbent materials was noticed, thus, as presented in the table 3, the shell sand proved to be the most suitable support. In these conditions, the metallic ions removal efficiency was between 42.9 and 70.0% for total Fe, 10.0 and 30.5% for Cu, 36.8 and 65.2% for Zn, 47.1 and 100.0% for Al. Among the microbial systems immobilized on shell sand, a good metallic ions and SO_4^{2-} removal efficiency proved: the consortium of acidophilic heterotrophic bacteria and the mixed culture of yeasts, both isolated from waste waters of Şesei Valley decantation pond area. Good results were also obtained by using cyanobacteria and the cultures of *Pseudomonas* exopolysaccharides producing strains. Some exopolysaccharides contain a number of useful functional groups, which play important roles in binding and stabilizing metallic ions (Jang and Geesy, 1993; Etemadi et al, 2003; Kim et al., 2004, 2005).

Microorganisms uptake metal either actively (bioaccumulation) and/or passively (biosorption). Feasibility studies (Hussein et al., 2003) demonstrated that the biosorption process is more applicable than the bioaccumulation process, because active uptake by living systems often requires the addition of nutrients, increase biological oxygen demand (BOD) or chemical oxygen demand (COD) in the effluent. In addition, maintenance of healthy microbial population is difficult due to metal toxicity or other unsuitable environmental factors and potential for desorptive metal recovery is restricted since metal may be intracellularly bound.

Sulphate-reducing bacteria are among the most active microorganisms involved in the metallic ions removal from industrial effluents (Panchnadikar and Kar, 1993; Send and Johnson, 1999). The precipitating metallic ions efficiency is significantly influenced by these pollutants concentration and environment pH. The inoculum was represented by a mixed culture of sulphate-reducing bacteria belonging to *Desulfovibrio* and *Desulfobacter* genera isolated from natural environments. When using acid mining effluent from Roşia Poieni containing 300 ppm Cu and strong acid value of pH (2.0), the bioprecipitation of Cu ions varied between 62.0 to 75.0% and between 88.0 to 93.0% under slightly acid pH (5.0), as presented in the figure below. In both cases, supplementation of the mining effluent with some ingredients appropriate for sulphate- reducing bacteria cultivation influenced to a lesser extent the efficacy of Cu precipitation, the main factor being the pH value of the effluent submitted to microbiologic treatment.

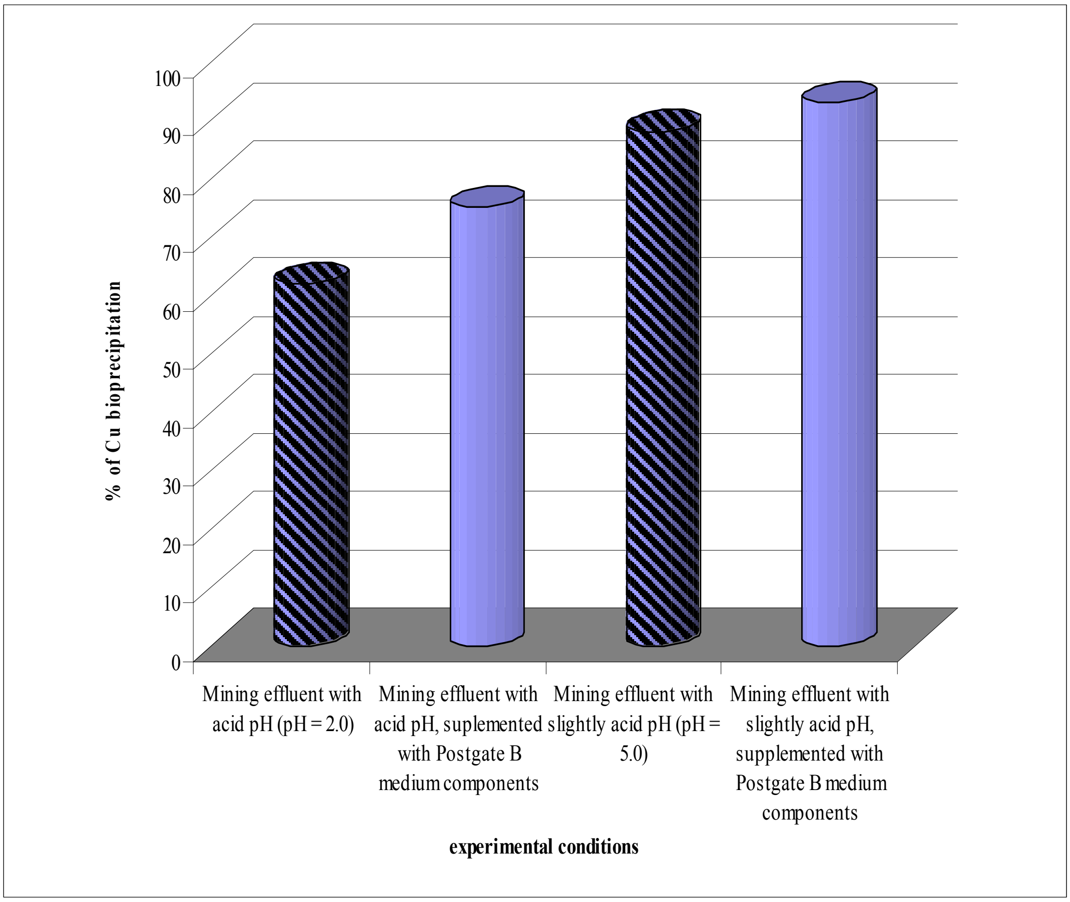

Figure 3: Bioprecipitation of Cu ions contained in Roşia Poieni effluent.

Table 3: The removal of metallic ions and SO_4^{2-} from the waste water using immobilized microbial systems; * - microorganisms isolated from the waste water, collected from the Roşia Poieni area.

Used adsorbent materials	Used immobilized microbial systems	% of concentration decrease				
		Total Fe	Cu	Zn	Al	SO_4^{2-}
Activated charcoal	-	24.3	18.2	0	17.1	11.0
	*Consortium of acidophilic heterotrophic bacteria	35.6	30.8	26.8	25.7	11.5
	Culture of *Spirulina platensis* cyanobacteria	36.2	10.5	62.2	100.0	10.8
	*Mixed culture of *Rhodotorula* and *Candida* genera yeasts	35.3	16.5	61.9	100.0	9.4
Molecular sieve	-	39.2	15.6	5.7	0	15.5
	*Consortium of acidophilic heterotrophic bacteria	50.5	30.6	8.7	5.8	16.3
	Culture of *Spirulina platensis* cyanobacteria	51.2	21.8	58.0	88.7	16.0
	*Mixed culture of *Rhodotorula* and *Candida* genera yeasts	45.1	27.5	59.6	90.0	15.7
Shell sand	-	37.5	10.0	11.2	41.2	25.0
	*Consortium of acidophilic heterotrophic bacteria	70.0	25.0	36.8	47.1	12.5
	Culture of *Spirulina platensis* cyanobacteria	60.3	29.0	65.2	100.0	25.1
	*Mixed culture of yeasts of *Rhodotorula* and *Candida* genera	43.7	30.5	63.7	100.0	21.0
	Mixed culture of *Pseudomonas* producing exopolisaccharides bacteria	68.1	30.0	0	50.0	12.5
	*Mixed culture of fungi	42.9	10.0	0	47.1	12.5

CONCLUSIONS

The acid water samples collected from few sites from Roşia Poieni mining area, before the evacuation in Arieş River, are populated by rich microbial communities. This microbial diversity represents an ideal source for isolation of microorganisms already adapted to acidophilic environment with high metallic ions concentrations, which can be involved in bioremediation processes such as biosorption, bioaccumulation, bioprecipitation or biosolubilisation of metals.

Among the adsorbent materials used in percolator columns, the best efficiency in metallic ions and SO_4^{2-} removal proved shell sand, molecular sieve and activated charcoal, the first being suitable from the cost point of view also.

The immobilization of microbial systems (bacteria and yeasts) on selected adsorbent materials leads to an increase of their efficiency, obtaining more than 50% removal of metallic ions contained in the studied waste water.

The use of adsorbents of biological origin is one of the promising alternatives to conventional heavy metal remove technologies. The only method for identifying efficient biosorbent is the screening of microorganisms.

Bioprecipitation of copper ions from mining waste water by sulphate-reducing bacteria is influenced by their concentration and the pH value, higher efficiency being obtained under slightly acid pH conditions.

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OVERVIEW OF THE SEMI-NATURAL GRASSLAND COMMUNITIES FROM THE MIDDLE AND LOWER ARIEŞ RIVER VALLEY, (TRANSYLVANIA, ROMANIA) SINTAXONOMICAL CHECKLIST

*József Pál FRINK **

* Apuseni Nature Park Administration, Sudrigiu Locallity, Rieni Commune, Bihor County, Romania, RO-417419, jpfrink@gmail.com

KEYWORDS: Romania, Transylvania, Arieş River valley, semi-natural grassland communities, floristic structure, ecology, distribution, management.

ABSTRACT

The paper is dealing with the survey of the semi-natural grassland vegetation of the middle and lower Arieş River valley, between the localities Lupşa and Mihai Viteazu. Field surveys were carried out in the period of 2002 - 2005. Syntaxonomical checklist of the identified grassland communities and a short characterization of their floristic structure, ecology, distribution and management are presented. A total number of 149 phytosociological relevés were recorded; 17 grassland communities (associations), 4 subassociations and 10 facieses were identified and included in 3 vegetation classes, highlighting a large diversity of semi-natural grassland types in the study area.

RÉSUMÉ: La présentation générale des communautés des prairies semi-naturelles de la vallée moyenne et inférieure de la rivière Arieş (Transylvanie, Romanie), conspectus syntaxonomique des associations.

L'article présente la végétation des prairies semi-naturelles de la vallée moyenne et inférieure de la rivière Arieş, entre les localités Lupşa et Mihai Viteazu. Les études de terrain ont été réalisées pendant 2002 - 2005. On présente la liste syntaxonomique des communautés praticoles identifiées, ainsi qu'une courte caractérisation de la structure floristique, l'écologie, la distribution et l'utilisation de chaque communauté. Au total, on a réalisé 149 relevés phytosociologiques; 17 communautés (associations) praticoles, 4 sous-associations et 10 faciès ont été identifiées et encadrées en 3 clases de végétation. Ceci indique une diversité élevée des prairies semi-naturelles de la région étudiée.

REZUMAT: Prezentarea generală a comunităţilor de pajişti seminaturale de pe cursul mijlociu şi inferior al Arieşului (Transilvania, România). Conspectul syntaxonomic al asociaţiilor.

Prezentul articol se referă la vegetaţia pajiştilor seminaturale de pe cursul mijlociu şi inferior al văii râului Arieş, dintre localităţile Lupşa şi Mihai Viteazul. Cercetările de teren au avut loc în perioada 2002 - 2005. Este prezentat conspectul syntaxonomic al comunităţilor praticole identificate, respectiv o scurtă caracterizare a structurii floristice, ecologiei, răspândirii şi utilizării fitocenozelor fiecărei comunităţi. S-au efectuat un număr total de 149 ridicări (relevee) fitosociologice. S-au identificat 17 comunităţi (asociaţii) vegetale praticole, 4 subasociaţii şi 10 faciesuri, incluse în 3 clase de vegetaţie, evidenţiind, astfel, o diversitate ridicată a tipurilor de pajişti seminaturale din arealul studiat.

INTRODUCTION

Semi-natural grasslands belong to the most valuable ecosystems and represent very important habitats with an inestimable value for the diversity of plants and for other groups of organisms. They have been recognized as key habitats for maintaining biodiversity in European landscapes (Michalik et Zarzycki, 1995; Poschlod et Bonn, 1998; Olsson et al., 2000; Luoto et al., 2003). In accordance with the differences in climate conditions, semi-natural grasslands show a great variety across Central and Eastern Europe.

The various types of Romanian grasslands are still rich, having a great floristic diversity, but very fragile in the context of the socio-economic changes of the last decades. Thus, the changes in the traditional land use practices affected about 50% of the Romanian grasslands (Sârbu et al., 2004). Therefore, the evaluation of the floristic structure and diversity of the semi-natural grasslands at community level is still a very important objective.

The semi-natural grasslands occupy large surfaces in the Arieş River basin. The Arieş River is the most characteristic and most important watercourse of the Apuseni Mountains (Western Romanian Carpathians), due to the surface of its hydrographic basin (which covers about 3,000 km^2), to its length (approximately 167 km) and to its flow from west to east, which separates the main groups of the Apuseni Mountains (Fig. 1): to north the high crests and plateaus of Bihor Mountains and Gilău-Muntele Mare Mountains and to south the lower crests of Metaliferi Mountains and Trăscăului Mountains (Popescu-Argeşel, 1984; Ghinea, 1996).

The Arieş River valley provides a good access into the Apuseni Mountains, an area often visited by scientists. Thus, the calcareous massifs and the gorges situated on its tributaries have been systematically studied from floristic and phytosociologic point of view (Ercsei, 1844; Simkovics, 1882; Nyárády, 1939; Gergely, 1957, 1962, 1964, 1967, 1968, 1969; Csűrős, 1958; Soran, 1962; Csűrös et Spârchez, 1963; Pop et al., 1964; Csűrös and Pop, 1965; Csűrös-Káptalan and Odangiu, 1969; Pop, 1971a, 1971b; Hodişan, 1971, 1972; Csűrös and Csűrös-Káptalan, 1975, 1996; Csűrös et al., 1988; Csergő, 2002; Frink, 2002; Frink et al., 2005). However, the grasslands that occupy large areas on both sides of the Arieş River valley, extending on its tributaries, were never systematically studied. This lack of information determined the starting of our research regarding the grassland vegetation from the middle and lower Arieş River valley, between the localities Lupşa and Mihai Viteazu.

The aims of this paper are: i). to present a syntaxonomical overview (checklist) of the identified semi-natural grassland communities; ii). to give a short characterization of these communities regarding their floristic structure, ecology, distribution and management.

MATERIAL AND METHODS

Study area

The study area between Lupşa and Moldoveneşti overlies to the middle Arieş River valley, on a total distance of approximately 60 - 65 km, and between Moldoveneşti and Mihai Viteazu overlies to the lower Arieş River valley, on a total distance of approximately 10 km (Fig. 1).

The major elements of the relief are (Popescu-Argeşel, 1984; Fischeux, 1996): 1. slopes, crests and ridges of the mountain units located along the middle Arieş River; from geographic point of view, these belong to the following subdivisions of the Apuseni Mountains (Fig. 1), Gilău-Muntele Mare, Metaliferi and Trăscăului mountains; 2. canyons; 3. intra-mountainous depressions, developed at the contact of the neighboring mountain units; 4. terraces, alluvial flats in the depressions; 5. hills and terraces along the lower Arieş River course.

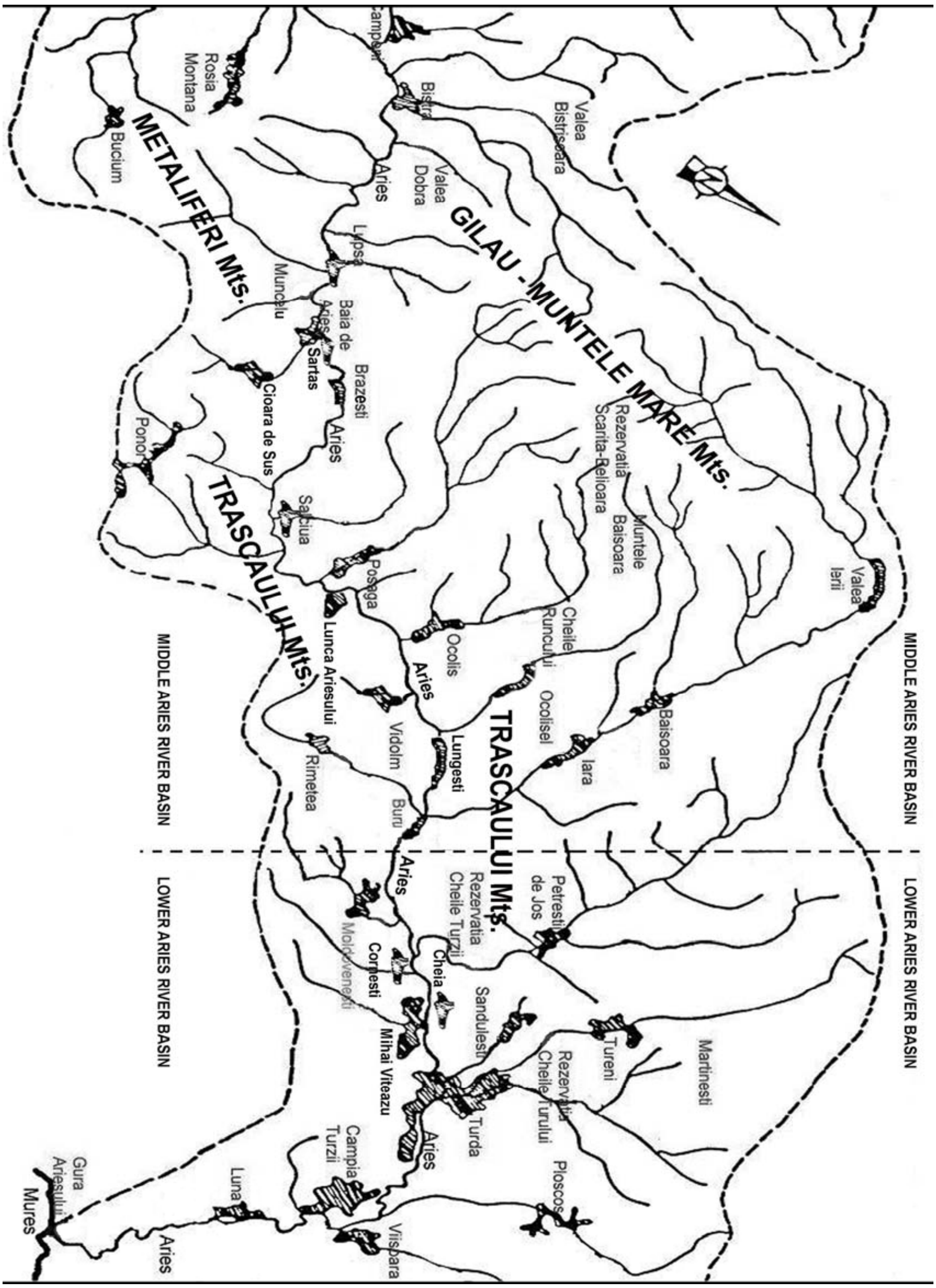

Figure 1: Middle and Lower Arieş River basin with mountain units and localities.

The geological structure of the Arieş River valley has a high petrographic diversity: sedimentary and volcanic-sedimentary rocks, magmatic rocks (with various chemical reactions from acid to basic) and metamorphic rocks (Ianovici et al., 1976).

In the study area, the following soil types can be found (Florea et al., 1970-1971): 1. acid brown soils; 2. brown (slightly and medium debasified) soils; 3. brown podzolic soils; 4. andosols; 5. rendzinas; 6. slightly leached chernozems; 7. strongly and very strongly leached chernozems; 8. brown lessivé soils; 9. alluvial soils; 10. rhegosols; 11. alluvial humic gley.

In the general frame of the climate, the following topoclimates can be distinguished (Popescu-Argeşel, 1984; Kun et al., 2004): 1. the hard and humid topoclimate of the high mountains (Gilău-Muntele Mare Mountains); 2. the soft and semihumid topoclimate of the middle mountain ranges (Metaliferi and Trăscăului mountains), intra-mountain depressions along the middle Arieş River valley, and canyons; 3. semihumid-semiarid topoclimate of the lower Arieş River valley, with more evident thermic contrasts and reduced precipitations.

Working methods

In order to identify the grassland communities, field surveys were carried out in the period of 2002 - 2005. The areas covered by grasslands were identified using satellite images and topographic maps, both on scale 1:25.000. In each grassland patch several phytosociological relevés were performed according to the Braun-Blanquet methodology (Braun-Blanquet, 1964). Potential plot sites were selected to include all possible combinations of surficial geology, macro-topography, elevation (low- and high-elevation within each macro-topographic unit) and meso-topography (slopes with different exposure, crests, ridgelines, alluvial flats). For a correct identification of communities, sites with comparatively homogeneous vegetation were subjectively chosen for sampling (Cristea et al., 2004).

Assignment to different plant communities is based on the floristic structure of the relevés, taking into account the presence of recognition species. The checklist presents the grassland communities arranged syntaxonomically, according to the European syntaxonomical approaches (Rodwell et al., 2002). In some particular cases, required by the specific character of the vegetation, the Romanian syntaxonomical classification systems were followed (Coldea, 1991; Sanda et al., 1997, 1999; Kovács, 2001, 2004; Pop et al., 2002, Sanda, 2002). For the correct name of the communities, the International Code of Phytosociological Nomeclature (ICPN - Weber et al., 2000) was also consulted. However, the ICPN accepts only the subassociation as lower syntaxonomic unit, facieses were also identified, in order to give a more complex overview of the vegetation and to highlight the existing fine scale ecological differences between the habitats. The nomenclature of plant taxa follows Flora Europaea (Tutin et al., 1964 - 1980).

For the characterization of each grassland community, the following features are indicated: 1. number of relevés performed; 2. floristic structure (recognition, frequent or constant species); 3. species number range/relevé; 4. red list taxa (according to Oltean et al., 1994; Negrean, 2001, Sârbu et al., 2007); 5. ecology (habitat conditions); 6. distribution of the certain community in the study area (indicated with rare, sporadic, frequent or common, and followed by the locality); 7. altitudinal range; 8. management (including practical recommendations). The practical advices for the management of the studied grasslands are given according to the literature (Puşcaru-Soroceanu et al., 1963; Ghişa et al., 1970; Kelemen, 1997; Pop et al., 2002; Mojzes, 2003; Enyedi, 2005; Rotar et Cartier, 2005), but considering our field observations, as well.

RESULTS

A total number of 149 phytosociological relevés were recorded; 17 grassland communities (associations), 4 subassociations and 10 facieses were identified and included in 3 vegetation classes, highlighting a large diversity of semi-natural grassland types. A total number of 372 vascular plant species, 28 subspecies and 1 hybrid had been recorded in the studied grasslands. Among the identified taxa, 23 are red list included, phytogeographically important, endemic or subendemic.

Along the middle Arieş River valley, displayed in a mountainous area, the grassland patches are dominated by mesic phytocoenosis of *Festuco rubrae - Agrostietum capillaris* community. This is the most common and the most widespread community in the study area, covering large surfaces with various ecological features, between altitudes of 450 - 1,300 m a.s.l.

The alluvial flats and the base of slopes with nutrient rich soils are covered by phytocoenosis of *Arrhenatheretum elatioris* community. The manured meadows consisting mainly of this community, and rarely combined with *Trisetetum flavescentis,* are very common along the middle, as well as the lower Arieş River valley. The slopes with southern and southeastern exposure, along the middle Arieş River valley, are dominated by mesic and xeric-mesic phytocoenosis of *Agrostio-Festucetum rupicolae* and *Agrostio-Festucetum valesiacae* communities. Dry grassland communities (*Stipetum lessingianae, Stipetum pulcherrimae, Stipetum capillatae*) were identified along the lower Arieş River valley, in the area of Corneşti - Cheia - Mihai Viteazu localities.

The main environmental factors supposed to contribute to the dynamic processes in the studied grassland communities are: 1. increase and decrease of soil moisture (ground water level); 2. controlled use of organic fertilizers (manure); 3. decrease of nutrients in the soil; 4. acidification of the soil; 5. overgrazing; 6. soil erosion.

Syntaxonomical checklist

I. MOLINIO - ARRHENATHERETEA R. Tx. 1937

MOLINIETALIA *Koch 1926*

A. Mesic-hygric and mesic flood plain meadows

Agrostion albae Soó 1943

1. *Agrostio-Deschampsietum caespitosae* Ujvárosi 1947 (no. of relevés 4)

[- *nardosum strictae* (facies with *Nardus stricta*) - 2 relevés]

Floristic structure: *Agrostis canina, Agrostis stolonifera, Anthoxanthum odoratum, Deschampsia cespitosa, Holcus lanatus, Juncus conglomeratus, Lysimachia nummularia* and *Nardus stricta.*

Species number range: 18 - 27 sp./relevé. Ecology: moist places, alluvial flats, microdepressions; mesic and mesic-hygric phytocoenosis. Distribution: rare; between Muşca and Lupşa (plateau microdepression on Munceluşului Hill); Baia de Arieş (right terrace of the Arieş River). Altitudinal range: 500 - 650 m. Management: hay meadows with reduced economic value due to the reduced nutritional quality of the dominant *Deschampsia cespitosa*; we recommend to keep this management type, with one mown/year, in august.

2. *Agrostetum albae* Ujvárosi 1941 (no. of relevés 4)

Floristic structure: *Agrostis stolonifera, Cirsium canum, Dactylis glomerata, Festuca pratensis, Leucanthemum vulgare, Lolium perenne, Poa pratensis* subsp. *pratensis, Ranunculus repens, Trifolium pratense, T. repens.*

Species number range: 17 - 33 sp./relevé. Ecology: moist places, alluvial flats; mesic and mesic-hygric phytocoenosis. Distribution: sporadic; Brăzeşti (right side of the Arieş River); Sălciua de Jos (left side of the Arieş River); between Moldoveneşti and Corneşti (left side of the Arieş River). Altitudinal range: 340 - 460 m. Management: hay meadows with medium economic value; we recommend to keep this type of management.

3. *Festucetum pratensis* Soó 1938 (no. of relevés 9)

Floristic structure: *Achillea millefolium, Anthoxanthum odoratum, Centaurea phrygia* subsp. *phrygia, Dactylis glomerata, Erigeron annuus, Festuca pratensis*, *Leucanthemum vulgare, Lotus corniculatus, Plantago lanceolata, P. media, Poa pratensis* subsp. *pratensis, Polygala major, Prunella vulgaris, Taraxacum officinale, Trifolium campestre, T. pratense.*

Species number range: 26 - 43 sp./relevé. Red list taxa: *Orchis coriophora*. Ecology: alluvial flats, terraces, base of the hills, slightly inclined slopes; mesic phytocoenosis. Distribution: common; Sălciua de Jos (right side of the Arieş River); Lunca Arieşului (right terrace of the Arieş River; at the base of Măgulicea de Sus Hill; Măgulicea de Jos Hill); Ocoliş (right side of Ocoliş Rivulet); Vidolm (left side of the Arieş River); Lungeşti (left side of the Arieş River); Buru (left side of the Arieş River). Altitudinal range: 370 - 450 m. Management: hay meadows; we recommend two mown/year, organic fertilization (with manure) in late autumn or in early spring.

Holco-Juncion Pass. 1964

3. *Holcetum lanati* Issler 1936 *em.* Pass. 1964 (no. of relevés 3)

[- *caricosum vulpinae* (facies with *Carex vulpina*) - 1 relevé]

Floristic structure: *Carex vulpina, Carum carvi, Cerastium fontanum*, *Cirsium rivulare, Equisetum palustre, Holcus lanatus, Leucanthemum vulgare, Lysimachia nummularia, Symphytum officinale, Ranunculus repens* and *Trifolium pratense.*

Species number range: 27 - 30 sp./relevé. Red list taxa: *Orchis laxiflora* subsp. *elegans*. Ecology: moist places, alluvial flats; mesic and mesic-hygric phytocoenosis. Distribution: rare; Sălciua de Jos (left side of the Arieş River); Buru (right side of the Trăscău Rivulet). Altitudinal range: 350 - 420 m. Management: hay meadows with reduced economic value.

ARRHENATHERETALIA Pawlowski 1928

B. Hill - mountain mesic manured meadows

Arrhenatherion elatioris Koch 1926

Arrhenatheretum elatioris Br.-Bl. *ex* Scherrer 1925 (no. of relevés 23)

[- *trisetetosum flavescentis* Horvatić 1930 - 5 relevés]

Floristic structure: *Achillea millefolium, Arrhenatherum elatius, Dactylis glomerata, Leucanthemum vulgare, Plantago lanceolata, Rhinanthus angustifolius, Trifolium pratense, T. repens* and *Trisetum flavescens.*

Species number range: 18 - 43 sp./relevé. Red list taxa: *Dactylorhiza fuchsii*, *Gymnadenia conopsea, Orchis coriophora*. Ecology: well drained alluvial flats, terraces, base of the hills, slightly inclined slopes with fertile soils; mesic and xeric-mesic phytocoenosis. Distribution: common; Lupşa; Muncelu; Cioara de Sus; between Brăzeşti and Sălciua de Sus; Sălciua de Jos; Lunca Arieşului (Măgulicea de Jos Hill); Ocoliş; Vidolm; Buru; Moldoveneşti; between Moldoveneşti and Corneşti; Corneşti; Cheia (Sardău Hill). Altitudinal range: 350 - 580 m. Management: hay meadows with high economic value; we recommend the total interdiction of grazing, regular traditional mown, organic fertilization with manure in the late autumn or the in early spring.

6. *Trisetetum flavescentis* Rübel 1911 (no. of relevés 2)

Floristic structure: *Achillea millefolium, Anthoxanthum odoratum, Arrhenatherum elatius*, *Dactylis glomerata, Rhinanthus rumelicus, Trifolium pratense, Trisetum flavescens.*

Species number range: 32 - 34 sp./relevé. Red list taxa: *Orchis coriophora*. Ecology: slightly inclined slopes with fertile soils; mesic phytocoenosis. Distribution: rare; Lungeşti; betweem Lungeşti and Buru (left side of the Arieş River). Altitudinal range: 380 - 420 m. Management: hay meadows with good economic value; we recommend interdiction of grazing, one mown/year, organic fertilization with manure in late autumn or early spring.

C. Hill - mountain mesic meadows

Cynosurion cristati R. Tx. 1947

7. *Festuco rubrae-Agrostietum capillaris* Horvat 1951 (no. of relevés 41)

[- *genistetosum sagittalis* Coldea 1991 - 1 relevé; *danthoniosum decumbentis* (facies with *Danthonia decumbens*) - 1 relevé; *nardosum strictae* (facies with *Nardus stricta*) - 2 relevés]

Floristic structure: *Achillea millefolium, Anthoxanthum odoratum, Agrostis capillaris, Briza media, Campanula patula* subsp. *patula, Chamaespartium sagittale, Cynosurus cristatus, Dactylis glomerata, Danthonia decumbens, Festuca rubra, Leontodon autumnalis*, *Leucanthemum vulgare, Lotus corniculatus, Nardus stricta, Pimpinella saxifraga, Plantago lanceolata, Prunella vulgaris, Plantago media* and *Trifolium pratense.*

Species number range: 24 - 48 sp./relevé. Red list taxa: *Arnica montana, Dactylorhiza maculata*, *Orchis morio, Pseudorchis albida, Trollius europaeus* subsp. *europaeus*. Ecology: slopes with different inclination and exposure, ridges, crests, plateaus; mesic and xeric-mesic phytocoenosis. Distribution: most common; Lupşa (Arsura Hill, Bunălaşa Peak); Muncelu (Bârlii Hill; "Bârla pasture"; the place "Dumbrava"); Baia de Arieş (Hermeneasa Valley; Piatra Băii; under Pleşul Peak); Cioara de Sus ("La Bicăşei"); Sartăş (Smida Peak; Upper Sartăş Valley); Brăzeşti; Sălciua de Sus (Dealul Caselor Hill; Largă Valley); Sălciua de Jos (Sălciuții Valley; under Citera Peak; „Țicul Blagului"); Bedeleu Mountains (Prislop Peak; „La Şipote"); Poşaga (Măgulicea de Sus Hill; Dealul Lung Hill); Lunca Arieşului (Bedeleu Mountains); Ocoliş; Vidolm (Vidolm Valley); between Vidolm and Lungeşti. Altitudinal range: 450 - 1,300 m. Management: mainly hay meadows with high economic value, rarely pastures; keeping the actual management recommend, one or two mown/year, fertilization organic with manure in the late autumn for pastures and in the early spring for hay meadows.

II. NARDO - CALLUNETEA Preising. 1949

NARDETALIA Oberd. *ex* Preising. 1949

D. Oligotrophic mountain pastures with heather

Violion caninae Schwickerath 1944

8. *Nardo-Callunetum vulgaris* (Šmarda 1953) Csűrös 1964 (no. of relevés 4)

Floristic structure: *Agrostis capillaris, Calluna vulgaris, Danthonia decumbens, Festuca rubra, Lotus corniculatus, Nardus stricta* and *Viola canina.*

Species number range: 12 - 29 sp./relevé. Ecology: oligotrophic swards and heather on medium inclined slopes with acid, nutrient-poor soils; xeric-mesic and mesic phytocoenosis. Distribution: rare; Lupşa (Bună Laşa Hill); Muncelu. Altitudinal range: 650 - 1000 m. Management: pastures with reduced economic value, irregularly grazed by cattle; we recommend the use of organic fertilizers (manure) and to confine the development of *Calluna vulgaris*, in order to improve the economic value of the grasslands, or the interdiction of grazing, to facilitate the natural succession of vegetation towards wooden communities.

III. FESTUCO-BROMETEA Br.-Bl. et R. Tx. ex Klika et Hadač 1944

FESTUCETALIA VALESIACAE Br.-Bl. et R. Tx. ex Br.-Bl. 1949

E. Xeric feathergrass steppe grasslands

Stipion lessingianae Soó 1947

9. *Stipetum lessingianae* Soó (1927 n. n.) 1947 (no. of relevés 5)

(- *botriochloosum ischaemi* (facies with *Dichanthium ischaemum*) - 2 relevés]

Floristic structure: *Adonis vernalis*, *Carex humilis*, *Dichanthium ischaemum, Festuca rupicola*, *Helianthemum nummularium*, *Leontodon crispus* subsp. *crispus*, *Muscari tenuiflorum*, *Potentilla cinerea, Stipa lessingiana* and *Thymus pannonicus.*

Species number range: 13 - 22 sp./relevé. Red list taxa: *Adonis vernalis, Peucedanum tauricum.* Ecology: dry-sunny places, hillsides with high inclination; xeric-mesic, xeric phytocoenosis. Distribution: rare; Cheia (Sardău Hill). Altitudinal range: 400 - 450 m. Management: pastures with reduced economic value, grazed by sheep; we recommend a controlled (limited) grazing by sheep or the grazing by cattle, which is more effective to maintain the floristic diversity.

10. *Stipetum pulcherrimae* Soó 1942 (no. of relevés 5)

[- *botriochloosum ischaemi* (facies with *Dichanthium ischaemum*) - 4 relevés]

Floristic structure: *Carex humilis, Dichanthium ischaemum, Eryngium campestre, Festuca rupicola*, *Helianthemum nummularium*, *Potentilla cinerea, Stipa pulcherrima*, *Thymus pannonicus.*

Species number range: 19 - 32 sp./relevé. Red list taxa: *Adonis vernalis*, *Onosma heterophylla, Stipa dasyphylla, Seseli elatum* subsp. *osseum*. Ecology: dry-sunny, rocky places, medium inclined hillsides; xeric-mesic and xeric phytocoenosis. Distribution: rare; between Corneşti and Cheia (Sardău Hill). Altitudinal range: 350 - 490 m. Management: pastures with reduced economic value, irregularly grazed by sheep, or unused because of soil erosion and earlier practiced overgrazing; we recommend a controlled (limited) grazing by cattle, which is more effective to maintain the floristic diversity.

Festucion rupicolae Soó 1940 *corr*. 1964

11. *Stipetum capillatae* (Hueck 1931) Krausch 1961 (no. of relevés 6)

[- *botriochloosum ischaemi* (facies with *Dichanthium ischaemum*) - 2 relevés]

Floristic structure: *Allium rotundum, Cleistogenes serotina, Dichanthium ischaemum, Eryngium campestre, Euphorbia cyparissias, Falcaria vulgaris, Festuca rupicola*, *Salvia nemorosa, Scorzonera hispanica* and *Stipa capillata.*

Species number range: 16 - 39 sp./relevé. Red list taxa: *Adonis vernalis, Allium albidum* subsp. *albidum, Ephedra distachya* subsp. *distachya, Dictamnus albus, Peucedanum tauricum, Seseli elatum* subsp. *osseum*. Ecology: dry-sunny places, medium inclined slopes; xeric-mesic and xeric phytocoenosis. Distribution: rare; Cheia (Sardău Hill); Mihai Viteazu (left side of the Arieş River). Altitudinal range: 350 - 400 m. Management: mainly unused or pastures with reduced economic value, irregularly grazed by sheep in the early spring.

12. *Festuco rupicolae - Caricetum humilis* Soó 1930, 1947 (no. of relevés 8)

[- *botriochloetosum* Raţiu et al. 1969 - 2 relevés; *festucosum valesiacae* (facies with *Festuca valesiaca*) - 4 relevés; *stiposum pulcherrimae* (facies with *Stipa pulcherrima*) - 1 relevé]

Floristic structure: *Achillea millefolium, Brachypodium pinnatum, Carex humilis, Dichanthium ischaemum, Eryngium campestre, Euphorbia cyparissias, Festuca rupicola, Festuca valesiaca, Fragaria viridis, Galium verum, Helianthemum nummularium, Plantago lanceolata, P. media, Stipa pulcherrima, Teucrium chamaedrys* and *Veronica chamaedrys.*

Species number range: 21 - 44 sp./relevé. Red list taxa: *Adonis vernalis, Echium russicum, Silene nutans* subsp. *dubia*. Ecology: dry places, sunny slopes with various inclination; xeric-mesic and xeric phytocoenosis. Distribution: sporadic; Poşaga (Măgulicea de Sus Hill); Lunca Arieşului (Bedeleu Mountains); Vidolm (Vârfuiata Hill); Buru (left side of Arieş River); Cheia (Sardău Hill). Altitudinal range: 400 - 640 m. Management: pastures grazed by sheep, hay meadows or unused; we recommend to avoid the overgrazing.

F. Hill and plateau xeric-mesic grasslands

13. *Agrostio - Festucetum rupicolae* Csűrős-Káptalan (1962) 1964 (no. of relevés 7)

Floristic structure: *Achillea millefolium, Agrostis capillaris, Asperula cynanchica, Briza media, Festuca rubra, F. rupicola, F. valesiaca, Filipendula vulgaris, Euphorbia cyparissias, Leucanthemum vulgare, Lotus corniculatus, Medicago lupulina, Medicago sativa* subsp. *falcata, Pimpinella saxifraga, Plantago lanceolata* and *Trifolium pratense.*

Species number range: 25 - 43 sp./relevé. Red list taxa: *Orchis coriophora*. Ecology: dry-sunny places, slightly and medium inclined slopes; xeric-mesic and mesic phytocoenosis.

Distribution: frequent; Brăzeşti (left side of the Arieş River); Poşaga (Dealul Lung Hill); Lunca Arieşului (Bedeleu Mountains); Ocoliş (right side of the Ocoliş Valley; Vârfuiata Hill); Vidolm (right side of the Vidolm Valley; right side of the Arieş River). Altitudinal range: 400 - 700 m. Management: mainly hay meadows with medium economic value, pastures with reduced value; we recommend avoiding the overgrazing.

14. *Agrostio-Festucetum valesiacae* Borisavljević Jovanović-Dunjić et Mišic 1955 (no. of relevés 7)

Floristic structure: *Achillea millefolium, Agrostis capillaris, Anthoxanthum odoratum*, *Anthyllis vulneraria, Asperula cynanchica, Dianthus carthusianorum, Dorycnium pentaphyllum* subsp. *herbaceum, Festuca valesiaca, Leucanthemum vulgare, Lotus corniculatus, Plantago media* and *Prunella laciniata.*

Species number range: 26 - 47 sp./relevé. Red list taxa: *Cnidium dubium*, *Gymnadenia conopsea*. Ecology: sunny places, slightly to highly inclined slopes; xeric-mesic and mesic phytocoenosis. Distribution: frequent; Sălciua de Sus (near the "Streminoasa" forest); Sălciua de Jos (under the Citera Peak; Holdelor Hill); Ocoliş (left side of the Arieş River), between Ocoliş and Runc (Ocoliş Valley); Vidolm (left side of the Vidolm Valley). Altitudinal range: 550 - 850 m. Management: mainly pastures, rarely hay meadows with reduced economic value; we recommend avoiding the overgrazing.

Festucetum valesiaco-rupicolae Csűrös *et* Kovács 1962 (no. of relevés 9)

[- *botriochloosum ischaemi* (facies with *Dichanthium ischaemum*) - 1 relevé]

Floristic structure: *Achillea millefolium, Centaurea biebersteinii biebersteinii, Eryngium campestre, Dichanthium ischaemum, Euphorbia cyparissias, Festuca rupicola, F. valesiaca, Medicago lupulina, Pimpinella saxifraga, Plantago lanceolata, P. media, Thymus pannonicus.*

Species number range: 21 - 37 sp./relevé. Red list taxa: *Adonis vernalis, Echium russicum, Seseli gracile*. Ecology: alluvial flats, base of the hills, slightly inclined slopes, crests; xeric-mesic phytocoenosis. Distribution: frequent; Ocoliş (Vârfuiata Hill); Vidolm (left side of the Arieş River); Moldoveneşti (left side of the Arieş River); Corneşti ("Cetatea Moaşei", Sardău Hill); Cheia (Sardău Hill). Altitudinal range: 360 - 580 m. Management: pastures with reduced economic value, grazed by cattle or/and sheep; we recommend a moderate grazing between 15th of April and 15th of June.

BROMETALIA ERECTI Br.-Bl. 1936

Cirsio pannonicae - Brachypodion pinnati Hadač *et* Klika 1944

Carici humilis - Brachypodietum pinnati Soó 1947, 1949 (no. of relevés 4)

[- *festucetosum rupicolae* Kovács *et* Coldea 1967 - 1 relevé]

Floristic structure: *Anthyllis vulneraria, Brachypodium pinnatum, Carex humilis, Ferulago sylvatica, Festuca rupicola, Genista tinctoria, Leucanthemum vulgare, Helianthemum nummularium, Onobrychis viciifolia, Polygala major, Teucrium chamaedrys.*

Species number range: 32 - 40 sp./relevé. Ecology: mesic-dry, sunny places, slightly to highly inclined slopes; xeric-mesic phytocoenosis. Distribution: sporadic; Lunca Arieşului (Bedeleu Mountins); Ocoliş (Vârfuiata Hill); Buru (left side of the Arieş River). Altitudinal range: 450 - 900 m. Management: mainly hay meadows with reduced to medium economic value, rarely pastures grazed by cattle; we recommend the rotation of mown with a moderate grazing on different strips (lots).

Festuco rupicolae - Brachypodietum pinnati (Soó 1927) Schneider-Binder 1971 (no. of relevés 8)

Floristic structure: *Achillea millefolium, Brachypodium pinnatum, Eryngium campestre, Euphorbia cyparissias, Festuca rupicola, F. valesiaca, Medicago lupulina, Onobrychis viciifolia, Potentilla cinerea, Plantago media* and *Thymus pannonicus.*

Species number range: 17 - 33 sp./relevé. Red list taxa: *Adonis vernalis, Echium russicum, Prunus tenella*. Ecology: half-sunny places, base of the hills, slightly inclined slopes, crests; xeric-mesic and xeric phytocoenosis. Distribution: sporadic; Corneşti ("Cetatea Moaşei", Sardău Hill); Cheia (Sardău Hill; Lupilor Hill); Mihai Viteazu (left side of the Arieş River). Altitudinal range: 450 - 900 m. Management: mainly pastures grazed by sheep, rarely hay meadows with medium economic value, or unused; we recommend the rotation of mown with a moderate grazing on different strips (lots).

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SECONDARY SUCCESSION AND FLUCTUATIONS IN MEADOWS OF THE APUSENI MOUNTAINS (TRANSYLVANIA, ROMANIA) UNDER DIFFERENT FERTILISATION REGIMES

Katja BRINKMANN *, *Florin PĂCURAR* **
and *Albert REIF* ***

* University of Kassel, Organic Plant Production and Agroecosystems Research in the Tropics and Subtropics, Stein Street 19, Witzenhausen, Germany, D-37213 brinkmann@uni-kassel.de
** Agriculture Sience and Veterinary Medicine University, Meadows Culture and Forage Plants Department, Mănăştur Street 3, Cluj-Napoca, Cluj County, Romania, RO-400372, fpacurar@gmail.com
*** University of Freiburg, Institute of Forestry, Tennenbacher Street 4, Freiburg, Germany, D-79106, albert.reif@waldbau.uni-freiburg.de

KEYWORDS: Romania, Transylvania, Apuseni Mountains, hay meadows, farmyard manure, fertilization experiments, principle response curves, species-productivity relationship.

ABSTRACT

Experimental research was undertaken to analyze the effects of different fertilization regimes on the floristic composition and productivity of hay meadows in the Apuseni Mountains. Three experimental plots treated with varying intensities of mineral (NPK) and organic fertilizer (farmyard manure) were established on two different meadow types. Vegetation, sward structure and aboveground biomass production were sampled yearly based on a permanent plot design over an observation period of four years. Univariate and multivariate methods with non-parametric Monte Carlo significance tests were used to analyze species-productivity relationships and differences between the treatments. A principle response curve analysis was performed to distinguish between vegetation succession and natural, interannual fluctuation processes.

A significant negative correlation between species richness and biomass production was detected after the third year of fertilization. Significant floristic changes occurred in the fourth year of observation. The Violo declinatae-Nardetum was replaced by a Festuca rubra - Agrostis capillaris community after four years of fertilization with 100 kg NPK ha^{-1}. Fertilization levels of 100 - 150 kg NPK ha^{-1} induced vegetation changes with a shift from the Festuca rubra - Agrostis capillaris meadow to a Polygono-Trisetion community. Altogether, 24 species reacted to fertilization with a significant negative correlation. A relatively low fertilizer input ($\leq$ 10 t manure ha^{-1} or 50 kg NPK ha^{-1}) barely changed the initial plant community and can thus be recommended for already semi-improved meadow sites.

ZUSAMMENFASSUNG: Sukzessionen und Bestandesfluktuationen in Wiesen des Apuseni-Gebirges (Transylvanien, Rumänien) als Folge unterschiedlicher Düngungsmaßnahmen.

In einem experimentellen Ansatz wurden die Auswirkungen unterschiedlicher Düngungsmaßnahmen auf die Pflanzenartenzusammensetzung und die Biomasseproduktion in Heuwiesen des Apuseni-Gebirges untersucht. Drei Versuchsfelder mit variierenden Mengen an Mehrnährstoffdünger (NPK) und Stallmist wurden auf zwei unterschiedlichen

Wiesentypen eingerichtet. In einem Beobachtungszeitraum von vier Jahren wurden auf der Basis von Dauerbeobachtungsflächen die Vegetationszusammensetzung, Bestandesstruktur und oberirdische Biomasse jährlich aufgenommen. Mittels uni- und multivariater Methoden (Monte Carlo-Testverfahren) wurden die Zusammenhänge zwischen Düngung, Artenzahl und Produktivität ermittelt. Anhand von Hauptreaktionskurven konnte zwischen sukzessionalen Vegetationsveränderungen infolge von Düngung und jährlich schwankenden Witterungsbedingungen und Vegetationsfluktuationen unterschieden werden.

Im dritten Jahr nach Anlage des Düngungsexperiments konnte eine signifikant negative Korrelation zwischen Artenreichtum und Biomasseproduktion festgestellt werden. Im vierten Jahr änderte sich die Artenzusammensetzung stark. Das Violo declinatae-Nardetum wurde nach vier Jahren mit jährlichen Düngermengen von 100 kg NPK ha^{-1} in eine Festuca rubra - Agrostis capillaris-Gesellschaft umgewandelt. Jährliche Düngermengen von 100 - 150 kg NPK ha^{-1} veränderten eine Versuchsparzelle der Festuca rubra - Agrostis capillaris-Gesellschaft hin zu einer Fettwiese des Polygono-Trisetion. Insgesamt 24 Pflanzenarten nahmen infolge Düngung ab. Relativ geringe Düngermengen (10 t Stallmist ha^{-1} oder 50 kg NPK ha^{-1}) dagegen veränderten die Artenzusammensetzung kaum. Eine derartige, maßvolle Düngung kann für die Wirtschaftswiesen empfohlen werden, da hierdurch der Ertrag bereits besser wird, die Artenvielfalt jedoch erhalten bleibt.

REZUMAT: Succesiuni şi fluctuaţii secundare în pajiştile din Munţii Apuseni (Transilvania, România) sub diferite regimuri de fertilizare.

Studiile noastre au urmărit efectul diferitelor regimuri de fertilizare asupra compoziţiei floristice şi a productivităţii pajiştilor din Munţii Apuseni. În acest scop, s-au instalat trei experienţe cu îngrăşăminte minerale (NPK) şi organice (gunoi de grajd) pe două tipuri de pajişti. S-a analizat evoluţia compoziţiei floristice şi recolta de substanţă uscată pe o perioadă de patru ani. Pentru a urmări relaţiile specii-productivitate şi diferenţele cantitative dintre variantele experimentale s-au folosit metode de interpretare statistică univariate şi multivariate cu testele de semnificaţie Monte Carlo non-parametrice. Procesele de succesiune a vegetaţiei şi cele de fluctuaţie naturală şi interanuală s-au diferenţiat după analiza curbei principale de răspuns. După cel de-al treilea an de studiu, se constată o relaţie semnificativ negativă între fitodiversitate şi recolta de substanţă uscată. Schimbările mai importante la nivelul covorului ierbos au avut loc în anul al patrulea. Comunitatea Violo declinatae-Nardetum a fost înlocuită de Festuca rubra - Agrostis capilaris la varianta cu 100 kg NPK/ha^{-1}. Aplicarea a 100 - 150 kg NPK/ha^{-1} a determinat schimbări puternice, transformând comunitatea de Festuca rubra - Agrostis capilaris într-una de Polygono-Trisetion. Ca urmare a aplicării fertilizanţilor în cantităţi mari 24 de specii şi-au redus puternic participarea, folosirea cantităţilor reduse de fertilizanţi (10 t/ha gunoi de grajd sau 50 kg NPK/ha^{-1}) a determinat o modificare minoră a structurii covorului ierbos. O astfel de folosire (fertilizare) s-ar putea recomanda pentru zona de studiu deoarece, în acest mod, se produce o sporire uşoară a recoltei de substanţă uscată şi o reducere minimă a fitodiversităţii.

INTRODUCTION

The Apuseni Mountains consists of a wide range of mountain grassland types of high natural value including Natura 2000 habitats (Doniță et al., 2005), as a result of the prevailing small-scale farming structure. The basic needs of the local farmers are still provided by subsistence production and animal husbandry following traditional land management techniques (Păcurar, 2005; Brinkmann, 2006).

However, the E. U. agricultural policy adoption and the decreasing pressure of costs currently provoke a process of abandonment of the low productive grasslands or increasing farm size and intensified use of the more fertile soils. Such processes have already taken place in other mountain areas of central and Western Europe over the last decades, with negative effects for biodiversity and landscape patterns (Forman, 1995; Tasser et al., 2001). The effects of such land use changes and higher fertilization regimes on the grasslands floristic composition have been well studied on the basis of experiments carried out throughout Europe (e.g., Dähler, 1992; Schellberg et al., 1999; Kopeć, 2002; Aude, 2004; Briemle, 2006; Silverton et al., 2006), but only a few studies in mountain grasslands have tried to evaluate the speed of succession and identified the point in time at which vegetation changes increased significantly.

It is well-known, that fertilization, be it organic or inorganic, has effects on plant productivity, species richness and vegetation composition. However, predicting plant species responses to management and fertilization is difficult, because of the high spatial-temporal variation of the abiotic and biotic environment (Herben et al., 2003). Secondary succession is a time depending process, whereas underground and aboveground disturbances, different plant life cycles and intra-specific competition for space and resources simultaneously lead to natural fluctuations in species composition (Rosén, 1984; Stampfli, 1992; Rabotnov, 1995; Kammer, 1997). In contrast to successional changes, fluctuations may occur in seasonal or annual cycles without a clear directional trend in the vegetation and they are reversible (Rabotnov, 1995).

A proper separation of such fluctuations from successional trends is a crucial task in the analysis of vegetation changes, particularly in short-term environmental experiments. Statistical analysis based on principle response curves (PRC) is a powerful tool for distinguishing between trends and fluctuations and determining the start of significant plant community changes, since this method focuses on the succession towards the composition of a control plot over time (van den Brink et al., 2003; van den Brink and ter Braak, 1999). The PRC diagram has a distinct advantage over other ordination techniques such as redundancy analysis or principal component analysis, because it allows for the determination of the start and end points of effects (Frampton et al., 2000), based upon the statistical significance of differences from the reference treatment (van den Brink and ter Braak, 1999).

In the present study experimental research was undertaken to analyze the effects of different organic and inorganic fertilization intensities on yields and the floristic composition of two different mountain meadow types. The aim of this study was to answer the following questions: (1) What are the effects of different fertilization intensities on Romanian mountain meadows? (2) How quickly does the vegetation react to fertilization and when do the vegetation changes become significant? (3) How does one distinguish between succession and fluctuation?

MATERIALS AND METHODS

Study area

The study area is located in Ghețari (46.49°N, 22.81°E, 1,100 m a.s.l.), a local village of the Apuseni Mountains in Transylvania, the north-western Romania. Limestone and mudstone are predominant in the area. The soils are rendzinas, rendsinic lithosols, slightly acidic, deep para brown earths, and "terra rossa", a tropical relic soil (Parichi and Stănilă, 2005). The climate is montane (mean annual temperature of aproximatively 5°C, mean annual precipitation of about 1,200 mm) with long and cold winters.

Each household in the Ghețari Village owns approximately four hectares of farmland consisting of grassland, gardens and small fields. Meadows of the Polygono-Trisetion alliance are located on deeper soils and more fertile sites, and provide hay for the winter months. They cover 72% of the open land with a yield potential of between 2.5 and 4.5 t DM ha^{-1}. 26% of the open land is covered by unfertilized less productive meadows and pastures of the Anthyllido-Festucetum rubrae (Festuco-Brometea) on shallow soils (limestone) and the Violo declinatae-Nardetum (Nardo-Callunetea) on acidic soils. Diagnostic species of the acidic grasslands are *Nardus stricta*, *Potentilla erecta*, *Viola declinata*, *Potentilla aurea*, *Luzula multiflora*, *Carex pilulifera Euphorbia carniolica* and *Hieracium aurantiacum* (Reif et al., 2005). A transitional grassland type between the Polygono-Trisetion meadows and the less productive grassland can be distinguished and differentiated as Festuca rubra - Agrostis capillaris community. All meadows are mowed using scythes during July and August, with an aftermath in September. During either the winter or spring they are fertilized with farmyard manure, transported using horse drawn carts, deposited in heaps, and spread manually.

Experimental design and sampling method

Two fertilizer experiments were established on a Festuca rubra - Agrostis capillaries community employing different intensities of mineral (0; 50; 100; 150 kg NPK ha^{-1}) and organic fertilizer (0; 10; 20; 30 t manure ha^{-1}). A further experimental design on a Violo declinatae-Nardetum involved a mixed combination of macro-nutrient fertilizer (20:10:10 NPK) and manure with the following variants: 0; 20 t manure ha^{-1}; 10 t manure ha^{-1} + 50 kg NPK ha^{-1}; 100 kg NPK ha^{-1} ; 10 t manure ha^{-1} +100 kg NPK ha^{-1}. The experiment fields were all set up on the same soil type, classified as "terra rossa". They consisted of four replicate plots for each variant (Fig. 1). The chemical composition of the farmyard manure during the observation period from 2001 to 2004 was about 0.40 - 0.55% nitrogen, 0.40 - 0.60% phosphorus and 0.35 - 0.50% potassium (Păcurar, 2005). Both fertilizer types were applied annually in the spring, before the start of the vegetation period.

Vegetation, sward structure and above ground productivity were sampled annually from 2001 to 2004. The dry matter production was determined on each replicate plot with the first cut in July and the second in September.

Each replicate plot was divided into subplots for vegetation sampling. To measure the percent cover of the species a square meter frame with 10 by 10 cells was applied. Each cell of this sampling frame represented 1% cover. The species cover was estimated using Gehlker's (1977) cover comparison sheet, with the following proportional ranks: 1- 2- 3- 4- 5- 8- 10- 15- 20- 25- 30- 40- 50- 60- 70- 80- 90%. Relevés were taken between the beginning of the flowering of the grasses and the first cut of the meadows with five replication per variant.

Statistical analysis

The analysis of the data was based on univariate and multivariate statistical analysis with non-parametric Monte Carlo significance tests using CANOCO Version 4.5 (ter Braak and Šmilauer, 2002), SPSS 11.0 (SPSS Inc., 2001) and Statistika 6.0 (StatSoft, 2001). The effects of treatment on biomass production were tested by means of analysis of variance (ANOVA) with repeated measurement.

To determine the overall spatial and temporal floristic dissimilarities between the experimental plots an unconstrained linear ordination method was used. Natural fluctuations during the four year observation period were investigated on the unfertilized plots with a principal component analysis (PCA) and tests of significance (Friedman ANOVA, Wilcoxon test).

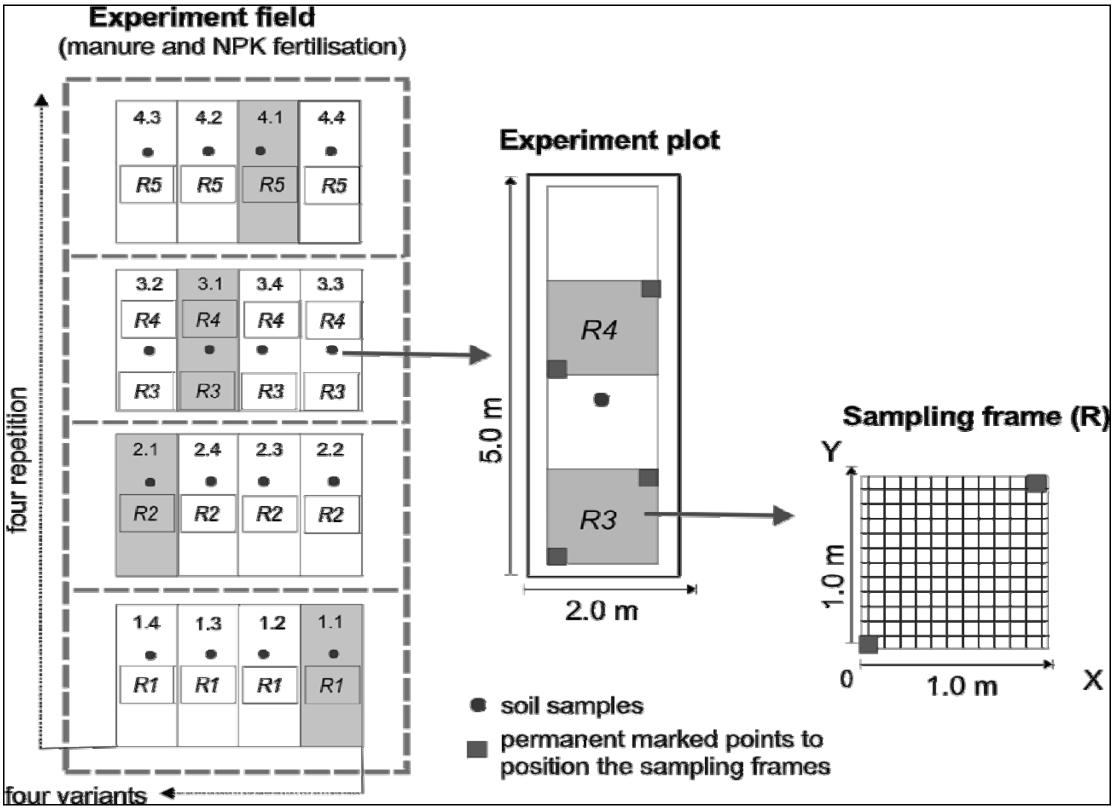

Figure 1: Experimental design
(example of an experiment field with four variants)
and vegetation survey method on permanent plots (5 * 1 m²)
using sampling frames.

The secondary succession was assessed with a principle response curve analysis (PRC), whereby the temporal changes effected by treatment were contrasted against the control (unfertilized) plots. The PRCs were evaluated by a partial redundancy analysis (pRDA) with the observation years (time) as covariables and the treatment (fertilization variant * time interaction) as environmental variables. Both variables were recoded into dummy variables and the species data were logarithmically transformed. For the analysis in CANOCO, the PRC scores (c_{dt}) for the first axis was found using the equation according to ter Braak and Šmilauer (2002).

The results were depicted in a diagram showing the years on the x-axis and the principal component of variance explained by treatment (c_{dt}) on the y-axis. The coding used in PRC standardizes the control to be zero-valued for all times (horizontal line and second x-axis in the diagram). Temporal trends were depicted by plotting the principal response (c_{dt}) against the control for each year. Variant curves were obtained for each fertilization, and could be interpreted as the principal response curves of a community (van den Brink and ter Braak, 1999). The species weights (b_k) resulting from the pRDA were depicted on a separate y-axis and allowed an interpretation at the species level. The greater the weight, the more the actual response pattern of the species is likely to follow the pattern in the PRC. Species with near-zero scores are indifferent to the trends recognized by the PRC axis (ter Braak and Šmilauer, 2002). The product $c_{dt} * b_k$ gives the fitted change in log-abundance (- or +) of the species for the treatment relative to the controls (van den Brink and ter Braak, 1999).

The significance test of the axis was based on the Monte Carlo permutation test. The PRC axes were tested within the pRDA, from which the PRC was obtained, as a split-plot design, with freely exchangeable whole-plot levels and no permutation on the split-plot levels. In this case, each experimental variant was defined as a whole plot, with four observations within each (split-plot level). Changes in treatment effects over time were evaluated in sequential tests for each sampling time, permuting the census data freely within blocks. A total of 999 permutations were run in all cases (see van den Brink and ter Braak, 1998, 1999 for more details).

RESULTS

Productivity and plant species richness

The annual dry matter production increased after fertilization on average from 1.2 - 2.0 t DM ha^{-1} to 4.5 - 5.0 t DM ha^{-1} over an observation period of four years, whereas the plant species richness declined. Unfertilized plots usually exhibited species numbers in excess of 36, and occasionally 42 per m^2. The greatest species decline was on the variants with 30 t manure ha^{-1} and those with 150 kg NPK ha^{-1}, amounting to a loss of between 25-30% in comparison to the situation at the outset. At the end of the observation period, the species number declined to 26 species per m^2 on the plots with the highest nutrient input (150 kg NPK ha^{-1}).

The figure 2 shows the relationship (Pearson's correlation coefficient at $p = 0.05$) between the productivity and species richness for all experiment fields in the second and the last years of observation. In the first two years of observation there was no significant relationship. On the more intensively fertilized plots the original floristic composition changed slightly, with an average of 35 species per 1 m^2 plot. At the same time, the biomass production increased to 5.0 t DM ha^{-1}. A significant negative correlation between the number of species and the yield potential was detected in the observation years 2003 and 2004. A separate analysis of each experiment field revealed the strongest negative correlation with $r = -0.87$ and $r^2 = 0.76$ for the experiment field with NPK fertilizer.

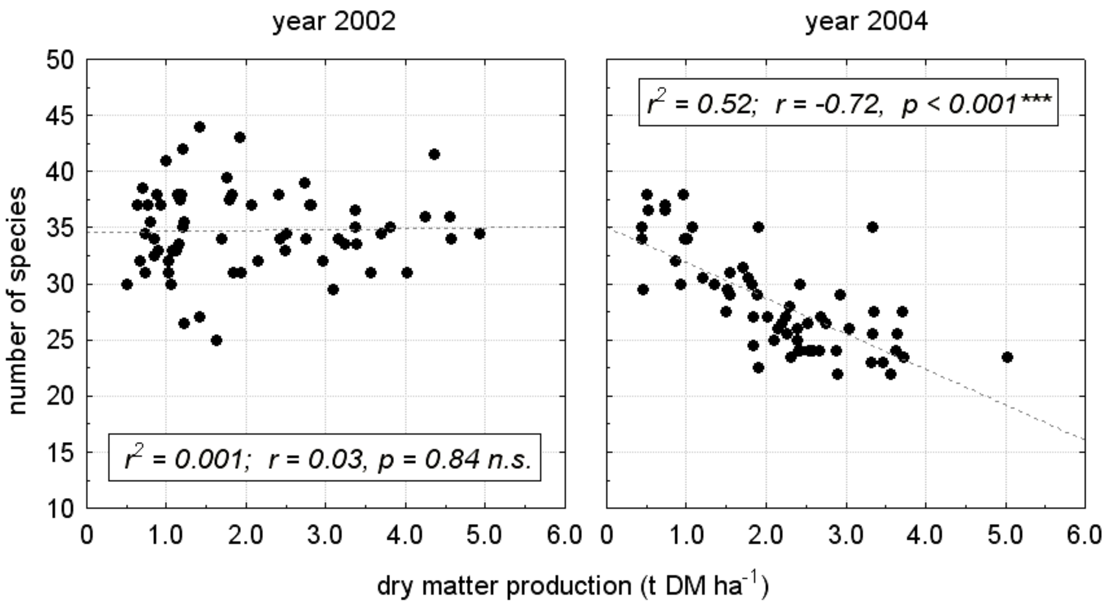

Figure 2: Correlation between productivity (t DM ha^{-1}) and species numbers (a 1 m² sampling frame) in the observation years 2002 and 2004.

Annual fluctuation and succession

The results of a principal component analysis of the unfertilized plots indicated both a seasonal variation and an annual fluctuation of the floristic composition, which occurred in combination with succession. In some cases the species composition of the unfertilized permanent plots changed significantly during the four year observation period. Highly significant differences (Wilcoxon test with $p \leq 0.001$) occurred between the years 2001 and 2004 in both plant communities. Conversely, no significant differences were detected between 2004 and 2003, or between 2004 and 2002. To test the differences between the observation years on the species level, a Friedmann ANOVA was applied to the species cover data for the unfertilized plots from 2001 to 2004. Altogether 15 species with a pronounced annual dynamic were identified in the *Festuca rubra - Agrostis capillaris* community. In the Violo declinatae-Nardetum community only five species exhibited a significant annual variability, namely *Rhinanthus minor, Gentianella lutescens, Trifolium repens, Rumex acetosa* and *Ranunculus bulbosus* (Brinkmann, 2006).

Table 1: Percentage of the total variance in the pRDA that can be attributed to time and treatment regime for each fertilization experiment. Treatment included the interaction between treatment and time, the remaining fraction of variance was residual. The next row indicates the fraction of variance explained by the treatment regime that is captured by the first two axes and the results of the Monte Carlo permutation tests ($p < 0.01$) of the first two axes.

Fertilization experiment/vegetation type	Variance accounted for by (%)		Variance explained by treatment regime captured by (%)		Significance level	
	covariable (years)	environmental variable	1st axis	2nd axis	1st axis	2nd axis
Violo declinatae-Nardetum community						
combined fertilization (manure + NPK)	28.4	26.6	16.1	7	*	n.s.
Festuca rubra - Agrostis capillaris community						
manure	27.6	25.9	21.3	4.3	*	n.s.
mineral fertilizer (NPK)	26.6	30.1	22.8	4.8	*	n.s.

A principal response curve analysis (PRC) focused on the succession, namely the temporal changes effected by treatment contrasted against the unfertilized plots. The PRC analysis for the data set obtained from the Violo declinatae-Nardetum indicated the fact that the overall variation between the observation years was greater than between the treatments (Tab. 1). The first PRC axis was statistically significant, the second not. In the case of the manure fertilization of the Festuca rubra - Agrostis capillaris community, 28% of all variance could be attributed to the observation years and 26% to treatment. Of this treatment variance, 21.3% was displayed on the vertical axis of the first PRC. The Monte Carlo permutation tests permuting the whole time series indicated that the first PRC axis displayed a significant part of the treatment variance. In the NPK fertilization case, the variation between treatments was higher than between observation years. The treatment explained 30% of the total variance. The Monte Carlo permutation tests revealed that the differences between the treatments and the reference were statistically significant, with the PRC diagram explaining 22.8% of the variance in treatment effects.

Monte Carlo permutation tests were performed for each sampling date in order to test the observation years in which fertilization had significant effects on the floristic composition (Tab. 2). A significant influence of the fertilization regime was found after the third application with 100 and 150 kg/ha NPK. In the fourth year all variants, including the manure fertilization, had a significant influence on the floristic composition of the Festuca rubra - Agrostis capillaris community. The combined fertilization with ’10 t manure ha^{-1} + 50 kg NPK ha^{-1}’ and ‘10 t manure ha^{-1} + 100 kg NPK ha^{-1}’ had no significant effect on the floristic composition of the Violo declinatae-Nardetum throughout the four years of application.

Table 2: Observation years in which there was a significant influence of fertilization ($p < 0.01$) on the floristic composition of each experimental variant. c_{dt} = principal response and value on the y-axis, p = significance level of the Monte Carlo permutation test, F-test = F-type test statistic of pRDA.

Treatment	Third year			Fourth year		
	c_{dt}	p	F-Test	c_{dt}	p	F-Test
Festuca rubra-Agrostis capillaris community						
10 t manure ha^{-1}	-0.602	n.s.	1.26	**-0.750**	*	**1.98**
20 t manure ha^{-1}	-0.748	n.s.	1.13	**-1.311**	*	**2.49**
30 t manure ha^{-1}	-0.990	n.s.	1.43	**-1.470**	**	**3.24**
50 kg NPK ha^{-1}	-0.612	n.s.	1.54	**-0.959**	**	**2.92**
100 kg NPK ha^{-1}	**-0.762**	*	**1.71**	**-1.187**	*	**2.39**
150 kg NPK ha^{-1}	**-1.242**	*	**2.88**	**-1.633**	**	**3.26**
Violo declinatae-Nardetum community						
20 t manure ha^{-1}	-0.748	n.s.	1.43	**-1.066**	**	**3.32**
10 t manure ha^{-1} + 50 kg NPK ha^{-1}	-0.794	n.s.	1.32	-1.158	n.s.	1.67
100 kg NPK ha^{-1}	**-0.792**	**	**1.66**	-1.091	n.s.	1.39
10 t manure ha^{-1} + 100 kg NPK ha^{-1}	-0.951	n.s.	1.32	-1.226	n.s.	1.51

The figure 3 illustrates the effect of different combinations of fertilization on a Violo declinatae-Nardetum. The first PRC axis is shown, expressing the most dominant effects of fertilization on the floristic composition. The PRC scores decreased continuously for all treatments between 2001 and 2004. The diagram indicates clear deviations from the control (non-fertilized plots) for all treatments, with the highest response to '10 t manure ha^{-1} + 100 kg NPK ha^{-1}'. For this variant the PCR scores amounted to 1.23 (Tab. 2). The diagram on the right illustrates the species weights. Species indicated with a positive weight are expected to decrease in percent cover after fertilization, relative to the controls, whereas species with a negative weight are expected to increase. Thus, *Nardus stricta*, which has the highest positive weight in the diagram, is shown to have decreased most at the higher fertilization concentrations. On the opposite, the negative weights for *Stellaria graminea, Rumex acetosa* and *Veronica chamaedrys* indicate that these species have a positive relationship with fertilization. For a quantitative evaluation of the species reaction, the quotient $\exp(c_{dt} * b_k)$ can be calculated for each species *k* at treatment *d* and observation year *t* (van den Brink and ter Braak, 1999). For example, the fitted rise of *Stellaria graminea* in plots fertilized with '10 t manure ha^{-1} + 100 kg NPK ha^{-1} ' in the year 2004 was exp(-1.2*-1.6) = 22.6 times higher percent cover than in the unfertilized plot. This fitted value agreed well with the observed cover differences between treatments. Most species had positive scores on the first axis. Fertilization suppressed the diagnostic species of the acidic grasslands such as *Nardus stricta*, *Potentilla erecta*, *Potentilla aurea*, *Arnica montana, Luzula multiflora* and *Euphorbia carniolica.* For *Arnica montana* the fitted relative difference in percent cover between the treatment with 100 kg NPK ha^{-1} and the unfertilised control in the year 2004 was exp(-1.1*1.9) = 0.12, which means a reduction of around 90%. Further grassland species indicative of poor nutrient status such as *Carlina aucalis, Gymnadenia conopsea, Carex pallescens* and *Scabiosa columbaria* were greatly reduced under the higher fertilization regime.

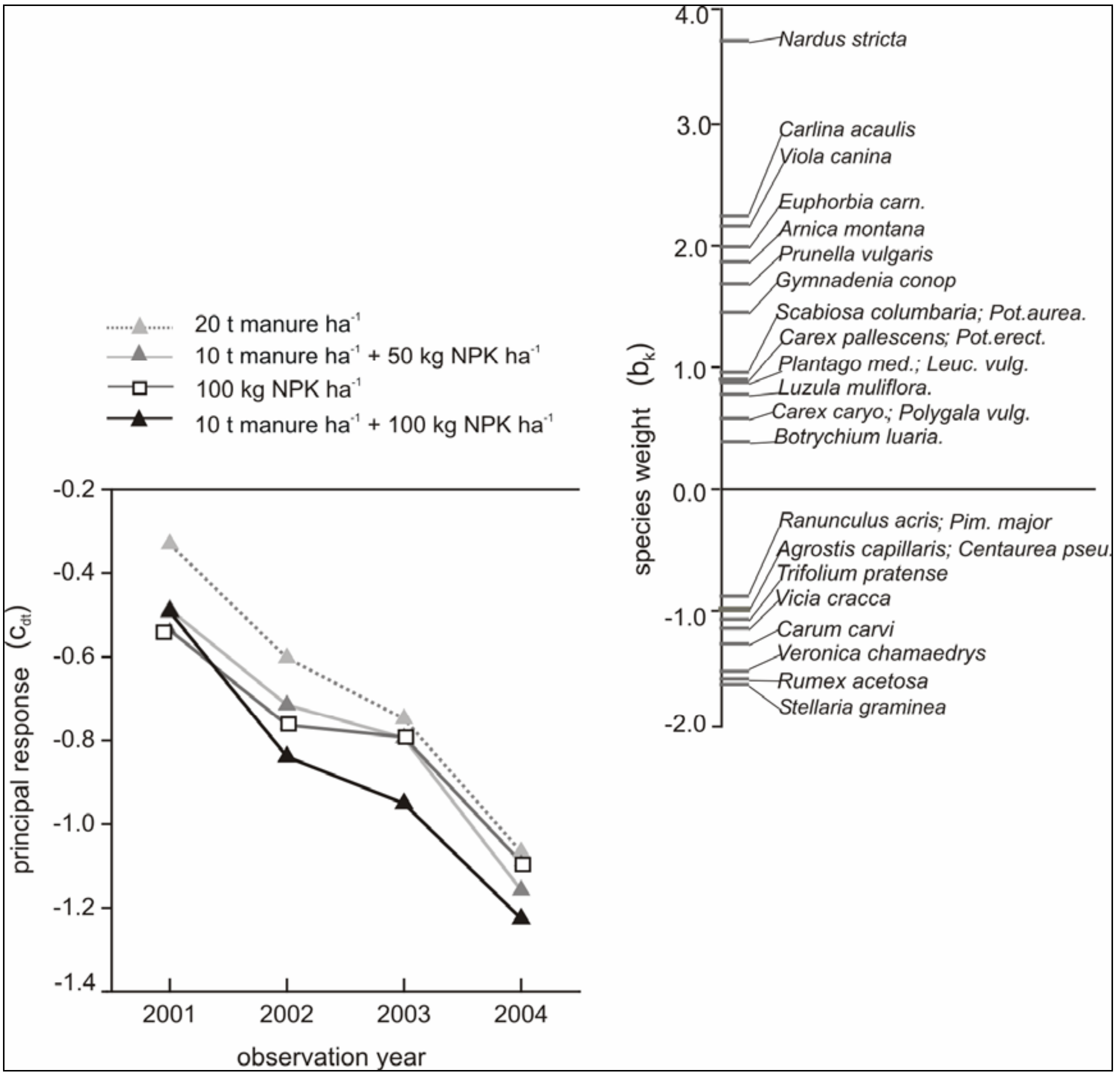

Figure 3: Principal response curves (PRC) of the first axis
showing the effect of combined fertilization regimes on a Violo declinatae-Nardetum.
The PRC shows the effect of each regime relative to the control, which is indicated by the y = 0 line.
The species weights indicate the affinity of each species to the principal response.
Species with weights of between 0.5 and -0.5 are not shown for clarity.
For the significance level see the table 1.

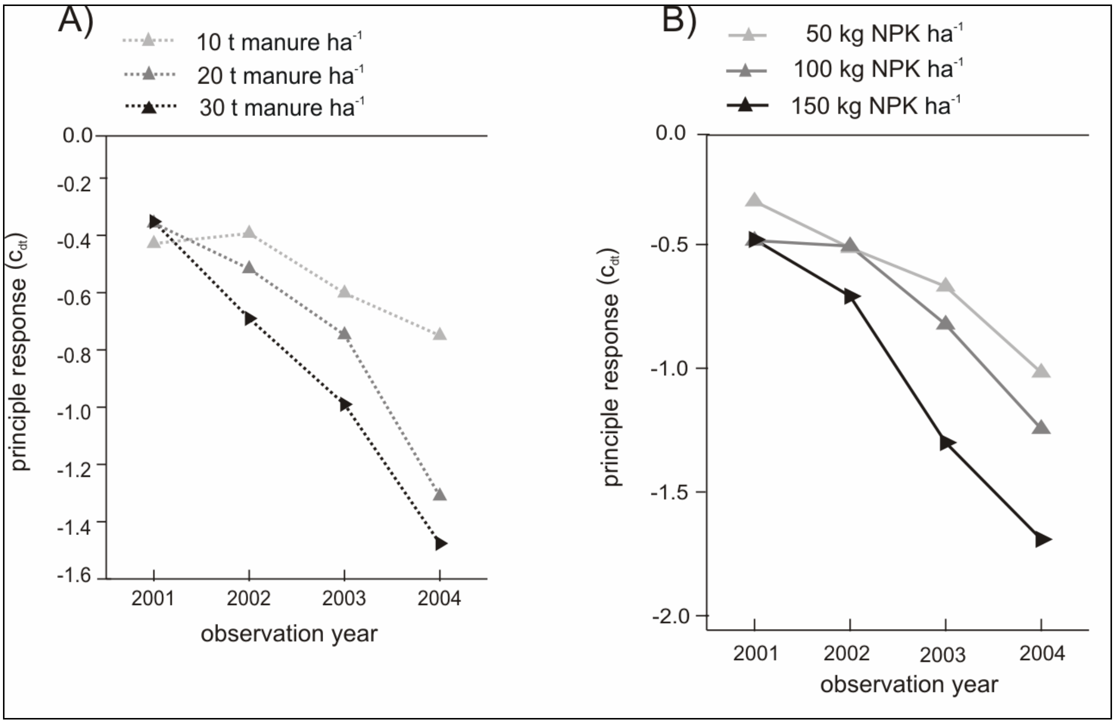

Figure 4: Principal response curves (PRC) of the first axis showing the effect of different intensities of manure (A) and mineral fertilization (B) on a *Festuca rubra-Agrostis capillaris* community. The weights (b_k) of the most important species are listed in the table 3. For the significance level see the table 1.

The effects of different intensities of manure (A) and mineral (B) fertilization on the *Festuca rubra-Agrostis capillaris* community are shown in the figure 4. Between the treatments a clear dose-response was evident after the second application. The higher the fertilization intensity, the greater the deviations from the unfertilized plot. The effects of manure fertilization (A), as displayed in the PRC diagram were smaller and less persistent than those of mineral fertilization (B). After four years of NPK application, the sward was dominated by grasses such as *Trisetum flavescencs* and *Agrostis capillaris. Festuca pratensis* colonized the NPK fertilized plots after the third year of application. Species of nutrient rich grasslands, such as *Rumex acetosa*, *Carum carvi*, *Taraxacum officinale*, *Ranunculus acris* and *Crepis biennis*, grew in dominance, irrespective of the type of fertilization.

How many species reacted significantly to fertilization?

Species exhibiting a significant decline in abundance with an increasing intensity of the fertilization regime could be defined as indicator species for the detection of the effects of fertilization regimes. The relationship between each species and the fertilization regime was analyzed using a rank correlation (Kendall's Tau). In PRC analysis the species weights b_k may also be used to identify indicator species (Frampton et al., 2000). The greater the species weight, the more the response of that species resembles the principal response. The table 3 summarizes the results for the most important species showing either a significant decrease or increase with fertilization (b_k = species weights on first axis of the partial RDA, Ken.Tau = Kendall's Tau correlation coefficient, p = significance level. - = infrequent species).

Table 3: Plant species exhibiting a significant increase or decrease for each fertilisation experiment.

		Festuca rubra-Agrostis capillaris community						**Violo declinatae-Nardetum**		
	significant species	**manure fertilization**			**NPK fertilization**			**combined fertilization**		
		b_k	Ken.Tau	p	b_k	Ken.Tau	p	b_k	Ken.Tau	p
INCREASE	*Agrostis capillaris*	0.37	-0.02	0.86	**-1.38**	0.02	0.86	**-1.07**	0.35	***
	Centaurea pseudophrygia	-0.53	0.33	**	-0.37	0.03	0.74	-0.99	0.02	0.79
	Crepis biennis	**-1.44**	0.42	***	**-1.00**	0.39	***	0.02	0.04	0.63
	Hypericum maculatum	**-1.19**	**0.24**	*	**1.24**	0.17	0.08	-0.02	0.06	0.48
	Pimpinella major	-0.58	0.31	**	-0.65	0.41	***	-0.56	0.13	0.15
	Ranunculus acris	-0.59	0.18	0.07	**-1.36**	0.16	0.11	-0.88	0.37	***
	Rumex acetosa	**-1.12**	0.28	**	**-1.92**	0.22	*	**-1.50**	0.40	***
	Stellaria graminea	-0.61	0.22	*	-0.16	0.06	0.52	**-1.60**	0.31	***
	Taraxacum officinale	**-1.15**	0.27	**	**-1.32**	0.25	*	0.08	-0.08	0.39
	Trifolium pratense	**-2.04**	0.43	***	-0.23	0.26	**	**-1.14**	0.04	0.66
	Trifolium repens	**-1.25**	0.38	***	-0.03	0.16	0.11	-0.23	-0.08	0.35
	Trisetum flavescens	**-1.63**	0.34	***	**-2.60**	0.07	0.49	-0.33	0.21	0.02
	Veronica chamaedrys	-0.52	0.13	0.21	-0.57	0.02	0.88	**-1.56**	0.20	*
	Vicia cracca	**-0.98**	0.14	0.16	-0.50	0.23	*	**-1.18**	0.04	0.66
DECREASE	*Arnica montana*	0.19	0.06	0.54	1.05	-0.02	0.81	**1.87**	-0.22	*
	Botrychium lunaria	-	-	-	-	-	-	0.35	-0.34	***
	Carlina acaulis	-	-	-	-	-	-	**2.25**	-0.34	***
	Carex caryophyllea	-	-	-	-	-	-	0.60	-0.23	*
	Carex pallescens	0.45	-0.32	**	0.35	-0.14	0.15	0.87	-0.20	*
	Colchicum autumnale	0.43	-0.11	0.27	0.66	-0.32	**	0.45	-0.32	**
	Euphorbia carniolica	-	-	-	-	-	-	**1.99**	-0.27	**
	Festuca rubra	**2.02**	-0.35	***	**1.13**	-0.17	0.08	0.33	0.15	0.08
	Gentianella lutescens	0.04	-0.26	*	0.18	-0.22	*	0.28	-0.38	***
	Gnaphalium sylvaticum	-	-	-	-	-	-	0.22	-0.33	***
	Gymnadenia conopsea	0.91	-0.26	*	0.81	-0.37	***	**1.45**	-0.51	***
	Hieracium aurantiacum	**1.07**	-0.31	**	0.40	-0.29	**	-0.06	-0.07	0.94
	Leontodon hispidus	**2.39**	-0.42	***	**1.05**	0.17	0.09	0.05	-0.16	0.07
	Linium carthaticum	0.57	-0.27	**	0.59	-0.29	**	0.12	-0.05	0.54
	Luzula campestris	0.87	-0.28	***	0.76	-0.02	0.83	0.71	-0.10	0.26
	Nardus stricta	-	-	-	-	-	-	**3.69**	-0.59	***
	Plantago media	**1.32**	-0.33	**	**2.55**	-0.17	0.08	0.77	-0.20	*
	Polygala vulgaris	0.75	-0.36	***	0.76	-0.36	***	0.67	-0.22	*
	Potentilla aurea	**2.26**	-0.53	***	**1.83**	-0.32	***	**1.07**	-0.11	0.20
	Potentilla erecta	**2.09**	-0.47	***	**2.17**	-0.31	**	0.89	-0.07	0.44
	Prunella vulgaris	**2.40**	-0.46	***	**1.94**	-0.26	***	**1.69**	-0.50	***
	Scabiosa columbaria	0.62	-0.06	0.58	**1.30**	-0.21	*	**0.96**	-0.13	0.15
	Thymus pulegioides	0.85	-0.31	**	0.50	-0.36	***	**-**	-	**-**
	Viola canina	0.02	-0.08	0.42	**1.33**	-0.36	***	**2.16**	-0.57	***

The species showing no considerable reaction are: *Achillea millefolium, Alchemilla vulgaris, Anthoxanthum odoratum, Campanula patula, Cerastium holosteoides, Chrysanthemum leucanthemum, Cynosurus cristatus, Hypochaeris radicata, Leontodon autumnalis, Lotus corniculatus, Myosotis nemorosa, Plantago lanceolata* and *Tragopogon pratensis*.

The infrequent species are: *Cardamine pratensis, Euphrasia rostkoviana, Festuca pratensis, Galium album, Heracleum sphondylium, Minuartia verna, Ophioglossum vulgatum, Ranunculus polyanthemos, Ranunculus bulbosus, Rhinanthus minor, Sanguisorba minor, Traunsteinera globosa, Trifolium montanum* and *Trollius europaeum.*

Altogether, twenty four species reacted to fertilization with a significant negative correlation, including *Arnica montana, Gymnadenia conopsea, Gentianella lutescens, Botrychium lunaria* and *Carlina aucalis.*

Nearly all were light demanding and typical of oligotrophic grasslands under extensive management. The uppermost species weight amounted to 3.7 and was investigated for *Nardus stricta* in the Violo declinatae-Nardetum. This species exhibited a significant negative (-0.59***) reaction to combined fertilization. Additionally, *Plantago media, Luzula campestris, Polygala vulgaris, Potentilla aurea* and *P. erecta* also had high species weights and revealed a considerable negative reaction to all fertilizer treatments. The majority reacted most strongly to mineral fertilization, whereas *Festuca rubra, Leontodon hispidus, Prunella vulgaris* and *Hieracium aurantiacum* revealed a greater reduction on manure fertilized plots.

Mineral fertilization of the *Festuca rubra-Agrostis capillaris* community brought about a considerable increase in the proportion of grasses. The tall grass *Trisetum flavescens* showed the greatest increase with a species weight of 2.6. Herbs such as *Rumex acetosa, Ranunculus acris, Taraxacum officinale, Crepis biennis* and *Pimpinella major* also profited from the improved nutrient regime. *Trifolium pratense* and *T. repens* had high species weights on the first PRC axis (-2.04 and 1.25) and revealed a significant positive correlation with manure fertilization.

DISCUSSION

The changes observed in the experiments presented relate to short term fertilization trials over a period of only four years. This may be too brief to determine the main trends in vegetation change and the relationship between productivity and species richness (Bakker et al., 1996; Symstad et al., 2003). However, grasslands are extremely sensitive to changes in environmental conditions and respond to such alterations rather quickly (Herben and Huber-Sannwald, 2002). To determine the start of community recovery, a significance test within a PRC analysis indicates the point in time at which differences between a fertilizer treatment plot and the control plot cease to be statistically significant (van den Brink and ter Braak, 1999). The Monte Carlo permutation tests signify that in the case of most of the fertilization treatments changes in species composition were significant in the fourth year of observation. In some cases changes were already evident in the third year, with the vegetation reacting rather quickly.

Productivity and plant species richness

Nitrogen supply is known to greatly affect biomass and floristic change, whereas manure fertilization is characterized by a slow release of nutrients and benefits an increase in soil organic matter with residual effects (Schilling, 2000). As a consequence, the manure fertilized plots achieved nearly the same yield potential as mineral fertilized plots by the time of the fourth application. As was expected, and has already been described in other experimental studies (Willems et al., 1993; Kopeć, 2002; Aude, 2004; Silvertown, et al. 2006), the species richness decreased with the fertilization intensity, whereas the productivity increased. The main factor which is involved in the species decline is the increasing competition for light. Tall, fast growing plant species close to the canopy, thereby excluding slower-growing and smaller or light demanding species from the community. Nevertheless, explanations of the relationship between species richness and productivity have been controversially discussed (Schmid, 2003) and often interpreted in the context of a hump-shaped relationship with a peak in richness at a low to intermediate level of productivity (Grime, 1973; Al-Mufti et al., 1977; Waide et al., 1999; Mittelbach et al., 2001). The experimental studies presented here provided no evidence for this widely accepted unimodal model of species richness-productivity levels. In dependence of the range of productivity sampled, the detected negative relationship may also be simply a part (decreasing phase) of the unimodal shape (Rosenzweig and Abramsky, 1993). The short observation period in the present study affects the results as well. Gough et al. (2001) argued that hump-shaped relationships are the result of long term processes. An insufficient range of productivity levels prevented the detection of the curve peak resulting in a positive or negative relationship. In addition, the out-competing of some species following fertilizer addition may be faster than the colonization of new species that are well adapted to the higher nutrient status (Mittelbach et al., 2001).

Fluctuation and succession

Several species exhibited a pronounced yearly and seasonal dynamic, especially for annuals such as *Linum catharticum, Rhinanthus minor* and *Gentianella lutescens*. Possible causes were the underground and aboveground disturbances (weather conditions, grazing, trampling, etc.), different plant life cycles and intra-specific competition for space and resources. As a result, natural fluctuation occurs in combination with successional change (Rosén, 1984; Stampfli, 1992; Rabotnov, 1995; Kammer, 1997) and covers the underlying effects of fertilization.

The present PRC results demonstrated that higher fertilization regimes caused a successional process with a shift in species composition and the establishment of other plant communities. After three years of fertilization with 100 kg/ha NPK the Violo declinatae-Nardetum community changed significantly and was replaced by a *Festuca rubra-Agrostis capillaris* meadow. The acidophilous species *Nardus stricta* was greatly reduced under both mineral and manure fertilization regimes. Even the first application in the year 2001 was sufficient to reduce the cover of *Nardus* by around 70%. Examples of long term fertilizer experiments on a Nardetum site were presented by Dähler (1992) and Schellberg et al. (1999). They also investigated an increase of *Festuca rubra* and *Agrostis capillaris*, together with *Trifolium repens, T. pratense* and *Trisetum flavescens.* Clear changes were still noticeable even forty years after the last fertilizer application (Hegg et al., 1992).

Fertilization levels of 100 - 150 kg NPK ha^{-1} changed the *Festuca rubra-Agrostis capillaris* meadow to a Polygono-Trisetion type. Mineral fertilisation with 150 kg NPK ha^{-1} prompted an increase of 30% in the proportion of the grasses, dominated by *Agrostis capillaris* and *Trisetum flavescens*. The tall fodder grass *Trisetum flavescens*, in particular, became an increasingly dominant component of the aboveground biomass, and the species number declined to a total of 26 per m². Nearly all species representing oligotrophic grassland communities were suppressed. With manure fertilization, the amount of legumes increased by up to 45%. *Trifolium* species formed a dense canopy in the middle layer of the sward. This accumulation of biomass, especially when dominated by herbs, may lead to unfavorable light conditions, near or below the light compensation point of some species (Aude, 2004).

Nutrient enrichment leads to higher productivity but it does not have a negative influence on the species richness of grasslands in any case. A relatively low fertilizer input (10 t manure ha^{-1}, 50 kg NPK ha^{-1}) and combined fertilization with '10 t manure ha^{-1} + 50 kg NPK ha^{-1}' and '10 t/ha manure + 100 kg NPK ha^{-1}' barely changed the initial plant community. Briemle (2006) investigated a twenty year fertilization experiment established on a species-rich calcareous (brome grass) grassland. He found that the highest botanical diversity developed with low mineral fertilization and not, as might be expected, without any fertilization whatsoever. Also, the Park Grass Experiment (Silverton et al., 2006) implied that whilst large applications of farmyard manure can reduce botanical diversity, it is possible to maintain a diverse sward through appropriate levels of farmyard manure application. The management of species-rich extensive grassland under a two-cut system may require a certain level of nutrient input depending on the vegetation type and environment (Schellberg et al., 1999). Crofts and Jefferson (1994) suggested applying 20 t manure ha^{-1} in one dressing every three to five years on grasslands with a high nature conservation value. Annual rates of application should be guided by past practice but should not exceed 12 t ha^{-1}. However, the provision of a clear recommendation based on the amount of manure used in the past is difficult due to a lack of available data (Simpson et al., 1996). The nutrient content and its availability is variable and will depend on manure type, livestock diet, storage conditions, age and application time and method. Also specific conditions at sites can alter the level needed. In some circumstances, for example, where grassland is already semi-improved, the continued use of existing low levels of mineral fertilizer (less than 50 kg NPK ha^{-1}) may be acceptable (Brinkmann, 2006).

GENERAL CONCLUSIONS

The continued existence of grassland management in mountain areas depends mainly on the implementation of measures improving the economic circumstances of the farmers. From the agriculture perspective, better management techniques and an efficient use of natural resources (storage and application of farmyard manure, mowing dates, harvesting techniques) are necessary, whereas in terms of nature conservation, the grassland types with a high natural value, especially the Natura 2000 habitats, should be maintained. The maintenance of these habitats has to be based on management strategies that mimic the management under which these grasslands have developed. Thus, a low fertilizer input with farmyard manure should be incorporated into management strategies, depending on the natural soil conditions and the intensity of land use (mowing, grazing). Organic farming and sustainable tourism may provide new economic opportunities, helping to maintain this unique landscape.

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THE MANAGEMENT OF OLIGOTROPHIC GRASSLANDS AND THE APPROACH OF NEW IMPROVEMENT METHODS

Florin PĂCURAR *, *Ioan ROTAR* *,
Nicoleta GÂRDA * and *Adriana MOREA* *

* University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Faculty of Agriculture, Department of Grasslands and Forage Crops, Calea Mănăştur 3-5, Cluj-Napoca, Cluj County, Romania, RO-400372, fpacurar@gmail.com, rotarioan52@yahoo.fr, nicoleta_garda@yahoo.com, adrianamorea@yahoo.com

KEYWORDS: Romania, Transylvania, Apuseni Mountains, traditional management, phyto-diversity, mulching, organic and mineral fertilization.

ABSTRACT

The performance of a traditional management on the grasslands in Apuseni Mountains has generated certain landscape elements, which give a peculiarity to this region. This way of use has created a high phyto-diversity on Gheţari - Poiana Călineasa Plateau in Gârda de Sus community. The rigorous knowledge of the traditional use management of oligotrophic grasslands is extremely important in order to maintain theses grasslands within the mountainous landscape and, implicitly, the high phyto-diversity which they shelter. It has been observed that the most frequently practiced maintenance activities are the following: gathering rocks, destroying anthills, fighting against wooden vegetation, controlling weeds and fertilization. The use system is mostly mixed (mowing and grazing), followed by grazing and, lastly, by mowing. Elaborating a calendar of oligotrophic grasslands' use is essential for actual and future actions of phyto-diversity conservation. Grasslands' mulching combined with organic and mineral fertilization could be viable solutions of sustainable use of the oligotrophic grasslands. The productivity of our grasslands - *Agrostis capillaris* with *Festuca rubra* is much reduced, and by applying technological inputs, no significant growths of dry matter yield can be noticed. The studied phytocenosis has a medium phyo-diversity, and, by applying technological inputs in the first year, no important changes are brought at the sward's level.

ZUSAMMENFASSUNG: Die Pflege nährstoffarmen Grünlands und die Herangehensweise mit neuen Verbesserungsmethoden (Transsylvanien, Rumänien).

Die Anwendung eines traditionellen Wiesenmanagements im Apuseni Gebirge führte zur Entstehung von Landschaftselementen, welche der Region eine spezielle Eigenart gewähren. Die traditionelle Art der Bewirtschaftung führte zu einer hohen Phytodiversität auf dem Platou Gheţari - Poiana Călineasa in der Gemeinde Gârda de Sus. Eine gründliche Kenntnis der traditionellen Bewirtschaftung dieser oligotrophen Wiesen ist besonders wichtig für ihre Erhaltung in der montanen Landschaft und implizit für die Aufrechterhaltung ihrer hohen Pflanzenvielfalt. Es wurde festgestellt, dass am häufigsten folgende Pflegemaßnahmen durchgeführt werden: das Sammeln der großen Steine, die Bekämpfung der Erdhügel, Bekämpfung der holzigen Vegetation und des Unkrautes und Düngung der Flächen. Die Nutzung der Offenlandflächen ist meistens gemischt (Mähwiese und Weide), gefolgt von ausschließlich beweideten Flächen und an dritter Stelle die ausschließlich gemähten Wiesen.

Die Aufstellung eines Zeitplans zur Nutzung der oligotrophen Wiesen ist besonders wichtig für die Planung sowohl der laufenden als auch der zukünftigen Maßnahmen zur Erhaltung der Phytodiversität. Das Mulchen kombiniert mit einer organischen und mineralischen Düngung könnte eine tragfähige Lösung für eine nachhaltige Nutzung des oligotrophen Grünlandes darstellen. Die Produktivität des Wiesentypus mit *Agrostis capillaris* und *Festuca rubra* ist sehr niedrig. Auch unter Anwendung von neuen Techniken (Mulchen mit kombinierter Düngung) konnte im ersten Jahr der Anwendung kein signifikanter Anstieg des Ertrages an Biomasse (Trockensubstanz) erzielt werden. Die Phytodiversität der untersuchten Flächen ist durchschnittlich und auch die Anwendung von Mulchen mit Düngung führte im ersten Jahr nicht zu wesentlichen Veränderungen in der Pflanzendecke.

REZUMAT: Managementul pajiştilor oligotrofe şi abordarea unor noi metode de îmbunătăţire (Transilvania, România).

Aplicarea mangementului tradiţional pe pajiştile din Munţii Apuseni a generat anumite elemente de landşaft care dau o particularitate regiunii. Acest mod de folosinţă a creat o fitodiversitate ridicată pe Platoul Gheţari - Poiana Călineasa, din comuna Gârda de Sus. Cunoaşterea riguroasă a managementului tradiţional de folosire a pajiştilor oligotrofe este deosebit de importantă în vederea menţinerii acestor pajişti, în cadrul landşaftului montan şi implicit a fitodiversităţii ridicate pe care o deţin. Se constată că cele mai frecvent practicate lucrări de îngrijire sunt următoarele: strângerea pietrelor, combaterea muşuroaielor, combaterea vegetaţiei lemnoase, combaterea buruienilor şi fertilizarea. Sistemul de folosire este de cele mai multe ori mixt (cosit şi păşunat), urmat de păşunat şi, în ultimul rând, de cosit. Întocmirea unui calendar de folosire a pajiştilor oligotrofe este esenţială pentru acţiunile actuale şi viitoare de conservare a fitodiversităţii. Mulcirea pajiştilor combinată cu fertilizarea organică şi minerală pot fi soluţii viabile de folosire sustenabilă a pajiştilor oligotrofe. Productivitatea pajiştii noastre de *Agrostis capillaris* cu *Festuca rubra* este foarte redusă, iar prin aplicarea inputurilor technologice nu se constată sporuri semnificative de recoltă de substanţă uscată. Fitocenoza studiată are o fitodiversitate medie, iar aplicarea inputurilor tehnologice din primul an nu aduc modificări importante la nivelul covorului ierbos.

INTRODUCTION

The grasslands' way of use has implications in productivity, species composition and in the obtained forage quality. In many studies performed on grasslands (especially on the oligotrophic ones) the grasslands management, most of the times, is being ignored and, this actually being the factor that has generated the present status. The management is the one that is creating and maintaining a high phyto-diversity, but it could dramatically reduce it in a short period of time. Recent studies performed by Reif et al. (2005), support this affirmation, revealing that the phyto-diversity of grasslands ecosystems from the Gheţari - Poiana Călineasa Plateau, Gârda de Sus commune, Apuseni Mountains (the study area) is very rich and is due to the traditional management applied for a long period of time. A negative example of fast decrease of phyto-diversity is given by Păcurar (2005), showing that by applying 100 N 50 P_2O_5 50 K_2O (kg/ha) fertiliser, during eight years, the phyto-diversity has considerably reduced (17 plant species have disappeared).

The consequences of the use manner go even further - by the aesthetics of the mountainous cultural landscape. By not applying a traditional management in our study area, it would lead towards the disappearance of numerous landscape elements (piles of rocks, wooden fences, solitary trees etc.), fact that it will considerably deteriorate the peculiarity of the mountainous cultural landscape. Its alteration would generate a remarkable decrease of the area's tourism potential. Pflimlin and Todorov (2003) states that the agrotourism is a possibility to enhance the incomes of the farms situated in mountains like Tatra, Balkans, Tyrol, Carpathiens etc. The activities diversification of the farms took place after imposing the milk quota, when many farms, especially the ones in mountainous areas, had started to practice tourism as a secondary activity. In the French Alps and Pyrenees, 65% of the summer pastures are crossed by walk paths which serve the agrotourism and ecotourism, with shelters built for tourists, and 15% of them serve for skiing activities. Also, on these grasslands, hunting is performed (Parquedu et al., 2003). The species rich grasslands with various combinations of colours play an essential role in landscape's aesthetics and create a special appearance for it. The colours combinations in natural grasslands, at all levels (from lowland to mountains) are vital signs for a healthy environment (Rotar, 2003).

The lack of management (grasslands' abandonment) induced by the depopulation of mountainous areas, has also negative effects upon the phyto-diversity and, implicitly, upon the landscape. The respective areas will become afforested and the mountainous cultural landscape will become a "forest". Similar situations happened also in countries of European Community, for example in Switzerland, during 1985 - 1995, 4% of the country's grassland area has suffered afforestation (Jeangros and Thomet, 2004). The abandonment of the grassland areas in Italy has induced areas' afforestation and, implicitly, the decrease of species biodiversity (Lombardi et al., 2001; Sabatini et al., 2003; Susan and Ziliotto*,* 2004). The same issue was point out by Biala and Zyszkowska (2004) in Poland, Hejcman et al. (2004) in Czech Republic. In our research area, the population of Ghețari - Poiana Călineasa Plateau has 2,418 inhabitants in 1956, diminishing down to 1,478 inhabitants in 2001 (Wehinger et al., 2005).

After all these, we can state that the secondary grasslands are strongly related to the way of use and, very easily, they can be "driven" by an extreme to another (abandonment - intensive exploitation). That is why, is extremely important to elaborate some "recipes" for the ways of use in order to maintain the secondary natural grasslands within the mountainous cultural landscape. The traditional way of grasslands use is the one that generated a high phyto-diversity and certain landscape elements which offer the peculiarity to the cultural landscape, but this type is less studied. There are different publications which describe the traditional management but most of them are not rigorous studies, but some conclusions drawn by some "tourists" who spent a few days in a certain place, and, in consequence, they have a high degree of partialism.

In order to make a description of some grasslands' traditional way of use, first of all, it needs a long period of time assigned to this action, than a proper questionnaire and a suitable ability to communicate with the locals.

The objectives of this paper are the following: describing the management applied on the oligotrophic grasslands from Ghețari - Poiana Călineasa Plateau; elaborating a calendar of oligotrophic grasslands use based on the obtained results; approaching some new methods for using the oligotrophic grasslands in order to improve the traditional management.

MATERIALS AND METHODS

Our research activity was performed in Gârda de Sus commune from the Apuseni Mountains. The description of the management applied on oligotrophic grasslands was performed by using a questionnaire, which contains 79 questions and it was applied to 83 landowners. The questionnaire contains questions concerning the way of performing the maintenance activities and the grasslands' way of use. The questionnaire's application was performed in 2005 - 2006 during winter and in spring of 2006. The experience has been placed in 2009 at 1,320 m elevation, using randomized blocks method with seven variants in five repetitions. Species studies had been performed using modified Braun-Blanquét method, and the mowing was done at *Poaceaes* blooming using a spinning mowing machine. Data processing and interpretation was made using variance analysis.

RESULTS AND DISCUSSIONS

All these landscape elements are the result of traditional management's application for a long time. The exploitation system of pastures and hay meadows is rather complex because implies, besides exploitation and maintenance works, locals' seasonal moving towards Călineasa communal pasture. The exploitation system of grasslands begins early in the spring with an extensive grazing around farmsteads. Then, at the end of May, the locals move with the animals on Călineasa communal pasture where they stay until the beginning of July. In July, they return to the village to mow the grasslands in their property. This activity lasts for approximately one month, and at the beginning of August, the locals, along with the animals, return to the communal pasture, where they remain until the conditions become proper for grazing. The majority of the questioned landowners have plots of land for over 20 years (60 positive answers out of 83) (to spare writing space we will further express ourselves more simple in answers interpretation, for example 60 out of 83). The maintenance works applied on grasslands are the following: gathering rocks, destroying anthills, fighting against wooden vegetation and weeds, fertilization and others (Tab. 1). Most frequent maintenance activities are rocks gathering (85.5%) and fertilization (80.3%). All maintenance works are manually performed with different tools, and, for fertilisation, animal traction carts are being used (horses). Grasslands' fertilization is only organic (60 out of 60), generally with stable manure having six months of existence (57 out of 60), coming from cattle and horses (59 out of 60).

Table 1: Status of maintenance works application.

Question	Answering possibilities	Answers (number)	Answers (%)
What kind of maintenance works do you apply on grasslands?	Rocks gathering	65	85
	Anthills destroying	52	68
	Wooden vegetation fighting	46	60
	Weed fighting	21	27
	Fertilization	61	80
	Others	11	14
Total		76	100

Information regarding the applied manure quantity was obtained, but they are not real, because the locals never weigh the manure and can neither estimate it. After spreading, the manure is broken up by a “harrow”. This harrow is a fir tree with rocks on it and it is drawn by a horse. The unbroke manure is gathered by rake and placed in piles (47 out of 60). Grasslands are mostly used through a mixed way (mowing and grazing) or only through grazing (Tab. 2). The mowing is performed usually manually (62 out of 63), the starting moment is established according to the calendar date (60 out of 63). The mowing height is 2 - 3 cm (25 out of 63) or scraped (22 out of 63). In general, grasslands are manually mowed (44 out of 63) and one yield per year is obtained (58 out of 63). The grass is dried on the soil (62 out of 63) and the dry matter yield could never been estimated by landowners.

Table 2: Grasslands way of use.

Question	Answering possibilities	Answers (number)	Answers (%)
How do you use the meadow?	Grazing	20	24
	Mowing	2	2
	Mixed	61	74
Total		83	100

Regarding the grazing, the moment to begin this activity is randomly established (57 out of 81) and rarely depending on the grass’s height (17 out of 81). The grazing activity stops at winter season coming (54 out of 81). Based on the questionnaire results’ interpretation and also on other previous studies regarding the traditional management, a calendar was elaborated with oligotrophic grasslands’ use on the Gheţari - Poiana Călineasa Plateau. The result is summarized and documented as a seasonal work plan (Tab. 3).

The management of oligotrophic grasslands assumes a considerable contribution of human and animal energy through the activities performed manually or with the help of horses’ force. Considering that the local population is rather old, soon the oligotrophic grasslands will be abandoned. The traditional management must be improved in the way that the oligotrophic grasslands and their biodiversity are maintained. A solution might be the grasslands’ mulching combined with organic and mineral fertilization.

The productivity of the respective meadow is very low, situation which explains one of the reasons for the abandonment of oligotrophic grasslands in the area. The low DM (dry matter) yield can be explained through the reduced quantities of rainfall from spring and, of course, through the reduced trophicity of the soil. The effect of mineral fertilisers’ application upon our grassland is very poorly felt at the level of the DM’s level (Tab. 4). Even if in some treatments’ case a weak yield rising is noticed, the differences do not have statistic insurance. The same situation is seen also in the case of organic fertilisers’ application (Tab. 5).

Table 3: Seasonal work plan for oligotrophic grasslands.

	Month	Activity	Execution	Observations
Spring	March (the end)	Fertilisation	For transport horse carts are used. Spreading is manually performed. The stable manure quantity applied on *Arnica* meadows is smaller than the one that is applied on meadows that are more productive.	The fertilizer quantities differ very much. The majority of landowners fertilize in spring (38 answers out of 60 possible ones, the others do not fertilize the land). In general, the stable manure is from cattle and horses. It is six months old and mixed with saw dust from wood processing and dried beech leaves which are used as litter in the stables. The manure is spread manually from small piles deposited by horse and cart.
	April	Gathering rocks	Manually	The rocks are frequently deposited in piles at the site's margin.
	April	Destroying anthills	Manually	In general, the anthills are destroyed in spring and rarely in autumn and summer by the landowners. This activity is only manually performed, using different tools: hoe, harrow, plough drawn by horses etc.
	April	Controlling wood growth	Manually	Mostly *Salix caprea, Sorbus aucuparia* and *Prunus spinosa* are eliminated.
	April	Crushing applied manure	A horse drags a branch, on which rocks are fixed to make it heavier.	This work is performed generally one week after the manure has been applied (valid for the ones that fertilize in spring). The crushing of manure applied in autumn is performed in spring. Rain determines when work starts.
	April	Gathering uncrushed remnants and beech leaves	Manually by rake	The gathering of uncrushed remnants is generally performed not later than one month after crushing. The uncrushed remnants are deposed in a pile on the area on which they have been gathered. Simultaneous with remnants, the dry beech leaves are gathered.
	May	Weeds fighting	Manually with scythe, reaping with hock and knife	In general, the following species are eliminated: *Colchicum autumnale, Veratrum album, Pteridium aquilinum* and *Arctium lapa*. This work is done regularly by only a quarter of the respondents (21 out of 83).
	May	Repairing damages caused by wild boars	Manually by hock or rake	The biggest damage is done on meadows. This work is done along the entire year as many times as necessary.
	May	Grazing	-	Some grasslands are grazed only in spring and in autumn (22 of 78 answers) others are grazed from spring to autumn (10 of 78 answers)) and others only in autumn (38 out of 78 answers). The grazing is generally done by cattle and horses. Grazing starts randomly.

	Month	Activity	Execution	Observations
Summer	July-August	Mowing of meadows	Manually	The oligotrophic meadows are mown at the most once per year at the end of the mowing period. Firstly, the locals cut productive meadows, and then the less productive ones are cut. The mowing height is very low (2-3 cm above soil). The grassland remains sometimes un-mown. The reasons for this are: -the grass is not needed because the locals have already enough from sites that are more productive; -the productivity of the grassland is too low to take the effort to cut it; -the owners didn't manage to cut the grass in time; -the owners are too old to do the exhausting job.
	July-August	Drying grass	Manually	The grass is dried on the surface. This method has a great disadvantage; the nutritional value of hay is quickly lost. The drying time of grass depends very much on the climatic conditions. It is very different from one area to another and less productive meadows have shorter drying times than more productive meadows.
Autumn	September-October	Grazing	-	The grazing is generally performed in autumn, when animals return from the communal pasture (38 out of 78 answers). The grazing animals are generally cattle and horses. The starting point is random. The grass's height is about 5 and 10 cm (estimated by owners). When winter (snow) comes, the grazing stops.
	October	Hay transport	By horse carts	After returning from the communal pasture, the hay is transported and deposited either in sheds, or in large hay stacks.
	October-November	Fertilization	The manure is transported by horse carts and spread manually. Oligotrophic meadows are typically less fertilised than the other meadows.	The quantities of fertilizer differ very much. Some grassland owners administer the manure in autumn (31 out of 60 possible ones). After the transport, the manure is spread or deposited into piles. In spring, it is distributed on the surface and later crushed.

Table 4: The influence of mineral fertilizers on the dry matter yield (2009).

Year	Variant	DM t/ha	%	Difference	Significance
2009	Witness	0.34	100	0.0	-
	Mulching 1/year	0.45	130.2	+ 0.10	-
	Mulching 2/year	0.35	101.7	+ 0.01	-
	Mulching 1/year + NPK 25:25:25 (annual)	0.44	127.3	+ 0.09	-
	Mulching 1/year + NPK 25:25:25 (1/2years)	0.27	78.5	- 0.07	-
	Mulching 1/year + PK 25:25 (annual)	0.31	89.5	- 0.04	-
	Mulching 1/year + PK 25:25 (1/2years)	0.19	54.1	- 0.16	-

DL(p 5%) + 0.22 DL(p 1%) + 0.30 DL(p 0.1%) + 0.40

Table 5: The influence of mineral fertilizers on the dry matter yield (2009).

Year	Variant	DM t/ha	%	Difference	Significance
2009	Witness	0.83	100	0.0	-
	Mulching 1/year	0.67	80.7	- 0.16	-
	Mulching 1/ year + 5t/ha manure	0.94	113.2	+ 0.11	-
	Mulching 1/ year + 5t/ha manure 1/2 years	0.7	84.3	- 0.13	-
	Mulching 1/ year + 10t/ha manure 1/2 years	0.68	81.9	- 0.15	-
	Mulching 1/ year +10t/ha manure 1/3 year	0.86	103.6	+ 0.03	-
	Witness	0.83	100	0.0	-

DL(p 5%) + 0,26 DL(p 1%) + 0,36 DL(p 0.1%) + 0.48

As result of technological inputs administration, there were no changes recorded at the level of the treated variants' canopy. That is why, we propose to characterise the species composition of the untreated witness in all five repetitions of the experience (Tab. 6). The vegetation type of the witness is *Agrostis capillaris - Festuca rubra*. The plants from Poaceae family range in cover from 29.25 up to 47.75%. The cover of species *A. capillaries* is ranging between 11.25 and 27.5%, and the one of the species *F. rubra* is 17.5% in all five repetitions. Also, the persistence (K) of the species is minimum (V). Besides these two Poaceaes, *Anthoxantum odoratum* is also present, but with a smaller cover ranging from 0.5 to 2.75%. This species occurs in four out of the five relevees. The Cyperaceaes and Juncaceaes are poorly represented (*Luzula campestris* - 0.5%). The Fabaceaes have a quite reduced presence being represented by *Trifolium pratense* (cover: 0.5%, K = I) and *T. repens* (cover: 0.5 - 2.75%, K = II). The plants from other botanical families (OBF) have a cover ranging from 41 up to 51.25%. Among these, a few species that are present in all five repetitions can be noticed, like: *Pimpinella major, Plantago lanceolata, Rhinanthus minor, Trollius europaeus, Viola canina,* having in general a low cover - aprox. 2.75%. Certain OBF plants are present in four out of the five repetitions: *Arnica montana*, *Centaurea mollis*, *Euphrasia stricta*, *Hieracium aurantiacum*, *Hypericum maculatum*, etc., and some species occur only accidentally (K = I, II) such as: *Centaurea pseudophrygia, Cirsium erisithales*, etc.

The number of species of the studied phytocenosis is ranging from 20 up to 24. The Shannon index values are comprised between 2.079 and 2.469, fact that corresponds to a medium phyto-diversity according to some specialists.

Table 6: The species composition of the witness in five repetitions of the experience.

Repetitions	R1	R2	R3	R4	R5	Persistence
Cover %	85	86	85	82	88	
Species %						
Poaceae	29.25	45.5	45	37.75	47.75	-
Agrostis capillaris	11.25	27.5	27.5	17.5	27.5	V
Anthoxanthum odoratum	0.5	0.5		2.75	2.75	IV
Festuca rubra	17.5	17.5	17.5	17.5	17.5	V
Cyperacee and Juncaceae	0.5	-	-	-	-	-
Luzula campestris	0.5					I
Fabaceae	-	-	3.25	0.5	-	-
Trifolium pratense			0.5			I
Trifolium repens			2.75	0.5		II
Other Botanical Families	51.25	42.25	41	45.5	46.25	
Alchemilla vulgaris		2.75	2.75		5	III
Arabis hirsuta		0.5	0.5		0.5	
Arnica montana	27.5		0.5	5	0.5	IV
Centaurea mollis	2.75	0.5		2.75	0.5	IV
Centaurea pseudophrygia				5		I
Cirsium erisithales				0.5		I
Leucantheum vulgare				0.5		I
Euphrasia stricta	0.5	0.5	0.5	0.5		IV
Gallium mollugo				0.5		I
Genistella sagittalis	0.5					I
Gentianella lutescens			0.5	0.5		II
Hieracium aurantiacum	0.5	0.5	2.75		2.75	IV
Hypericum maculatum		5	0.5	0.5	5	IV
Knautia dipsacifolia	0.5			2.75		II
Linum catharticum		0.5	0.5			II
Pimpinella major	2.75	2.75	2.75	2.75	5	V
Plantago lanceolata	0.5	2.75	0.5	2.75	2.75	V
Plantago media	0.5					I
Polygala comosa			0.5		0.5	II
Potentilla erecta	2.75					I
Primula veris					0.5	I
Ranunculus bulbosus		0.5	2.75	0.5	0.5	IV
Rhinanthus minor	0.5	5	2.75	2.75	11.25	V
Rumex acetosa		0.5	0.5	0.5	0.5	IV
Scabiosa columbaria	0.5			0.5		II
Silene nutans		0.5	0.5			II
Stellaria graminea		0.5	0.5	0.5		III
Trollius europaeus	2.75	5	11.25	5	5	V
Thymus pulegioides	5	11.25	5	11.25		IV
Vaccinium myrtillus	2.75					I
Veratrum album	0.5				0.5	II
Veronica chamaedrys		2.75	2.75		2.75	IV
Viola canina	0.5	0.5	2.75	0.5	2.75	V
Number of species	21	21	24	24	20	
Shannon Index	2.095	2.079	2.311	2.469	2.290	

CONCLUSIONS

The management applied on oligotrophic grasslands from Gârda de Sus commune is a traditional one. The maintenance activities are only manually performed, among them the fertilisation with stable manure being the most important one. The most frequent using system is the mixed one. Application of organic and mineral fertilisers in the first year of experiences placing was not noticed at the level of DM yield. The grassland type of the untreated witness is *Agrostis capillaris - Festuca rubra*. The species diversity of the studied phytocenosis is medium, and the number of species ranges from 20 up to 24.

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PRELIMINARY DATA UPON THE AQUATIC OLIGOCHAETA COMMUNITIES IN THE UPPER SECTOR OF ARIEŞ RIVER (TRANSYLVANIA, ROMANIA)

Diana CUPŞA *

* University of Oradea, Faculty of Sciences, Department of Biology, Universităţii Street 1, Oradea, Bihor County, Romania, RO-410087, dcupsa@uoradea.ro

KEYWORDS: Romania, Transylvania, Arieş River, macrozoobenthos, aquatic Oligochaeta, human impact.

ABSTRACT

The present study represents an inventory of the aquatic Oligochaeta form the upper basin of the Arieş River, with the aim of characterizing the community formed by these organisms, important components of the macrozoobenthos, and the determination of the environmental conditions which influence their spreading. During our study we have determined the species inventory, the abundance, frequency and constancy, the diversity and evenness indexes. As a result of the statistic analysis we found out that in the sector near the spring a small number of species of oligochaeta have settled because the lack of the trophic base, an increasing in the species number at the following sample sites as a result of the emergence of the sediments in the waterbed which offer good trophic condition to the oligochaeta. The community is characterized by low diversity and stability because this river sector undergo frequent variations of water level and flow because of the abundant precipitations which occur periodically, variations determining a strong wash out of the river substratum and the removal of the benthic invertebrate communities.

RĖSUMĖ: Données préliminaires sur les communautés d'oligochètes aquatiques du secteur supérieur de la rivière d'Arieş (Transylvanie, Roumanie).

La présente étude représente un inventaire de la forme aquatique d'oligochètes le bassin supérieur d'Arieş rivière, dans le but de la caractérisation de la communauté constituée par ces organisations, composants importants des macrozoobenthos, et la détermination des conditions environnementales qui influencent leur propagation. Pendant notre étude nous avons déterminé l'inventaire d'espèces, l'abondance, fréquence et constance, la diversité et des index de régularité. En raison de l'analyse de statistique nous avons découvert que dans le secteur près du ressort un petit nombre d'espèces d'oligochètes ont arrangé parce que le manque de la base trophique, une augmentation dans les espèces numérotent aux emplacements suivants témoin en raison de l'apparition des sédiments dans waterbed qui offrent le bon état trophique à l'oligochètes. La communauté est caractérisée par basses diversité et stabilité parce que ce secteur de fleuve subissent des variations fréquentes de niveau d'eau et coulent en raison des précipitations abondants qui se produisent périodiquement, des variations déterminant un lavage fort hors du substrat de fleuve et le déplacement des communautés invertébrées benthiques.

REZUMAT: Date preliminarii asupra comunităților de oligochete acvatice din sectorul superior a râului Arieş (Transilvania, România).

Acest studiu reprezintă o inventariere a speciilor de oligochete acvatice din bazinul superior al Arieşului, pentru caracterizarea acestor comunități, componente importante ale macrozoobentosului şi a precizării condițiilor de mediu, care le influențează răspândirea. S-a urmărit determinarea inventarului de specii, a abundenței, frecvenței şi constanței, indicilor de diversitate şi echitabilitate. Ca urmare a acestor analize statistice s-a constatat că în sectorul apropiat izvorului există un număr mic de specii de oligochete, datorită lipsei unei baze trofice adecvate, şi creşterea numărului de specii în stațiile următoare ca urmare a apariției în apă a sedimentelor, care oferă condiții de hrănire oligochetelor. Comunitatea este caracterizată prin diversitate şi stabilitate scăzută, deoarece acest sector de râu este supus variațiilor frecvente de nivel şi debit al apei, datorită precipitațiilor abundente periodice, variații care determină o spălare accentuată a substratului albiei şi îndepărtarea comunităților de nevertebrate bentonice.

INTRODUCTION

The macrozoobenthic communities of the aquatic basins differ depending riverbed, hydrological conditions and water quality. The structure of the macrozoobenthic community and of the oligochaetes community varies with the quality of the water (Cupşa, 1997; Cupşa, et al., 2002; Florea et. al., 2000; Popescu-Marinescu et al., 1980; Prunescu-Arion, 1969; Rogoz, 1969). The aquatic oligochaeta are an almost permanent component of the macrozoobenthos and consist from species adapted to different environmental conditions. Their community structure reflects very well the quality of the water and their modifications in species appear due to the variations in the water quality, nature of the riverbed and hydrologic regime.

MATERIAL AND METHODS

We made the study along the Arieş River in the upper sector which borders the south of the Apuseni Natural Park from the spring to the point where it leaves the park border. Here we search the aquatic oligochaeta in 5 sample sites. There were collected 3 samples from each site, in 25^{th} and 26^{th} of September 2005. The samples were preserved on field in 4% formalin. In the laboratory there were sorted and transferred in 70% ethylic alcohol under a 40X magnifying stereomicroscope. The species were determined under 400X magnifying microscope.

Pasul Vârtop (n-5) sampling site. The Arieş has the aspect of a small creek which flows through a swamp in a spruce forest. The filamentous algae and other indicators show an obvious domestic pollution, probably with residual water containing faecal residues from the cottages, hostels and the other constructions of the area. The general aspect is very bad for the expectations; very many dumps of different provenances in the riverbed and on the riverbanks. Many heap of dumps in the whole valley. GPS: 46,51504 N / 22,67394 E / h = 987 m.

Arieşeni (n-4) site. Mountainous river aspect, significantly smaller than downstream. In the riverbed there are boulders some rock fragments and gravels. Near the banks rough sand. The width is of aproximativelly 8 m, the maximum depth of 30 cm. Apparently not too many organisms are there and no tecton or deposits. GPS: 46,47550 N / 22,76219 E / h = 827 m.

Downstream Gârda de Sus (n-3) site. The minor riverbed is 10 - 15 m wide. Big rocks form small waterfalls alternating with calm flows, big boulders and rock fragments, moderate quantities of biotecton, many *Ancylus* specimens mainly near banks. Maximum depth less than 40 cm. General aspect better than downstream. GPS: 46,45704 N / 22,85077 E / h = 690 m.

Downstream Scărişoara (n-2) site. Slow flow but alternates with fast flowing sectors. In the riverbed rock fragments fallen from the slopes. Boulders covered by a lot of sediment especially inorganic, less biotecton. Much debris on the banks left by the high level water in the past. Width 10 - 12 m. GPS: 46,45069 N / 22,91739 E / h = 668 m.

Upstream Albac (n-1) site. The river comes out from a gorge with rocky walls. The flow is fast and the river is deep in some portions. Many boulders and rock fragments, depth of 0.75 m, width of 15 - 20 m. Very much biotecton. GPS: 46,45568 N / 22,94283 E / h = 643 m.

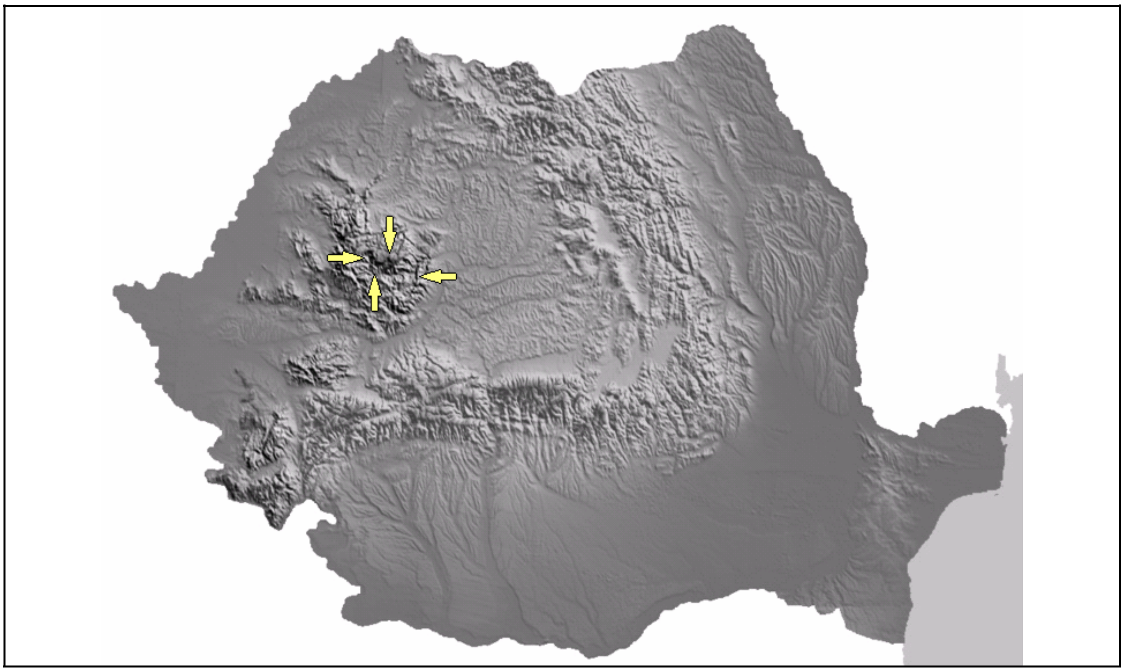

Figure 1a: The localization of the Apuseni National Park in Romania.

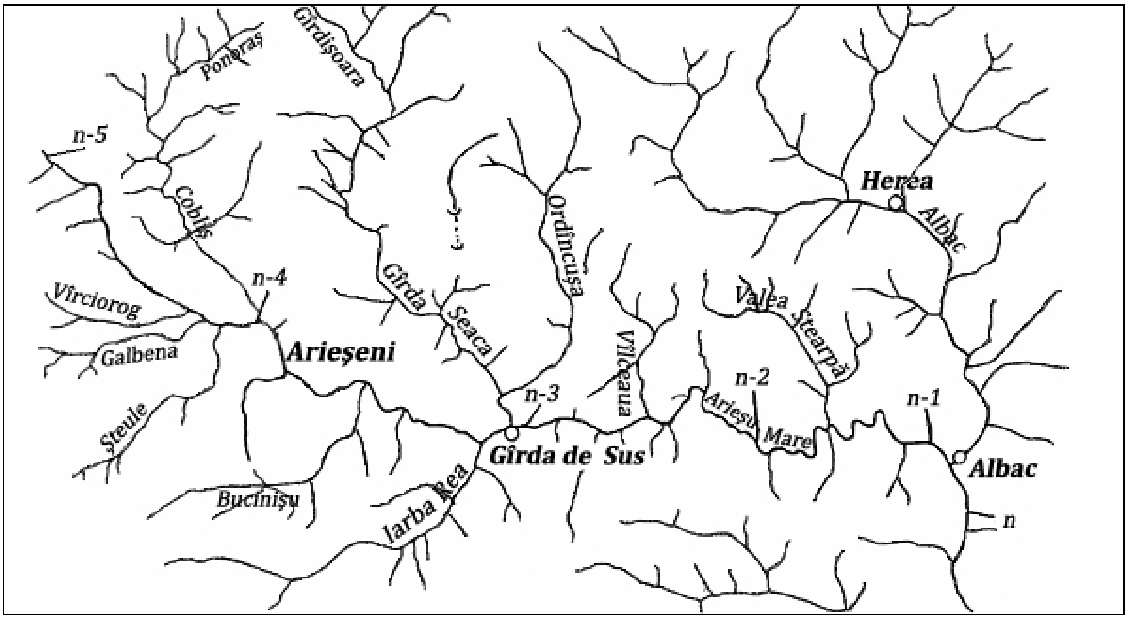

Figure 1b: The localization of the sampling sites along Arieş River.

Downstream Albac (n) site. Depths of 20 - 30 cm, width of 10 - 15 m, slow laminar flow. Riverbed with boulders covered by inorganic sediments but also detritus, respectively biotecton; sedimented sawdust under the banks. GPS: 46, 43777 N / 22,96714 E.

RESULTS AND DISCUSSIONS

In the six sampling sites we found a number of 16 species of aquatic oligochaeta from which 12 are Naididae, 1 Enchytreidae and 3 Lumbriculidae.

They are distributed in each sample site as follows:

At **n-5** sample site we found only one species *Spercaria josinae* with a small density of individuals. (Tab. 1, Fig. 2)

At **n-4** we found only *Nais simplex* with a small density also. In these two sample sites the small number of oligochaeta species and individuals is due to the small organic contents of the water and the rocky riverbed where the oligochaeta can't settle. This is a characteristic situation for all the mountainous portions of the rivers (Cupşa, 1998; Cupşa, 2000 a, b and c; Cupşa, 2002; Cupşa, 2006; Szito and Mozes 1997, 1999). So here only a small number of eurybiontic species can be found in small number. (Tab. 1, Fig. 2)

At **n-3** we found 6 species from which one is from family Tubificidae. Here the riverbed has some biotecton and regions of slow flow which allows the settling of the oligochaeta community and offer a scarce trophic base for them. (Tab. 1, Fig. 2)

At **n-2** we found the greatest number of species from all investigated sample sites (12). Here are sectors with slow flow and accumulations of organic substances in the riverbed, so the oligochaeta found better environmental conditions, they are not so easy washed away by the currents. (Tab. 1, Fig. 2)

At **n-1** and **n** the oligochaeta community consist of almost the same number of species 7 for **n-1** and 9 for **n**. Here the biotecton is present in a greater quantity and the flowing speed is slower, so the environmental conditions are better for the settlement of the oligochaeta community. (Tab. 1, Fig. 2)

Table 1: Relative abundances of the oligochaeta from the studied sample sites.

Species/sample sites	n-5	n-4	n-3	n-2	n-1	n
Pristina aequiseta	-	-	-	-	-	1.32
P. bilobata	-	-	-	-	-	2.64
Nais behningi	-	-	-	29.8	21.56	-
N. simplex	-	100	14.04	4.93	1.8	15.79
N. pseudoptusa	-	-	-	0.25	0.6	-
N. bretscheri	-	-	40.35	48.78	49.7	11.84
N. pardalis	-	-	24.56	7.64	22.16	61.84
N. elinguis	-	-	15.79	2.22	-	-
N. communis	-	-	-	2.22	2.4	1.32
N. variabilis	-	-	-	0.99	-	-
Spercaria josinae	100	-	-	1.23	-	1.32
Amphichaeta leydigii	-	-	1.75	-	-	1.32
Propappus volki	-	-	-	0.49	1.8	-
Rhynchelmis limosella	-	-	-	1.23	-	-
Trichodrilus strandi	-	-	-	0.25	-	-
Lumbriculus variegatus	-	-	3.51	-	-	2.64
Nr. of species	1	1	6	12	7	9
Shannon-Wiener index	0	0	1.466	1.434	1.276	1.26
Evenness	0	0	0.53	0.52	0.46	0.45

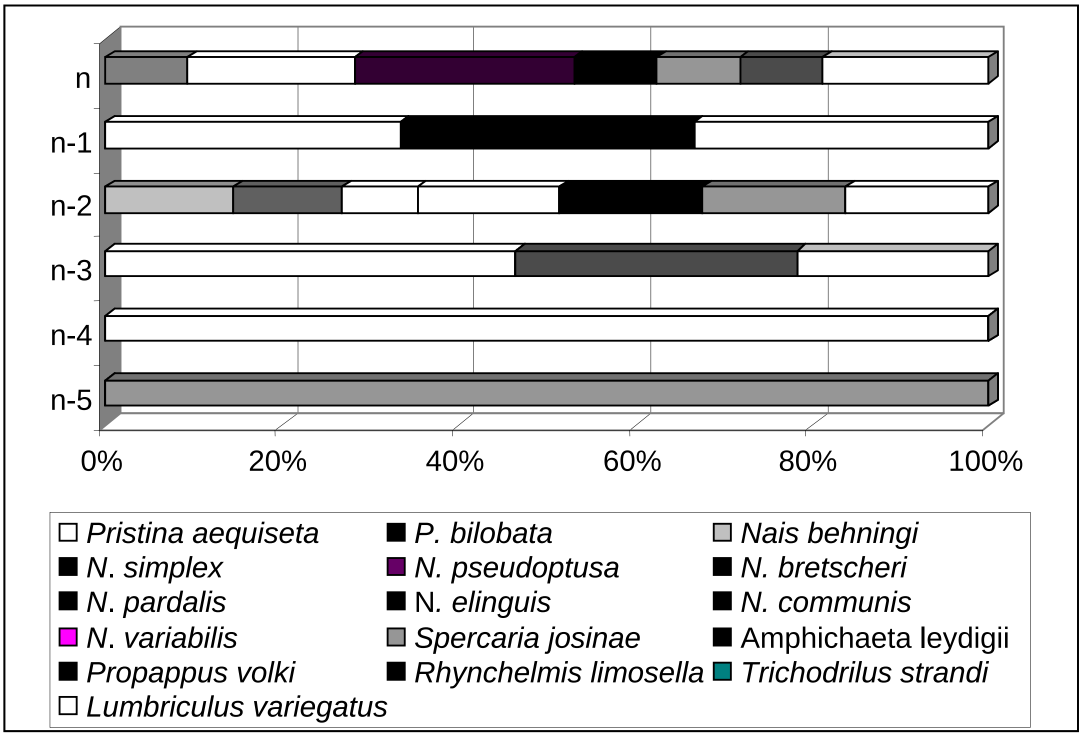

Figure 2: Relative abundances of the most abundant oligochaeta species from the studied sample sites.

In the investigated period none of the species are found in all sample sites, even if the environmental conditions in this river portion allow this fact (Tab. 2, Fig. 3). There is only one euconstant species *Nais simplex*, 4 constant species *Nais bretscheri, N. pardalis, N. communis, Spercaria josinae* and the rest are accidentally or accessory. This fact shows that the community is not very constant because here the water level varies a lot during the year together with the variation of the quantity of the precipitations. In spring when the snow is melting the water level is high and also during the summer and autumn periods often occurs heavy rains which wash the substratum with the benthic organisms. This is also the reason why there are differences between the species structure between different sample sites with similar environmental conditions.

Table 2: The frequency and constancy of the oligochaeta species.

Species/sample sites	F	C	Species/sample sites	F	C
Pristina aequiseta	16.66	accidentally	*N. communis*	50	constant
P. bilobata	16.66	accidentally	*N. variabilis*	16.66	accidentally
Nais behningi	33.33	accessory	*Spercaria josinae*	50	constant
N. simplex	83.33	euconstant	*Amphichaeta leydigii*	33.33	accessory
N. pseudoptusa	33.33	accessory	*Propappus volki*	33.33	accessory
N. bretscheri	66.66	constant	*Rhynchelmis limosella*	16.66	accidentally
N. pardalis	66.66	constant	*Trichodrilus strandi*	16.66	accidentally
N. elinguis	33.33	accessory	*Lumbriculus variegatus*	33.33	accessory

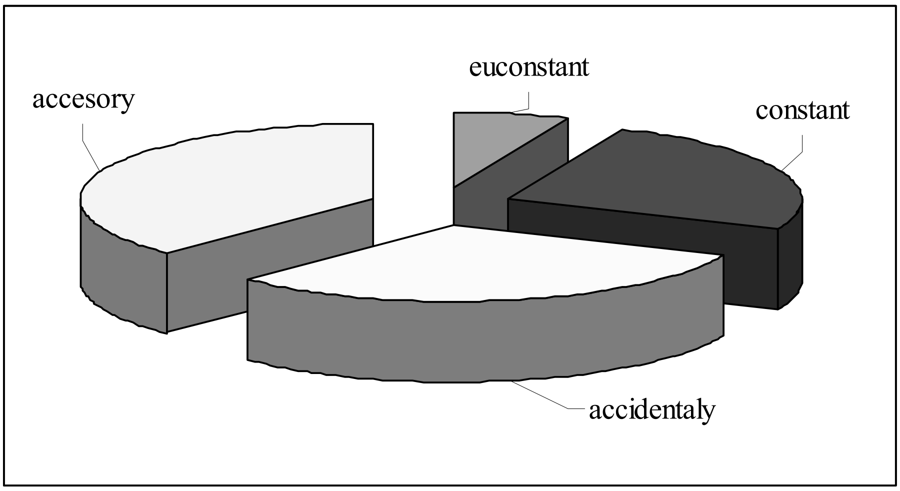

Figure 3: The proportion between different constancy categories.

The diversity index and the evenness have small values because of the small number of species and at the sample sites where are more species usually one has a high abundance and the rest have small abundances. (Tab. 1, Fig. 4).

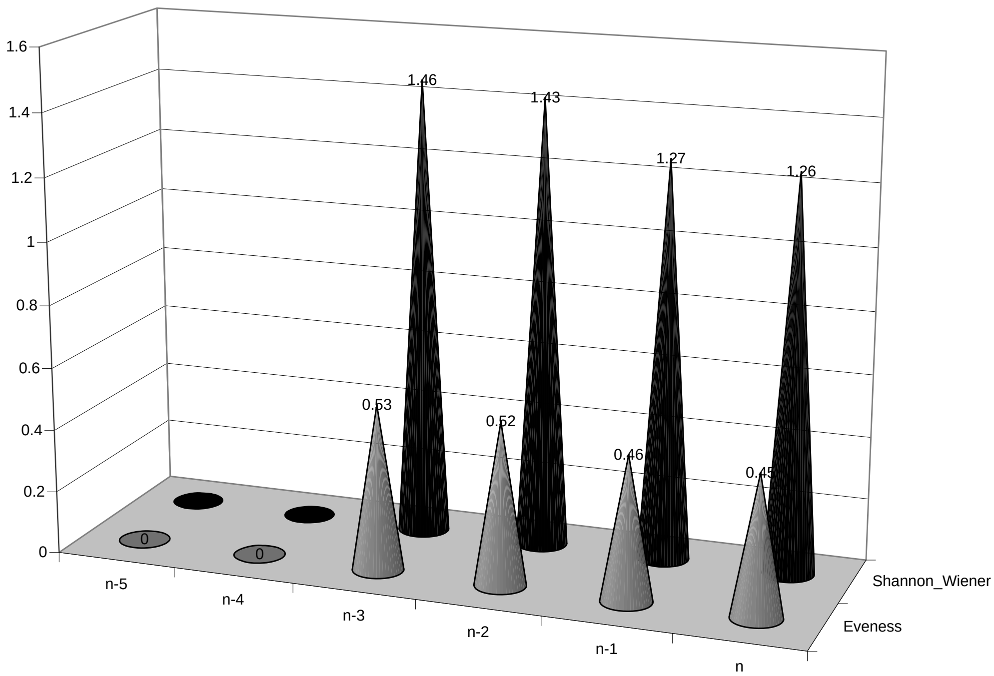

Figure 4: Shannon-Wiener diversity index and evenness.

The Whittaker index shows the greatest value between sample sites n-5 and n-4, but the values are very close to all pairs of sample sites. This fact shows that in the investigated area the differences between two pairs of sample sites are relatively high because of the small value of the index. (Sîrbu and Benedek, 2004). In the sample sites the environmental conditions are very similar, so the differences are caused by the instability of the communities.

Table 3: The Whittaker index for the sample site pairs.

Sample pairs	n-5; n-4	n-4; n-3	n-3; n-2	n-2; n-1	n-1; n
Whittaker index	2	1.71	1.55	1.26	1.5

CONCLUSIONS

- the upstream sector (n-5, n-4) is not favourable for the aquatic oligochaeta species settling. We found in each site only one species with a small number of individuals because the lack of the trophic base in this sector where the riverbed is covered by stones and boulders.
- at n-3 the small amount of biotecton from the riverbed ensures the trophic base for the oligochaeta species, so here they are present in a greater number of species and individuals.
- n-2 is the richest site in species (12). The river is in a good condition for the oligochaeta community development.
- n-1 and n have very similar environmental conditions. The number of species is between 7 and 9 especially because of the high speed of the water and the great quantity of sediments in the substratum.
- the oligochaeta community is not very firm, we found only 1 eudominant species and 4 dominant. The rest are accessory or accidental species. This is due especially for the often variation of the water level which does not allow the settlement of a constant community.
- the diversity is not very high, the values are very close between the sample sites n-3 and n, but 0 in n-4 and n-5 where we found only one species of oligochaeta.
- the similarity between the sample sites is also low in some cases 0 and reaching 0.58 between n-1 and n-2; this fact show also the instability of the oligochaeta community in the studied sector.

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AQUATIC AND SEMIAQUATIC HETEROPTERA FROM ARIEŞ RIVER BASIN (TRANSYLVANIA, ROMANIA) - METHODS IN ESTIMATING BIODIVERSITY

Daniela Minodora ILIE *
and *Horea OLOŞUTEAN* *

* "Lucian Blaga" University of Sibiu, Faculty of Sciences, Department of Ecology and Environment Protection, Raţiu Street 5 - 7, Sibiu, Sibiu County, Romania, RO-550337, iliedf@yahoo.com, mesaje.facultate@yahoo.com

KEYWORDS: Romania, Transylvania, Heteroptera, α-biodiversity, β-biodiversity, γ-biodiversity, numeric equivalent.

ABSTRACT

This paper is part of a study made in order to establish the Arieş Basin water quality. The aim was to inventory the habitats of aquatic and semiaquatic Heteroptera (inventory that will regard the number and quality of those habitats, and also the human intervention in the area), and to establish the biodiversity degree, using two different methods that estimate both α-, β- and γ-biodiversity. In order to reach that, we took samples from 16 sampling stations along the hydrographic basin, the results showing the presence of at least 17 species, most of them eurivalent ones, but also with exceptions like *Gerris gibbifer* Schummel 1832, *Hebrus pusillus* (Fallén, 1807) or *Hesperocorixa sahlbergi* Fieber 1848, species with rare sightings in Romanian fauna. The α-biodiversity analysis reveals low values, counterbalanced by higher β-biodiversity values for most of the hydrographic basin, the gradient used in this case being the altitude. Both methods used for diversity estimation show more or less similar results.

ZUSAMMENFASSUNG: Die aquatischen und semiaquatischen Heteropteren aus dem Einzugsgebiet des Arieş (Transylvanien, Rumänien) - Methoden zur Schätzung der Biodiversität.

Die Arbeit ist Teil einer Untersuchung, die Bewertung der Wasserqualität im Einzugsgebiet des Arieş diente. Das Ziel war die Erfassung der von den aquatischen und semiaquatischen Heteropteren bevorzugten Habitate (berücksichtigt wurden Zahl und Qualität der Habitate sowie der menschliche Einfluss) und die Bestimmung der Biodiversitätswerte mit Hilfe von zwei Methoden zur Schätzung der α- und β-, oder γ-Diversität. Dafür wurden an 16 Punkten im Einzugsgebiet Proben entnommen. Die Auswertung der Proben ergab das Vorhandensein von mindestens 17, vorwiegend eurivalenten Arten, aber auch Ausnahmen wie *Gerris gibbifer* Schummel 1832, *Hebrus pusillus* (Fallén, 1807) oder *Hesperocorixa sahlbergi* Fieber 1848, die in Rumänien als selten gelten. Die Analyse der α-Biodiversität ergibt geringe Werte für jede Sammelstelle, denen jedoch hohe Werte der β-Biodiversität für den größeren Teil des Einzugsgebietes gegenüber stehen, wobei der verwendete Gradient die Höhenlage ist. Beide Schätzungsmethoden der Diversität haben mehr oder weniger ähnliche Ergebnisse erbracht.

REZUMAT: Heteropterele acvatice şi semiacvatice din bazinul râului Arieş (Transilvania, România) - metode de estimare a biodiversităţii.

Lucrarea face parte dintr-un studiu realizat cu scopul evaluării calităţii apei din Bazinul Arieşului. Ţinta a fost inventarierea habitatelor preferate de Heteropterele acvatice şi semiacvatice (inventarierea ţine cont de numărul şi calitatea habitatelor şi de impactul antropic), şi stabilirea valorilor biodiversităţii, cu ajutorul a două metode, ce vor estima biodiversitatea α, β şi γ. Au fost colectate probe din 16 puncte, de-a lungul bazinului, rezultatele aratând prezenţa a cel puţin 17 specii, majoritatea eurivalente, dar şi excepţii ca *Gerris gibbifer* Schummel 1832, *Hebrus pusillus* (Fallén, 1807) sau *Hesperocorixa sahlbergi* Fieber 1848, specii considerate rare în România. Analiza de biodiversitate α oferă valori reduse pentru fiecare punct de colectare, contrabalansate de valori mari ale biodiversităţii β pentru marea parte a bazinului, gradientul, folosit fiind altitudinea. Ambele metode au oferit rezultate mai mult sau mai puţin similare.

INTRODUCTION

Arieş River drains the central part of the Apuseni Mountains in western Romania, being one of the largest tributaries of Mureş River. The upper basin is formed from two separate rivers (Arieşul Mare and Arieşul Mic) wich unite near the city of Câmpeni to form the main river. In the upper basin, the two rivers run mostly trough crystalline rocks, while the lower basin is characterized by the presence of sedimentary rocks (especially limestone).

Aquatic Heteroptera belong, according to the latest classifications, to Infrasuborder Nepomorpha Popov 1968, while the semiaquatic ones belong to Infrasuborder Gerromorpha Popov 1971 (Gaby Viskens, 2005, on www.earthlife.net). There are insects associated, more or less, to water surfaces, forming, along other groups, the nekton and the epineuston. They inhabit a large variety of micro biotopes, from those lacking in vegetation, to those completely covered (Andersen, 1982; Davideanu, 1999). The typical habitats for the group are ponds, lakes, slow flowing creeks or little bays formed at the shore of rivers. Most species are not sensible to moderate human impact in the habitat, as well to the presence of vegetation.

The measurement of biodiversity is possible with the use of different techniques, the most common one technique involving indices that will reflect the particular aspects of the group in study. Using several measurement techniques can be revealed with greater precision the way in which the group has adapted to the habitats present in the specific area of the study.

MATERIALS AND METHODS

The study took place in June 2009, and the goal was to take qualitative samples. 16 sampling stations were taken in concern, covering the upper and lower basin of Arieş River (Fig. 1). There was taken one sample from each station, of 8 to 15 meters, covering the entire habitat (water surface and interior, aquatic vegetation if present, bottom); the samples were collected with an entomological net with 60 square centimeters opening.

The identification of the species was made by their morphological features, studying the insects at the stereo binocular, or, in some of the cases, by genitalia, using data from other specialists (Jansson, 1986; Davideanu, 1999). The insect larvae found were not identified at the species' level, due to difficulties regarding this specific operation, and they will not be considered in the biodiversity analysis; the exception is the larvae of *Nepa cinerea* Lineé 1758, identifiable up to species' level, but the larvae of the species will not take part in the biodiversity analysis, because of the unitary approach we want for this study; from that point of view, two of the sampling stations, S2 and S8, will not take part in the analysis, since only larvae was sampled there. In station S10, one female *Dichaetonecta* sp. Hutchinson, 1940 was found, impossible to identify at species' level in the absence of the male (Poisson, 1986), but, since is the only *Dichaetonecta* found in the entire studied area, it will be considered as a different species in the biodiversity analysis.

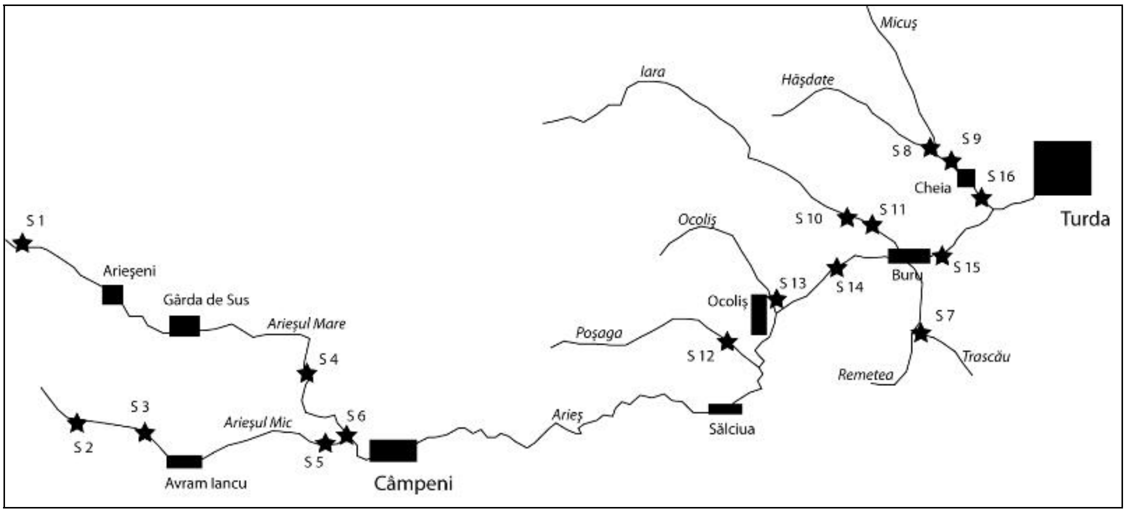

Figure 1: The location of the sampling points from Arieş River basin: stars represent sampling stations, rectangles represent cities and villages, and lines, creeks and rivers (personal representation).

The results obtained from the sampling points will be analyzed from the biodiversity point of view, using two different approaches: the classical one, with specific α and β indices, and a more unconventional one.

The classic approach in biodiversity states that biodiversity of an area (γ biodiversity) is obtained by adding or multiplying medium α values to β values. In our case, indices used will be Menhinick, for α biodiversity, calculated for each sampling station, and Whittaker Index, for β biodiversity, using altitude as a gradient. α values obtained will be used in calculating average α, which will be multiplied to Whittaker value, giving the value for γ biodiversity.

A total different point of view is provided by Jost (2006, 2007). This author is proposing a new type of measurement, using the entropy like indices (Shannon, Renyi, Gini-Simpson etc.), with modified formulas as is the so called number equivalent. This number equivalent is used for calculation of the α and γ (total) biodiversity, the value of β being deduced from the other two. For our case study, in which community weights are different, Jost is suggesting the use of the Shannon Entropy ($-\Sigma p_i*\ln(p_i)$), with the number equivalent of $\exp(-\Sigma p_i*\ln(p_i))$, for which the β value is obtained by dividing γ to α (Jost, 2007).

RESULTS AND DISCUSSION

The specific habitats for the group are scarcely present in the area, especially in the middle Arieş Basin and in the middle basin of Arieşul Mare River, due to intense human impact, represented by territorial improvement (terrain levelling, water banking) which leads to absence of specific habitats to the group (still waters, puddles, low flow sectors). Physico-geographical conditions take their part in the Arieş upper basin, where crystalline rock present in most areas, leads to rapid meteoric water infiltration, and the rapid flows of the local rivers and springs, concurs to the absence of a category of habitats that are preferred by Heteroptera.

The 16 sampling stations from the studied area were selected to cover the entire diversity of habitats preferred by the target group. Station numbers (S1 to S16) were established by altitude basis (for β-biodiversity gradient), S1 being the highest, and S16 the lowest of the sampling stations. A short characterization of the stations is presented as following.

S1 (Arieşul Mare River 1 kilometer downstream the spring): altitude 1,042 meters; 46°28'59" northern latitude; 22°42'11" eastern longitude; a small slow flowing sector of the river and small swampy creek (left side affluent) at the confluence; muddy bottom; hydrophiles vegetation present; total size of sampling station: 7 meters long, 1 meter wide.

S2 (Arieşul Mic River at confluence with Ţoha Creek): altitude 733 meters; 46°22'26" northern latitude; 22°51'44" eastern longitude; a canal at the side of the road, rocky bottom, with two spring sources; a low amount of hygrophilous vegetation is present, and there are marks of human impact (garbage, patches of petroleum based substances); total size of sampling station: 25 meters long (samples were taken from four different places, totaling about 12 meters), around 1 meter wide.

S3 (Arieşul Mic River 4 kilometers upstream Avram Iancu village): altitude 652 meters; 46°22'21" northern latitude; 22°54'04" eastern longitude; a canal at the side of the road, sandy bottom, with pluvial and spring sources; a low amount of hygrophilous vegetation is present, and there are no marks of human impact; total size of sampling station: 10 meters long, around 40 centimeters wide.

S4 (Arieşul Mare River 10 kilometers upstream the confluence with Arieşul Mic): altitude 621 meters; 46°25'39" northern latitude; 22°57'50" eastern longitude; a river shore sector with stagnant water, low amount of hygrophilous vegetation and a large quantity of garbage flowing; total size of sampling station: around 20 meters long, 30 centimeters wide.

S5 (Arieşul Mic River 1 kilometer upstream the confluence with Arieşul Mare): altitude 575 meters; 46°22'06" northern latitude; 23°00'40" eastern longitude; a lateral slow flowing sector surrounding a small island, small hygrophilous vegetation at shoreline, marks of human impact (wood scraps, garbage); total size of sampling station: 4 meters long, 4 meters wide.

S6 (Arieşul Mare at confluence with Arieşul Mic): altitude 570 meters; 46°22'17" northern latitude; 23°01'03" eastern longitude; a large lake at the bottom of the dam; uniform shores with wooden vegetation; evidence of human impact (little amount of garbage, traces of petroleum products, turbid water with whitish color); total size of sampling station: 5 meters long, 1 meter wide.

S7 (Trascău Valley at the confluence with Remetea Steram): altitude 501 meters; 46°28'04" northern latitude; 23°34'45" eastern longitude; small slow flowing creek, rocky bottom; no signs of human impact; total size of sampling station: 5 meters long, 30 centimeters wide.

S8 (small creek at the confluence with Hăşdate River): altitude 484 meters; 46°34'46" northern latitude; 23°39'22" eastern longitude; small creek at the conjunction with Hăşdate; bottom filled with leaves and branches, without characteristic vegetation; total size of sampling station: 1.5 meters long, 60 centimeters wide.

S9 (Hăşdate at the Turda Gorge): altitude 452 meters; 46°33'47" northern latitude; 23°41'19" eastern longitude; river shore with limestone bottom, fast flowing stream, without hygrophilous vegetation; very turbid water; total size of sampling station: 3 meters long, around 50 centimeters wide.

S10 (Iara Creek downstream Surduc Gorge): altitude 429 meters; 46°32'15" northern latitude; 23°33'22" eastern longitude; sector with limestone bottom, fast flowing stream, low amount of hygrophilous vegetation; total size of sampling station: 10-12 meters long, around 1 m wide.

S11 (Iara Creek 500 meters downstream Surduc Gorge): altitude 427 meters; 46°32'05" northern latitude; 22°33'69" eastern longitude; permanent pond; muddy bottom, both hydro- and hygrophilous vegetation; total size of sampling station: around 4 meters long, 1,5 meters wide.

S12 (Poşaga Creek 1 kilometer upstream the confluence with Arieşul Mare River): altitude 424 meters; 46°28'04" northern latitude; 23°34'45" eastern longitude; a small slow flowing sector of the creek; rocky bottom, low amount of hygrophilous vegetation at shore; total size of sampling station: 4 meters long, 30 centimeters wide.

S13 (Ocoliş creek 200 m upstream the confluence with Arieşul Mare River): altitude 409 meters; 46°26'32" northern latitude; 23°27'26" eastern longitude; small bay of the creek; rocky bottom, low amount of hygrophilous vegetation present; total size of sampling station: 1.5 meters long, 60 centimeters wide.

S14 (Arieşul Mare River 7 kilometers upstream Buru village): altitude 390 meters; 46°30'11" northern latitude; 23°33'01" eastern longitude; small pond in the river meadow, with pluvial source; muddy bottom, small amount of hygrophilous vegetation; total size of sampling station: 2 meters long, 2 meters wide.

S15 (Arieşul Mare River 1 kilometer downstream the Buru village): altitude 365 meters; 46°30'18" northern latitude; 23°36'23" eastern longitude; a canal at the side of the road, sandy bottom, with pluvial sources; no hygrophilous vegetation present, and there are no marks of human impact; total size of sampling station: 2 meters long, around 1 meter wide.

S16 (Arieşul Mare River at Cheia village): altitude 338 meters; 46°32'26" northern latitude; 23°42'42" eastern longitude; small slow flowing sector of the river under a bridge; muddy bottom, low amount of hygrophilous vegetation; size of sampling station: 3 meters long, 1 meter wide.

The samples showed 17 species of the target group (Tab. 1), ten belong to Infrasubordo Gerromorpha (semiaquatic Heteroptera): *Aquarius paludum* Fabricius 1794, *Gerris lacustris* Lineé 1758, *Gerris costae* Herrich-Schäffer 1853, *Gerris argentatus* Schummel 1832 B, *Gerris gibbifer* Schummel 1832 B, *Gerris odontogaster* Zetterstedt 1828 B, *Gerris thoracicus* Schummel 1832 B, *Hydrometra stagnorum* Lineé 1758, *Hebrus pusillus* (Fallén, 1807) and *Microvelia reticulata* (Burmeister, 1835), and seven to Infrasubordo *Nepom* and *orpha* (aquatic Heteroptera), *Sigara* (*Pseudovermicorixa*) *nigrolineata* Jaczewski 1962, *Sigara* (*Vermicorixa*) *lateralis* Leach 1817, *Sigara* (*Sigara*) *striata* Lineé 1758, *Hesperocorixa sahlbergi* Fieber 1848, *Nepa cinerea* Lineé 1758, *Notonecta glauca* Lineé 1758, *Plea minutissima* (Füssly, 1775).

Also, were found one female (*Micronecta*) *Dichaetonecta* sp. Hutchinson, 1940, not possible to identify as a species in the absence of the male (Poisson, 1986), and several larvae of *Velia* sp. Fabricius 1794, and *Gerris* sp. Fabricius 1794, again impossible to identify at species's level (all the veliids are, probably, *Velia* (*Plesiovelia*) *rivulorum* Fabricius 1794, but we will not take it in consideration, since there is no information about the way different veliids occupy the same habitat, therefore existing the possibility of more than one species). All species are first time mentions in the area (Paina, 1975), but they were all sampled between Aiud and Cluj-Napoca, therefore only the lack of studies made in the area can be the reason for that.

Considering *Dichaetonecta* and at least one *Velia*, we have 19 species out of 67 found so far in Romania (Davideanu, 1999; Ilie, 2008). That means around 29% of the aquatic and semiaquatic Heteroptera species sampled in the country found on 14 sampling stations covering a very small area along a medium size river. The 71 imago sampled offer an individual/species ratio of 3.94, not considering *Velia*, and they belong to a huge number of Heteroptera families (9), which means under 8 individuals per family. A special situation is the one reffering to gender *Gerris* Fabricius 1794, represented in the area by six species out of the nine present in Europe (Visken, 1995, on earthlife.net), a very large proportion if we consider the relatively poor conditions from the area and the gathering of one sample from each station.

The relatively high amount of variation, depicted by β diversity is the result of that the most aquatic and semiaquatic Heteroptera species are well adapted to particular habitats, and they will occupy different types of habitats with different species (Andersen, 1982). Due to the stations small surface, almost each of it offers few ecological niches for Heteroptera, fact reflected by α diversity results described above. The geographical conditions change along altitude has an effect in the change of habitat type and, in the Heteroptera species that will occupy it. The β results of the upper sector are in consistence with the relatively homogenous geological conditions.

Nevertheless, the biodiversity analisys (Tab. 2) using the described methods show similar results: low α values and relatively high β values, leading to a high γ for the lower basin and for the entire area; the upper basin has 5 out of six stations only with gerrids, therefore a lower β component, and an overall diversity much lower than the lower basin or the entire studied river. The similarity of the results obtained with two completely different methods gives a stability in conclusions to be made, also confirming the practical applicability of Jost's method, much easier to use.

Table 1: List of aquatic and semiaquatic Heteroptera sampled on Arieş River basin.

Crt.	Taxons (families, species)	Stations (S)															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Infrasuborder Gerromorpha																
	Fam. Gerridae	No. of individuals															
1	*A. paludum*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
2	*G. lacustris*	-	-	-	1	4	5	4	-	3	-	8	-	4	-	-	-
3	*G. costae*	1	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-
4	*G. argentatus*	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
5	*G. gibbifer*	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	*G. odontogaster*	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-
7	*G. thoracicus*	-	-	-	-	-	-	-	-	-	-	-	-	2	4	-	-
8	*Gerris* sp. larvae	5	-	20	1	12	34	5	-	-	-	15	-	-	-	-	-
	Fam. Veliidae																
9	*Velia* sp. larvae	7	3	-	-	-	-	-	5	-	-	-	-	-	-	-	-
	Fam. Microveliidae																
10	*M. reticulata*	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
	Fam. Hebridae																
11	*H. pusillus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
	Fam. Hydrometridae																
12	*H. stagnorum*	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1
	Infrasuborder Nepomorpha																
	Fam. Corixidae																
13	*S. nigrolineata*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
14	*S. lateralis*	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	
15	*S. striata*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
16	*H. sahlbergi*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
17	*Dichaetonecta* sp.	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
	Fam. Nepidae																
18	*N. cinerea*	-	-	-	-	-	-	-	-	-	1	4	2	-	-	-	-
19	*N. cinerea* larvae	1	-	-	-	-	-	-	-	1	-	10	-	-	-	-	4
	Fam. Notonectidae																
20	*N. glauca*	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-
	Fam. Pleidae																
21	*P. minutissima*	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
	Total (imago)	3	-	5	1	8	5	4	-	3	2	18	2	6	4	1	9

Table 2: Biodiversity indices values for the study area (α1, β1 and γ1 calculated with classical indices, α2, β2 and γ2, with Jost's method).

Station	α 1	average α 1	β 1	γ 1	α 2	average α 2	β 2	γ 2
S1	3.322	Upper basin: 1.107	Upper basin: 2.215	Upper basin: 2.452	2.000	Upper basin: 1.530	Upper basin: 2.317	Upper basin: 3.545
S2	-				-			
S3	0				1.000			
S4	0				1.000			
S5	2.215	Total: 1.309	Total: 7.5	Total: 9.818	2.649	Total: 1.612	Total: 5.322	Total: 8.580
S6	0				1.000			
S7	0				1.000			
S8	-				-			
S9	0				1.000			
S10	3.322				2.000			
S11	3.983				4.860			
S12	0				1.000			
S13	1.285	Lower basin: 1,420	Lower basin: 5	Lower basin: 7,100	1.890	Lower basin: 1.657	Lower basin: 4.710	Lower basin: 7.804
S14	0				1.000			
S15	0				1.000			
S16	4.192				4.166			

Low α values come from the poor habitats quality and samplings small amount. Well adapted to specific habitat conditions, particular aquatic and semiaquatic Heteroptera species will need a certain type of bottom, flow, vegetation etc., difficult to be found in small sampling station like the one we studied. Therefore, the only stations with high α values are the relatively large ones, like S1 or S11, where different habitat conditions make way for different species to coexist. The situation is explained the best by the high number of stations with only one species sampled (9 such stations, particularly the smallest and the most homogenous ones).

CONCLUSIONS

Aquatic and semiaquatic Heteroptera are represented in the Arieş River basin by at least 17 species, mostly the common ones for the group in Romania. Compared to the total number of species from Romania (67 - Ilie, 2008), the results are very consistent, despite the small number of individuals captured (71 imago).

Biodiversity analysis results are showing low α values for both upper and lower basins, as well for all the sampled area. β results show a high variation in the lower basin and for the entire Arieş Basin, but a consistently smaller variation along the gradient in the upper basin. These results are more or less similar in both estimation methods used, which gives them an additional stability.

The low values from sampling points are the result of the quality of the aquatic habitats, explainable from intense antropic impact (mostly territorial improvement - terrain leveling, water banking - leading to absence of specific habitats) and physico-geographical conditions (crystalline substratum in most areas, rapid flows of the local rivers and springs, possibly harsh climatic conditions in some areas). High values of β and γ are related to changing habitat conditions for the group, due to the geological and geographical conditions modification from upper to lower basin.

The species sampled are new to the area, as far as we know, probably due to the lack of previous researches.

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CONTRIBUTION TO THE KNOWLEDGE OF THE MYRMECOFAUNA (HYMENOPTERA, FORMICIDAE) OF THE UPPER ARIEŞ RIVER BASIN (TRANSYLVANIA, ROMANIA)

Ioan TĂUŞAN *

* Natural History Museum of Sibiu, Cetăţii Street 1, Sibiu, Sibiu-County, Romania, RO-550166.

KEYWORDS: Romanian Carpathians, ants, fauna, community structure, *Myrmica hellenica*.

ABSTRACT

In the present paper the author offers new data to the knowledge of the ant-fauna of the Upper Arieş River basin. Altogether 23 species were identified during this study. Upon these results the number of known species reaches 39 in this region. The majority of species are common in Romania, with the exception of *Myrmica hellenica* Finzi, 1926, which is reported for the third time for Romania.

ZUSAMMENFASSUNG: Beiträge zur Kenntnis der Ameisenfauna (Hymenoptera, Formicidae) des höher Arieş Fluss Einzugsgebiete (Transylvanien, Rumänien).

In der vorliegenden Studie präsentieren die Autoren neuer Daten über ameisenfauna das obere Becken des Widders. In insgesamt 23 Arten festgestellt wurden. Die meisten Arten sind in Rumänien weit verbreitet, mit Ausnahme der Arten *Myrmica hellenica* Finzi, 1926, die dritte Ausschreibung, in Rumänien ist, bringen bis 39 die Zahl der untersuchten Spezies Bereich.

REZUMAT: Contribuţii la cunoaşterea Mirmecofaunei (Hymenoptera, Formicidae) bazinului superior a râului Arieş (Transilvania, România).

În lucrarea de faţă, autorii prezintă date noi, privind mirmecofauna din bazinul superior al Arieşului. În total, 23 de specii au fost identificate. Majoritatea speciilor sunt răspândite în România, cu excepţia speciei *Myrmica hellenica* Finzi, 1926, care se află la a treia semnalare pentru România, ridicând la 39 numărul de specii pentru zona studiată.

INTRODUCTION

Ants are widely used as indicator group (Agosti et al., 2000), thus comprehensive checklists of small areas constitute good starting points for local nature protection activities. Studies of the role of ecological corridors like river valleys contribute essentially to the elaboration of nature conservation strategies. High community-level similarities could indicate the homogenizing effect of habitats, and therefore true ecological corridor function of the river valley (Gallé et al., 1995).

The ant fauna of the Arieş River valley was previously studied and 29 species are known from this area (Paraschivescu, 1982). Similar studies which deal with ant fauna of river meadows (Paraschivescu, 1963; Markó, 1997, 1999; Kiss and Fetykó, 2008) or wider areas (Knechtel, 1956; Paraschivescu, 1967, 1975, 1976; Csősz et al., 2001; Gallé et al., 2005) were carried in Romania in the last decades. Only a few studies treated the role of river valleys in the dispersal of insects, like Gallé et al. (1995) study regarding the role of Tisa River Valley.

MATERIAL AND METHODS

The Arieş River basin is located in the western part of Transylvania (Romania). The Arieş River has its springs in the Bihor Mountains and it is approximately 164 km long. The upper basin is formed of two separate rivers (Arieşul Mare and Arieşul Mic), wich unite near the town of Câmpeni (Alba County) to form the main river. The vegetation is represented mainly by beech (*Fagus* sp.), spruce (*Picea* sp.) and mixed forests, while along the valleys alder (*Alnus* sp.) and willow-groves (*Salix* sp.) hardly subsist to the village's development or agricultural needs (Goia and Schumacker, 2004).

The study took place in June, 2009. Ant species from different habitats were sampled in the Upper Arieş River basin, along the Arieşul Mic and Arieşul Mare rivers. Grassland, spruce forest and gravel bank were the main habitats from which ant were collected (Fig. 1, Tab. 1).

Table 1: Sampling points in the Upper Arieş River basin.

River	Sampling point	Localization	Altitude (m)	Coordinates	Vegetation
Arieşul Mare	AM1	1 kilometer downstream the spring	1,043	46°28'16" N 22°42'11" E	spruce forest
	AM2	upstream of Arieşeni	984	46°28'36" N 22°44'17" E	grassland
	AM3	upstream of Gîrda de Sus	920	46°27'12" N 22°48'57" E	spruce forest
	AM4	upstream of Scărişoara	894	46°27'24" N 22°50'19" E	spruce forest
	AM5	downstream of Scărişoara	823	46°27'11" N 22°51'36" E	grassland
	AM6	downstream of Albac	671	46°27'2" N 22°57'15" E	gravel bank and grassland
	AM7	confluence with Arieşul Mic	570	46°22'17" N 23°01'03" E	gravel bank and grassland
Arieşul Mic	Am1	confluence with Ţoha Creek	733	46°22'26" N 22°51'44" E	grassland and spruce forest
	Am2	4 kilometers upstream Avram Iancu	652	46°22'21" N 22°54'04" E	grassland
	Am3	3 kilometers downstream Avram Iancu	633	46°22'17" N 22°57'3" E	grassland
	Am4	1 kilometer downstream Ponorel	589	46°21'59" N 22°59'16" E	grassland
	Am5	1 kilometer upstream the confluence with Arieşul Mare	575	46°22'06" N 23°00'40" E	grassland

Ants were collected by hand mainly from nests along a transect of 100 meters starting from the river bank; the collected individuals were preserved in 70% ethanol. The samplings were carried out in summer 2009, as follows: Arieşul Mare Valley 25 May and 28 June, Arieşul Mic Valley 27 June. The identification of ant species was carried out on the basis of several available identification keys (Collingwood, 1979; Agosti and Collingwood, 1987a, b; Seifert, 1988, 1992, 1996; Czechowski et al., 2002; Markó et al., 2009).

Comparison of ant communities was carried out by the use of hierarchical cluster analysis based on Euclidean distances, average linkage method. The diversity of communities was assessed by calculating Shannon-Wiener general entropy values (log2) on the basis of colonies number. In the case of AM3, AM4, AM6 and Am3 sampling sites, colonies from one species was collected; consequently, no values for Shannon-Wiener index are recorded.

RESULTS

Altogether 23 species belonging to three subfamilies were collected in the upper Arieş River basin meadows, during this study (Tab. 2). The majority of the species are common for the myrmecofauna of Romania (Markó et al., 2006), except for *Myrmica hellenica* Finzi, 1926. *Myrmica hellenica* was reported not long ago for the first time in Romania (Markó, 1998b) and recently it was mentioned for the second time for Romania (Csősz and Markó, 2005).

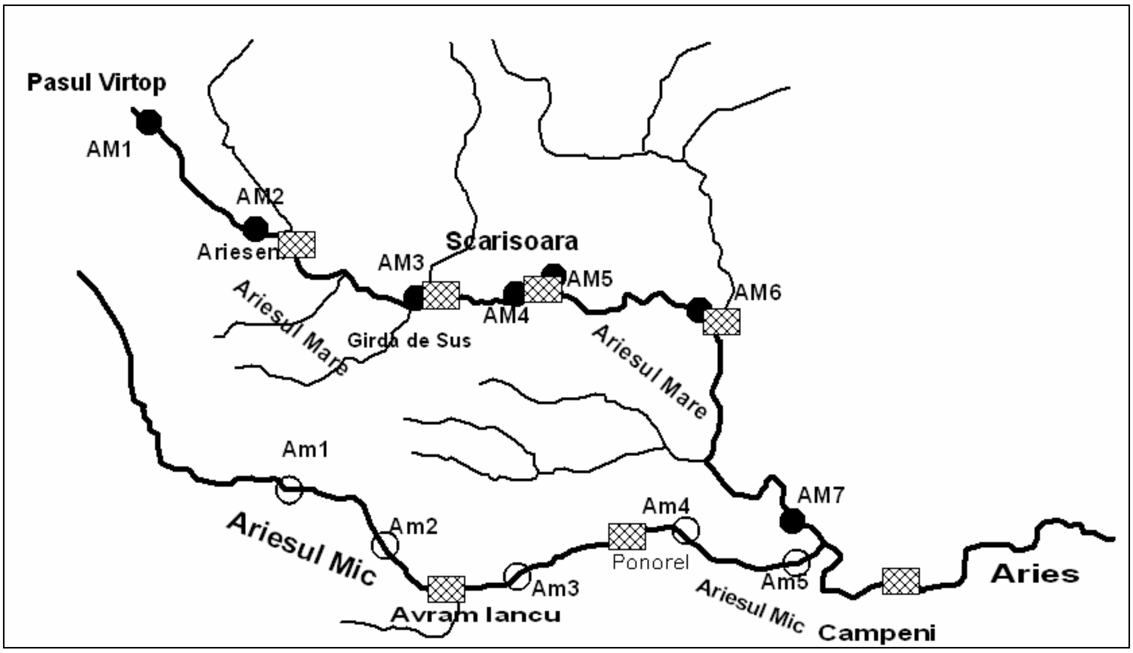

Figure 1: Map of sampling points in the upper Arieş River basin; empty dots for Arieşul Mic River and filled dots for Arieşul Mare River, rectangles represent cities and villages, and lines, creeks and rivers (the codes are explained in text about - personal representation)

Myrmica hellenica was collected from Crişul Repede (Markó, 1998a) river bank, from the "Fânețele Clujului" near Cluj-Napoca city (Cluj County) from Sălard (Mureş County) and Moacşa (Covasna County) (Markó, 1998b).

Myrmica rubra is the most abundant ant species followed by *M. ruginodis* and *Formica cinerea* (Tab. 2, Fig. 2). These three species are present in almost all transects (Tab. 2). The two Myrmica species are characteristic forest inhabitants (Czechowski et al., 2002), though *M. rubra* was collected from open habitats, meadows. *M. rubra* can occur in mesophilic to very moist meadows and tolerates high vegetation much better, than other *Myrmica* species found in the frame of this study. *Formica cinerea* is a typical species of open habitats (Seifert, 1998).

Table 2a: The list of the collected species: total number of colonies with their relative abundance (%); x - species collected outside of colonies; Am1, Am2, Am3, Am4, Am5 - sampling sites.

Species	Arieşul Mare River						
	AM1	AM2	AM3	AM4	AM5	AM6	AM7
Subfam. Formicinae Lepeletier, 1836							
Formica cunicularia Latreille, 1798	-	-	-	-	-	X	X
Formica rufa Linnaeus, 1761	-	2 (11.7 7)	-	-	1 (14.2)	-	-
Formica pratensis Retzius, 1783	-	-	-	-	X	-	-
Formica cinerea Mayr, 1853	-	-	-	-	X	5 (100)	X
Formica lemani Bondroit, 1917	-	2 (11.77)	-	-	-	-	-
Formica fusca Linnaeus, 1758	-	-	-	X	-	-	-
Formica rufibarbis Fabricius, 1793	-	-	-	-	-	-	-
Formica clara Forel, 1886	-	-	-	-	-	-	-
Lasius niger (Linnaeus, 1758)	-	X	-	X	1 (14.2)	X	1
Lasius plathytorax Seifert, 1992	-	2 (11.77)	-	-	-	X	-
Lasius flavus (Fabricius, 1781)	-	2 (11.77)	-	-	-	-	-
Lasius paralienus Seifert, 1992	-	-	-	-	-	-	-
Camponotus ligniperda (Latreille, 1802)	-	-	-	-	X	-	-
Camponotus herculaneus (Linnaeus, 1758)	1 (33.3)	-	X	X	-	-	-
Subfam. Myrmicinae Lepeletier, 1836							
Myrmica rubra (Latreille, 1867)	2 (66.6)	8 (47.05)	X	-	5 (71.42)	-	1 (50)
Myrmica ruginodis Nylander, 1846	-	1 (5.87)	2 (100)	1 (100)	-	-	-
Myrmica scabrinodis (Nylander, 1846)	-	-	-	-	-	-	-
Myrmica sabuleti (Meinert, 1861)	-	-	-	-	-	-	-
Myrmica schencki Viereck, 1903	-	-	-	-	-	-	-
Myrmica hellenica Finzi, 1926	-	-	-	-	-	-	-
Leptothorax acervorum (Fabricius, 1793)	-	-	-	X	-	-	-
Tetramorium cf. *caespitum.*	-	-	-	-	-	-	-
Subfamilia Dolichoderinae Forel, 1878							
Tapinoma erraticum (Latreille, 1798)	-	-	-	-	-	X	-
Total number of species: 32	2	7	3	5	6	5	4

Table 2b: The list of the collected species: total nomber of colonies with their relative abundance (%); x - species collected outside of colonies; Am1, Am2, Am3, Am4, Am5 - sampling sites.

Species	Arieşul Mic River				
	Am1	Am2	Am3	Am4	Am5
Subfam. Formicinae Lepeletier, 1836					
Formica cunicularia Latreille, 1798	-	-	-	-	-
Formica rufa Linnaeus, 1761	-	X	-	-	-
Formica pratensis Retzius, 1783	3 (50)	X	-	-	-
Formica cinerea Mayr, 1853	-	-	X	X	-
Formica lemani Bondroit, 1917	-	-	-	-	-
Formica fusca Linnaeus, 1758	-	-	-	-	-
Formica rufibarbis Fabricius, 1793	-		-	X	-
Formica clara Forel, 1886	-	1 (14.29)	-	X	-
Lasius niger (Linnaeus, 1758)	-	X	-	X	X
Lasius plathytorax Seifert, 1992	-	X	-	-	-
Lasius flavus (Fabricius, 1781)	-	2 (28.57)	-	-	-
Lasius paralienus Seifert, 1992	-	-	-	X	-
Camponotus ligniperda (Latreille, 1802)	-	-	-	-	-
Camponotus herculaneus (Linnaeus, 1758)	-	-	-	-	-
Subfam. Myrmicinae Lepeletier, 1836					
Myrmica rubra (Latreille, 1867)	1 (16.6)	-	1 (100)	1 (50)	X
Myrmica ruginodis Nylander, 1846	2 (33.3)	-	-	-	-
Myrmica scabrinodis (Nylander, 1846)	-	-	-	1 (50)	-
Myrmica sabuleti (Meinert, 1861)	-	X	X	-	-
Myrmica schencki Viereck, 1903	-	1 (14.29)	-	-	-
Myrmica hellenica Finzi, 1926	-	X	-	-	-
Leptothorax acervorum (Fabricius, 1793)	-	-	-	-	-
Tetramorium cf. *caespitum.*	-	3 (42.85)	-	-	-
Subfamilia Dolichoderinae Forel, 1878					
Tapinoma erraticum (Latreille, 1798)	-	-	X	-	-
Total number of species: 26	3	10	4	7	2

Myrmica hellenica is characteristic for sun-exposed, but only superficially dry areas (Seifert, 1988). In our case the species was collected from grassland. Seifert (1988) considers *Myrmica hellenica* as being a species with pioneer characters, due to the fact that it mostly occurs in unstable environment, like riverbanks, where the flood ensures a constant instability.

According to Seifert (1998), *Myrmica schencki* is found on all kinds of xerothermous grasslands, open heath, and xerothermous border lines of woodland or along ways. *Myrmica sabuleti*, is found on all types of semidry grasslands and at sunny margins of woodland, rather independent from the geological outcrop (Seifert, 1998).

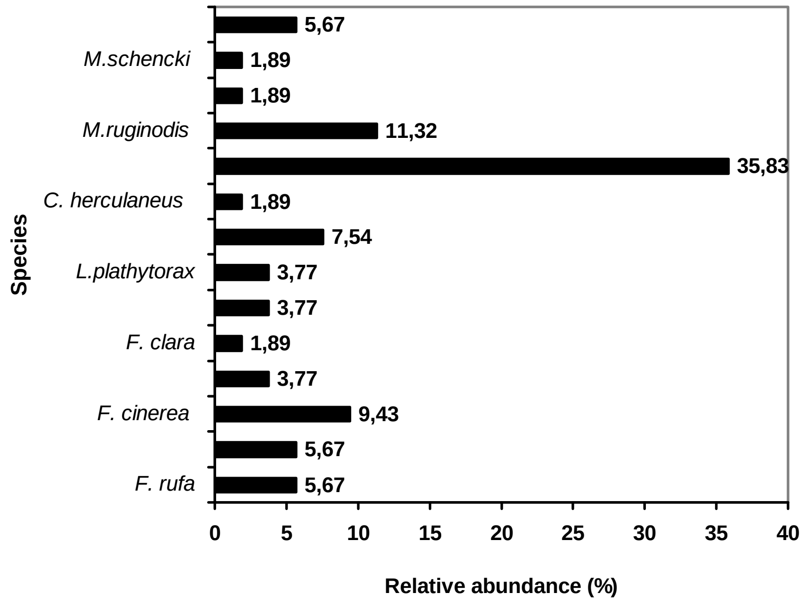

Figure 2: Relative abundance of ant species' colonies in the upper Arieş River basin.

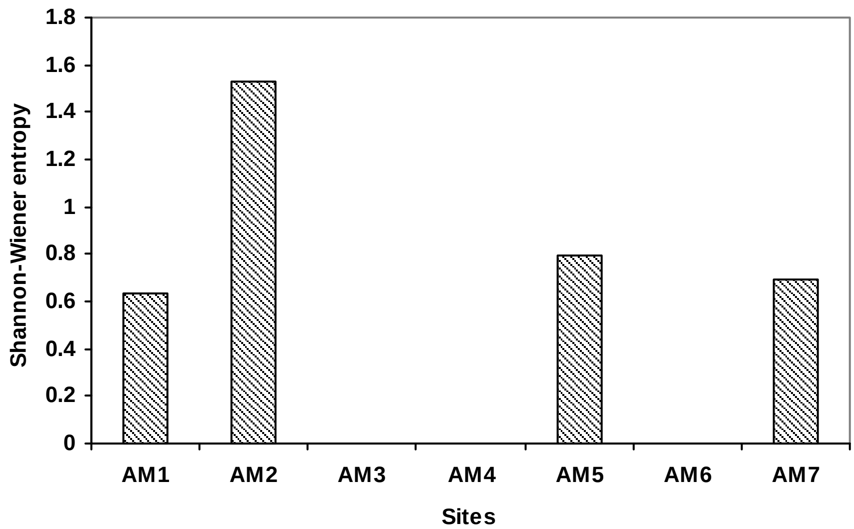

Figure 3: Diversity (Shannon-Wiener general entropy, log2) of the ant communities along Arieşul Mare.

The ants of the genus *Formica* are a significant component of forest ecosystems. They influence soil qualities and the presence of some plant species and they also have a strong influence on surrounding zoocoenosis (Véle and Holuša, 2007 in Véle and Holuša, 2009).

F. pratensis is a polytopic species of dry habitats; it lives in open sites in forests, treeless plains, meadows and pasturelands (Czechowski et al., 2002). It is very rare in spruce forests, it is found only in young stands (up to 10 years) and on the edges of older stands (Punttila et al., 1991; Niemelä et al., 1996).

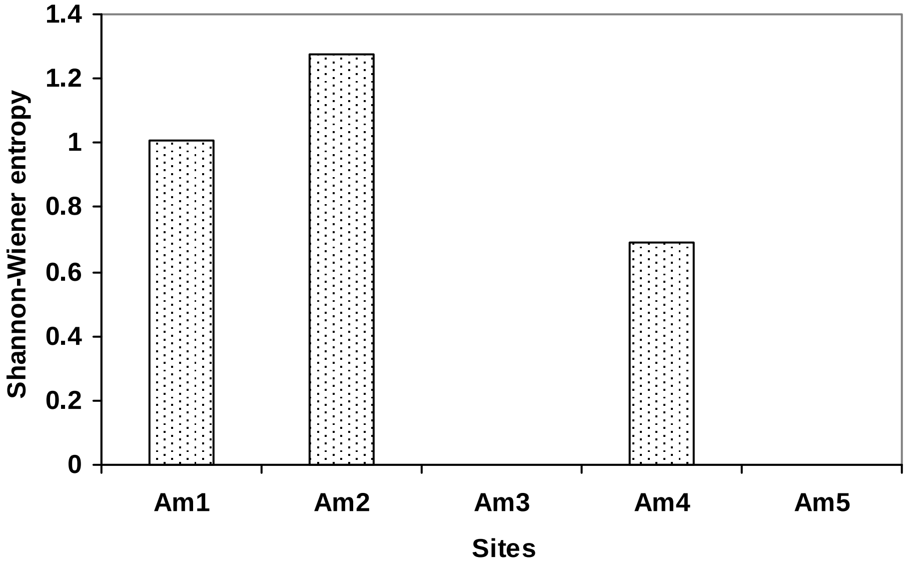

Figure 4: Diversity (Shannon-Wiener general entropy, log2) of the studied ant communities along Arieşul Mic River. In Am5 no colonies were found.

Regarding the changes in diversity in both Arieşul Mare and Arieşul Mic rivers (Figs. 3 and 4) the highest value is recorded in the upper part of the rivers, while towards the confluence, lower values are recorded, probably because of the human impact.

The hierarchical cluster analysis (Fig. 5) shows that there is a grouping tendency on habitat preferences; the ant communities from spruce forest sites like I_MARE, III_MARE and I_MIC form a distinct group.

DISCUSSIONS

On the basis of this study the number of known ant species from the upper Arieş River meadows sums up to 39. There are several new species for this region, as: *Formica lemani, F. clara, Lasius plathytorax, L. paralienus, Myrmica ruginodis, M. scabrinodis, M. sabuleti, M. schencki, M. hellenica* and *Leptothorax acervorum*.

The high heterogeneity of the ant communities shows important changes in habitats quality along Arieşul Mare and Arieşul Mic, meaning that the valley can work as a corridor for species that can support a greater disturbance as *L. niger, L. flavus* and *F. cinerea* etc. However, the high number of additional species obtained by free hand collection outside of the nest suggests that the sampling method was not efficient in collecting all the existing species.

Although hand-collecting is more time-consuming and liable to individual differences among collectors with differing field experiences, the method supplements the results obtained by pitfall trapping (Vepsäläinen et al., 2000).

The Romanian fauna currently contains 107 ant species (Markó et al., 2006; Markó 2008a, 2008b; Moscaliuc, 2009; Ionescu-Hirsch et al., 2009) however the number of species is expected to be bigger as some wider regions have been studied insufficiently. The high diversity of the ant fauna of the upper Arieş River basin disserves further research. Such studies could yield important additional data to the fauna of protected areas or of those areas which would be worth of protecting in the future.

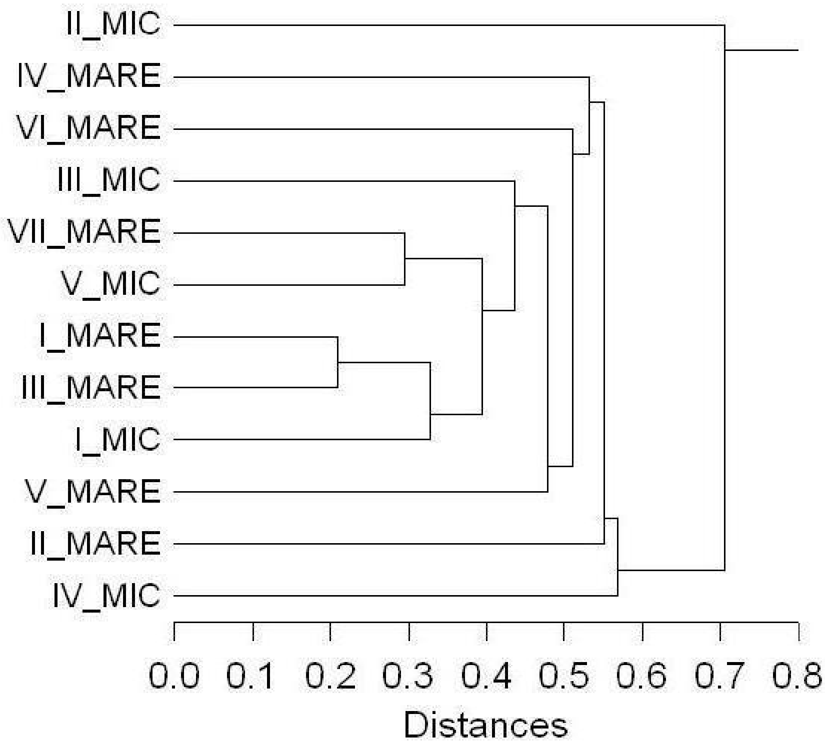

Figure 5: Hierarchical cluster analysis on Euclidean distances (average linkage method) of ant communities from the Arieşul Mare and Arieşul Mic rivers' valleys (I_MARE-VII_MARE – Arieşul Mare sampling sites; I_MIC-V_MIC - Arieşul Mic sampling sites).

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ORDER TRICHOPTERA (INSECTA) FROM THE APUSENI NATURE PARK (TRANSYLVANIA, ROMANIA)

Constantin CIUBUC *

* Zoological Station Sinaia, Cumpătu Street 5, Prahova County, Romania, RO-106100, ciubuc@ilcofon.net

KEYWORDS: Romanian Carpathians, Transylvania, Apuseni Mountains, Apuseni Nature Park, Arieş Basin, Someş Basin, Trichoptera, bioindicators, Shannon diversity index, population distribution.

ABSTRACT

54 caddisfly species (imago) belonging to 12 families were identified during 2006 and 2008 in three sampling sites in the upper Arieş and Someşul Cald catchment areas, representing about one fifth of the Romanian Trichoptera fauna. 23 species were common to the three sites (Gârda Seacă, Vârtop - the upper Arieş catchment area and Ic Ponor - the source of the Someşul Cald River); 15 species were present only in the Someşul Cald, 1 only in Vârtop and 11 only in Gârda Seacă. *Hydroptila taurica* Martinov belonging to Hydroptilidae was recorded for the first time in the Romanian fauna. The following species were cited for the first time for this park: *Lype reducta* Hag., *Hydropsyche botosaneanui* Marink, *Rhadicoleptus alpestris* Kol., *Limnephilus hirsutus* Pictet, *L. rhombicus* Linneaus, *L. sparsus* Curtis. Other species, like *Hydropsyche tabacarui* Bots. (Family Hydropsychidae), *H. botosaneanui* Marink. and *H. pellucidula* Curtis were identified in the considered sites, even if they are known to occur mostly in submountainous waters in Romania. A high number of species belonged to Limnephilidae (44%) (23 species), Rhyacophilidae and Hydroptilidae (12%) (7 species). High values of Shannon Wiener diversity index showed an increased microhabitat diversity and good water quality. Caddisfly populations recorded a normal distribution along an altitudinal gradient, but there were major human pressures that influenced the diversity of Trichoptera species.

RÉSUMÉ: Les Trichoptères (Insecta) du Parc Naturel d'Apuseni (Transylvanie, Romanie).

Pendant les années 2006 et 2008, dans trois stations du bassin supérieur de l'Arieş et de Someşul Cald, on a identifié 54 espèces de Trichoptères à l'état d'imagos appartenant à 12 familles, qui représente un peu plus de 1/5ème du total de la faune des Trichoptères de Roumanie. Vingt-trois espèces sont communes pour trois sites: Gârda Seacă, Vârtop - le bassin supérieur de l'Arieş - et Ic Ponor - la source du Someş Cald. Quinze espèces n'ont été trouvées qu'à Someşul Cald, 1 à Vârtop et 11 à Gârda Seacă. Parmi les Hydroptylidae, *Hydroptyla taurica* Martinov est nouvelle pour la faune de Roumanie. On a enregistré pour la première fois sur le territoire du Parc Naturel d'Apuseni les espèces de Trichoptères suivantes: *Lype reducta* Hag., *Hydropsyche botosaneanui* Marink., *Rhadicoleptus alpestris* Kol., *Limnephilus hirsutus* Pictet, *L. rhombicus* Linnaeus, *L. sparsus* Curtis. Cependant, d'autres espèces comme *Hydropsyche tabacarui* Bots., *H. botosaneanui* Marink. et *H. pellucidula* Curtis (Hydropsychidae) y ont été récoltées bien qu'elles soient plus communément présentes dans les eaux du piémont en Roumanie. Nos recherches ont mentionné la présence d'un grand nombre d'espèces appartenant aux Fam. Limnephilidae (23) et Rhyacophilidae (7). Les valeurs élevées des indices de diversité spécifique Shannon Wienner, montrent une diversité élevée des microhabitats et une qualité supérieure de l'eau des deux bassins supérieurs de ces deux rivières. En dehors de la distribution normale des populations par rapport au gradient altitudinal, on constate des influences majeures d'origine anthropique induisant des conséquences sur la diversité spécifique des Trichoptères.

REZUMAT: Ordinul Trichoptera (Insecta) din Parcul Nat. Apuseni (Transilvania, România).

În 2006 şi 2008, în trei stații din bazinul superior al Arieşului şi Someşului Cald au fost identificate 54 specii de trichoptere (imago), aparținând la 12 familii, ceea ce reprezintă ceva mai mult de 1/5 din totalul faunei de trichoptere a României. 23 specii sunt comune celor trei situri (Gârda Seacă, Vârtop - bazinul superior al Arieşului şi Ic Ponor - obârşia Someşului Cald), 15 au fost doar în Someşul Cald, 1 în Vârtop şi 11 doar în Gârda Seacă. Dintre Hydroptilidae, *Hydroptila taurica* Martinov este înregistrată prima dată în România. Au fost înregistrate prima dată pe teritoriul PNA speciile de Trichoptere: *Lype reducta* Hag.; *Hydropsyche botosaneanui* Marink; *Rhadicoleptus alpestris* Kol.; *Limnephilus hirsutus* Pictet; *L. rhombicus* Linneaus; *L. sparsus* Curtis, iar alte specii, *Hydropsyche tabacarui* Bots. (Fam. Hydropsychidae) *H. botosananui* Marink. şi *H. pellucidula* Curtis au fost identificate ca prezente, deşi acestea sunt prezente în general în apele submontane din România. În cercetările noastre, este subliniată prezența unui număr mare de specii, aparținând familiilor Limnephilidae (23) şi Rhyacophilidae (7); valorile ridicate ale indicilor de diversitate specifică Shannon Wiener induc ideea unei diversități crescute a microhabitatelor şi o calitate superioară a apei celor două bazine superioare ale celor două râuri. În afară de distribuția normală a populațiilor pe gradient altitudinal, există influențe majore de origine antropică cu consecințe asupra diversității specifice a Trichopterelor.

INTRODUCTION

The diversity of bioindicator species always represented a topic of debate in all research activities of ecosystems. The following aspects represent the framework of previous research of Trichoptera community structure in Apuseni Nature Park: the main challenge of the present study was the existence of previous research studies on Trichoptera communities from the Apuseni Mountains aquatic ecosystems (and not only) (Botoşăneanu, 1952, 1957, 1959, 1966; Botoşăneanu and Por, 1957; Botoşăneanu and Schneider, 1978; Murgoci, 1951; Murgoci and Marcoci, 1955); another challenge was the heterogeneous sampling of Order Trichoptera in these ecosystems along the years. All previous studies were based on individuals collected on different occasions from the caves or the water bodies of the Apuseni Mountains in different expeditions and in different periods of time. Most species cited in these papers and most samplings were described many times by specialists on other macroinvertebrate groups; no previous study described a sampling method with efficient results; at present there is no complete list of caddisfly species from the running waters of the Apuseni Nature Park; after the Apuseni Nature Park was declared a protected area, its administration demanded a database of macroinvertebrate biodiversity from the aquatic and terrestrial ecosystems included in the Park area; nowadays, fewer researchers focus on fauna and flora structure from the Romanian protected areas, thus numerous databases include only historic data; in order to implement the Framework Directive - a request for Romania as new EU member, a complete inventory of bioindicator groups (including numerous Trichoptera from aquatic ecosystems) must be made.

MATERIAL AND METHODS

Three unpolluted aquatic ecosystems were chosen, two in Arieş Basin (Gârda Seacă and Vârtop) and one in Someşul Cald Basin (Fig. 1). The first was located in Vârtop at 1,140 m altitude and the second one in Gârda Seacă at 760 m (near Dobra house in Gârda Seacă), while the third one is near the Ic Ponor locality, in the upper Someşul Cald Basin - near the river source: Vârtop - North 46030` 58``, East 22041`11`` (1,139 m); Gârda Seacă - North 46027`54``, East 22049`35`` (853 m); Someşul Cald - North 46037`47``, East 22046`55`` (1,081 m). At the last station, caddisflyes were collected from two close sites (100 m distance). Three light traps were used along the Someşul Cald, situated about 50 m from one another. A third light trap was on the Alunul Mic River, 100 m upstream from its junction with the Someşul Cald River.

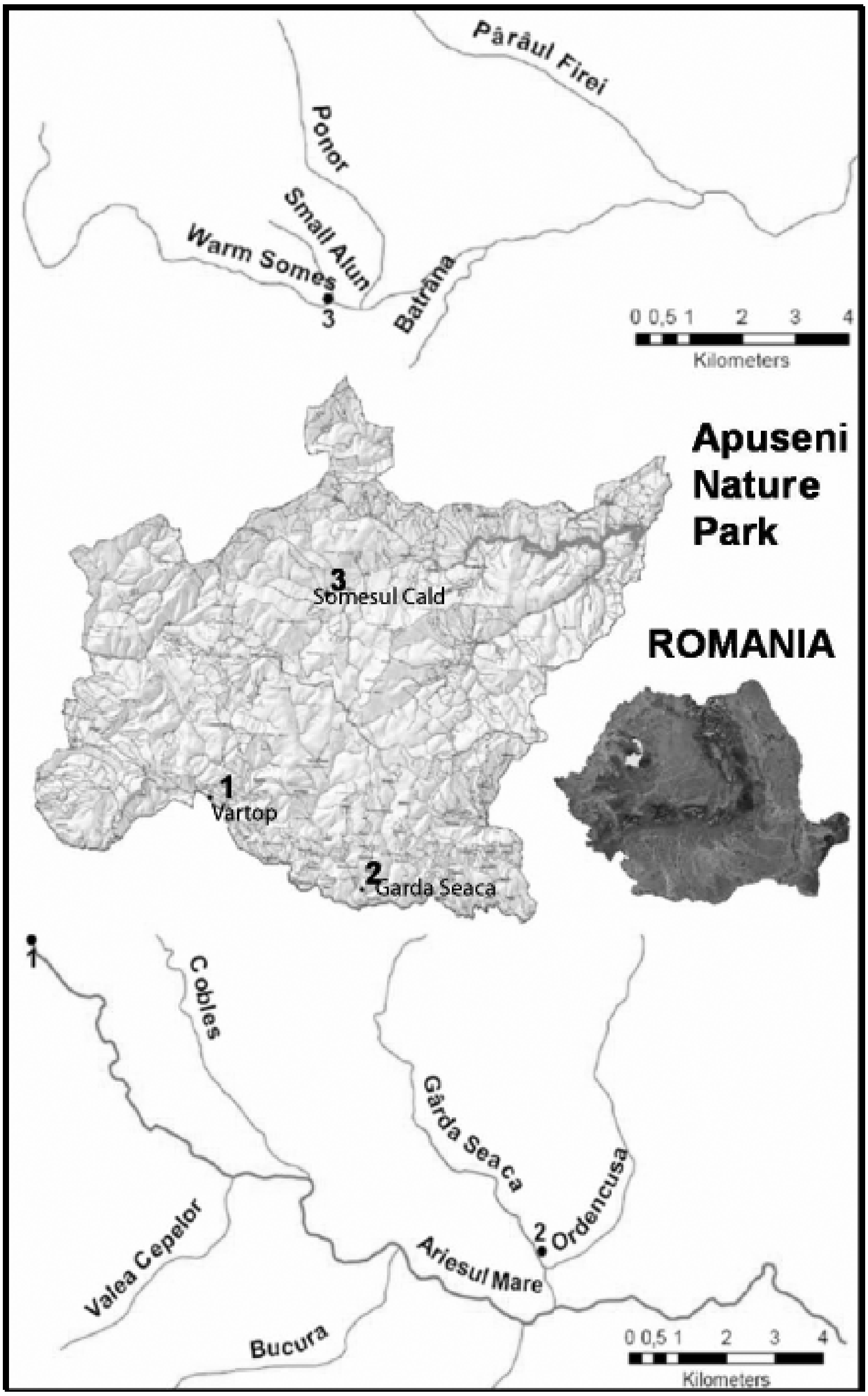

Figure 1: The location of the following sampling sites: Vârtop,
Gârda Seacă (the upper Arieş River) and the Someşul Cald (source).

Light traps are metal cylindrical tools, 30 cm in diameter, having three holes 10 cm in diameter. Inside the traps are 250 W white light bulbs with mercury vapors. The light bulbs were connected to a 3 KW electrical generator. They were on from nine o'clock in the evening till five - five thirty o'clock in the morning the next day. The biological material was collected in plastic recipients with 80% alcohol and a few ml glycerin. After the sampling, the material was sorted, identified up to species level, divided by sex and then preserved in 80% alcohol. The collection is located at the The Bucharest University Zoological Institute of Sinaia.

15 samples were taken from the Someşul Cald Basin (Someşul Cald - River source and Alunul Mic) in July 2008 (between 18th July to 23rd July 2008), while the samples from the Arieş catchment area (Vârtop and Gârda Seacă) were collected from June the 5th till August the 29th 2006. The last samples were collected in two consecutive nights every two weeks. Thus, 13 samples were taken from Gârda Seacă, the Dobra house, and 11 samples from Vârtop. At the three sampling sites the light traps worked with the same type of bulb described above.

Characteristics of aquatic ecosystems considered for the study:

The Arieş River source (Vârtop) was characterized by the presence of bryophytes and mountainous limno- and helocrene springs, with low water flow, benthic substratum with organic load and large stones. The water came from a complex of springs of the Vârtop area, collected by the main river which became larger on going downstream (broader river bed reaching up to 2 - 3 m, increased water flow and water velocity - up to a few m/s). The main characteristic of these springs was the strong human impact coming from numerous buildings located in the area, chalets, local houses, small hotels, access roads, fences etc. The flora was dominated by the spruce forest (*Picea excelsa*), covering the whole upper Arieş Basin area.

Gârda Seacă. (Gârda de Sus - the Dobra house) had a width of 3 - 4 m, increased water flow and a water velocity of 10 - 15 m/s. Pollution sources coming from human settlements were located downstream from the sampling site. The forest growing on the two river terraces included mostly *Fagus sylvatica* and herbaceous flora: *Impatiens nolitangere*, *Epilobium montanum*, *Mercurialis perenis*, *Heleborus purpurascens*, *Alnus viridis*, *Salix* sp., *Sambucus* sp. etc. were found on the river banks. A mountainous meadow of several hundred square meters, with a characteristic herbaceous flora (*Petasites*, *Tusilago farfara* and graminaceous plants) was located upstream from the site, on the left river bank.

The Someşul Cald and Alunul Mic rivers. The river was 8 - 10 m wide; the substratum was made of rock fragments measuring from a few centimeters to 30 - 40 cm. Microhabitats dominated by sand and gravel were located laterally, in the riverbed regions with decreased erosion. Artificial waterfalls made by wood logs were situated every 50 m, causing decreases in water velocity. The aquatic ecosystem had an increased stability in the study area, not only from a hydrological point of view, but also as regards the structure of the adjacent communities. No traces of floods or erosion and sedimentation were found in the riverbed and in the floodplain. Before the junction, both rivers drained a system of caves and gorges that caused an increased stability of hydrological levels, so pluvial waters and those coming from the sudden snow melt had little influence. All these aspects influenced the diversity of aquatic microhabitats, leading to a stable structure of Trichoptera communities. The three light traps from the Someşul Cald catchment area were located at 30 m upstream the river junction with the tributary Alunul Mic, in a forest dominated by *Picea excelsa*. *Alnus viridis, Sambucus* sp. and *Salix* sp. were found on the riverbanks, together with shrub species: *Sorbus* sp., *Lonicera* sp., next to characteristic herbaceous flora: *Simphytum* sp., *Aconitum* sp., bryophytes in the shadows etc.

RESULTS AND DISCUSSIONS

There is only one monograph that characterize caddisfly fauna from the Arieş River catchment area (Gârda Seacă), but the number of taxa identified by the authors was very low - only 6 species (larvae and also adults): *Rhyacophila laevis, Wormaldia triangulifera, Plectocnemia conspersa, Adicella filicornis, Potamophylax luctuosus* and *Beraea pullata* (Botoşăneanu and Por, 1957). Only three of these six species were identified in the three sites considered for the present study (*Rhyacophila laevis, Plectocnemia conspersa, Potamophylax luctuosus*). Other species registered with a very low frequency in our samples (*Drusus tenellus, Potamophylax latipennis* and *Rhyacophila nubila*) (Tab. 3) were not identified by the authors even if their research took place in the same region - Gârda Seacă.

From the total of about 113 taxa identified in the Apuseni Mountains area from the beginning of Trichoptera research in Romania (Ciubuc, 1993), only 56 were found in these three sites considered for the present study, representing about 49%. The total number of 113 taxa also includes the ones caught in submountainous and hilly regions of the mountain. Trichoptera species identified in our samples belonged to 12 families. Family Limnephilidae included the highest number of species (23), representing 44% from the taxonomical structure of the community (Fig. 2 and Tab. 1). Other families included less taxon: Families Rhyacophilidae and Hydropsychidae 6 (12%), Glossosomatidae 5 (10%). The rest of the families: Hydroptilidae, Philopotamidae, Polycentropodidae, Psycomyidae, Brachicentridae, Goeridae, Sericostomatidae and Odontoceridae only had 1 - 3 species, representing 2 - 6% (Fig. 2, Tab. 1).

Good water quality from the upper Someşul Cald River and the Alunul Mic River led to the presence of several species with specific ecological requests, like *Rhyacophila polonica, Polycentropus excisus, Wormaldia pulla, Agapetus ochripes, Potamophilax latipennis* etc.

For the present study, six Trichoptera species was first cited in the Apuseni Nature Park: *Lype reducta*; *Hydropsyche botosaneanui*; *Rhadicoleptus alpestris*; *Limnephilus hirsutus*; *L. rhombicus*; *L. sparsus. Hydroptila taurica* was first identified in our country (Fig. 9). *Synagapetus slavorum*, described by Botoşăneanu on species coming from the former Yugoslavia (Botoşăneanu, 1960) was found in Romania in only a few locations: in Runcu (North Oltenia), Apuseni - in a few sites (Botoşăneanu, 1995) and Plavişeviţa, The Iron Gates (Ciubuc, 2008, unpublished data). The number of taxa identified in Gârda Seacă and the Someşul Cald source was the same - 38, but the species composition in the two sites was different. Thus, in Gârda Seacă 12 species were identified; in the Someşul Cald - Alunul Mic Rivers 15 species and at the Arieş River source (Vârtop) only one species (*Micropterna nycterobia*) (Tab. 2). The other species included on the list were found at all three sites. The high number of different taxa, especially in Gârda Seacă and in the Someşul Cald was probably due to the following factors: the existence of different microhabitats in the sites, different hydrological characteristics of the rivers, the altitude, the temperature regime and last but not least the flora composition in the adjacent terrestrial ecosystems or the species composition of benthic primary producers. Despite the good water quality in the Someşul Cald and in the Arieş (Gârda Seacă), there were differences between the two rivers. Four species belonging to the Hydropsyche genus (*H. botosaneanui, H. bulbifera, H. pellucidula, H. tabacarui*) (Tab. 2) were identified in Gârda Seacă. On the other hand, in the Someşul Cald River dominant species were those belonging to Family Limnephilidae (*Ecclisopteryx madida, L. extricatus, L. decipiens, L. rhombicus*), known to be eurybiont species. However, stenobiont species were also found: *Potamophylax nigricornis, Rhyacophila polonica* or *Philopotamus montanus,* which were rhithrobiont or crenobiont species. Other species, like *Rhyacophila nubila, Potamophylax latipennis* or *Limnephilus extricatus*, even if they were known to be mountainous rhithrobiont species, they were identified at all three sampling sites together with eurybiont species (*Limnephilus bipunctatus, L. griseus, L. lunatus*). *Rhadicoleptus alpestris*, which was an alpine species, was identified at high altitudes exceeding 1000 m, in Vârtop (the Arieş and Someşul Cald source), even if in Vârtop the springs were highly impacted. However, this species was present at lower altitudes as well (in Gârda Seacă).

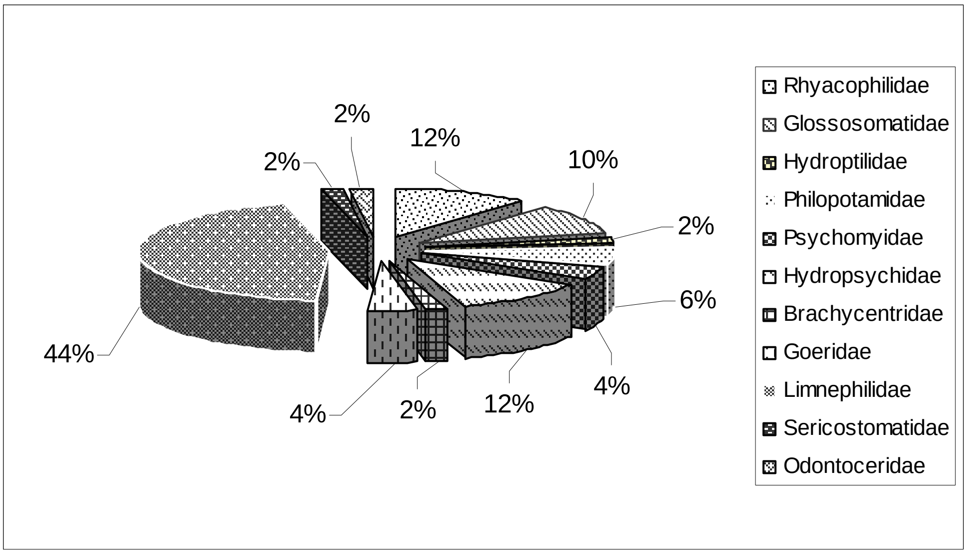

Figure 2: Species percentage belonging to different Trichoptera families from the Apuseni Nature Park area.

The common taxa identified in the Someşul Cald and Vârtop were species that preferred alpine and subalpine regions (*Limnephilus coenosus, Rhadicoleptus alpestris*), or rhithrobiont species (*Plectrocnemia conspersa*), together with species with larger ecological requests (*Limnephilus vittatus*). Five common species were found in Gârda Seacă and Vârtop, despite the differences in altitude: *Limnephilus sparsus* (eurybiont), *Potamophylax luctuosus* (mountainous rhithrobiont), *Silo piceus* (rhithrobiont and epi-potamobiont), *Rhadicoleptus alpestris* (alpine and subalpine) and *Stenophylax permistus* (rhithrobiont).

All the examples presented above prove the adaptability of some caddisfly eurybiont species to different ecological conditions but also the high specificity of others to different types of brooks, to a specific temperature regime with or without particulate organic load. Hydropsychidae species were identified in higher numbers in Gârda Seacă compared to the other two sites: the Someşul Cald and Vârtop. Thus, five taxa were found: *Hydropsyche botosaneanui*, *H. bulbifera, H. pellucidula*, *H. tabacarui* and *Hydropsyche* sp., compared to only one - *Hydropsyche instabilis* in the Someşul Cald and Vârtop stations. The species belonging to genus Hydropsyche did not build cases and they were collectors, feeding on particulate organic matter that was why they were present in higher numbers at the Gârda Seacă site, where leaf fragments were numerous in the riverbed. On the other hand, most species from Family Hydropsychidae were found in plain and hilly regions, up to 600 - 700 meters a.s.l.

The table 3 presents 38 taxa identified in the Gârda de Sus (Dobra house) between June 5th and August 29th 2006. *H. instabilis* and *H. pellucidula* recorded the highest abundance. Sex ratio was in favor of females for both species. *Hydropsyche tabacarui* and *H. botosaneanui* had very low populations (*H. tabacarui* 5 ♂ and 5♀; *H. botosaneanui* only 1 ♂). The highest frequency (70 - 80%) was recorded by *Drusus tenellus*; *Potamophylax latipennis* and *Rhyacophila nubila*. The imagoes found throughout the warm season suggested that the emergence took place from June to August-September, leading to numerous populations belonging to the three species. In only three sampling occasions in June no emergence occurred.

Table 1: List of Trichoptera taxa identified in the Apuseni Nature Park area.

Fam. Rhyacophilidae	*Hydropsyche tabacarui* Botoşăneanu, 1960
Rhyacophila fasciata Hagen, 1859	**Fam. Brachycentridae**
Rhyacophila laevis Pictet, 1834	*Micrasema minimum* McLachlan, 1876
Rhyacophila mocsaryi Klapalek 1898	**Fam. Goeridae**
Rhyacophila nubila (Zetterstedt, 1840)	*Silo graellsii* Pictet, 1865
Rhyacophila torrentium Pictet, 1834	*Silo piceus* (Brauer, 1857)
Rhyacophila tristis Pictet, 1834	**Fam. Limnephilidae**
Rhycophila polonica McLachlan, 1879	*Ecclisopetryx dalecarlica* Kolenati, 1848
Fam. Glossosomatidae	*Ecclisopetryx madida* McLachlan, 1867
Glossosoma boltoni Curtis, 1834	*Drusus tenellus* Klapalek, 1898
Glossosoma conformis Neboiss, 1963	*Grammotaulius nigropunctatus* (Retzius, 1783)
Glossosoma discophorum Klapalek, 1902	*Rhadicoleptus alpestris* Kolenati, 1848
Agapetus laniger (Pictet, 1834)	*Limnephilus auricula* Curtis, 1834
Agapetus ochripes Curtis, 1834	*Limnephilus bipunctatus* Curtis, 1834
Synagapetus slavorum Botoşăneanu, 1960	*Limnephilus coenosus* Curtis, 1834
Fam. Hydroptilidae	*Limnephilus decipiens* (Kolenati, 1848)
Hydroptila taurtica Martynov, 1934	*Limnephilus extricatus* McLachlan, 1865
Fam. Philopotamidae	*Limnephilus griseus* (Linnaeus, 1758)
Philopotamus montanus (Donovan, 1813)	*Limnephilus hirsutus* (Pictet, 1834)
Wormaldia occipitalis (Pictet, 1834)	*Limnephilus ignavus* McLachlan, 1865
Wormaldia pulla (McLachlan, 1878)	*Limnephilus lunatus* Curtis, 1834
Fam. Polycentropodidae	*Limnephilus rhombicus* (Linnaeus, 1758)
Polycentropus excisus Klapalek, 1894	*Limnephilus sparsus* Curtis, 1834
Polycentropus flavomaculatus (Pictet, 1834)	*Limnephilus vittatus* (Fabricius, 1798)
Plectrocnemia conspersa (Curtis, 1834)	*Micropterna nycterobia* McLachlan, 1875
Fam. Psychomyidae	*Micropterna sequax* McLachlan, 1875
Psychomyia pusilla (Fabricius, 1781)	*Potamophylax latipennis* (Curtis, 1834)
Lype reducta (Hagen, 1868)	*Potamophylax luctuosus* (Piller and Mitterpacher, 1783)
Fam. Hydropsychidae	*Potamophylax nigricornis* (Pictet, 1834)
Hydropsyche botosaneanui Marinkovic 1966	*Stenophylax permistus* McLachlan, 1875
Hydropsyche bulbifera McLachlan, 1878	**Fam. Sericostomatidae**
Hydropsyche instabilis (Curtis, 1834)	*Sericostoma flavicorne* Schneider, 1845
Hydropsyche pellucidula (Curtis, 1834)	**Fam. Odontoceridae**
Hydropsyche sp.	*Odontocerum hellenicum* Malicky, 1972

Among the six new species from the Apuseni Nature Park, three were identified in Gârda Seacă (*Hydropsyche botosaneanui,* 1♂; *Limnephilus hirsutus* 6♂ and 4♀, *L. sparsus*), 2 were found in Someşul Cald (*Lype reducta* and *L. rhombicus*) and 1 in Vârtop (*L. sparsus*). (Tabs. 2 - 5). The following species recorded a very low number of individuals: *Agapetus laniger*, 3♀; *Glossosoma conformis*, 3♀; *G. boltoni*, 1♀; *Grammotaulius nigropunctatus*, 4♂ and 1♀; *Limnephilus griseus*, 4♂ and 1♀; *Hydropsyche bulbifera*, 3♀; *Rhyacophila tristis*, 3♂, *R. torrentium* 4 ♂ and 5♀; *Silo graellsii*, 2♂, 6♀ and *Wormaldia occipitalis*, 1♂, *Micropterna nycterobia*, 1♀ (Tabs. 3 - 5).

Table 2: List of Trichoptera imago instars present in the three stations considered for the present study.

12 species identified only at the Gârda Seacă	**16 species identified only in the Someşul Cald**
Agapetus laniger	*Agapetus ochripes*
Hydropsyche botosaneanui	*Ecclisopetryx madida*
Hydropsyche bulbifera	*Hydroptila taurtica*
Hydropsyche pellucidula	*Limnephilus decipiens*
Hydropsyche sp.	*Limnephilus extricatus*
Hydropsyche tabacarui	*Limnephilus griseus*
Limnephilus hirsutus	*Limnephilus rhombicus*
Limnephilus ignavus	*Lype reducta*
Micropterna sequax	*Odontocerum hellenicum*
Rhyacophila laevis	*Philopotamus montanus*
Synagapetus slavorum	*Polycentropus excisus*
Wormaldia occipitalis	*Polycentropus flavomaculatus*
	Potamophylax nigricornis
	Rhycophila polonica
	Sericostoma flavicorne
	Wormaldia pulla
1 sp. identified only in the Vârtop	
Micropterna nycterobia	
10 common sp. for the three stations	**12 sp. common at Gârda Seacă and Someşul Cald**
Drusus tenellus	*Ecclisopetryx dalecarlica*
Glossosoma conformis	*Glossosoma discophorum*
Hydropsyche instabilis	*Grammotaulius nigropunctatus*
Limnephilus bipunctatus	*Limnephilus auricula*
Limnephilus extricatus	*Micrasema minimum*
Limnephilus griseus	*Psychomyia pusilla*
Limnephilus lunatus	*Rhyacophila fasciata*
Potamophylax latipennis	*Rhyacophila mocsaryi mocsaryi*
Rhadicoleptus alpestris	*Rhyacophila torrentium*
Rhyacophila nubila	*Rhyacophila tristis*
	Silo graellsii
	Rhadicoleptus alpestris
4 sp. comon for Vârtop and Someşul Cald	**5 sp. common for the Gârda Seacă and Vârtop**
Limnephilus coenosus	*Limnephilus sparsus*
Limnephilus vittatus	*Potamophylax luctuosus*
Plectrocnemia conspersa	*Silo piceus*
Rhadicoleptus alpestris	*Stenophylax permistus*
	Rhadicoleptus alpestris

The presence of new species of caddisflies in the Apuseni Nature Park, even with low populations, proves that species diversity from these ecosystems is not yet fully discovered.

Table 3a: Caddisfly imago instars caught with light traps at Gârda Seaca (the Dobra house) in 2006.

Taxa	The sampling date						
	sex	05.06.06	06.06.06	19.06.06.	20.06.06	03.07.06	04.07.06
Agapetus laniger	♀						
Drusus tenellus	♂				3		49
	♀			1	12	1	12
Ecclisopetryx dalecarlica	♂	22	14	39	40	3	
	♀		1	20	431		
Glossosoma boltoni	♀						1
Glossosoma conformis	♀						2
Glossosoma discophorum	♂						3
	♀						2
Grammotaulius nigropunctatus	♂	1	1	1			1
	♀	1					
Hydropsyche botosaneanui	♂				1		
Hydropsyche bulbifera	♀						
Hydropsyche instabilis	♂						
	♀						74
Hydropsyche pellucidula	♂						5
	♀				1	4	37
Hydropsyche sp.	♀				1		
Hydropsyche tabacarui	♂			5	1		
	♀			5			
Limnephilus auricula	♀				1		1
Limnephilus bipunctatus	♂				1		
Limnephilus extricatus	♂						11
	♀						
Limnephilus griseus	♂		1				1
	♀						
Limnephilus hirsutus	♂						6
	♀					3	

Taxa	**The sampling date**						
	sex	05.06.06	06.06.06	19.06.06.	20.06.06	03.07.06	04.07.06
Limnephilus ignavus	♂						
Limnephilus lunatus	♀	1					
Limnephilus sparsus	♀				1		
Micrasema minimum	♀			1	1		
Micropterna sequax	♂						
Potamophylax latipennis	♂		1			1	34
	♀		1	1		1	26
Potamophylax luctuosus	♂	5	1	5	7		
	♀	4	4	26	42		
Psychomyia pusilla	♂						
	♀						10
Rhadicoleptus alpestris	♂			4	2		
Rhyacophila fasciata	♂			1			
Rhyacophila laevis	♂			2	2		
Rhyacophila mocsaryi mocsaryi	♂	1		49	18	3	
	♀				8		
Rhyacophila nubila	♂				4	4	72
	♀			1	5	2	40
Rhyacophila torrentium	♂						1
	♀						
Rhyacophila tristis	♂			1	2		
Silo graellsii	♂				2		
	♀				4		1
Silo piceus	♂			1	5		
	♀			1	10		
Stenophylax permistus	♂	1			1		
	♀	2	2		1		
Synagapetus slavorum	♂						
Wormaldia occipitalis	♂		1				

Table 3b: List of caddisfly imago instars caught with light traps at the Gârda Seacă sampling site (the Dobra house) in 2006.

Taxa	**The sampling date**							
	sex	18.07.06	31.07.06	01.08.06	14.08.06	15.08.06	28.08.06	29.08.06
Agapetus laniger	♀		3					
Drusus tenellus	♂	12	74	7	24		4	6
	♀	3	52	12	12	1	4	6
Ecclisopetryx dalecarlica	♂		1					
	♀	1						
Glossosoma boltoni	♀							
Glossosoma conformis	♀							1
Glossosoma discophorum	♂	1	1				1	
	♀		2					
Grammotaulius nigropunctatus	♂							
	♀							
Hydropsyche botosaneanui	♂							
Hydropsyche bulbifera	♀		1		2			
Hydropsyche instabilis	♂			1	1			
	♀		27		2			5
Hydropsyche pellucidula	♂		1					
	♀		22					5
Hydropsyche sp.	♀							
Hydropsyche tabacarui	♂							
	♀							
Limnephilus auricula	♀							
Limnephilus bipunctatus	♂		2					
Limnephilus extricatus	♂	2	4					1
	♀							
Limnephilus griseus	♂						1	
	♀		2					
Limnephilus hirsutus	♂							
	♀		1					
Limnephilus ignavus	♂						1	

Taxa	**The sampling date**							
	sex	18.07.06	31.07.06	01.08.06	14.08.06	15.08.06	28.08.06	29.08.06
Limnephilus lunatus	♀							
Limnephilus sparsus	♀							
Micrasema minimum	♀							
Micropterna sequax	♂						1	
Potamophylax latipennis	♂	9	38	6	2		9	9
	♀	7	47	7	11	1	3	7
Potamophylax luctuosus	♂							
	♀							
Psychomyia pusilla	♂				2			
	♀		10					9
Rhadicoleptus alpestris	♂							
Rhyacophila fasciata	♂							
Rhyacophila laevis	♂							
Rhyacophila mocsaryi mocsaryi	♂							
	♀							
Rhyacophila nubila	♂	10	53	2	2		2	9
	♀	1	101	4	6		2	15
Rhyacophila torrentium	♂							1
	♀	1	1					1
Rhyacophila tristis	♂							
Silo graellsii	♂							
	♀		1					
Silo piceus	♂							
	♀							
Stenophylax permistus	♂							
	♀							
Synagapetus slavorum	♂				1			1
Wormaldia occipitalis	♂							

Table 4a: List of Trichoptera imago instars collected with light traps from the Someşul Cald, source.

Taxa	Sampling date										
	sex	18-19.07.08.Pb.I	18-19.07.08 Pb.II	18-19.07.08 Pb.III	19-20.07.08. Pb.I	19-20.07.08 Pb.II	19-20.07.08. Pb.III	20-21.07.08. Pb. I	20-21.07.08 Pb.II	20-21.07.08 Pb.III	21-22.07.08 Pb.I
1	2	3	4	5	6	7	8	9	10	11	12
Agapetus	♂								2		
ochripes	♀	1				1					
Drusus	♂	34	19	17	6	5	9	15	15	21	17
tenellus	♀	21	6	7	3			30	5	5	22
Ecclisopetryx	♂	1		1						1	
dalecarlica	♀	7	2	5				2		1	
Ecclisopetryx	♂	7	13	12	1	1		3		6	4
madida	♀	21	20	19	3	2	2	11	12	7	12
Glossosoma	♂			1							1
conformis	♀								1		
Glossosoma	♂										
discophorum	♀	1			2			2			
Grammotaulius nigropunctatus	♂										
Hydropsyche	♂								1		
instabilis	♀	12	14	7	2	5	3	27	28	21	4
Hydroptila	♂										
taurtica	♀										
Limnephilus	♂										
auricula	♀										
Limnephilus bipunctatus	♂										
Limnephilus	♂	1	3	1		1			2		2
coenosus	♀	2	3					1	2		
Limnephilus decipiens	♀										
Limnephilus	♂										
extricatus	♀	1		1				1		1	
Limnephilus griseus	♂		1								
Limnephilus	♂										
lunatus	♀										
Limnephilus rhombicus	♂										
Limnephilus vittatus	♀										
Lype reducta	♂										

1	2	3	4	5	6	7	8	9	10	11	12
Micrasema minimum	♂							1	1		
Odontocerum	♀			4					2	4	
hellenicum	♂										
Philopotamus montanus	♀										
Plectrocnemia	♂			1	1					2	
conspersa	♀	2	1			1			1		
Polycentropus excisus	♂	1						1			
Polycentropus flavomaculatus	♀		1								
Potamophylax	♂	15	8	11	1	1	1	8	6	3	
latipennis	♀	2	4	2	2	1		2			1
Potamophylax nigricornis	♂		2								
Psychomyia	♂								1		
pusilla	♀		7	1			2	10	8	4	1
Rhadicoleptus alpestris	♂										
Rhyacophila fasciata	♂										
Rhyacophila m. mocsaryi	♂	2								2	
Rhyacophila	♂	10	12	14	1			1			1
nubila	♀	2	3	3	1	1				1	2
Rhycophila polonica	♂			1							
Rhyacophila	♂		2								
torrentium	♀										
Rhyacophila	♂		1						2		
tristis	♀							1	1		1
Sericostoma	♂	1		1		1		1			
flavicorne	♀	1						1	2	1	
Silo	♂	4	4	1	2			5	5		2
graellsii	♀	1	7	2				1	3	1	
Wormaldia	♂		1								
pulla	♀							1			

At the Arieş River source (Vârtop), all species were represented by populations with very low number of individuals. Only one species recorded higher values from this point of view: *Rhadicoleptus alpestris* - an alpine species, having 5♂ and 16♀, cumulative values for the whole summer (Tab. 4). The main cause for the decreased number of individuals was the alteration of microhabitats from the area due to the human impacts (buildings near or in the spring complex).

Table 4b: List of Trichoptera imago instars collected with light traps from the Someşul Cald, source.

Taxa	Sampling date										
	sex	21-22.07.08. Pb.II	21-22.07.08 Pb.III	22-23.07.08 Pb.I	22-23.07.08 Pb.II	22-23.07.08 Pb.III	18-19.07.08 The Alunul Mic	19-20.07.08 The Alunul Mic	20-21.07.08 The Alunul Mic	21-22.07.08.The Alunul Mic	22-23.07.08 The Alunul Mic
1	2	13	14	15	16	17	18	19	20	21	22
Agapetus ochripes	♂										
	♀										
Drusus tenellus	♂	18	12	14	8	3	28	9	15	22	19
	♀	5	3	5		2	4		2		1
Ecclisopetryx dalecarlica	♂					1	1				1
	♀		1	1			3				
Ecclisopetryx madida	♂	1		5	5	7	26	5	12	10	18
	♀	13	4	23	15	12	9	9	19	13	17
Glossosoma conformis	♂			1		3				1	1
	♀									1	1
Glossosoma discophorum	♂			3	3	1			1		6
	♀			1	1						1
Grammotaulius nigropunctatus	♂					1					1
Hydropsyche instabilis	♂								1	1	
	♀	6	2				13	1	14		
Hydroptila taurtica	♂									1	
	♀									1	
Limnephilus auricula	♂		1		1	1					2
	♀					1					
Limnephilus bipunctatus	♂			2		1					
Limnephilus coenosus	♂			6	4	4				1	16
	♀	1			1		1				
Limnephilus decipiens	♀										1
Limnephilus extricatus	♂			1		1					1
	♀						1				1
Limnephilus griseus	♂			3	5	4	1				9
Limnephilus lunatus	♂			5		1					5
	♀			3	1	6					3
Limnephilus rhombicus	♂										1
Limnephilus vittatus	♀										1

1	2	13	14	15	16	17	18	19	20	21	22
Lype reducta	♂						1				
Micrasema minimum	♂										
	♀	1			1						
Odontocerum hellenicum	♂			2		1					
Philopotamus montanus	♀									1	
Plectrocnemia conspersa	♂	1	2	1					1		
	♀	1					2		1		
Polycentropus excisus	♂										
Polycentropus flavomaculatus	♀										
Potamophylax latipennis	♂	1		32	22	17	18		7	2	25
	♀			13	5	2		1	2		8
Potamophylax nigricornis	♂		1		1					2	
Psychomyia pusilla	♂						1		2		
	♀	1	2					1	4		
Rhadicoleptus alpestris	♂								1		
Rhyacophila fasciata	♂			3			2		1		1
Rhyacophila m. mocsaryi	♂			1			2				
Rhyacophila nubila	♂			28	20	4	9	2	1	1	18
	♀	1	1	7	1		1		1		1
Rhycophila polonica	♂										
Rhyacophila torrentium	♂										1
	♀						1				
Rhyacophila tristis	♂				1						1
	♀				1						
Sericostoma flavicorne	♂										
	♀										
Silo graellsii	♂	2		3	8				1		5
	♀		2		1		1		2		
Wormaldia pulla	♂			1							
	♀										

Table 5: Trichoptera imago instars collected with light traps at Vârtop (the Arieş source), 2006.

Taxa	**sex**	**The sampling date**										
		05.06.06	19.06.06	20.06.06	03.07.06	04.07.06	31.07.06	01.08.06	14.08.06	15.08.06	25.08.06	29.08.06
Drusus tenellus	♂							1				
	♀							1				
Glossosoma conformis	♀									1		
Hydropsyche instabilis	♂							1				
Limnephilus bipunctatus	♂		2								1	
Limnephilus coenosus	♂				1							
Limnephilus extricatus	♂	2	1									
	♀		1			1	2		1			
Limnephilus griseus	♂		1									
	♀		1									
Limnephilus lunatus	♂						1					1
Limnephilus sparsus	♀			1							1	
Limnephilus vittatus	♂										2	
Micropterna nycterobia	♀		1									
Plectrocnemia conspersa	♀		1									
Potamophylax latipennis	♂	5			1		3					1
	♀							3				
Potamophylax luctuosus	♀		1								1	
Rhadicoleptus alpestris	♂		2							2	1	
	♀		7								14	
Rhyacophila nubila	♂							1				
	♀							1				
Silo piceus	♀							1				
Stenophylax permistus	♂									1		

Regarding the number of taxa, in Ic Ponor (the Someşul Cald-Source and the Alunul Mic) a similar status was recorded, compared to the Gârda Seacă sampling site (the same number of taxa in the two sites - 38) (Tab. 5). However, the species composition of caddisfly communities was different. Thus, six populations had high number of individuals, compared to three in Gârda Seacă. Next to the species identified in Gârda Seacă (*Drusus tenellus*; *Potamophylax latipennis, Rhyacophila nubila*), other species were found: *Ecclisopteryx madida*, *Hydropsyche instabilis* and *Silo graellsii* (the last one with highest frequency: 70 - 80%). The microhabitats from the Someşul Cald - source were more diverse, but also more stable, that is why the number of species with high populations was double compared to the Gârda Seacă area. However, due to the short sampling period which was happened in 18th to 23rd July 2008, changes might occur in the numerical dynamics or even in the species structure of the caddisfly communities in other sampling periods. The sampling surface was 200 m river length, thus there was no doubt that Trichoptera communities from the Someşul Cald - source had an increased stability (Tabs. 3 and 5).

Rhadicleptus alpestris, even if is alpine species, could be found at 700 - 800 m altitude and could dwell microhabitats strongly impacted by human activities (such Vârtop and Gârda Seacă).

Few species new for the Apuseni Nature Park were present in only one or two sampling sites: *Lype reducta*; *Hydropsyche botosaneanui*; *Limnephilus hirsutus*; *L. rhombicus*; *L. sparsus.* Their geographical distribution should be studied more accurately. The reason why these species were not found in previous samplings might be related also to the sampling method. The use of a high power light source (250W) led to a more efficient capture of imago instars.

Species diversity

For the calculation of the Shannon diversity index, not only the number of species but also the distribution of individuals in each species was considered. The values calculated for the present study expressed the dynamics throughout the year, even if they were low. The fact that the index equally considered all the species, without identifying the specificity or the characteristics of each species represented a drawback of the method.

Diversity indices calculated for caddis fly populations from Gârda Seacă ranged between 0.7 to 1.9, which represent a low to medium diversity, but constant throughout the sampling months (Fig. 3). The lowest values were recorded in August 15th 2006 and corresponded to the period when temperature dropped with 6 - 8^{0}C. Only three individuals were collected on that sampling date, belonging to the following species: *Drusus tenellus*, *Potamophylax latipennis* and *Synagapetus slavorum*. The highest values of diversity indices were recorded in June the 19th 2006 (1.70), July the 4th 2006 (1.80) and August the 29th 2006 (1.90). At these sampling dates the caddisfly community recorded the highest values of species richness (Tab. 6).

Even if the species diversity of caddisfly communities from Ic Ponor (Someşul Cald and Alunul Mic) was calculated only for five sampling nights, it brought new information on population dynamics on short periods. Diversity indices ranged according to diel variations of microclimate parameters, not only in aquatic ecosystems but also in the atmosphere. At all four sites where light traps were used, higher diversity values were recorded at the beginning and at the end of the sampling period. These values represented the response of caddisfly populations to water temperature but also to the air temperature and humidity for the sampling period and for the period prior to the sampling. At site I (pb. 1) the index recorded 1.99 in the first day (18th - 19th July 2008), and 2.11 in the last night (22nd - 23rd July 2008); all the intermediate values were lower. A similar situation was recorded at sites 2 and 3 and at the Alunul Mic. A slight decrease in temperature and in air pressure (to 740 mm Hg) was recorded during the days that followed the trap installation, on 15th - 17th July 2008, similar to the values recorded in the last sampling night. The first and the last sampling night were accompanied by heavy rains and increases in air humidity. Between 19th and 22nd July the air temperature increased to 27 - 28^{o}C. Caddisflies were sensitive to temperature, wind and air humidity changes, responding with an increased activity at dawn, when breeding took place. At the last sampling (22nd - 23rd July 2008) intermittent rains occurred all night long and diversity indices recorded the highest values (over 2) at all sites. At site 1 (pb. 1) diversity index recorded 2.11 (Fig. 4); at site 2 (pb. 2) 2.06 (Fig. 5); at site 3 (pb. 3) 2.33 (Fig. 6) and at the Alunul Mic 2.33 - the highest value (Fig. 7). In dry, sunny days, with temperatures exceeding 25 - 30^{0}C, the adults hide under the vegetation, waiting for the humidity to increase during the evening to resume activity. The figures 8 to 14 present the species new for Romania and Apuseni Nature caddisfly fauna.

Table 6: Diversity index Shannon-Wiener (H`) for the Gârda Seacă and Vârtop samples.

The sampling sites	5th 07. 2006	6th 07. 2006	9th . 07. 2006	th 07. 2006	3rd 07. 2006	4th 07. 2006	18th 07. 2006	31st 07. 2006	1st 07. 2006	14th 08. 2006	15th 08. 2006	28th 08. 2006	29th 08. 2006
Gârda Seacă	1.204	1.39	1.7	1.03	1.84	1.9	1.5	1.8	1.1	1.3	0.7	1.5	1.9
Vârtop	0.598	0	1.56	0	0.69	0	0	1	1.52	0	1	0.9	0.7

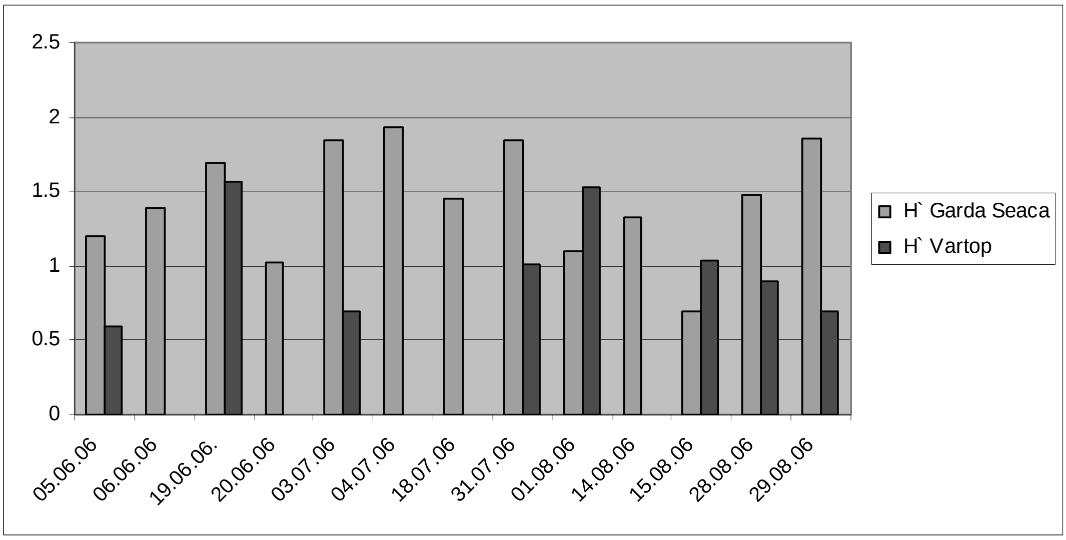

Figure 3: Shannon diversity indices (H `) for Gârda Seacă and Vârtop samples, June-September 2006.

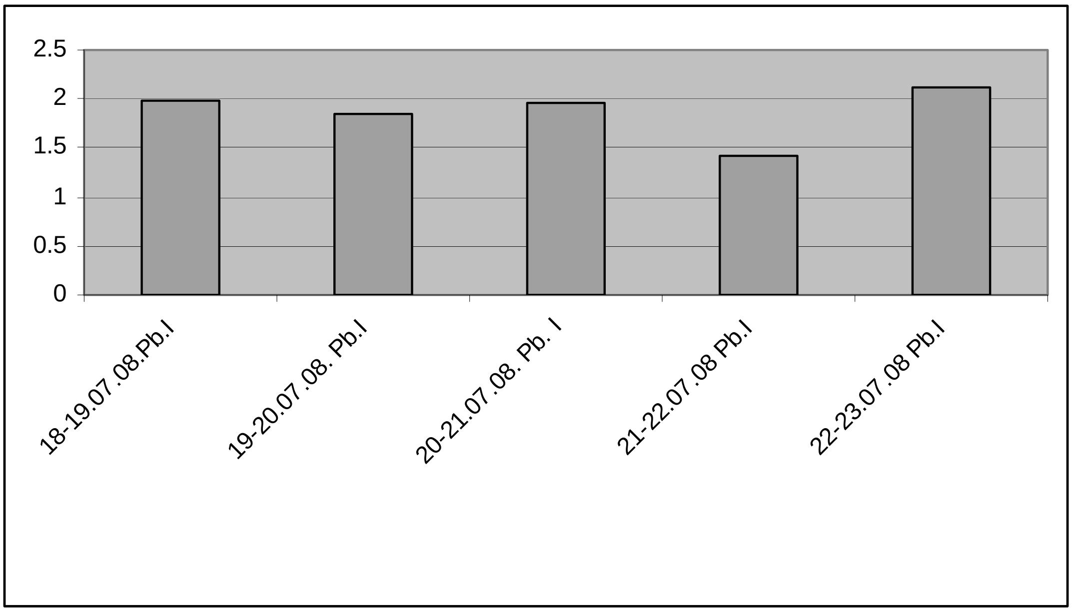

Figure 4: Species diversity indices (H`) calculated at the sampling site 1 (Pb 1), for five sampling nights.

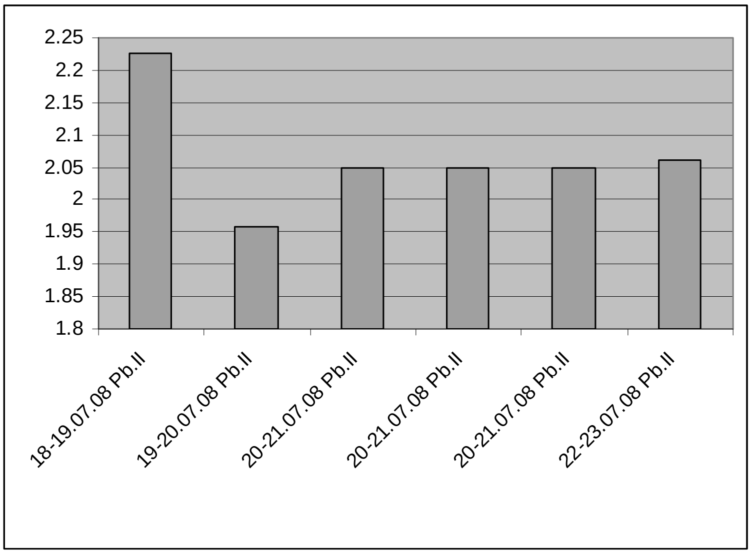

Figure 5: Species diversity indices (H`) calculated at the sampling site 2 (Pb. 2) for five sampling nights.

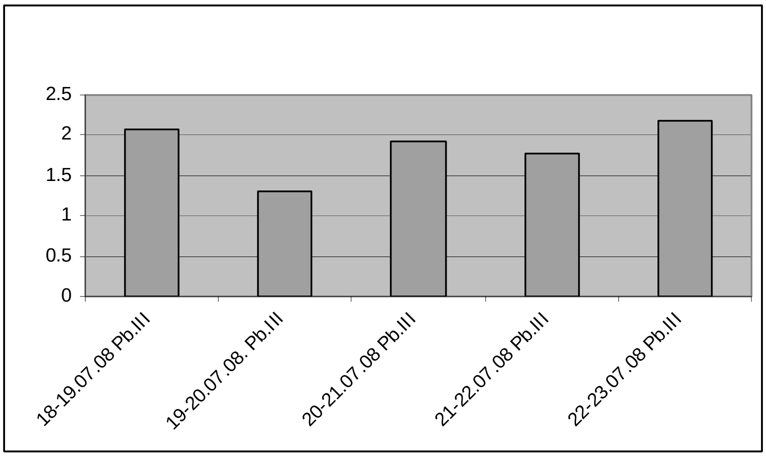

Figure 6: Species diversity indices (H`) calculated at the sampling site 3 (Pb. 3) for five sampling nights.

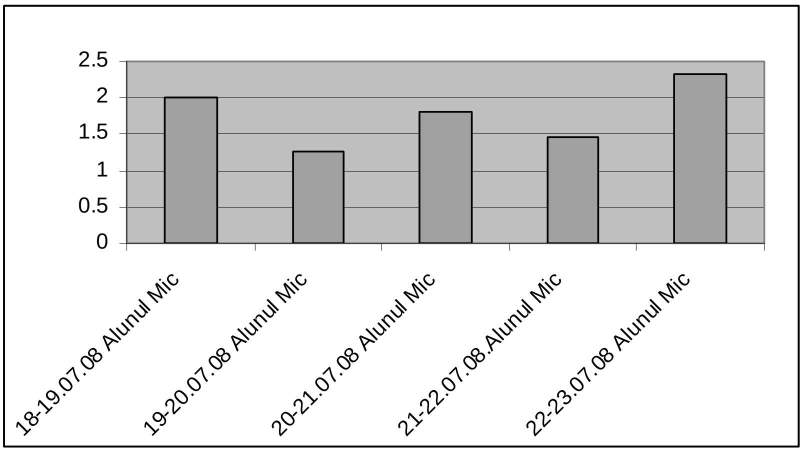

Figure 7: Species diversity indices (H`) calculated at the Alunul Mic for five sampling nights.

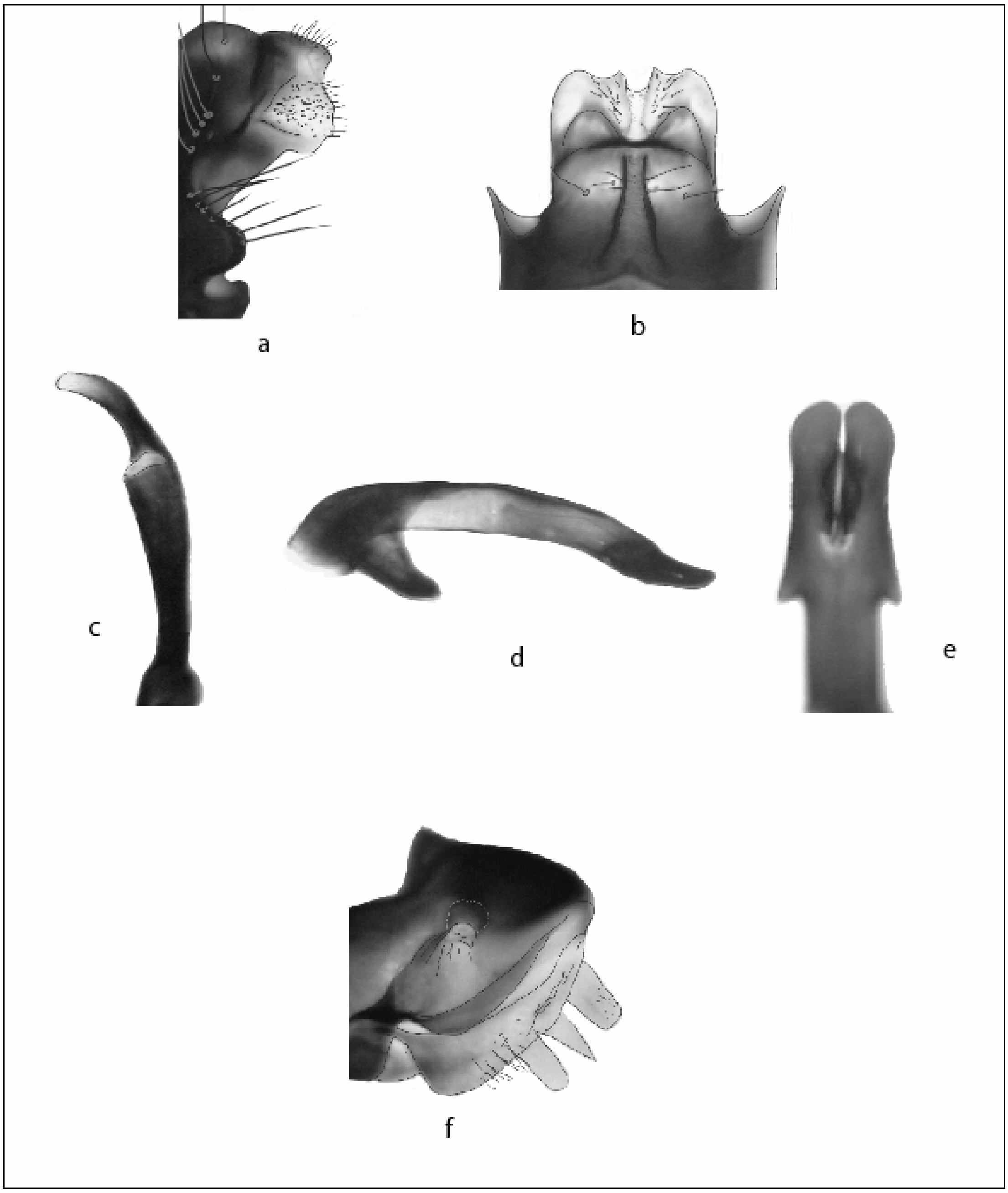

Figure 8: *Hydropsyche botosaneanui* Marinkovic. Male: a - abdominal segments 9 - 10, lateral view; b - abdominal segments 9 - 10, dorsal view; c - harpago, ventral view; d - aedeagus, lateral view; e - aedeagus, apex, dorsal view. Female: f - genitalia, lateral view.

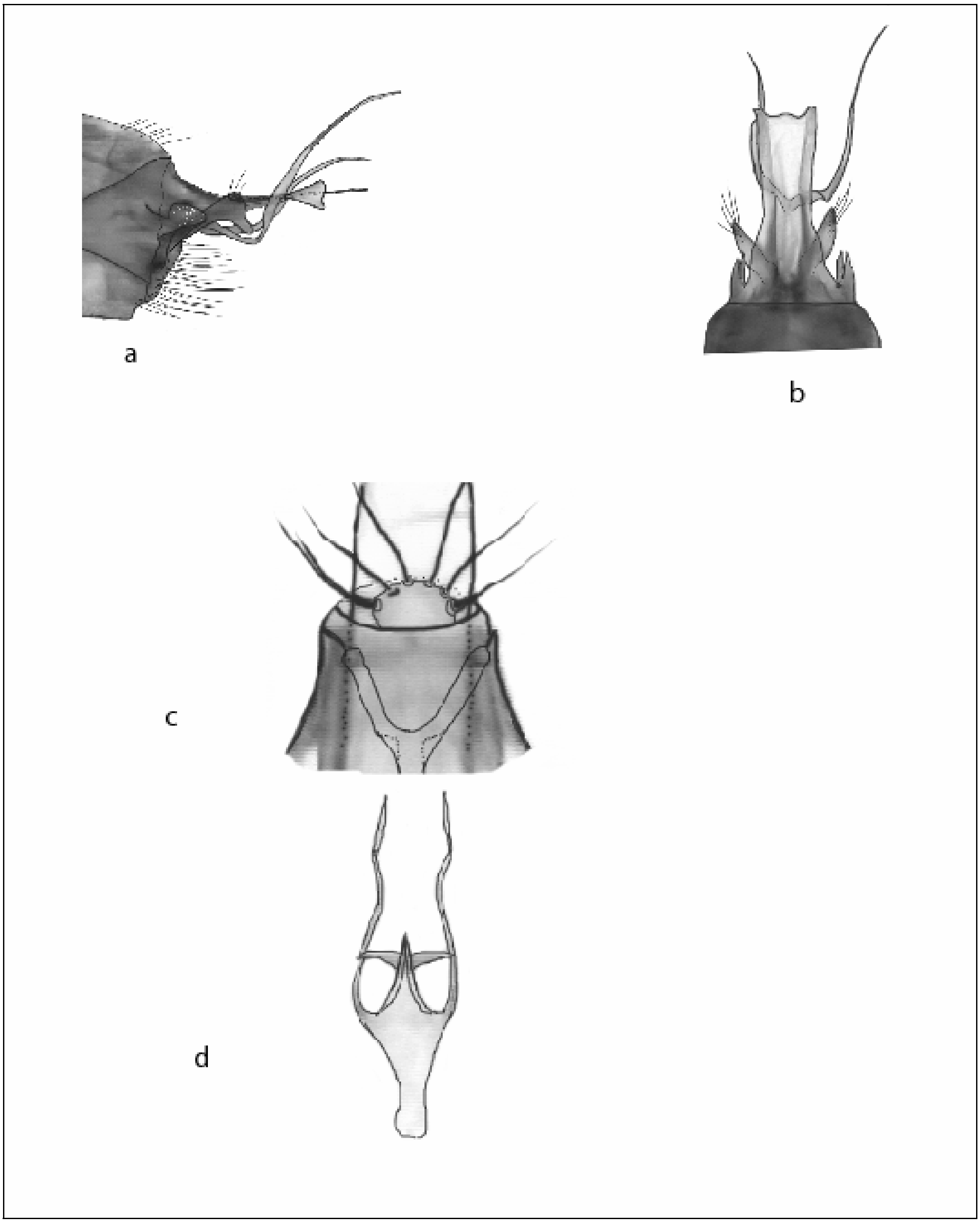

Figure 9: *Hydroptila taurica* Martynov. Male: a - genitalia, lateral view; b - genitalia, dorsal view; Female: c - genitalia, ventral view; d - spermatic process, ventral view.

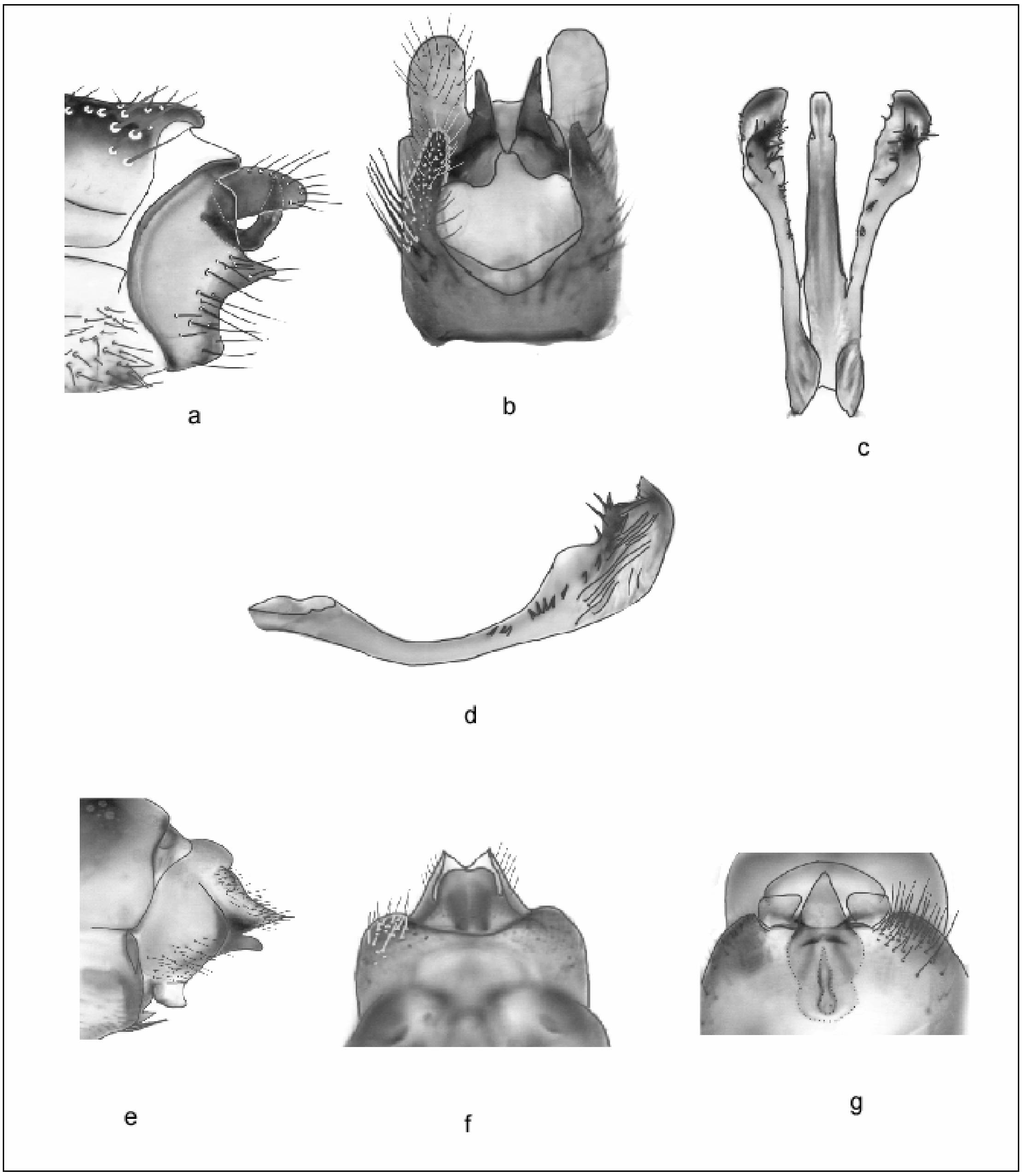

Figure 10: *Limnephilus hirsutus* (Pictet) Male: a - genitalia, lateral view; b - genitalia, ventral view; c - aedeagus with parameres, ventral view; d - parameres, lateral view; Female: e - genitalia, lateral view; f - genitalia, dorsal view; g - genitalia, ventral view, detail.

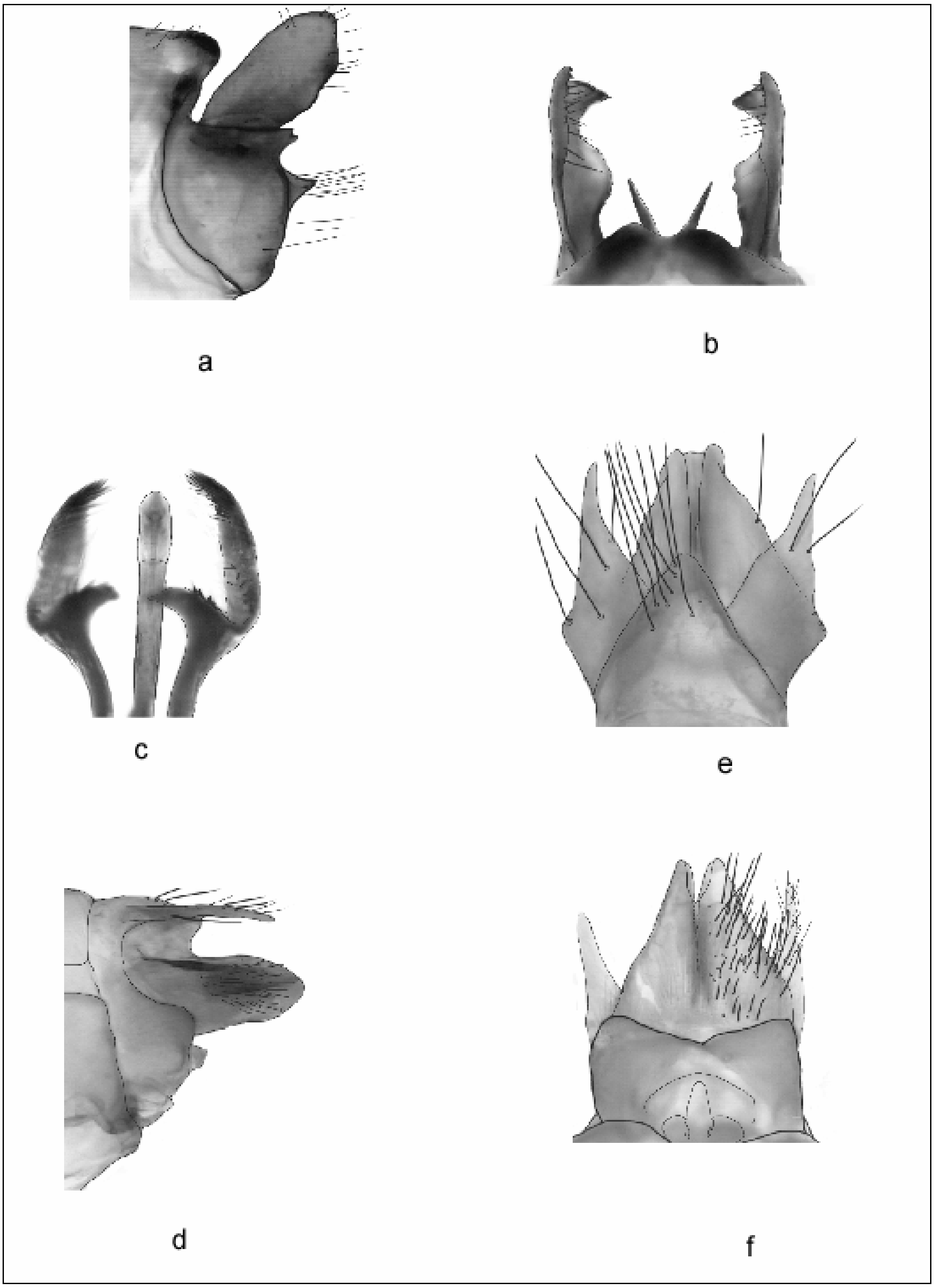

Figure 11: *Limnephilus rhombicus* (Linnaeus). Male: a - genitalia without aedeagus and parameres, lateral view; b - genitalia, dorsal view; c - aedeagus and parameres, dorsal view. Female: d - genitalia, lateral view; e - genitalia, dorsal view; f - genitalia, ventral view.

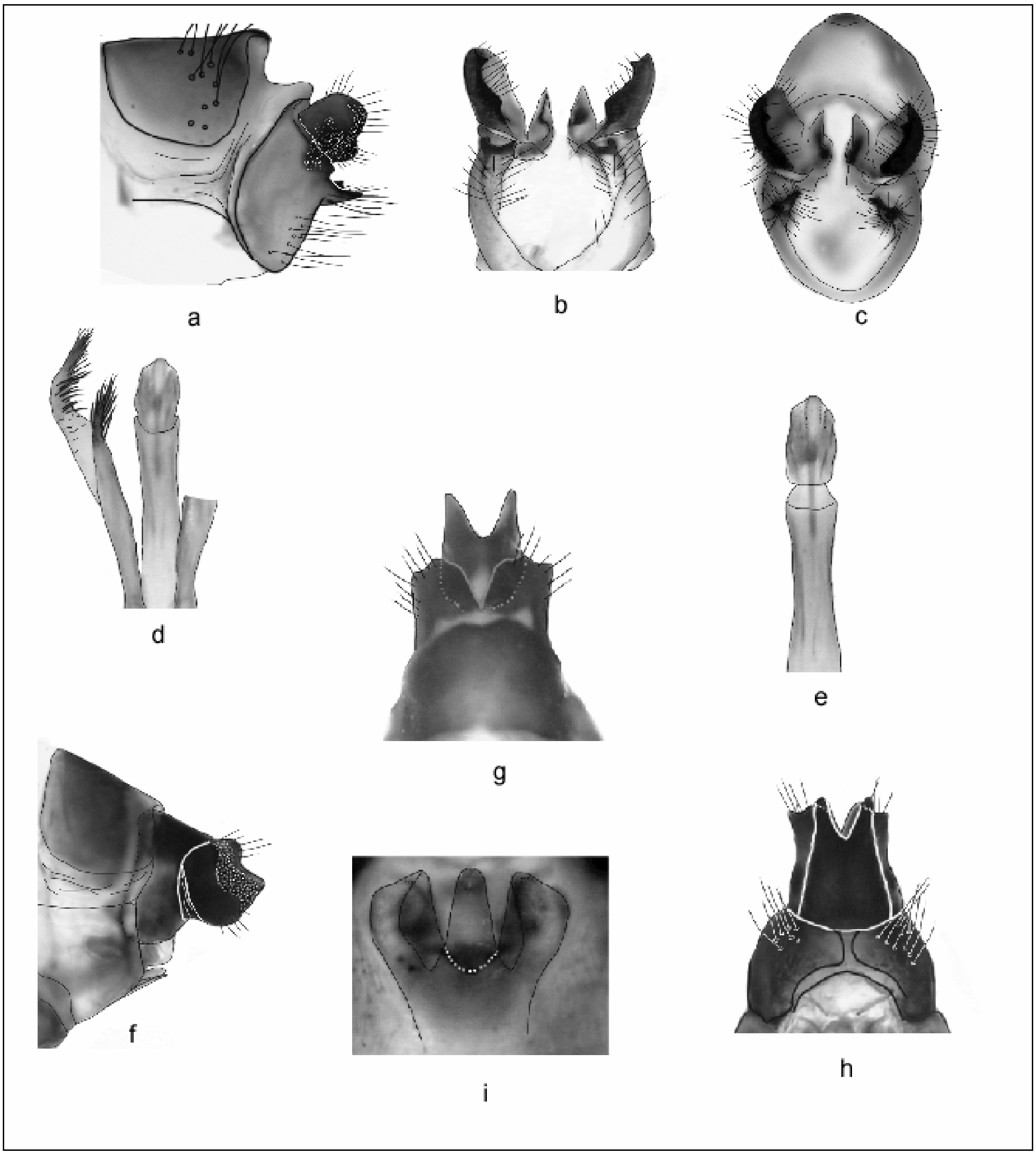

Figure 12: *Limnephilus sparsus* Curtis. Male: a - genitalia without aedeagus and parameres, lateral view; b - genitalia, ventral view; c - genitalia, caudal view; d - aedeagus with the right paramere, dorsal view; e - aedeagus, dorsal view. Female: f - genitalia, lateral view; g - genitalia, dorsal view; h - genitalia, ventral view; i - genitalia, detail, ventral view.

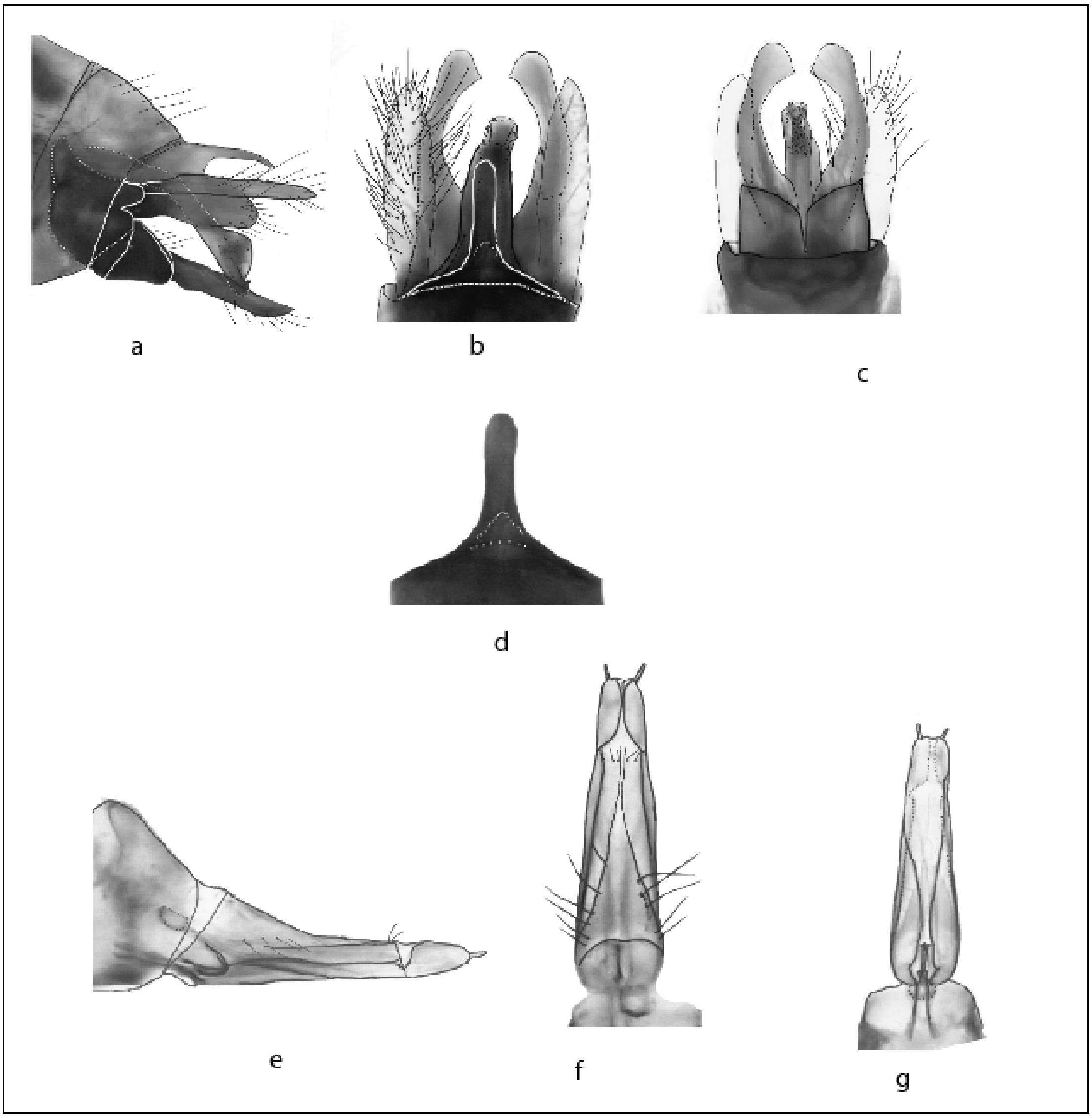

Figure 13: *Lype reducta* (Hagen). Male: a - genitalia with aedeagus, lateral view; b - genitalia, dorsal view, c - genitalia, ventral view; d - abdominal segment 9, dorsal view. Female: e - genitalia, lateral view; f - genitalia, dorsal view; g - genitalia, ventral view.

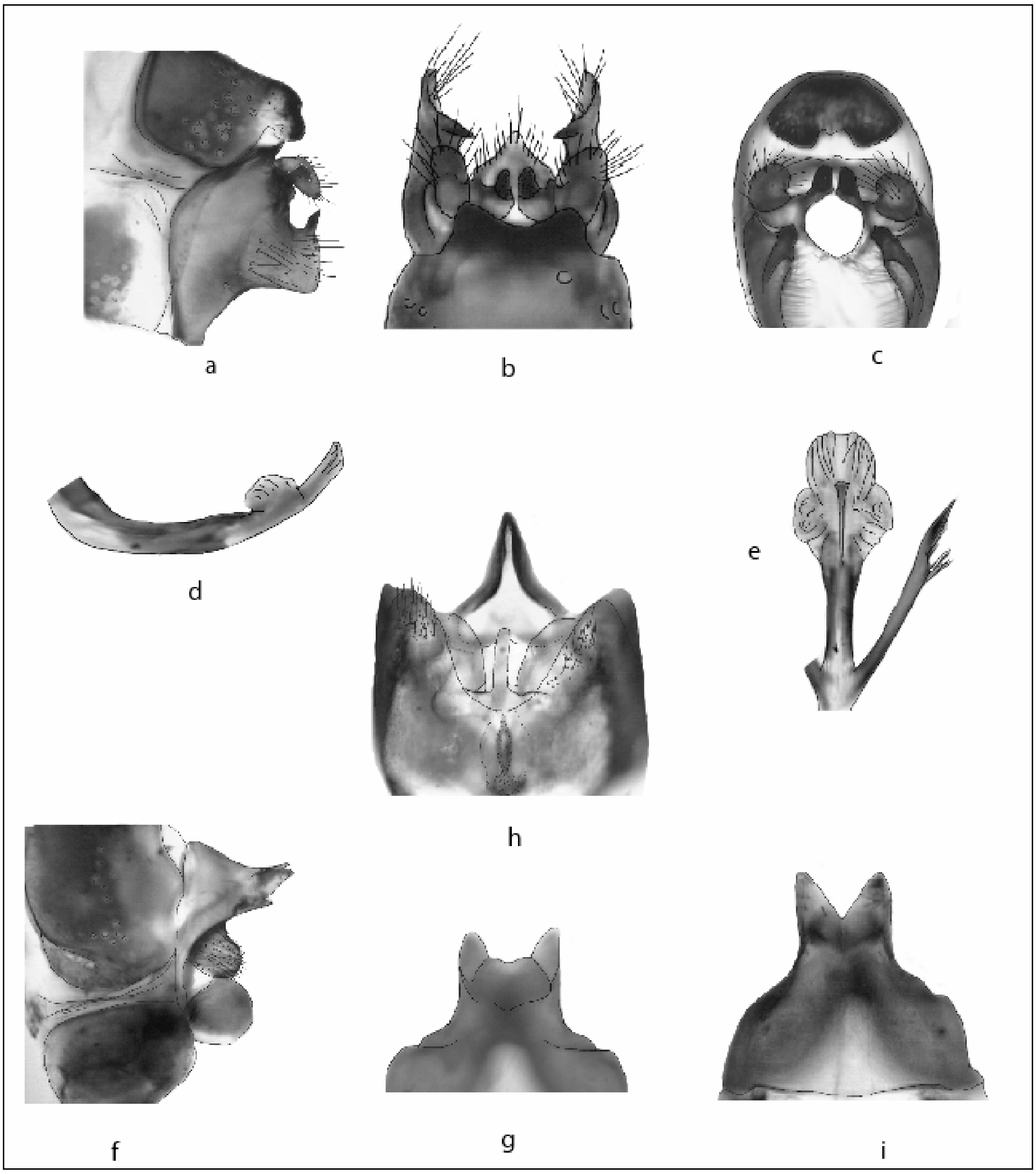

Figure 14: *Rhadicoleptus alpestris* Kolenati. Male: genitalia, lateral view; b - genitalia, dorsal view; c - genitalia, caudal view; d - aedeagus, lateral view; e - aedeagus with left paramere, ventral view. Female: f - genitalia, lateral view, g - genitalia, segment X, ventral view; h - genitalia, segment IX, ventral view; i - genitalia, segment X, dorsal view.

CONCLUSIONS

The present study added a new caddisfly species for Romania and six new species for the Apuseni Mountains, to complete the list of Trichoptera fauna. The distribution of caddisfly communities was influenced by human activities in aquatic habitats (springs, brooks, rivers, lakes) but also by human impacts on adjacent ecosystems (forests, meadows). The impact of human factors overlapped on natural environmental parameters, like rainfall, erosion, sedimentation - that caused changes in structure parameters of biotic communities (abundance, species diversity and richness, spatial distribution on an altitude gradient). The diel activity of imagoes was increased in days with heavy rainfall, high air humidity and low air pressure. On the other hand, they became inactive during sunny days with high temperature, these weather conditions causing them to seek shelter underneath the vegetation. Even if the diversity indices were calculated for short periods of time (one sampling night), they brought precious data on the intensity of emergence process of adults related to the dynamics of water physical and chemical parameters, temperature, air humidity, rainfall, wind. The sampling method used for the present study - white light trap with mercury vapors - was very efficient, leading to accurate results concerning species diversity of caddisfly community. However, the method should not be used excessively, over longer periods of time, to prevent the elimination of large numbers of individuals from the populations, thus affecting their balance.

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RELATIONSHIP BETWEEN HEAVY METALS AND HYPORHEIC INVERTEBRATE COMMUNITY STRUCTURE IN THE MIDDLE BASIN OF THE ARIEŞ RIVER (TRANSYLVANIA, ROMANIA)

Sanda IEPURE * and *Letiţia SELESCU* **

* Speleological Institute "Emil Racoviţă", Cluj Department, Clinicilor Street 5, Cluj-Napoca, Cluj County, Romania, RO-400006, sanda.iepure@iser-cluj.org, for_sanda@yahoo.com
** S. C. Minesa Mining Research Institute S. A., Tudor Vladimirescu Street 15 - 17, Cluj-Napoca, Cluj County, Romania, RO-407035, letitia.selescu@minesa.utcluj.ro

KEYWORDS: Romania, Transylvania, Arieş River, heavy metals, hyporheic, invertebrates.

ABSTRACT

Biota and chemistry of the hyporheic habitat are used to describe environmental changes in the middle basin of the Arieş River (Transylvania, north-western Romania), a river highly polluted with heavy metals and cyanides. Water from several gold and silver mine adits and their respective tailings storage facilities (TSF) flows into the river and affects fauna and sediments on about half of its length. Longitudinal and cross - sections were used in order to emphasize heavy metal pollution in two compartments of the hyporheic habitat: shoreline (A) and river bed (B), upstream and downstream the pollutant inputs from Roşia Poieni and Baia de Arieş ores. The surface water and groundwater at sites downstream the mine adits are excessively contaminated with Cu and Pb and moderately contaminated with Zn and Mn. Stations upstream the contaminated sites are inhabited mainly by insect larvae, while downstream sites are dominated by crustaceans with an important fraction of stygobite elements. Metal content increases in groundwater affect the abundance, frequency and spatial distribution of the hyporheic communities. The survey of the hyporheic fauna in the Arieş River suggests that detailed investigations of this habitat are essential for monitoring the impact of heavy metals in the polluted streams.

RĖSUMĖ: Relation entre les métaux lourds et la structure des communautés d'invertébrés du biotope hyporhéique du basin moyen de la rivière d'Arieş (Transylvanie, Roumanie).

Des recherches sur la faune aquatique et sur les caractéristiques physico-chimiques du biotope hyporhéique ont été effectuées afin de mettre en évidence les modifications survenues dans le milieu aquatique du basin moyen de l'Arieş, connu comme par sa forte pollution avec des métaux lourds et des cyanures. Les eaux provenant des mines d'or et d'argent, de même que celles des bassins de décantage afférents, sont déversées directement dans la rivière, en affectant la faune et les sédiments sur environ une moitié de sa longueur. La pollution avec des métaux lourds a été déterminée en sens longitudinal et transversal dans deux compartiments du biotope hyporhéique: les sédiments des plages (A) et ceux du lit de la rivière (B), en amont et en aval des sources de pollution représentés par les mines de Roşia Poieni et Baia de Arieş. En aval de ces mines, l'eau aussi bien de surface que souterraine est fortement polluées avec du plomb et du cuivre et contaminés de façon modérée avec du zinc et du manganèse. En amont, les stations sont peuplées surtout par des larves d'insectes, tandis qu'en aval la communauté faunistique est dominée par des crustacés, groupe qui renferme une importante fraction d'éléments stygobiontes. Le fort contenu en métaux lourds de l'eau souterraine se répercute sur l'abondance, la fréquence et la distribution spatiale des communautés hyporhéiques. L'examen de cette faune a fait ressortir son importance dans l'évaluation et la surveillance de l'impact que la pollution avec des métaux lourds a sur les organismes vivant dans divers habitats des rivières.

REZUMAT: Relaţia dintre metale grele şi structura comunităţii de nevertebrate din biotopul hiporeic, în bazinul mijlociu al râului Arieş (Transilvania, România).

Fauna acvatică şi caracteristicile fizico-chimice ale biotopului hiporeic sunt investigate pentru a ilustra modificările mediului în bazinul mijlociu al râului Arieş (Transilvania, nord-vestul României), cunoscut ca fiind puternic poluat cu metale grele şi cianuri. Apa provenită de la minele de aur şi argint şi cea a iazurilor de decantare aferente sunt deversate direct în albia râului, afectând fauna şi sedimentele pe aproximativ jumătate din lungimea sa. Poluarea apei cu metale grele a fost urmărită longitudinal şi lateral, în două compartimente ale biotopului hiporeic: sedimentele din linia malurilor (A) şi sedimentele din patul râului (B), în amonte şi în aval de sursele de poluare, respectiv minele Roşia Poieni şi Baia de Arieş. În aval de mine, apa de suprafaţă şi subterană sunt excesiv poluate cu Pb şi Cu şi moderat contaminate cu Zn şi Mn. În amonte, staţiile sunt populate cu larve de insecte, pe când în aval comunitatea este dominată de crustacee, care includ o importantă fracţiune de elemente stigobionte. Conţinutul mare de metale grele în apa subterană afectează abundenţa, frecvenţa şi distribuţia spaţială a comunităţilor din biotopul hiporeic. Analiza faunei din acest biotop a demonstrat importanţa investigării sale în studiile de monitorizare şi evaluare a impactului poluării cu metale grele asupra organismelor din diferite compartimente ale râurilor.

INTRODUCTION

Among industrial activities, mining causes the greatest and most persistent alterations in nature (Luoma and Carter, 1991; Hare, 1992; Clement et al., 2000; Marqués et al., 2000). The ecosystems from mining areas are very vulnerable and even with the technology applied in mining works nowadays they are usually highly affected. Although the acidity of the mine water and effluents is buffered to a certain extent, the water still contains a metal load, and can cause changes in the aquatic ecosystems (Kiffney and Clements, 1993; Farag et al., 1998).

Heavy metal pollution and its impact on aquatic ecosystems have been regarded with high interest over the last decades, due to metal accumulation in sediments and biocenoses (Clements, 1994; Gibert et al., 1995; Church et al., 1997; Clements, 1999; Marqués et al., 2001). Several studies in metal-polluted streams correlated metal concentrations with alterations in community structure (Winner et al., 1975, 1980; Nelson and Roline, 1996; Carlisle and Clements, 1999; Clements et al., 2000), but the mechanisms involved are still not completely known. Heavy metals can cause temporally irregular pollution in surface streams, but they are extremely difficult to remove from groundwater systems and their impact on the environment is reflected trough water quality and organisms biodiversity (Geraghty and Miller, 1978; Gibert et al., 1995; Plénet and Gibert, 1994, Gibert et al., 1995; Malard et al., 1999). The pollutants are generally present in groundwater in an insoluble form or are associated with organic or inorganic ligands that radically increase their toxicity.

One of the most vulnerable aquatic habitats to pollution is the transition zone (ecoton), or the hyporheic (the term hyporheic derives from Greek *hypo*-under and *rheos*-to flow, as referring to a stream). habitat located at the surface/groundwater interface (Gibert et al., 1995). The ecological significance of this habitat was first recognized by Orghidan (1965), who coined the term “hyporheic biotope” for the particular zone he observed. Stanford and Ward (1993) describe a “hyporheic corridor concept” and consider the hyporheic zone to be a part of the larger groundwater system in which epigean organisms with hyporheobiont life stages are present. Although the hyporheic zone is typically considered by river ecologists to be only a few centimetres to meters thick, Stanford and Ward (1988) and Danielopol (1981, 1989) noted that a hyporheic zone delineated by the presence of riverine animals may extend several kilometres from the water channel in flood-plain aquifers associated with large unregulated fluvial systems.

The impact of mining activities over water quality and aquatic organisms from hyporheic habitats have been documented in various river systems (Stanford and Ward, 1986; Resh et al., 1988; Roline, 1988; Murray, 1996; Schmidt et al., 1991; Notemboom et al., 1994; Plénet and Gibert, 1994; Plénet, 1995; Peace et al., 2007). Consequently, interest has recently started to concentrate on the attenuation capacity of the hyporheic zone for chemical pollutants. Studies have addressed the hyporheic zone in isolation or in combination with the riparian zone, as a buffer that may decrease the impact of polluted groundwater on receiving surface waters. In several cases this transition has been demonstrated not to provide water infiltration and auto-purification, thus affecting water quality and biota. It has been stated that the hyporheic zone plays a critical role in regulating metal fluxes between surface and groundwater environments; also, the composition of the associated invertebrate community can contribute to understanding the exchange mechanisms between polluted rivers and their floodplains (Marmonier and Dole-Olivier, 1986; Dole-Olivier and Marmonier, 1992; Hakekamp et al., 1993). The hyporheic habitat is significantly important also in the life cycle of several benthic invertebrates and of some strictly stygobite species (that is, restricted to groundwater through their entire life cycle), offering a refuge from high flows and sporadic pollution in surface waters and providing a source for the re-colonization of surface substrates (Gibert et al., 1995; Dole-Olivier et al., 1997).

Forray and Halbauer (2000) and Forray (2001, 2002) have previously examined the level of concentration in heavy metals in the Arieş River (Transylvania, north-western Romania). They found Cu, Pb, and Zn concentrations exceeding the standard limit downstream the pollution sources of Roşia Poieni and Baia de Arieş. No biologically-oriented studies of the Arieş River in order to asses the influence of the hydrochemistry processes on the surface or groundwater fauna are known up to now. This study, performed between the years 2000 - 2002, aims to quantify the influence of the contaminated surface and groundwater with heavy metals on the hyporheic community composition in the middle basin of the Arieş River. Annual collection of hyporheic invertebrates and water samples has been performed from seven sites located in along the shoreline and river bed sediments (both parts of the hyporheic habitat), upstream and downstream the main pollution sources from Roşia Poieni and Baia de Arieş mine adits (Figs. 1 and 2). Two questions arise: 1) which is the heavy metal spatial distribution in the surface stream and groundwater along the investigated sector of the Arieş River; and 2) how do hyporheic communities react when groundwater is contaminated?

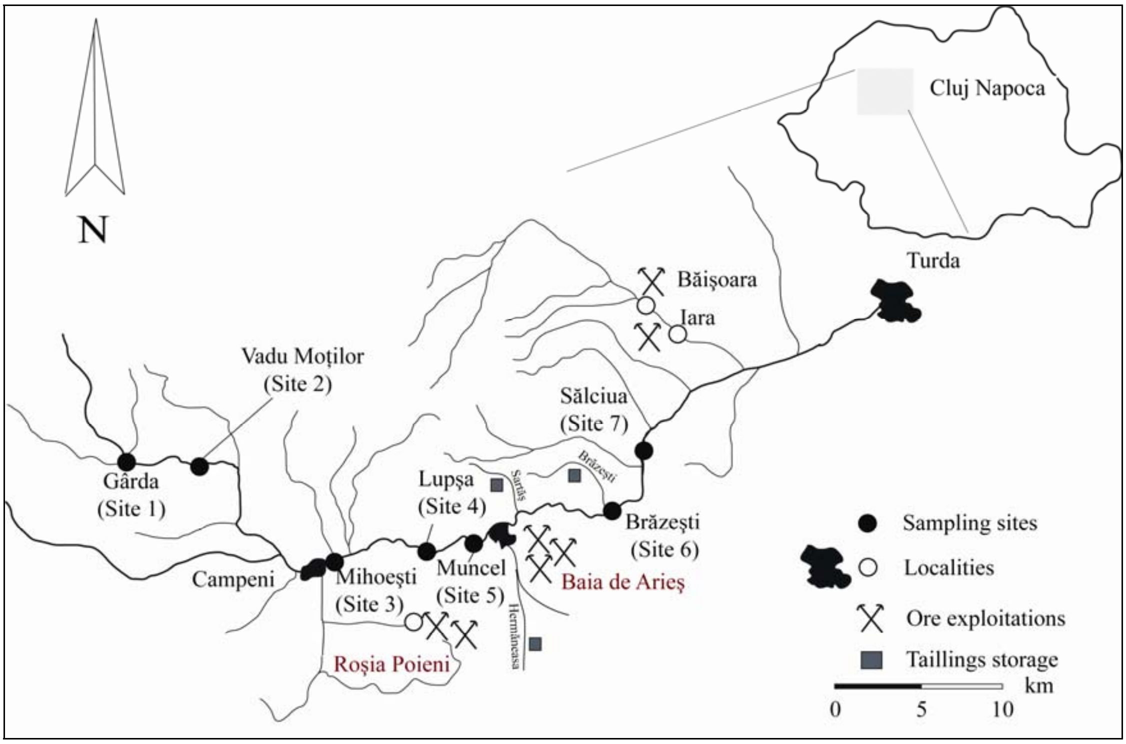

Figure 1: Map of the middle basin of the Arieş River with location of the study area and sampling sites: 1 - Gârda; 2 - Vadu Moţilor; 3 - Mihoeşti; 4 - Lupşa; 5 - Muncel; 6 - Brăzeşti; 7 - Sălciua.

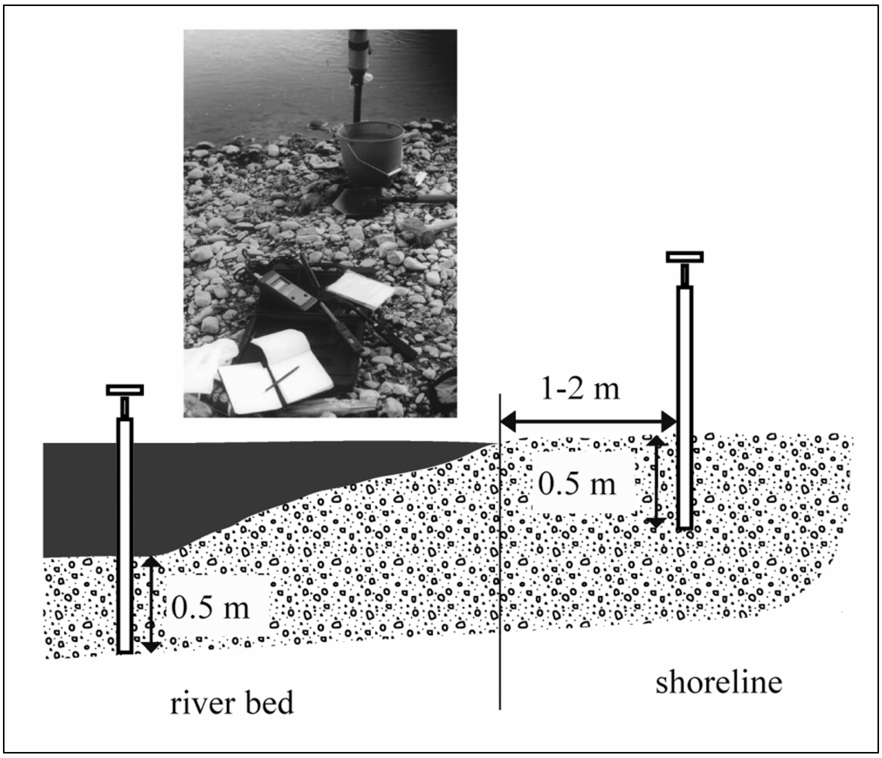

Figure 2: Schematic representation of fauna sampling in the hyporheic habitat.

As subterranean communities are affected by both degraded water and substratum quality, understanding the relative importance of the biotic component in the river will improve our ability to assess water quality at the surface and underground. By studying this habitat, new knowledge is provided about the nature of ecotone processes and their limits (Vanek, 1995). Such knowledge is crucial in establishing management policies for rivers polluted with heavy metals and other human-influenced ecotones.

Study area

The Arieş River, located in the Apuseni Mountains (Transylvania, north-western Romania) is a 110 km long sub-mountain stream (Fig. 1). The river is formed by two main tributaries: Arieşul Mare and Arieşul Mic, confluencing upstream the village of Mihoeşti (Fig. 1) and flows on a mixture of crystalline rocks, limestones, dolomites and igneous rocks. The latter, although with a lesser distribution, were emplaced during three different cycles (Upper Jurassic-Neocomian, Upper Cretaceous-Paleogene, and Neogene) and show a great petrographic variety (Forray, 2002).

The Neogene magmatism is represented in the area by the igneous bodies from Baia de Arieş, Roşia Montană - Roşia Poieni and Bucium, consisting of dacites, andesites and to lesser extent basaltic andesites (Balintoni and Vlad, 1996). They are accompanied by polymetallic, Au-Ag and Cu mineralizations which were mined since the Roman times (Abrudeanu, 1933). The accidental emission of residual emissions from the ores and TSFs highly contaminated the river with heavy metals (Cd, Pb, Zn, Mn and Cu) and cyanides (Forray and Hallbauer, 2000) (Fig. 1). Additionally, residual water effluents from adjacent localities highly contribute to organic contamination of the river and the nearby aquifer. The alluvial aquifer initially was the main source of drinking water for the locals (through wells), but nowadays it is inappropriate for this purpose. Although the mining along the river has decreased in the last ten years, metals from natural sources, abandoned mine adits and TSFs continue to degrade water and substratum quality.

Our investigations were focused on the impact of two exploitation platforms, Baia de Arieş and Roşia Poieni (Fig. 1).

Baia de Arieş exploitation is confined to underground mine workings (-500 m) and the acidic mine drainage resulted from ore processing rich in heavy metals and cyanides, flows directly into the river (Lazăr, 1966; Rădulescu and Dumitrescu, 1966; Forray and Hallbauer, 2000) or indirectly as TSF effluents on Hermăneasa, Brăzeşti and Sartăş Valleys (Fig. 1).

Roşia Poieni ore is located 12 km upstream Baia de Arieş (Fig. 1). It is a porphyry copper type deposit, with an average Cu concentration of 0.4% (Forray, 2001). Because of the quarries, the mineralised rocks were exposed to rainfall on a large extent, with high quantities of pyrite undergoing intense oxidation and decomposition. This induces the acidic character of the water (pH = 2.03) which cannot be buffered because of very low neutralisation capacities of the rocks outcropping in the area (Forray and Halbauer, 2000).

METHODS

Sampling sites

To evaluate the concentration of metals in surface and groundwater of the hyporheic zone, the sampling sites were selected to cover the upper, un-polluted Arieş Basin and the contaminated middle part as well as the tributaries (Fig. 1). In total, seven sites located between the localities Gârda and Moldoveneşti on an approximately 40 km long section have been investigated as follows: three "clean" sites at Gârda (site 1), Vadu Moţilor (site 2) and Mihoeşti (site 3); and four polluted sites, one located downstream the confluence with Arieşul

Mic, at Lupşa (site 4); one site downstream Roşia Poieni at Muncel (site 5); and two sites downstream Baia de Arieş: Brăzeşti (site 6) and Sălciua (site 7) (Fig. 1). When selecting the sampling points, indirect river pollution by TSFs from the tributaries Hermăneasa and Sartăş have also been considered (Fig. 1). Water, sediments and hyporheic fauna were collected in October 2000, September 2001 and May 2002 (a dry period compared to the previous years).

Site 1 (Gârda) is located downstream the village Gârda. The river is approximately 2 m wide, with a small shoreline (0.5 - 1 m) consisting mainly of pebbles that allow rapid water infiltration in the sediments (Figs. 3a and 3b).

Site 2 is located in the village Vadu Moților. The river is approximately 4 m large, with a shoreline of about 2 m wide, and a slope inclination of 10°.

Site 3 (Mihoeşti) is located at approximately 2 m downstream of the dam. The river is about 8 - 10 m large and the 1 m wide shoreline consists of large pebbles and gravel.

Site 4 (Lupşa) is located upstream the input coming from Roşia Poieni. The shoreline aspect changed between samplings, showing that on both river sides pebbles are quarried by the locals.

Site 5 (Muncel) is located downstream Şesei Valley (at aproximatively 1 km), a tributary carrying high amounts of effluents from Roşia Poieni mine adits. The river is about 10 - 15 m wide with an apximatively 3 m shoreline and the water is permanently reddish in colour.

Site 6 is located in the village Brăzeşti, 5 km downstream Baia de Arieş exploitation and of two tributaries carrying TSF effluents: 1) Hermăneasa Valley, right of Baia de Arieş; and 2) Sartăş Valley, left side of Arieş River, downstream Baia de Arieş. The bottom of the river is covered by a fine reddish-brown crust.

Site 7 is located in the Sălciua Village 15 km downstream of Baia de Arieş exploitation. The shoreline is 2 m large and the sample has been collected at about 1.5 m from the river.

Fauna sampling

Quantitative sampling was performed for the fauna by extracting hyporheic water with a Bou-Rouch pump and filtering 30 l of water (Bou and Rouche, 1967) (Fig. 2). We extracted water and sediments from the shoreline (A), 1 - 2 m from the stream and 0.5 m deep; and from the river bed (B) at a depth of 0.5 m (Fig. 2). Extracted water was filtered trough a net of 200 µm mesh. Faunal samples were fixed in the field with 78% alcohol. In the laboratory, meiofauna organisms were counted and sorted under a stereomicroscope (magnification 40x) and the selected groups were preserved in 78% alcohol. Taxa were identified at the order level, while cyclopoids, ostracods, amphipods, oligochaets and insect larvae at the species level.

Water and sediment analyses

Water quality variables: electrical conductance (EC), pH, temperature (t) and dissolved oxygen (DO) were measured using electronic portable instruments Piccolo plus (pH), Conmet 1 (conductivity) and HI 9142 oxygen meter (DO). For the chemical and physical analysis, both hyporheic (A, B) and surface water (C) were analysed (Tab. 1). For multi-elementary heavy metals analysis (Cu, Zn, Mn and Pb) the water was acidified in the field with 1% HNO_3. Atomic emission spectrometry (AES) was further used to measure their water concentrations.

The sediments where taken from the surface of each sampling site as these were the most recent deposits. The sediment was wet-sieved trough several mesh nets in the field and granulometric analyses have been further performed in laboratory. The < 0.625 µm fraction (silt-clay size) was saved for further laboratory processing. 30g of sediments were oven-dried 12 hours at 100ºC.

Table 1: Physical and chemical parameters of the surface and hyporheic water in Arieş River in October 2000 (standard values for heavy metals concentration in surface rivers is provided by STAS 4706/88) (DO, CCO-Mn, CCO-Cr and heavy metals concentrations in mg/l) (A - shoreline hyporheic water, B - riverbed hyporheic water, C - surface water).

Site		EC /µs	T (ºC)	pH	DO	CCO-Mn	CCO-Cr	Mn	Zn	Cu	Pb
1	A	169	8.70	6.38	7.30	109.85*	149.40	0.07	0.06	0.02	0.05
	B	150	8.70	6.40	7.30	-	-	0.10	0.20*	0.05	0.05
	C	164	7.00	6.41	8.60	-	-	-	-	-	-
2	A	162	13.5	6.44	6.90	-	-	-	-	-	-
	B	159	12.3	6.44	6.40	-	-	-	-	-	-
	C	152	12.6	6.46	7.30	-	-	-	-	-	-
3	A	221	11.1	6.35	7.00	-	-	-	-	-	-
	B	216	12.0	6.46	5.60	-	-	-	-	-	-
	C	229	7.50	6.39	6.90	-	-	-	-	-	-
4	A	309	12.1	6.48	6.10	28.13*	39.84	4.50*	1.07*	0.28*	0.09*
	B	289	10.5	6.52	6.80	50.57*	109.56	0.94*	2.66*	0.16*	0.09*
	C	286	11.3	6.49	7.50	-	-	-	-	-	-
5	A	407	12.3	6.42	1.80	118.24*	657.36	1.40*	0.55*	0.95*	0.05
	B	363	12.4	6.41	6.80	46.62*	49.80	0.31*	0.53*	0.21*	0.05
	C	339	11.8	6.42	6.90	-	-	1.11*	0.15*	0.12*	0.05
6	A	385	12.8	6.40	5.30	50.57*	109.56	3.00*	0.77*	0.64*	1.99*
	B	454	12.4	6.38	7.90	18.64	39.84	1.11*	2.01*	0.70*	0.20*
	C	410	12.2	6.41	7.20	-	-	0.90*	0.23*	0.21*	0.05
7	A	442	11.9	6.38	3.60	38.71*	79.68	3.60*	1.00*	0.85*	0.09*
	B	419	11.3	6.41	8.40	15.48	29.88	0.24*	0.50*	0.16*	0.05
	C	418	11.3	6.40	9.80	-	-	0.50*	0.09*	0.00	0.05
STAS	C			6.50				0.8	0.03	0.05	0.05

Statistical analyses

The chemical and biological data were statistically processed with XLSTAT-Pro (2007). In order to express a relationship between two chemical variables, we computed the Pearson correlation coefficient. Hyporheic invertebrate data have been analysed for abundance and frequency, two parameters typically used in pollution studies, with decreasing values associated with increased pollution (La Point and Fairchild, 1992). Patterns of chemical features and faunal groups in the catchments were investigated with the multivariate Principle Component Analysis (PCA).

RESULTS AND DISCUSSIONS

Granulometry and water chemistry

Granulometric analysis revealed a decrease of the sediment size in the hyporheic habitat downstream (Fig. 3). The shoreline sediments (A) are dominated by large fractions of sand (1 - 2 mm) alternating with fine sand (0.25 mm); riverbed sediments (B) consist of medium size sand (0.5 - 1 mm).

Water temperature ranged between 7 and 13.5°C (Tabs. 1 and 2). The lowest temperature values have been recorded in the surface water and the highest in the shoreline, where the water stagnates a longer period of time. Temperatures of the surface river (C) were positively correlated with Zn concentration ($r = 0.99$; $p < 0.049$).

Table 2: Physical and chemical parameters of the surface and hyporheic water in the Arieş River in September 2001 and May 2002 (A - shoreline hyporheic water, B - riverbed hyporheic water, C - surface water).

2001		EC/µS	T (ºC)	PH	CU	ZN
1	A	164	8.49	6.38	0.01	0.03
	B	146	8.83	6.40	0.02	0.17
	C	135	9.75	6.41	0.01	0.02
5	A	376	8.10	6.42	0.72	0.35
	B	353	8.15	6.42	0.12	0.32
	C	324	8.17	6.42	0.09	0.11
6	A	336	7.74	6.40	0.30	0.40
	B	327	8.05	6.38	0.40	1.01
	C	325	6.76	6.41	0.09	0.12
7	A	391	7.85	6.38	0.60	0.70
	B	492	7.80	6.41	0.13	0.20
	C	373	8.4	6.40	0.06	0.05
2002		EC/µs	T (ºC)	pH	Cu	Zn
1	A	156	8.23	8.49	0.01	0.11
	B	153	8.54	8.83	0.01	0.11
	C	143	8.79	9.75	0.01	0.09
5	A	443	6.76	8.10	0.01	0.06
	B	258	6.10	8.15	0.01	0.07
	C	226	5.83	8.17	0.01	0.07
6	A	245	7.33	7.74	0.01	0.06
	B	258	7.31	8.05	0.01	0.11
	C	214	6.86	6.76	0.04	0.13
7	A	874	7.50	7.85	0.02	0.02
	B	412	7.39	7.80	0.01	0.11
	C	267	7.58	8.40	0.01	0.10

Dissolved oxygen ranges around 6.88 mg/l in all the sites (Tabs. 1 and 2). As expected, water oxygenation was higher in the surface water (C). Oxygen concentration in the shoreline was observed to be 20 - 40% lower than in the surface (C) and riverbed water (B), as in this compartment the contact of the river water with the sediments promotes more extensive use of biological oxygen and heavy metal oxidation is higher than in the riverbed. Dissolved oxygen in the riverbed was positively correlated with CCO-Mn ($r = 0.95$; $p < 0.02$) (Tab. 4).

The high amounts of heavy metals are clearly reflected by the electrical conductance (EC) (Fig. 4) and pH. EC increases in all investigated substations (A, B, C) downstream the pollution sources, from the site 3 to site 7 in all the three years of sampling (Tabs. 1 and 2; Fig. 4). The highest values of conductivity have been registered in the shoreline (A), with the exception of sites 3C and 6B where EC is higher (Tabs. 1 and 2). Conductivity expresses well the degree of surface water pollution (C) with Zn in 2000 ($r = 0.995$; $p < 0.045$) (Tab. 6). During the dry sampling period (May 2002) the water EC was generally lower than in the previous years, except for site 7, where its value in shoreline was two times higher than in the riverbed (B), and almost four times higher than in the surface water (C) (Tab. 3).

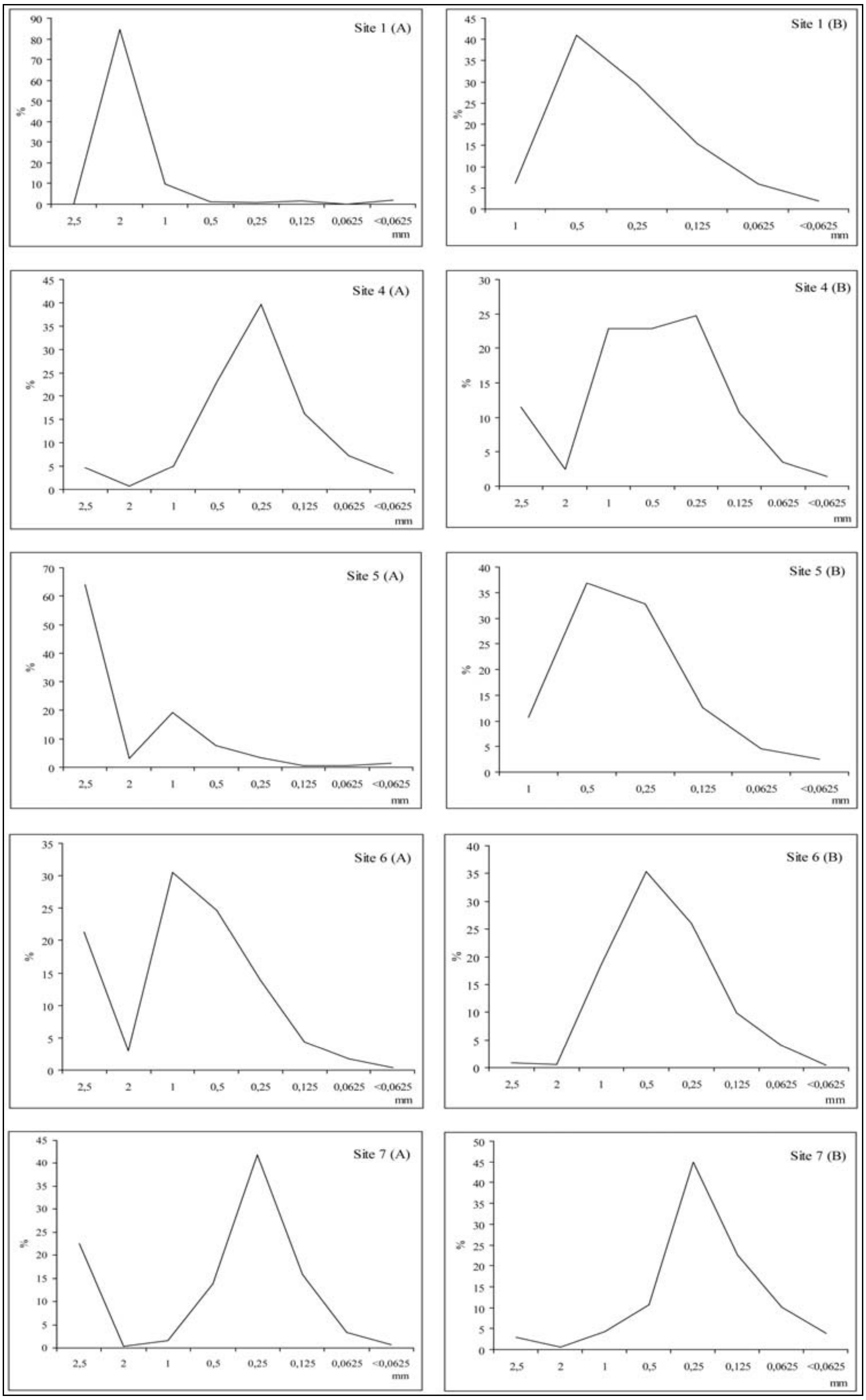

Figure 3: Hyporheic habitat sediments granulometry of the investigated sector of Arieş River in 2000.

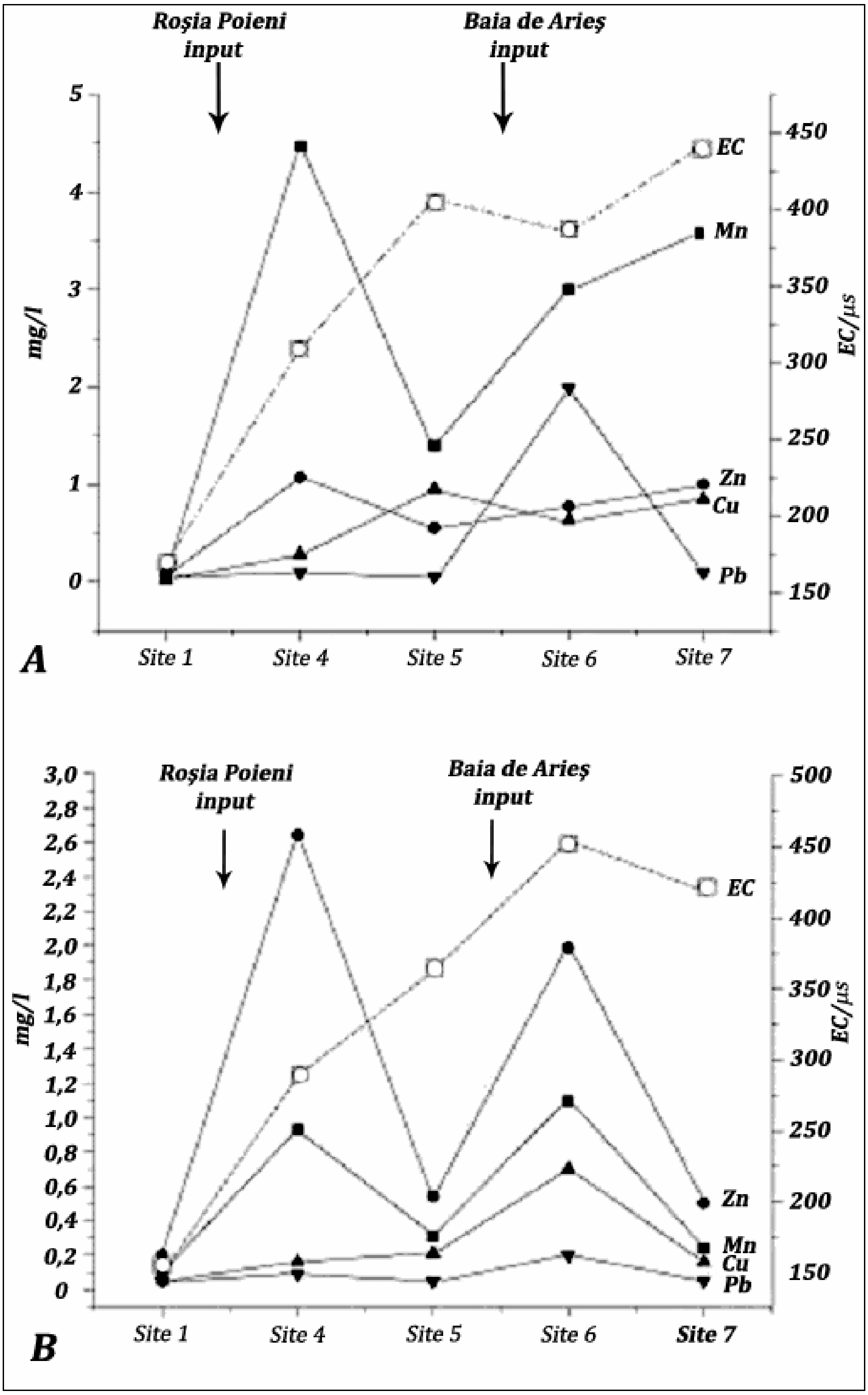

Figure 4: Heavy metal (Cu, Zn, Mn, Pb) content and conductivity in surface and groundwater of the hyporheic habitat in the investigated sector of Arieş River in 2000.

Table 3: Pearson correlations coefficients (n = 7) of physical and chemical parameters in shoreline hyporheic waters (A) of the Arieş River (values in bold are significantly different from 0 with a significance level alpha = 0.05).

Variables	EC	T (ºC)	pH	DO	CCO-Mn	CCO-Cr	Mn	Zn	Cu	Pb
EC	**1**									
T (ºC)	0.746	**1**								
pH	0.000	0.160	**1**							
ox	0.674	0.360	0.002	**1**						
CCO-Mn	0.122	0.245	0.130	0.039	**1**					
CCO-Cr	0.063	0.021	0.000	0.535	0.572	**1**				
Mn	0.237	0.367	0.362	0.013	**0.771**	0.189	**1**			
Zn	0.145	0.501	0.079	0.002	0.292	0.071	0.108	**1**		
Cu	0.175	0.489	0.024	0.001	0.179	0.026	0.040	**0.970**	**1**	
Pb	0.032	0.239	0.007	0.048	0.165	0.104	0.008	**0.913**	**0.926**	**1**

Table 4: Pearson correlations coefficients (n = 7) of physics and chemical parameters in the riverbed hyporheic waters (B) of the Arieş River (values in bold are significantly different from 0 with a significance level alpha = 0.05).

Variables	EC	T (ºC)	pH	DO	CCO-Mn	CCO-Cr	Mn	Zn	Cu	Pb
EC	**1**									
T(ºC)	0.447	**1**								
pH	0.857	0.758	**1**							
ox	0.651	0.014	0.341	**1**						
CCO-Mn	0.816	0.083	0.492	**0.959**	**1**					
CCO-Cr	0.817	0.485	0.898	0.530	0.618	**1**				
Mn	0.001	0.007	0.050	0.020	0.002	0.196	**1**			
Zn	0.709	0.650	**0.927**	0.321	0.416	**0.955**	0.228	**1**		
Cu	0.007	0.065	0.008	0.212	0.095	0.157	0.749	0.104	**1**	
Pb	0.729	0.686	**0.947**	0.312	0.417	**0.948**	0.194	**0.998**	0.078	**1**

Table 5: Pearson correlations coefficients (n = 7) of physical and chemical parameters in the surface water (C) of the Arieş River (values in bold are significantly different from 0 with a significance level alpha = 0.05).

Variables	EC	T(ºC)	pH	DO	Zn	Cu	Pb
EC	**1**						
T(ºC)	0.978	**1**					
pH	0.777	0.886	**1**				
ox	0.181	0.307	0.645	**1**			
Zn	**0.995**	**0.994**	0.833	0.239	**1**		
Cu	0.056	0.141	0.445	0.960	0.092	**1**	
Pb	0.004	0.007	0.171	0.765	0.000	0.911	**1**

Table 6: Abundance of taxa in the hyporheic habitat expressed as number of individuals per 30 l of extracted hyporheic water in 2000 (F - frequency of the faunal groups expressed in percentages).

Taxa/Sites	1	2	3	4	5	6	7	Total	F(%)
Hyporheic habitat - shoreline (A)									
Nematoda	0	0	0.15	0	0.15	0.05	0.05	0.39	57.14
Oligochaeta	0	0.25	0.29	0	0	0.05	0	0.59	42.86
Ostracoda	0.09	0	0.15	0	0.05	0.34	0.83	1.49	71.43
Cyclopoida	0.05	0.20	1.08	0.44	0	2.69	0.98	5.44	85.71
Harpacticoida	0	6.07	0.20	0.09	0.15	0	0.29	6.81	71.43
Amphipoda	0	0	0.15	0	0	0.20	0	0.34	28.57
Acarina	0.15	0.64	0.44	0.09	0.05	0	0	1.37	71.43
Colembola	0.44	0	0	0.09	0	0.15	0	0.69	42.86
Insecta	42.25	27.77	1.18	4.90	0.21	0.54	2.20	82.08	100
Bathynelacea	0	0	0	0	0	0.20	0	0.20	14.29
Isopoda	0.05	0	0.59	0	0	0	0	0.64	28.57
Total	46.08	34.92	4.21	5.64	0.64	4.21	4.36	100	-
Hyporheic habitat - river bed sediments (B)									
Nematoda	0	0.13	0.24	0.14	0.05	0	0.03	0.63	71.43
Oligocheta	0	1.10	0	0	0	0	0	0.10	14.29
Ostracoda	0.65	0.03	0	1.18	0	0	0.05	1.91	57.14
Cyclopoida	0.03	0.21	0.63	0.47	0.37	1.20	0.37	3.28	100
Harpacticoida	0.05	8.52	0	0.89	0	0.03	0.14	10.38	85.71
Amphipoda	0	0	0.10	0	0	0	0	0.10	14.29
Acarina	0.31	1.36	0.71	0.05	0	0	0	2.70	57.14
Colembola	0	0	0	0.03	0.03	0	0	0.05	28.57
Insecta	41.50	28.97	7.52	2.54	0.03	0.08	0.08	80.73	100
Bathynelacea	0	0	0	0	0	0	0	0	0
Hirudinee	0	0	0	0.03	0	0	0	0.03	14.29
Isopoda	0	0	0	0	0.03	0.05	0	0.08	28.57
Total	42.55	39.28	10.17	5.37	0.50	1.36	0.71	100	-

Water pH can also be associated with heavy metal pollution. pH values are slightly acid at around 6.41, as a result of the ore effluents and of the TSFs located on the tributaries. Higher pH variations have been recorded in the river (C) and the lowest in shoreline water (Tabs. 1 and 2). In 2000, the pH of the riverbed water was highly correlated with Zn ($r = 0.927$; $p < 0.03$) and Pb ($r = 0.947$; $p < 0.02$) (Tab. 5).

Heavy metal content

In agreement with previous studies (Forray and Hallbauer, 2000) the high EC of the surface and hyporheic water is considered the result of high concentrations of Cu, Zn, Mn and Pb (Tabs. 1 and 2). Heavy metal contents exceed the standard limit downstream the pollution sources of site 4 (Tabs. 1 and 2; Fig. 4). On one side, the high heavy metal concentrations are influenced by the emission of effluents into the river downstream the ores (Fig. 4); on the other, there are evidences that water/rocks interaction in areas with andesites highly contribute to metal presence in the water (Forray and Halbauer, 2000). Local variations in various heavy metal contents are influenced also by the TSFs located on the tributaries (Fig. 4). The heavy metals highly exceed the standard limits in the surface water (C) but they are accumulated to a greater extent in the interstitial water of both hyporheic habitat compartments (Tab. 1).

Differences have been remarked in water quality and metal content in cross-sections of the same sites (Tabs. 1 and 2; Figs. 4 and 5). It is known that groundwater can concentrate pollutants, and differences in water chemistry between the two investigated compartments of the hyporheic zone can be related to different residence times of the groundwater (Plénet and Gibert, 1994; Gibert et al., 1995). Our results show that shoreline water (A) concentrates higher amounts of heavy metals than the riverbed water (B) (Tabs. 1 and 2; Figs. 4 and 5).

In longitudinal transects, Cu and Zn have the highest concentrations of all four heavy metals considered (Tabs. 1 and 2). In 2000 and 2001 both exceeded the standard limits (0.05 mg/l for Cu and 0.03 mg/l for Zn), with values up to 20 times higher than the surface water of the clean site 1 (Tabs. 1 and 2).

Cu concentration is low at the uncontaminated site 1 (0.02 mg/l) and increases in site 5, downstream the Roşia Poieni input (Tab. 1, Fig. 4). In 2000 and 2001 the pollution with Cu was high (23 times higher than the standard limits) with high fluctuations mainly hyporheic water from the riverbed (Fig. 4). In 2002 (a low-flow rate period) the river was not contaminated with Cu, as shown by values lower than the maximum admitted in both surface and hyporheic water (Tab. 2). Generally, Cu is adsorbed in acid pH conditions (~ 5) but in case of neutral pH its concentration as a free ion is low, probably as a result of previous adsorption at low pH levels (Forray and Hallbauer, 2000). The presence of Cu is highly correlated with Zn in riverbed waters ($r = 0.97$; $p < 0.002$) (Tab. 4).

Zn concentration exceeded the standard value in the sites located downstream site 4 and is preferentially concentrated in the riverbed and not in the shoreline water (Tabs. 1 and 2; Fig. 1). In 2002, Zn concentration also exceeded the standard limits in all sites (0.03 mg/l), but the pollution was lower than in the previous years (almost three times lower) (Tab. 2). Zn concentration has been correlated in the shoreline water with CCO-Cr ($r = 0.95$; $p < 0.02$) (Tab. 3). The relatively high concentration recorded far from the pollution sources (site 7), confirm Zn's high mobility in water (Kelly et al., 1988 b; Tehrani, 2005; Zhang et al., 2006). Zn distribution shows that both mining sites highly contribute to surface and groundwater contamination (Fig. 4). The active and inactive TSFs located around Baia de Arieş, on Hermăneasa and Sartăş Valleys, also have a major influence on the Zn level in surface and hyporheic water.

Pb from the shoreline water exceeded the maximum admitted value at sites 6 and 7 in 2000 by almost 40 times than the standard limits (Tabs. 1 and 2; Fig. 4). Its concentration has been significantly correlated with CCO-Cr ($r = 0.95$; $p < 0.02$) and Zn ($r = 0.99$; $p < 0.001$) in the shoreline and with Cu ($r = 0.93$; $p < 0.009$) and Zn ($r = 0.91$; $p < 0.01$) in the riverbed (Tabs. 3 and 4). Concentration of Mn ranges between 0.24 - 4.5 mg/l in 2000 (Tab. 1). Mn is present in surface waters up to the pH value of 7.6 when its mobility increases (Stum and Morgan, 1981). Mn was significantly correlated in shoreline with CCO-Mn ($r = 0.77$; $p < 0.05$) that could be associated with the intensive oxidative activity of this ion (Tab. 3). The high values of Mn, in both compartments of the hyporheic habitats of the sites 4 and 6, shows that the groundwater contamination increases immediately after the pollution sources (Tab. 1; Fig. 4). According to our results and considering the standard limit for the surface water to 0.8 mg/l, it could be assumed that the investigated sector of the river is moderately polluted with Mn.

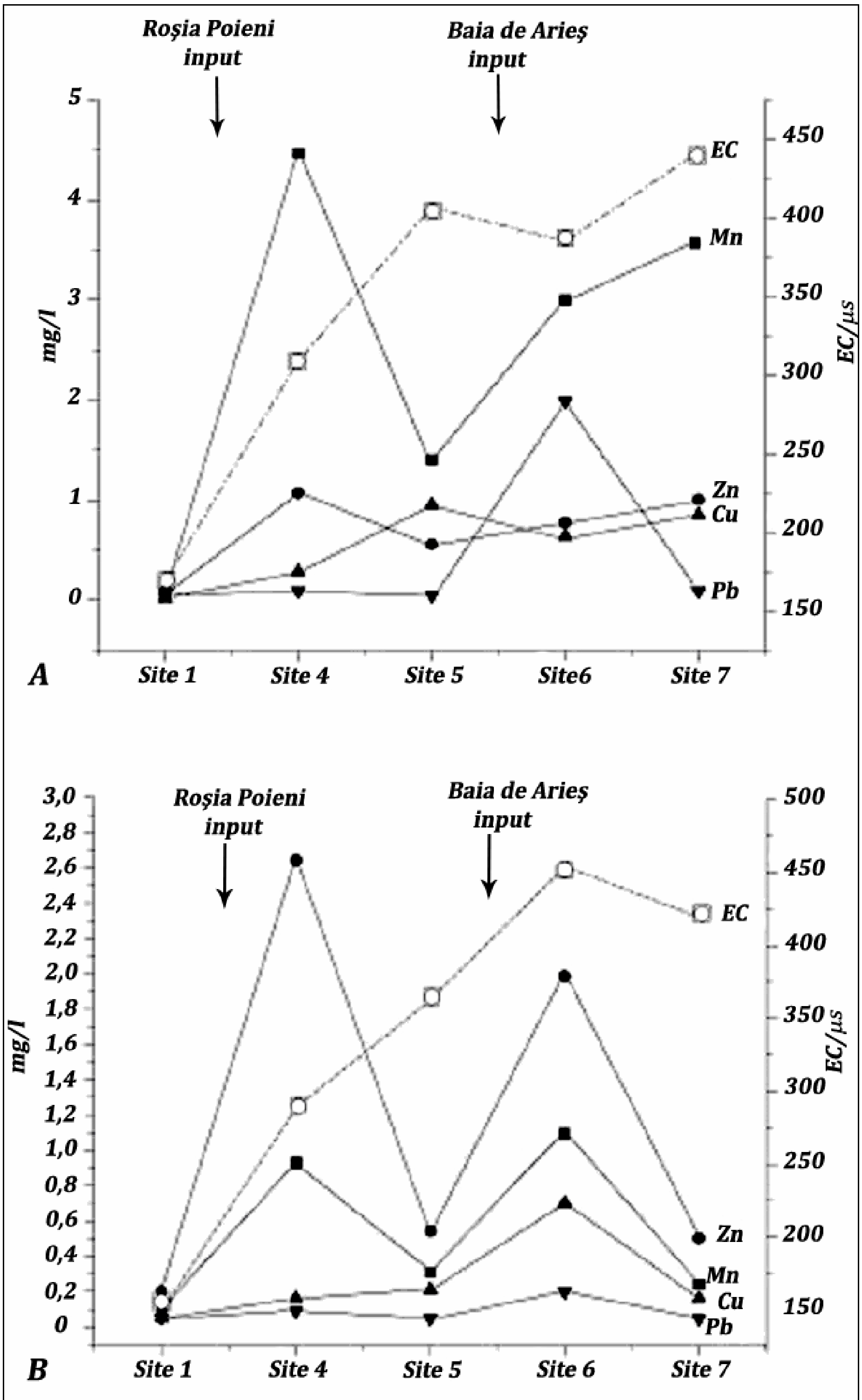

Figure 5: Heavy metal (Cu and Zn) content and conductivity in surface and groundwater of the hyporheic habitat in the investigated sector of Arieş River in 2001.

Faunal structure

Taxonomic pattern

During the three periods of survey, thirteen faunistic groups were found in the investigated sites (Tabs. 7 - 8). The analysis of taxonomic pattern of insects and various crustaceans founded in the hyporheic habitat is briefly discussed below.

The insects are represented by chironomid larvae and nymphae, followed by *Ceratopogonidae, Coleoptera*, *Ephemerelidae, Plecoptera, Nemouroidae* and *Leuctridae* (Tabs. 7 - 10).

Six groups of crustaceans are largely represented: cyclopoids, harpacticoids, ostracods, amphipods, bathynellids and also isopods (Tabs. 7 - 10). The cyclopoid copepods are the most frequent group of crustaceans and are represented by six species (Fig. 7). The most frequent taxa are *Diacyclops languidoides languidoides* Lilljeborg, 1901 (stygophile) and *Paracyclops fimbriatus* Fischer, 1853 (stygoxene), accounting for roughly 75% from the total individuals identified in the three years of sampling. Upstream the pollution sources, the cyclopoid community include *Diacyclops languidoides languidoides*, while the contaminated sites host assemblages formed by *Paracyclops fimbriatus, Diacyclops languidoides languidoides*, *Diacyclops crassicaudis crassicaudis* (Sars, 1863) (the latter two considered stygophiles) and the stygobite *Acanthocyclops kieferi* Chappuis, 1925 (Tab. 10). Among the harpacticoid copepods, representatives of the genus *Parastenocaris* have been recognized together with other not identified genera. Two stygophile ostracods have been identified in the riverbed sample of the clean site 1, *Pseudocandona albicans* (Brady, 1864) and *Potamocycpris* sp. The contaminated sites host three ostracods species of which one is stygobite, *Pseudocandona eremita* (Vejdovský, 1882), and two are stygophiles, *Pseudocandona albicans* and *Candona* sp. (Tab. 3). Amphipods are represented by two species at the contaminated sites 3, 5 and 6: *Niphargus andropus* Schellenberg, 1940 and *Niphargus romanicus* Dobreanu, 1942 (Tab. 3). Bathynellids are still in progress of identification, but they are representatives of the genus *Bathynella*.

Among crustaceans, worth mentioning is that several species were found for the first time in the Arieş River basin, as *Niphargus andropus* (amphipod), *Pseudocandona eremita*, *Pseudocandona albicans* (ostracods) and *Acanthocyclops kieferi* (cyclopoid).

Faunal assemblage distribution

The hyporheic habitats of the Arieş River support a highly diverse fauna. The most abundant groups in this section of the river, in both hyporheic compartments were: insects larvae (70.34%), followed by cyclopoids (12.21%), harpacticoids (7.63%), ostracods (2.67%), acarina (2.62%), nematodes (1.47%), oligochaets (1.09%), bathynellids (0.73%), collembolans (0.5%), isopods (0.32%), amphipods (0.30%) and tartigrada (0.07%).

The spatial distribution of the faunal groups is highly influenced by the water chemistry as shown by the PCA analysis (Tabs. 7 - 9; Figs. 6A - C). In all three years of sampling, the distribution of insect larvae was significantly correlated with DO, CCo-Mn and CCo-Cr; whilst crustaceans were highly correlated with heavy metal concentrations (mainly Cu and Zn), conductivity and pH (Figs. 6A - C).

Table 7: Abundance of taxa in the hyporheic habitat expressed as number of individuals per 30 l of extracted hyporheic water in 2001 (F - frequency of the faunal groups expressed in percentages).

Taxa Sites	1	2	3	5	6	7	Total	F(%)
Hyporheic habitat - shoreline (A)								
Nematoda	0	0	0	0.76	1.15	0	1.90	33.33
Oligochaeta	0	0.76	0	0	0	0	0.76	16.66
Ostracoda	1.15	4.58	0	1.15	1.15	1.15	9.16	83.33
Cyclopoida	6.11	4.20	0.38	0	21.37	0	37.02	83.33
Harpacticoida	0.76	4.58	0	0	1.90	0	7.25	50
Amphipoda	0	0	0	1.15	0	0	1.15	16.66
Acarina	0	0	1.90	0.76	0	12.21	13.59	50
Colembola	0	0	0	0	0.38	0	0.38	16.66
Bathynelacea	0	0	0	4.96	0.38	0	3.44	33.33
Isopoda	0	0	0	4.51	0	0	4.51	16.66
Insecta	8.78	3.05	3.44	1.90	2.29	0	19.47	83.33
Total	16.79	17.18	5.73	18.32	28.63	13.36	100	-
Hyporheic habitat - riverbed (B)								
Nematoda	0	1.00	0	0	0	-	1.00	20
Oligochaeta	0	0	0	0	0	-	0	0
Ostracoda	0	3.65	0	0	0	-	3.65	20
Cyclopoida	1.66	1.33	1.00	1.33	3.65	-	11.30	100
Harpacticoida	1.00	4.32	1.99	1.00	0	-	8.31	80
Amphipoda	0	0	0	0	0	-	0	0
Acarina	1.33	1.00	1.33	0	0.33	-	3.99	80
Colembola	0	0	0	0	0	-	0	0
Bathynelacea	0	0	0	0.64	0	-	0.64	20
Izopoda	0	0	0	0	0	-	0	0
Insecta	4.65	6.98	54.49	3.65	1.33	-	71.09	100
Total	8.64	18.27	58.80	6.64	7.64	-	100	-

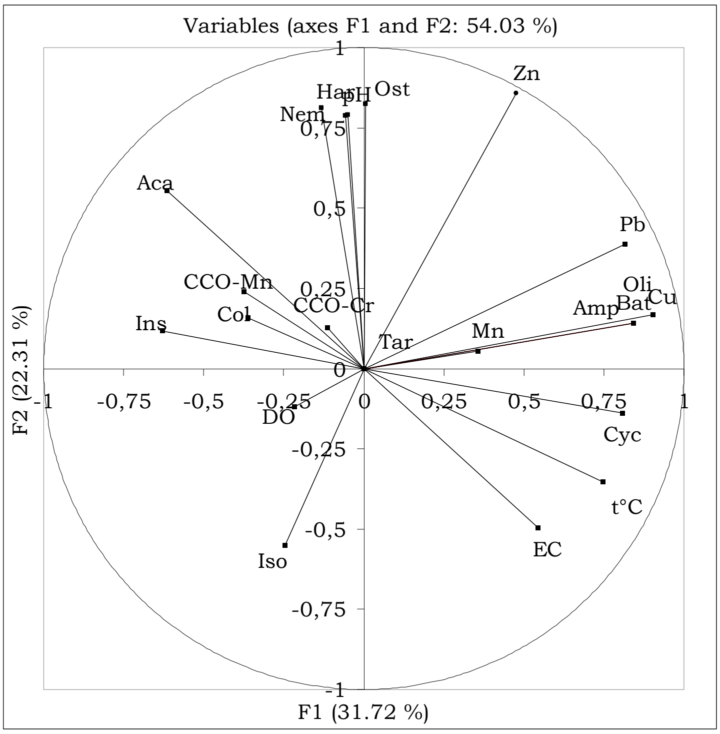

Figure 6a: PCA (Principal Component Analysis) showing the correlation between physical and chemical parameters of the surface and hyporheic waters and the faunistic groups in 2000.

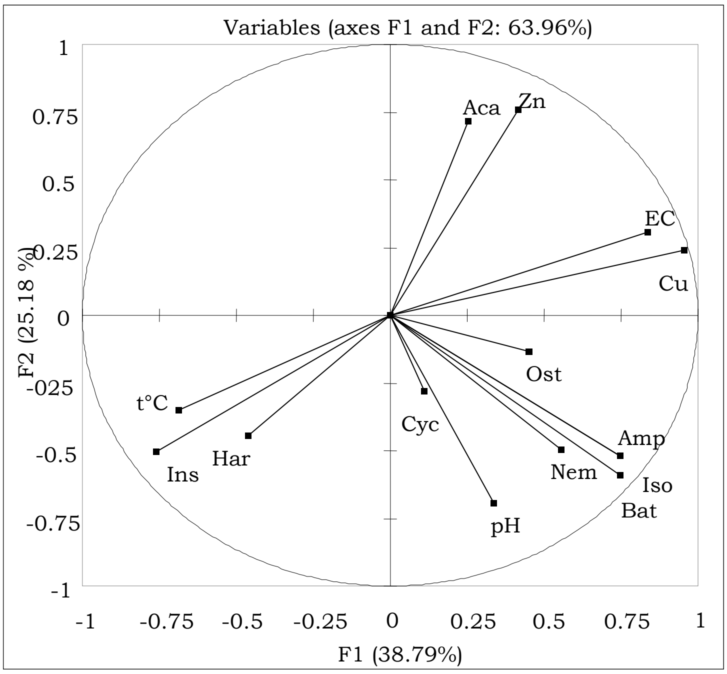

Figure 6b: PCA (Principal Component Analysis) showing the correlation between physical and chemical parameters of the surface and hyporheic waters and the faunistic groups in 2001.

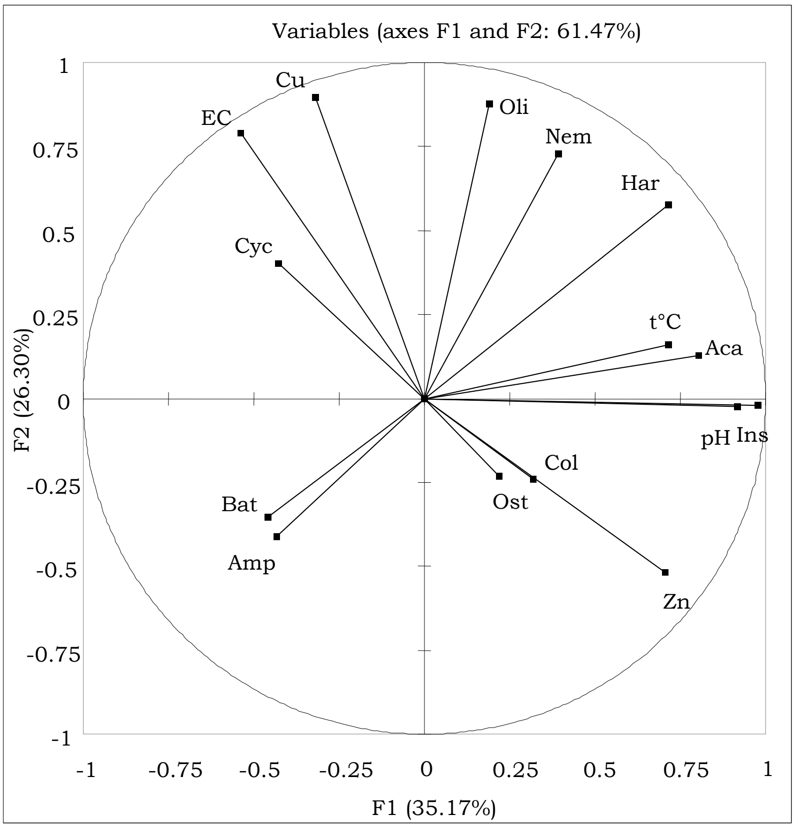

Figure 6c: PCA (Principal Component Analysis)
showing the correlation between physical and chemical parameters
of the surface and hyporheic waters and the faunistic groups in 2002.

Ordination patterns, measures of abundance, frequency, diversity and spatial distribution of the groups suggest that a longitudinal community gradient exists as expected, with increasing metal concentration downstream the pollution sources. If we consider these faunal characteristics, three distinct patterns were observed: 1) insect larvae and crustaceans dominate the faunal assemblages of the hyporheic habitat in both investigated compartments; 2) epigean groups were most abundant in clean sites with the dominance of insect larvae, whilst hypogean species/groups mainly of crustaceans, were most abundant in the sites highly contaminated with heavy metals; and, 3) changes in the number of individuals in cross sections were remarked, with densities of organisms higher in the riverbed (B) than in the shoreline (A).

Insects are dominant in the un-polluted sites (sites 1 - 2). Chironomid larvae and nymphae (95.4% of the total abundance in 2000) are followed by *Ceratopogonidae, Coleoptera*, *Ephemerelidae, Plecoptera, Nemouroidae* and *Leuctridae*. In contrast, the contaminated sites (sites 4 to 7) display low numbers and abundances of insects (14.10% of the total abundance) (Tabs. 7 - 9). These sites contain only chironomid larvae, whose tolerance to heavy metals has been previously mentioned (Jones, 1958; Winner et al., 1980; Clement et al., 1988; Leland et al., 1989).

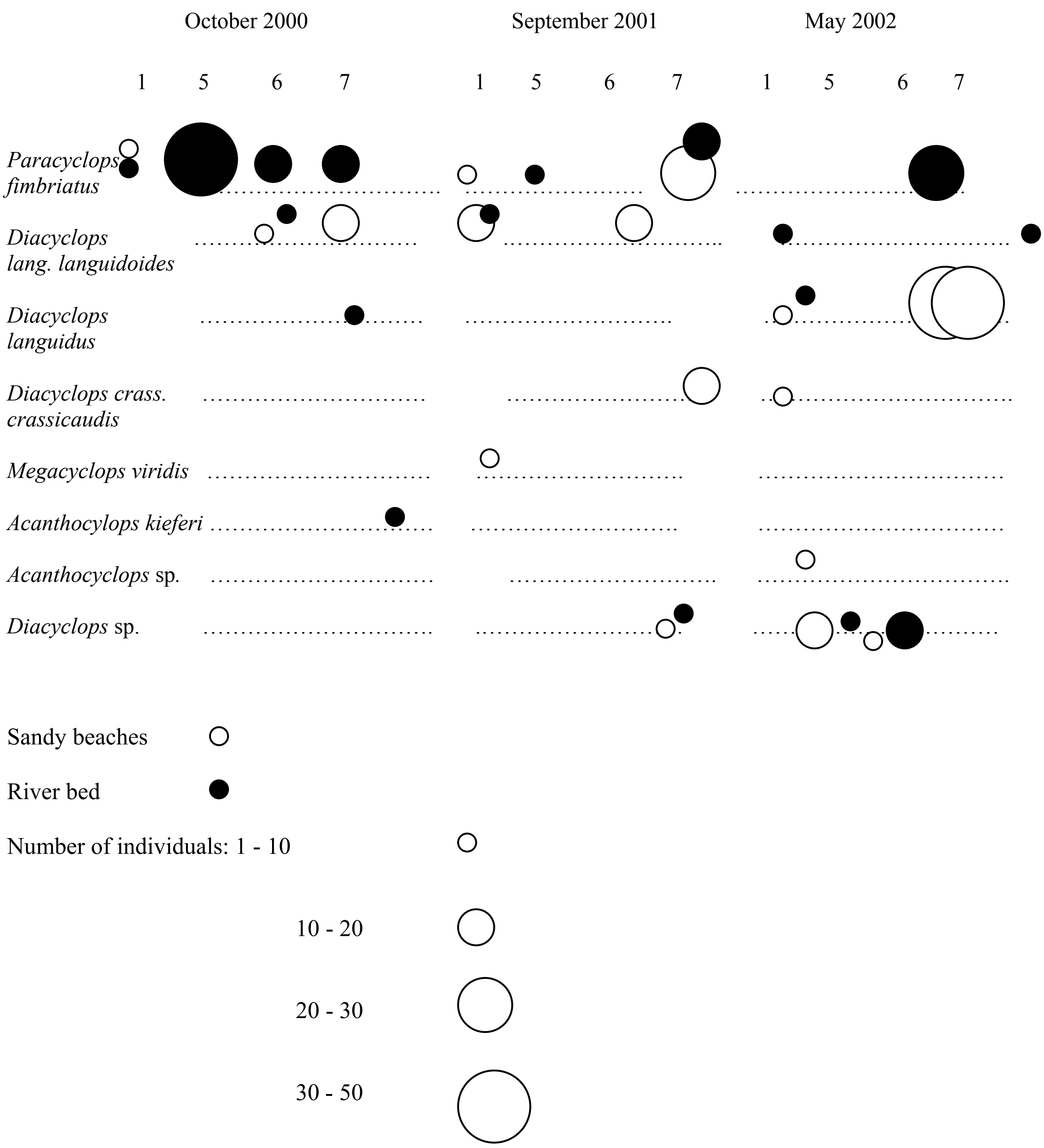

Figure 7: Distribution and number of cyclopoids species in hyporheic habitats along the investigated sector of the Arieş River.

Table 9: Abundance of taxa in the hyporheic habitat expressed as number of individuals per 30 l of extracted hyporheic water in 2002 (F - frequency of the faunal groups expressed in percentages).

Taxa Sites	1	5	6	7	Total	F(%)
Hyporheic habitat - shoreline (A)						
Nematoda	0	0	0.29	2.00	2.29	50
Oligochaeta	0.29	0.86	0	4.00	5.14	75
Ostracoda	0.29	0	2.86	0	3.14	50
Cyclopoida	10.29	2.29	14.29	18.00	44.86	100
Harpacticoida	2.29	0	0	2.57	4.86	50
Amphipoda	0	0	1.14	0	1.14	25
Colembola	0	0	0	0	0.57	25
Bathynelacea	0	0	4.29	0.29	4.57	50
Insecta	26.86	2.29	2.00	2.00	33.14	100
Tartigrada	0	0	0.29	0	0.29	25
Total	40.57	5.43	25.14	28.86	100	-
Hyporheic habitat - riverbed (B)						
Nematoda	1.92	0	1.69	0.48	4.10	75
Oligochaeta	1.92	0.24	2.89	0.24	5.30	100
Ostracoda	1.69	0	1.92	0	3.61	50
Cyclopoida	2.65	6.75	5.30	0.24	14.94	100
Harpacticoida	2.89	0.48	1.20	0	4.58	75
Acarina	4.58	0	0	0	4.58	25
Insecta	39.52	6.02	12.53	4.58	62.65	100
Tartigrada	0	0	0.24	0	0.24	25
Total	55.18	13.49	25.78	5.54	100	-

Polluted sites contain crustaceans, particularly the ones with short life cycles (e.g. cyclopoids, harpacticoids, ostracods), capable of developing rapidly abundant populations in the hyporheic habitats. The crustacean community did not change over time in terms of species composition, showing their stability in the groundwater habitat. Furthermore, an important fraction of the crustacean community is represented by strictly stygobite species, with metabolic, physiologic and ecologic characteristics allowing longer periods of exposure to metals: low metabolic rates, low competition for food and ecological niches, and specific life history traits (Plénet, 1995; Hoekstra et al., 1994). Previous surveys on amphipods from *Niphargus* genus shows that several species are able to accumulate high quantities of heavy metals from sediments (especially Zn and Cu) as a result of their low metabolism rates (Plénet, 1995).

The structure of biological communities represented by the same faunistic groups in both river beds and shorelines of the Arieş River clearly shows quantitative rather than qualitative differences. The total number of organisms was reduced in shoreline (density less than 300 individuals/30 l water), with values 2.5 times lower than in the river bed. One could assume that differences in substrate structure may influence the exposure of hyporheic organisms to heavy metals and also faunal abundance. Because of surface areas associated with smaller particle sizes, finer substrates absorb greater amounts of metals ions (Jain and Ram, 1997) which could differentially impact metal polluted areas during times of desorption. Differences in shoreline and riverbed sediment granulometry may explain some of the reasons for the different accumulation of heavy metals especially Cu and Zn, and the hyporheic fauna distribution differentiation. Furthermore, the presence of stygophile/stygoxene taxa especially in riverbeds and the presence of stygobite groups (amphipods, isopods, bathynellids) in the shoreline prove predominant vertical rather than lateral colonisation.

Although, no significant correlation could be established between meiofauna abundance and oxygen content, the low density of hyporheic fauna could be associated with the generally low content of oxygen recorded in shoreline (A).

Table 10: The identified species list.

Taxon	Sampling stations
Oligochaeta	
Pristinela sp.	2B, 6B, 7B
Amphipoda	
Niphargus andropus Schellenberg, 1940	3A, 3B
Niphargus romanicus Dobreanu, 1942	6A
Copepoda. Cyclopoida	
Paracyclops fimbriatus Fischer, 1853	1A, 2A, 3A, 1B, 2B, 5B, 6B, 7B
Acanthocyclops kieferi Chappuis, 1925	
Diacyclops crassicaudis crassicaudis (Sars, 1863)	4B
Diacyclops l. languidoides (Lilljeborg, 1901)	6A, 7A, 6B
Diacyclops languidus (Sars, 1863)	4A, 7A, 4B
Ostracoda	
Pseudocandona albicans (Brady, 1864)	
Pseudocandona eremita (Vejdovsky, 1882)	
Candona sp.	
Insecta	
Ephemerella sp.	1A, 1B
Habroleptoides modesta (Hahen, 1864)	1A, 1B
Heptagenia sp.	1A
Chloroperla tripunctata (Scopoli, 1763)	1A, 1B, 2B
Nemoura sp.	1A
Perla marginata (Panzer, 1799)	1A
Baetis muticus (Linnaeus, 1758)	1A
Torleya belgica Lestage 1923	1B
Leuctra sp.	4B
Chironomidae	1A, 2A, 3A, 5A, 7A, 1B, 2B, 3B, 4B, 5B, 7B
Ceratopogonidae	1A, 2A, 3A, 4A, 5A, 6A, 7A, 1B, 2B, 3B, 4B,
Rhagionidae	1A, 2A
Limoniidae	1A, 4B
Empididae	1B, 3B, 4B, 6B
Coleoptera	1A, 6A, 1B, 2B, 4B
Beradeidae	1A
Limnephilidae	1A, 1B, 2B
Sericostomatidae	1A, 1B
Hydropsichidae	1B, 2B, 4B
Molannidae	1B
Ecnomididae	2B, 7B

CONCLUSIONS

The present work suggests that the faunal assemblage of the hyporheic habitat situated at the surface river/groundwater boundary reflects the degree of pollution with heavy metals along the middle basin of the Arieş River. Faunal distribution patterns appear to be related to complex interactions of patterns, rather than to a single factor.

The water pollution with heavy metals in the investigated mining areas is reflected on the faunistic community by: 1) higher biodiversity but lower number of individuals; 2) smaller number of insect larvae; and 3) the presence of crustaceans with an important fraction of stygobite forms. The faunal assemblage distribution in the hyporheic habitat reflects that high concentrations of heavy metals alter first the development of insect communities, and have a lower effect on crustaceans and especially on their stygobite representatives. Moreover, distinct faunal assemblages differentiate between connections with surface water and also between the two compartments of the hyporheic habitats. This result provides useful information related to the flux and the transfer of pollutants occurring at the surface water/groundwater boundary and further to the deepest compartments of the aquifer.

The metal concentration in the hyporheic zone proves that the remediation of the surface water is not sufficient for the Arieş River and this zone could easily reflect the pollution that may further affect the aquifer through both chemistry and invertebrate community structure. In several cases the continuous presence of metals in surface and groundwater suggest that community recovery in this zone may take longer time. This is also evidenced by the presence of the same community assemblage but with differences in the number of individuals over the three periods of sampling.

Overall, our results are in good agreement with previous studies dealing with heavy metal pollution in groundwater and emphasize the important role of studying biological communities in the evaluation of water quality. High invertebrate abundance with differential spatial distribution at clean and contaminated sites emphasizes the importance of studying this zone. Detailed studies of this ecotone zone in the Arieş River may prove to be of great importance for understanding the function of the subterranean ecosystems in the presence of apparent surface heavy metal pollution

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ALGAE, MACROINVERTEBRATE AND FISH COMMUNITIES FROM THE ARIEŞ RIVER CATCHMENT AREA (TRANSYLVANIA, ROMANIA)

*Laura MOMEU *, Klaus BATTES **, Karina BATTES *, Ionuţ STOICA **, Anca AVRAM *, Mirela CÎMPEAN *, Ferdinand PRICOPE *** and *Dorel URECHE ***

* Babeş-Bolyai University, Faculty of Biology and Geology, Department of Taxonomy and Ecology, Clinicilor Street 5-7, Cluj Napoca, Cluj County, România, RO-400006, lmomeu@yahoo.com, kbattes@yahoo.com, avramanca105@yahoo.com, mirelacimpean78@yahoo.com
** Bacău University, Faculty of Sciences, Department of Biology, Calea Mărăşeşti 157, Bacău, Bacău County, România, RO-600115, klaus_battes@yahoo.com, ionut_stoica23@yahoo.com, pricope@ub.ro, dureche@ub.ro

KEYWORDS: Romania, Transylvania, Arieş River catchment, algae, macroinvertebrates, fish, communities, human impacts.

ABSTRACT

The present paper includes the results of a complex study on algae, macroinvertebrate and fish communities from the Arieş River catchment area. Biological samples of algae and macroinvertebrates were collected from 23 sampling sites in 2007 (spring, summer and autumn), while ichthyofauna was sampled from 15 sites in 2005, 2006 and 2007. Changes occurred in biotic communities were directly related to human impacts on the Arieş River catchment area, like the tourism, wood industry, mining industry, ballast exploitation sites, domestic and industrial waste waters discharges or waste pits located along most rivers from the catchment.

RÉSUMÉ: Les communautées algales, des invertébrées benthiques et des poissons du bassin de drainage de la rivière Arieş (Transylvanie, Romanie).

L'article présente les résultats d'une étude complexe sur les communautés algales, des invertébrées benthiques et des poissons du bassin de drainage de la rivière Arieş. Pendant l'année 2007 (le printemps, l'été et l'automne) on a prélèvé les algues et les invertébrées benthiques de 23 sites d'échantillonnage. Les prélèvements des poissons ont été réalisés de 15 sites d'échantillonnage pendant 2005, 2006 et 2007. Les changements qu'on a observés au niveau des communautés biologiques sont dus aux impacts anthropiques dans le bassin de drainage de la rivière Arieş (le tourisme, l'industrie de bois, l'industrie extractive, etc).

REZUMAT: Comunităţile de alge, macronevertebrate şi peşti din bazinul de drenaj al rîului Arieş (Transilvania, România).

Lucrarea de faţă prezintă rezultatele unui studiu complex, vizînd comunităţile de alge, macronevertebrate bentonice şi peşti din bazinul de drenaj al rîului Arieş. Probele biologice au fost prelevate din 23 de staţii de colectare pentru comunităţile de alge şi macronevertebrate, în trei sezoane de studiu: primăvara, vara şi toamna anului 2007. În ceea ce priveşte ihtiofauna, prelevările s-au realizat din 15 staţii de colectare pe o perioadă mai îndelungată de timp, între anii 2005 şi 2007. Modificările survenite, la nivelul comunităţilor biotice, pun în evidenţă activităţile umane cu impact asupra cursului rîului Arieş şi a afluenţilor acestuia, cum ar fi: turismul, industria lemnului, mineritul, exploatarea pietrişului din albie, deversările de ape menajere şi industriale provenite din centrele urbane sau depozitarea deşeurilor.

INTRODUCTION

The Arieş River, the largest right tributary of the Mureş River, flows through the Transylvanian Apuseni Mountains, having its source on the North-Eastern part of the Cucurbăta Massif (1,761m altitude). The total river course reaches 167 km; it has an average width of 20 - 35 m (at Cîmpeni) and an average depth that does not exceed 1 m (Ujvari, 1972). Three quarters from the total length of the river represents a mountainous water course, while the rest is in a plateau region. The altitude difference from the headwaters to the river mouth is 1,490 m. The catchment area of the Arieş River is 2,970 km^2, making it the second largest river in the Mureş Basin. However, it represents the river with the highest discharge in the Mureş system (26 m^3/s) because more than 2000 km^2 from the Arieş catchment represent mountainous region (Ujvari, 1972). The Arieş River can be divided into three main areas: the upper Arieş, also called the Arieşul Mare, stretching from the river source to the Cîmpeni locality, the middle Arieş, to the Corneşti locality and the lower Arieş, to the junction with the Mureş River. There are numerous tributaries that flow into the Arieş River, mostly right tributaries in the upper course of the river (e.g. the Arieşul Mic and Abrud rivers) and mostly left tributaries in the middle course (Bistra, Valea Mare, Ocoliş, Hăşdate, Tur etc.).

Impacts on the Arieş River biotic communities as a result of the human activities are present throughout the catchment area, on the main river course but also on its main tributaries. In the upper reaches of the river the main human impact is represented by tourism due to the numerous guesthouses and hotels built around the ski track in Arieşeni. The wood process industry represents a source of important pressures on rivers in the upper and middle areas, because of the activity of sawmills located in woodlands, the deforestation and the deposits of sawdust in the riverbed. However, the highest impact comes from the mining industry mainly in the middle reaches of the river, due to settling ponds, slag dumps and acid water discharges. Intensive pasture exploitation leads to chemical pollution mainly in the middle and lower areas. Human settlements, like Turda and Cîmpia Turzii, alter the good ecological status of the river in the lower reaches by means of industrial and domestic waste water discharges. Waste pits and ballast exploitation sites located near or directly into the riverbed represent constant pressures on the main river course but also on its tributaries.

The Arieş River catchment area represented the topic of several previous papers regarding the aquatic communities, but most of this papers considered only the algal populations present in this area (Péterfi and Momeu, 1984, 1985; Momeu and Péterfi, 2007) or only the groundwater fauna (Moldovan et al., 2002; Cîmpean et al., 2003); or they were focused only on limited impacted areas (Forray, 2002). Preliminary data on algal, macroinvertebrate and fish communities were published also recently (Momeu et al., 2007).

MATERIAL AND METHODS

The 23 total sampling sites, considered representative for this study area (considering the altitude, substratum, shadowing degree, human impacts etc.) were located not only on the main river course (15), but also on its main tributaries (8) (Fig. 1, Tab. 1).

Ten sampling sites were located in the upper reaches of the river, mostly in clean regions (e.g. AR3; AR4; AR5). AR1 (the river source) was situated in a swampy region at the river headwaters, characterized by decreased water velocity, discontinuity and low discharge, while AR2 (Arieşeni - ski track) was situated in an area impacted by tourism. The sites located on the tributaries from the upper region (T1 - T3) were unpolluted stations. Ten sites were also situated on the middle river reaches, both in heavily affected (T4, AR8, T5, AR10) and less affected regions (T6, T7). Only three sites were situated on the lower Arieş River. The stations from the main river course were characterized by wide riverbeds and increased depths, while the site from the Racoşa tributary was heavily impacted with industrial and domestic waste waters. The substratum was represented by rocks, boulders and gravel in mountainous regions, gravel and sand in lower hilly areas and mostly mud in the plains. After the junction with tributaries coming from the mining areas Roşia Montană and Roşia Poieni, the substratum was covered with fine deposits (e.g. AR10 - Brăzăşti).

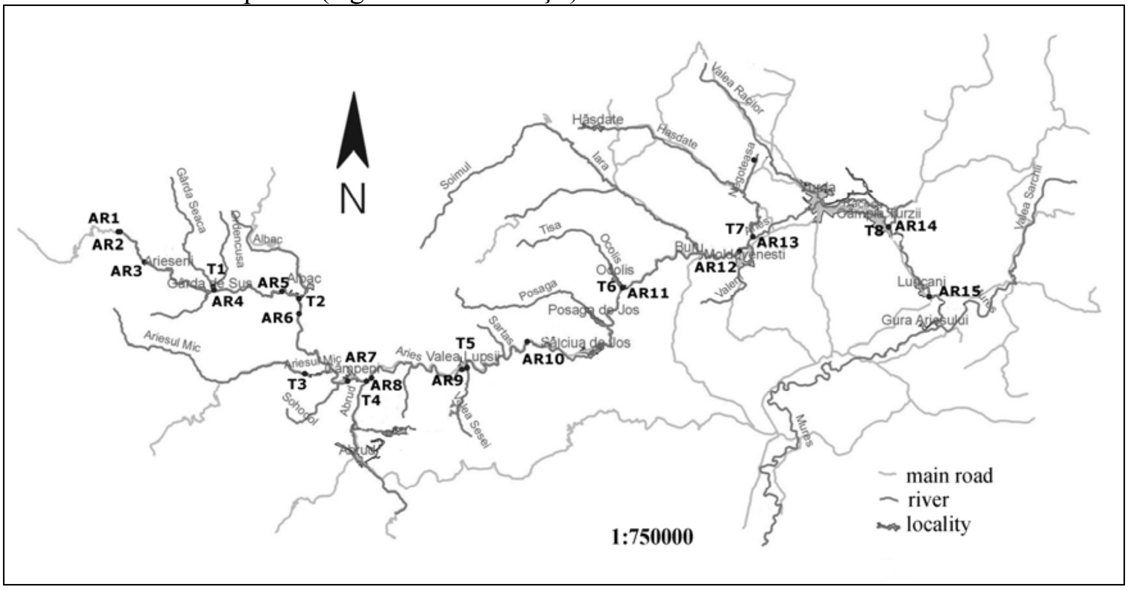

Figure 1: The sketch map of the Arieş Catchment area
with the 23 sampling sites.

Benthic algal and macroinvertebrate communities were sampled in 2007 in spring, summer and autumn.

Fish communities were sampled from 15 sites in 2005, 2006 and 2007 (Tab. 1). Physical and chemical parameters were measured in the field at all sampling sites.

For benthic algal communities, knives and brushes were used to sample different types of substratum (Vollenweider, 1969). Algal samples collected in the field were preserved in 4% formaldehyde. Laboratory analysis consisted of taxonomical identifications to species level for diatoms, because they represented the dominant algal group in benthic communities (Hindak, 1978; Stoermer and Smol (eds.), 1999). Diatoms were handled according to classical methods.

Macroinvertebrate qualitative samples were collected by means of a benthic 250 μ mesh size net. The samples were preserved in the field with 4% formaldehyde. In the laboratory they were sorted and identified to different taxonomical levels.

Fish sampling and handling were carried out according to methods used in the European Union (Davideanu, 2005). Species taxonomy followed the reviewed list of freshwater fish (Nalbant, 2003).

Table 1: The sampling sites located on the main Arieş River course and on its main tributaries, their coordinates and the altitude.

Sampling site	Sampling site name	Coordinates	Altitude (m)
AR1	The Arieş source	N 46°30'57" E 22°40'29"	1149
AR2	Arieşeni - ski track	N 46°30'57" E 22°40'42"	1134
AR3*	Arieşeni - village	N 46°29'02" E 22°43'04"	930
T1*	The Gîrda Seacă	N 46°27'31" E 22°49'41"	741
AR4*	Gîrda	N 46°27'19" E 22°49'46"	726
AR5*	Upstream Albac	N 46°27'21" E 22°56'14"	592
T2*	The Albac	N 46°26'53" E 22°57'52"	634
AR6	Downstream Albac	N 46°25'52" E 22°57'54"	615
T3*	The Arieşul Mic	N 46°21'57" E 22°58'36"	590
AR7*	Upstream Cîmpeni	N 46°21'33" E 23°02'41"	560
T4*	The Abrud	N 46°21'34" E 23°04'29"	543
AR8	Downstream junction with the Abrud	N 46°21'47" E 23°04'58"	532
AR9*	Valea Lupşii	N 46°22'29" E 23°13'31"	495
T5*	The Pârâul Şesei	N 46°22'36" E 23°14'01"	497
AR10*	Brăzăşti	N 46°24'22" E 23°19'39"	462
AR11	Upstream junction with the Valea Ocoliş	N 46°28'04" E 23°28'36"	417
T6*	The Valea Ocoliş	N 46°28'06" E 23°28'39"	417
AR12*	Moldoveneşti	N 46°30'39" E 23°39'40"	372
T7*	The Hăşdate	N 46°36'40" E 23°40'55"	347
AR13	Downstream junction with the Hăşdate	N 46°31'34" E 23°40'57"	350
AR14	Upstream junction with the Racoşa	N 46° 32'22" E 23°53'52"	296
T8	The Racoşa	N 46°32'21" E 23°53'51"	296
AR15*	Luncani	N 46°27'48" E 23°57'48"	278
AR 1 - 15 - sampling sites located on the main river course; T 1 - 8 - sampling sites located on the main tributaries; * - sites where fish were sampled as well.			

RESULTS AND DISCUSSIONS

The main physical and chemical parameters measured in the field for the 23 sampling sites from the Arieş Basin area are presented in the figures 2, 3 and 4.

pH values (Fig. 2) ranged roughly from 7 to 9, indicating neuter to alkaline waters. However, pH values not exceeding 5 were recorded at Pârâul Şesei (T5) in all sampling seasons, reflecting very acid waters because this particular tributary came directly from a settling pond located upstream. Lower, thus more acid pH values were also recorded at AR1 (the Arieş source) due to water inputs from near-by swampy region and AR2 (Arieşeni - ski track) probably due to domestic waste waters discharged into the river. Salinity values (Fig. 3) did not exceed 200 mg/l at most sampling sites located on the main river course throughout the year, except for the AR2 site (Arieşeni - ski track), where summer salinity values exceeded 500 mg/l, probably due to high tourism pressures in the warm season and to decreased rainfall. At the Abrud (T4) and the Pârâul Şesei (T5) sites salinity values were extremely high, especially at the last station, where the values exceeded 800 mg/l in all sampling seasons. These two tributaries, T4 and T5, collected acid waters coming from the mining area Roşia Montană, Roşia Poieni and Baia de Arieş. The Hăşdate (T7) and the Racoşa (T8) rivers also recorded high salinity values; the first probably due to the fish pond located upstream the junction with the Arieş River and the last due to industrial and domestic waste waters.

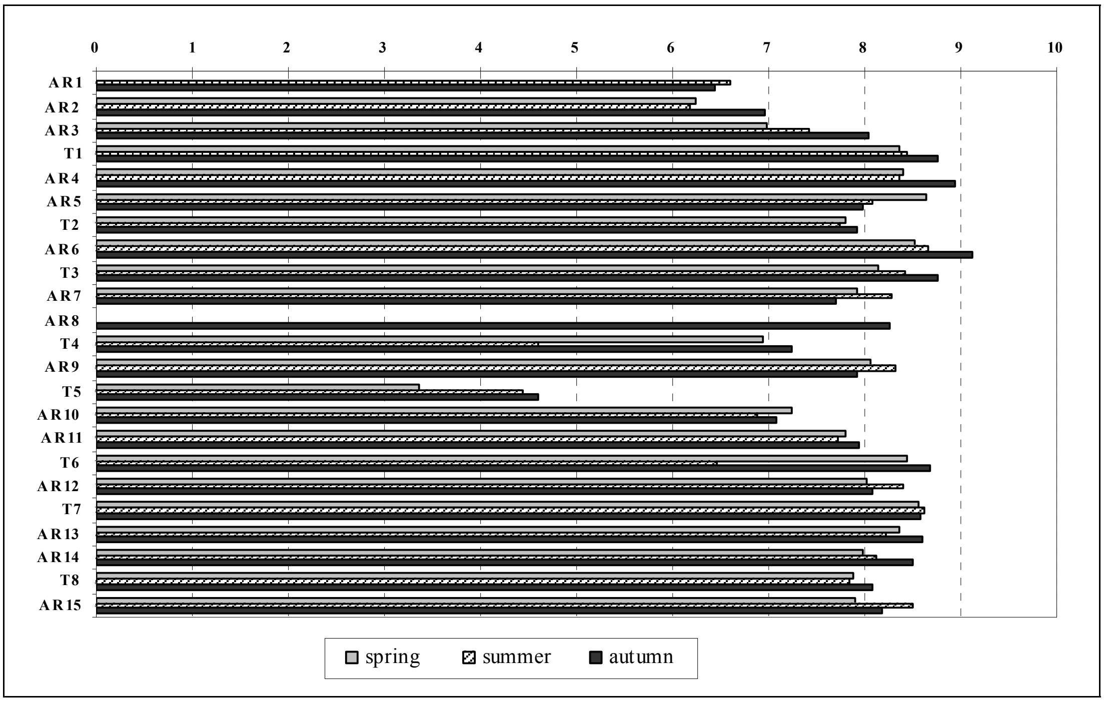

Figure 2: pH values measured on the Arieş River course and on its main tributaries in 2007.

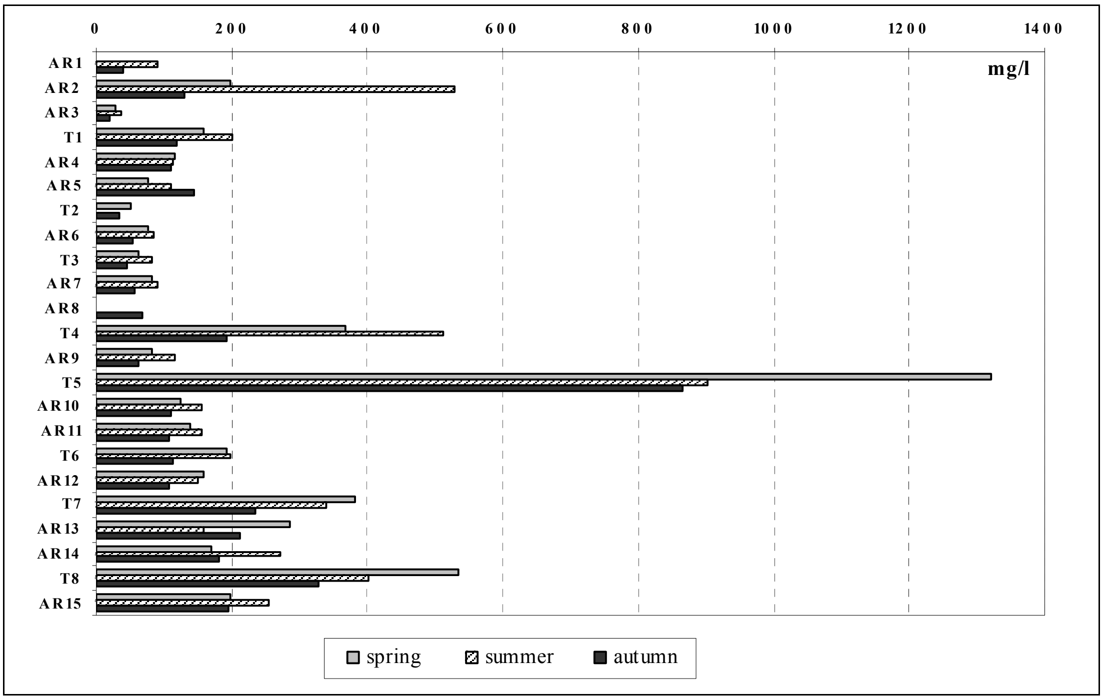

Figure 3: Salinity values measured in the Arieş catchment area in 2007.

Dissolved oxygen (Fig. 4) recorded values ranging between 6 and 8 mg/l in summer and exceeding 8 - 10 mg/l in spring and autumn, probably due to differences in temperature and other ecological factors.

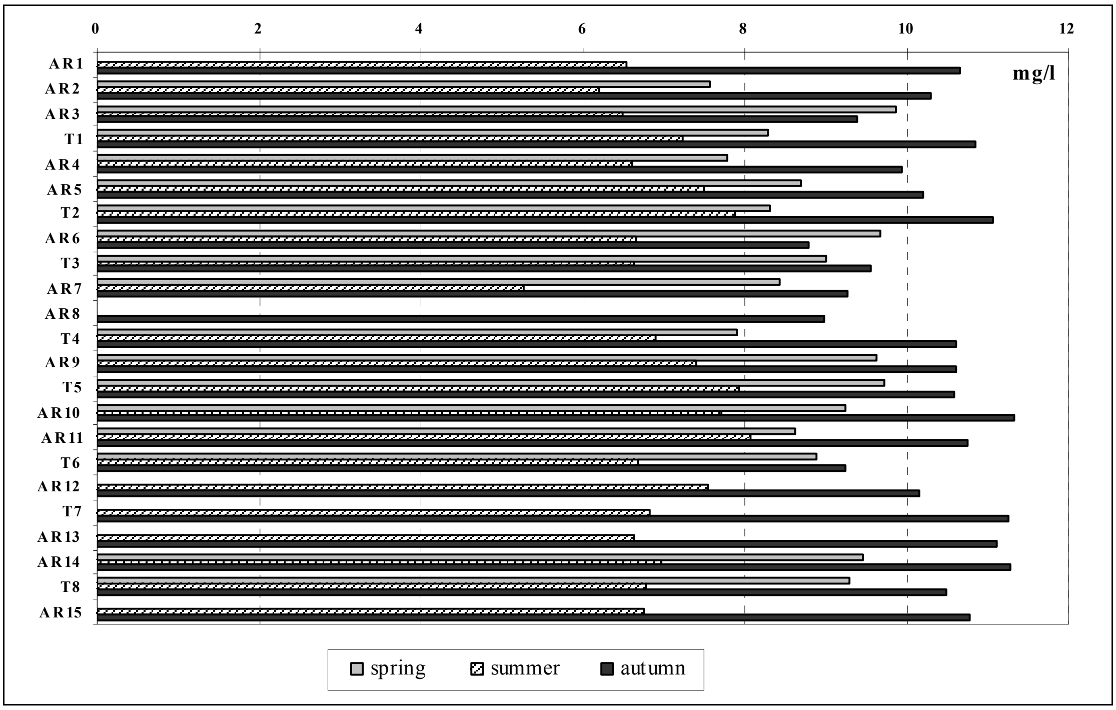

Figure 4: Dissolved oxygen values for the sampling sites located in the Arieş Basin area in 2007.

The diatom communities

188 taxa (182 species and six varieties) belonging to 32 genera were identified from the 15 sampling sites located on the main Arieş River (AR1 - AR15) and on six main tributaries (T1, T2, T3, T6, T7 and T8). The samplings from T4 - the Abrud River and T5 - Pârâul Şesei included no diatom species. The samplings were carried out in three seasons in 2007 (spring, summer and autumn), except for AR1 where only summer and autumn samples were collected and AR8 where only autumn samples were taken. This qualitative study suggests the existence of a typical seasonal dynamics for the diatom community of lotic ecosystems from temperate regions (Patrick, 1977), characterized by two peaks in diatom abundance, one in spring and a smaller one in autumn. The table 2 shows this typical pattern not only on the main river course but also on the main tributaries, with a lower number of diatoms during summer, except for the communities from AR2, AR5 and AR6. In these sampling sites the number of summer diatom species exceeded the spring ones due to previous floods or to local factors caused by human impacts.

The genera with the highest number of species were *Navicula* (with 38 species), *Nitzschia* (21), *Cymbella* (17), *Gomphonema* (13) and *Pinnularia* (11). Four genera were represented by 8 - 9 species (*Achnanthes*, *Diatoma*, *Fragilaria* and *Surirella*), another 11 genera included 2 - 5 species and 12 genera had only one species (Tab. 2). More than 60 species were cited for the first time in the Arieş Basin area.

Table 2a: List of diatom species identified in 2007 in seven sites located on the main river course (**1**/spring; **2**/summer; **3**/autumn; + the species was present; - the species was absent; ***** the site was not sampled).

Sampling sites	AR1	AR2	AR3	AR4	AR5	AR6	AR7
Seasons	123	123	123	123	123	123	123
Achnanthes biasoletiana	*--	---	+--	+++	---	---	---
Achnanthes bioretii	*--	+--	---	---	---	+--	---
Achnanthes delicatula	*--	---	---	---	---	---	---
Achnanthes helvetica	*--	+--	+--	---	---	+--	---
Achnanthes hungarica	*--	---	---	---	---	---	+--
Achnanthes kryophila	*+-	---	---	--+	---	+-+	---
Achnanthes lanceolata	*+-	+-+	+++	+++	+++	+++	+++
Achnanthes minutissima	*++	+++	+++	+++	+++	+++	+++
Achnanthes subatomoides	*+-	---	---	---	--+	---	+++
Amphipleura pellucida	*+-	---	---	+--	+-+	+++	+-+
Amphora lybica	*--	---	+-+	---	---	+++	---
Amphora ovalis	*--	---	---	--+	---	---	+-+
Amphora pediculus	*--	---	---	+++	+-+	+++	+--
Amphora venetea	*--	---	---	---	---	---	+--
Anomoeoneis vitrea	*--	-++	---	---	---	---	---
Aulacoseira granulata	*--	--+	---	---	---	---	---
Bacillaria paradoxa	*--	---	---	---	---	---	---
Caloneis amphisbaena	*--	---	---	---	---	---	---
Caloneis silicula	*--	---	---	---	--+	---	---
Cocconeis disculus	*--	---	---	+--	+++	---	---
Cocconeis neodiminuta	*--	---	---	---	---	+++	---
Cocconeis pediculus	*--	---	---	---	+++	+++	+++
Cocconeis placentula	*--	---	+++	+++	+++	+++	+++
Cyclotella iris	*--	---	---	---	---	---	---
Cyclotella meneghineana	*--	---	---	---	---	---	---
Cymatopleura elliptica	*--	---	---	---	---	---	---
Cymatopleura solea	*--	---	---	---	---	---	---
Cymbella affinis	*--	+-+	+++	+++	+++	+++	+++
Cymbella caespitosa	*--	---	---	---	---	---	+++
Cymbella cistula	*--	---	---	---	--+	+++	+++
Cymbella cuspidata	*++	---	---	+--	---	---	+-+
Cymbella gracilis	*++	---	---	---	---	---	---
Cymbella helvetica	*--	---	---	+++	+++	+++	+-+
Cymbella lanceolata	*--	---	---	---	---	+-+	+--
Cymbella mesiana	*--	+++	+++	+++	---	+-+	---
Cymbella minuta	*--	---	-+-	+++	+++	--+	+--
Cymbella naviculiformis	*-+	---	+++	---	---	+++	---
Cymbella prostrata	*--	---	--+	---	---	+++	+++
Cymbella silesiaca	*-+	++-	+++	--+	+++	+++	+++
Cymbella simoensenii	*--	---	---	+++	---	---	+++
Cymbella sinuata	*--	+-+	+++	---	+++	+++	+++
Cymbella tumida	*--	---	---	--+	---	--+	+--
Cymbella tumidula	*--	---	---	---	--+	+-+	--+

Table 2a continued

Cymbella turgidula	*--	---	--+	---	---	---	---
Diatoma anceps	*--	+--	---	---	---	---	---
Diatoma ehrenbergii	*--	---	---	+--	--+	---	---
Diatoma elongatum	*--	---	---	---	---	---	---
Diatoma hyemalis	*--	+-+	+++	+++	+--	+--	+++
Diatoma mesodon	*-+	+-+	+++	+++	+++	+-+	+++
Diatoma moniliformis	*--	---	---	---	---	---	---
Diatoma tenuis	*--	---	---	---	---	---	---
Diatoma vulgaris	*--	+++	+++	+++	+++	+++	+++
Didymosphenia geminata	*--	---	-++	+++	+++	+++	+++
Diploneis parma	*--	---	--+	---	---	---	---
Epithemia adnata	*--	---	--+	---	---	---	---
Eunotia bilunaris	*++	+-+	---	---	---	---	---
Eunotia exigua et var bidens	*++	+-+	---	---	---	---	---
Eunotia minor	*++	---	---	---	---	---	---
Eunotia tenella	*++	---	---	---	---	---	---
Eunotia veneris	*++	---	---	---	---	---	---
Fragilaria acus	*--	---	---	---	---	---	+++
Fragilaria arcus	*+-	+++	+++	+++	+++	+++	+++
Fragilaria capucina et var. gracilis, var rumpens, var vaucheriae	*++	+++	+++	+++	+++	+++	+++
Fragilaria construens	*-+	---	---	---	---	---	---
Fragilaria crotonensis	*--	---	---	---	---	---	+--
Fragilaria pinnata	*--	---	---	+++	---	---	+++
Fragilaria ulna	*-+	---	+++	+++	+++	+++	+++
Fragilaria virescens	*-+	-++	-+-	---	---	---	---
Frustulia rhomboides var. saxonica	*++	+++	-+-	---	---	---	---
Frustulia vulgaris	*++	+--	-++	---	---	---	---
Gomphonema acuminatum	*--	---	---	---	---	+++	---
Gomphonema angustatum	*-+	+--	-+-	+--	--+	+-+	+-+
Gomphonema angustum	*--	+--	---	--+	---	---	---
Gomphonema clavatum	*--	-++	---	--+	---	+++	+-+
Gomphonema gracile	*--	---	---	+-+	---	+++	---
Gomphonema minutum	*-+	---	-+-	---	---	---	---
Gomphonema longiceps	*--	---	---	---	---	---	---
Gomphonema olivaceum et var. calcareum	*--	---	---	--+	+++	+--	+++
Gomphonema parvulum	*++	+++	-+-	-++	---	+++	+++
Gomphonema pseudoaugur	*--	+--	---	---	---	---	+-+
Gomphonema pumilum	*--	---	---	--+	---	+++	+--
Gomphonema tergestinum	*--	---	---	---	--+	+++	+--
Gomphonema truncatum	*--	---	---	--+	--+	+-+	+--
Gyrosigma acuminatum	*--	---	---	---	---	---	---
Gyrosigma attenuatum	*--	---	---	---	---	---	---
Gyrosigma nodiferum	*--	---	---	---	---	---	---
Gyrosigma scalproides	*--	---	---	---	---	---	---
Hantzschia amphioxys	*--	---	---	---	---	+-+	+++
Melosira roseana	*-+	---	---	---	---	---	---
Melosira varians	*--	---	--+	--+	---	+--	+--
Meridion circulare	*+-	+--	-++	+++	+--	+--	---
Navicula accomoda	*--	---	---	---	---	---	---
Navicula ambigua	*--	---	---	---	---	---	---

Table 2a continued

Navicula angusta	*--	---	---	---	---	---	---
Navicula arvensis	*--	---	---	---	---	---	---
Navicula atomus	*--	---	---	---	---	---	---
Navicula bacillum	*--	---	---	-++	+--	+-+	---
Navicula capitata	*--	---	---	---	---	---	+--
Navicula capitatoradiata	*++	+++	+++	---	+++	+++	+--
Navicula cincta	*--	---	---	-++	+++	---	+++
Navicula cryptocephala	*-+	+--	---	-++	---	+++	+++
Navicula cryptotenella	*--	+--	--+	+++	+-+	+++	+++
Navicula cuspidata	*--	---	---	---	---	---	---
Navicula decussis	*+-	---	---	---	---	---	---
Navicula digitatoradiata	*--	---	--+	--+	---	---	---
Navicula elginensis	*-+	---	+-+	+--	---	---	+++
Navicula exigua	*--	---	---	---	---	---	---
Navicula goeppertiana	*--	---	---	---	---	---	---
Navicula gregaria	*--	---	---	---	---	---	+-+
Navicula lanceolata	*--	-++	+++	--+	+-+	+++	+--
Navicula menisculus	*--	---	---	+--	---	++-	+--
Navicula minima	*--	---	---	---	---	-++	+--
Navicula minuscula	*--	---	---	---	---	-++	---
Navicula mutica	*--	---	---	---	--+	---	--+
Navicula nivalis	*-+	---	---	---	+--	---	---
Navicula oblonga	*--	---	---	---	---	-++	---
Navicula placentula	*--	---	---	+++	++-	++-	-+-
Navicula phyllepta	*--	---	---	---	---	---	---
Navicula pupulla	*--	-+-	---	--+	---	---	---
Navicula radiosa	*--	---	-+-	--+	+-+	+--	---
Navicula recens	*--	---	---	---	---	---	---
Navicula reinhardtii	*--	---	---	+--	---	---	---
Navicula rhyncocephala	*++	+++	-+-	--+	--+	+++	+--
Navicula slesvicensis	*--	---	---	---	---	---	---
Navicula tripunctata	*--	--+	---	+--	---	+++	+++
Navicula trivialis	*--	---	---	---	---	---	---
Navicula tuscula	*--	---	---	---	---	---	---
Navicula veneta	*--	---	-+-	---	---	---	+++
Navicula viridula	*--	+--	---	-++	--+	+-+	+--
Neidium affine	*--	+-+	---	-++	---	-++	---
Neidium ampliatum	*--	-+-	---	---	---	---	---
Neidium binodis	*--	---	---	---	---	---	---
Neidium bisulcatum	*++	---	--+	---	---	---	---
Neidium dubium	*--	---	---	---	+-+	+++	---
Nitzschia acicularis	*--	---	---	---	---	+--	---
Nitzschia capitellata	*--	---	---	---	---	---	---
Nitzschia communis	*--	---	---	---	---	--+	---
Nitzschia dissipata	*--	+++	+++	-++	++-	+++	+++
Nitzschia dubia	*--	---	---	--+	---	---	---
Nitzschia filiformis	*--	---	---	---	---	---	---
Nitzschia fruticosa	*--	---	---	---	---	---	---

Table 2a continued

Nitzschia gracilis	*--	---	---	-++	---	+++	---
Nitzschia heufleriana	*--	---	---	-++	+-+	+--	---
Nitzschia hungarica	*--	---	---	---	---	---	+--
Nitzschia inconspicua	*--	---	---	---	---	---	---
Nitzscha intermedia	*--	---	---	--+	---	+++	---
Nitzschia linearis	*--	+++	+++	-++	---	---	+--
Nitzschia microcephala	*--	---	---	-++	---	---	---
Nitzschia palea	*++	+++	+++	---	+-+	+++	+++
Nitzschia paleacea	*--	---	---	---	---	+++	+++
Nitzschia perminuta	*--	---	---	---	--+	+--	+--
Nitzschia reversa	*--	---	---	---	---	---	---
Nitzschia sigmoidea	*--	---	---	---	---	---	-+-
Nitzschia tubicola	*--	---	---	---	---	---	---
Nitzschia umbonata	*--	-+-	---	---	---	---	---
Pinnularia borealis	*-+	-++	+--	---	+++	+++	+--
Pinnularia gibba	*++	+-+	---	+--	---	---	---
Pinnularia hemiptera	*++	++-	---	---	---	---	---
Pinnularia interrupta	*++	+--	+--	---	---	---	---
Pinnularia legumen	*++	-+-	---	---	---	---	---
Pinnularia major	*++	-+-	---	---	---	--+	---
Pinnularia microstauron	*++	++-	+++	---	+--	+++	--+
Pinnularia nodosa	*++	---	---	---	---	---	---
Pinnularia rupestris	*++	+-+	---	+--	+--	+-+	-+-
Pinnularia subcapitata	*++	+--	+--	+--	--+	+++	+--
Pinnularia viridis	*++	+++	+++	---	---	-++	+--
Rhoicosphaenia abbreviata	*--	---	---	-++	---	+++	+++
Rhopalodia gibba	*--	---	+-+	---	---	---	---
Stauroneis anceps	*++	+--	---	+--	+--	++-	---
Stauroneis phoenicenteron	*-+	+--	--+	---	---	---	---
Stauroneis smithii	*--	---	---	---	---	---	---
Surirella angusta	*++	+++	+++	+--	+--	+++	+++
Surirella biserata	*--	-+-	---	---	---	---	---
Surirella brebissonii	*-+	-++	-++	+++	+++	+++	+++
Surirella gracilis	*--	---	---	---	---	---	---
Surirella linearis	*--	---	---	---	+++	++-	---
Surirella minuta	*--	---	---	---	---	+--	+--
Surirella ovalis	*--	---	---	-++	---	+-+	+--
Surirella splendida	*--	---	---	---	---	++-	---
Surirella tenera	*--	---	---	---	---	---	---
Tabellaria flocculosa	*++	+++	+++	+--	---	---	---
Tetracyclus rupestris	*--	---	---	+--	---	---	---

Table 2b: List of diatom species identified in 2007 in eight sites located on the main river course (**1**/spring; **2**/summer; **3**/autumn; + the species was present; - the species was absent; * the site was not sampled).

Sampling sites	AR 8	AR 9	AR 10	AR 11	AR 12	AR 13	AR 14	AR 15
Seasons	123	123	123	123	123	123	123	123
Achnanthes biasoletiana	**-	---	---	---	---	---	---	---
Achnanthes bioretii	**-	---	---	---	---	---	---	---

Table 2b continued

Achnanthes delicatula	**-	---	---	---	---	---	-+-	+-+
Achnanthes helvetica	**-	---	---	---	---	---	---	---
Achnanthes hungarica	**-	---	---	---	---	---	+++	+++
Achnanthes kryophila	**-	---	---	---	---	---	---	---
Achnanthes lanceolata	**-	+++	---	+++	---	+-+	---	---
Achnanthes minutissima	**+	+++	+++	+++	+++	+++	+++	+++
Achnanthes subatomoides	**-	---	---	---	---	---	---	---
Amphipleura pellucida	**-	+--	---	---	---	---	---	---
Amphora lybica	**-	---	---	---	---	---	---	---
Amphora ovalis	**-	+--	--+	+++	+++	+++	---	---
Amphora pediculus	**-	---	---	---	---	---	---	---
Amphora venetea	**-	---	---	---	---	---	---	---
Anomoeoneis vitrea	**-	---	---	---	---	---	---	---
Aulacoseira granulata	**-	---	---	---	---	+-+	---	+++
Bacillaria paradoxa	**-	---	---	---	---	---	---	---
Caloneis amphisbaena	**-	---	---	---	---	---	+-+	+++
Caloneis silicula	**+	+--	---	---	---	---	---	+++
Cocconeis disculus	**-	---	---	---	---	---	---	---
Cocconeis neodiminuta	**-	---	---	---	+++	---	---	---
Cocconeis pediculus	**-	+++	+++	+++	+++	+++	+++	+++
Cocconeis placentula	**+	+++	---	+++	+++	+++	+++	+++
Cyclotella iris	**-	---	---	---	---	--+	---	---
Cyclotella meneghineana	**-	---	---	---	---	---	---	+-+
Cymatopleura elliptica	**-	---	---	---	---	---	---	+++
Cymatopleura solea	**-	+--	---	---	---	---	---	+++
Cymbella affinis	**-	+--	---	+++	+++	+++	---	---
Cymbella caespitosa	**-	+++	---	---	---	+++	---	+-+
Cymbella cistula	**-	+++	---	---	---	+++	---	+++
Cymbella cuspidata	**-	+-+	---	---	---	---	---	---
Cymbella gracilis	**-	---	---	---	---	---	---	---
Cymbella helvetica	**-	+-+	---	---	---	---	---	---
Cymbella lanceolata	**-	+--	---	---	---	---	---	---
Cymbella mesiana	**-	---	---	---	---	---	---	---
Cymbella minuta	**+	+++	+++	+-+	+++	+++	---	+-+
Cymbella naviculiformis	**-	---	---	---	---	---	---	---
Cymbella prostrata	**-	+++	---	---	---	---	---	---
Cymbella silesiaca	**+	+++	+++	+-+	+-+	+++	---	+++
Cymbella simoensenii	**-	---	---	---	---	---	---	---
Cymbella sinuata	**-	+++	---	-++	+++	---	---	---
Cymbella tumida	**+	---	---	---	---	+-+	---	+-+
Cymbella tumidula	**-	---	---	---	---	---	---	---
Cymbella turgidula	**-	+--	---	---	---	---	---	---
Diatoma anceps	**-	---	---	---	---	---	---	---
Diatoma ehrenbergii	**-	+-+	---	-+-	+++	+++	---	+-+
Diatoma elongatum	**-	---	---	---	---	---	---	---
Diatoma hyemalis	**-	--+	---	---	-+-	---	---	---
Diatoma mesodon	**-	+-+	---	---	---	+--	---	---
Diatoma moniliformis	**-	---	---	---	---	---	---	---

Table 2b continued

Diatoma tenuis	**-	---	---	---	---	---	---	---
Diatoma vulgaris	**+	+++	+-+	-++	+-+	+++	---	+-+
Didymosphenia geminata	**+	+++	---	---	+--	+--	---	+--
Diploneis parma	**-	---	---	---	---	---	---	---
Epithemia adnata	**-	---	---	---	---	---	---	---
Eunotia bilunaris	**-	---	---	---	---	---	---	---
Eunotia exigua et var bidens	**-	---	---	---	---	---	---	---
Eunotia minor	**-	---	---	---	---	---	---	---
Eunotia tenella	**-	---	---	---	---	---	---	---
Eunotia veneris	**-	---	---	---	---	---	---	---
Fragilaria acus	**-	+-+	---	---	---	---	---	---
Fragilaria arcus	**+	+++	---	+++	---	+++	---	+++
Fragilaria capucina et var. gracilis, var rumpens, var vaucheriae	**+	+++	--+	+++	+++	+++	+++	+++
Fragilaria construens	**-	---	---	---	---	---	---	---
Fragilaria crotonensis	**-	---	---	---	---	---	---	---
Fragilaria pinnata	**-	---	---	---	---	---	---	+--
Fragilaria ulna	**+	+++	+-+	+++	+++	+++	+++	+++
Fragilaria virescens	**-	---	---	---	---	---	---	---
Frustulia rhomboides var. saxonica	**-	---	---	---	---	---	---	---
Frustulia vulgaris	**-	+--	---	+--	---	+--	---	+--
Gomphonema acuminatum	**-	+-+	---	---	---	---	---	---
Gomphonema angustatum	**-	+-+	---	---	---	---	---	---
Gomphonema angustum	**-	---	---	---	---	---	---	---
Gomphonema clavatum	**-	+--	---	---	---	---	---	---
Gomphonema gracile	**-	---	---	-++	+-+	+--	---	---
Gomphonema minutum	**-	+--	---	---	---	---	---	---
Gomphonema longiceps	**-	---	---	---	---	---	---	---
Gomphonema olivaceum et var. calcareum	**-	---	---	--+	---	+-+	---	+-+
Gomphonema parvulum	**-	+++	+-+	+++	+++	+++	+++	+++
Gomphonema pseudoaugur	**-	---	---	---	---	---	---	---
Gomphonema pumilum	**-	+-+	---	---	---	---	---	---
Gomphonema tergestinum	**-	---	---	---	---	---	---	---
Gomphonema truncatum	**-	---	---	---	---	---	---	---
Gyrosigma acuminatum	**-	---	---	---	---	---	+-+	+++
Gyrosigma attenuatum	**-	---	---	---	---	---	+++	+-+
Gyrosigma nodiferum	**-	---	---	---	---	---	+-+	+--
Gyrosigma scalproides	**-	---	---	---	---	---	+-+	--+
Hantzschia amphioxys	**-	+++	---	---	---	---	+++	+++
Melosira roseana	**-	---	---	---	---	---	---	---
Melosira varians	**+	+++	---	-++	+-+	+-+	---	+++
Meridion circulare	**-	---	---	-+-	---	+--	---	---
Navicula accomoda	**-	---	---	---	---	---	+-+	+++
Navicula ambigua	**-	---	---	---	---	---	+-+	+--
Navicula angusta	**-	---	---	---	---	---	---	---
Navicula arvensis	**-	---	---	--+	---	---	+-+	--+
Navicula atomus	**-	---	---	---	---	---	+-+	+--
Navicula bacillum	**-	+++	---	---	---	---	---	---
Navicula capitata	**-	---	---	---	+-+	---	+-+	+-+
Navicula capitatoradiata	**-	+-+	---	+-+	+-+	+-+	---	+-+
Navicula cincta	**-	--+	--+	+-+	---	---	---	---

Table 2b continued

Navicula cryptocephala	**+	+-+	--+	-++	---	+-+	---	+--
Navicula cryptotenella	**+	+--	---	---	+++	+--	---	--+
Navicula cuspidata	**-	+--	---	---	---	---	+++	---
Navicula decussis	**-	---	---	---	---	---	---	---
Navicula digitatoradiata	**-	---	---	---	---	---	---	---
Navicula elginensis	**-	---	---	+--	+-+	+-+	---	---
Navicula exigua	**-	---	---	---	---	---	---	---
Navicula goeppertiana	**-	---	---	---	---	---	+-+	+-+
Navicula gregaria	**-	---	---	---	---	---	---	+--
Navicula lanceolata	**-	+--	--+	+-+	+++	+++	---	+-+
Navicula menisculus	**-	+--	---	---	---	---	+--	---
Navicula minima	**-	---	---	---	---	---	---	---
Navicula minuscula	**-	---	---	+-+	---	---	---	---
Navicula mutica	**-	---	---	---	---	---	---	---
Navicula nivalis	**-	---	---	---	---	---	---	---
Navicula oblonga	**-	---	---	---	---	---	---	---
Navicula placentula	**-	---	---	---	---	---	---	---
Navicula phyllepta	**-	---	---	---	---	---	---	+--
Navicula pupulla	**-	+--	---	+--	+--	+-+	---	---
Navicula radiosa	**-	+--	---	-+-	---	+--	---	---
Navicula recens	**-	---	---	---	---	---	---	---
Navicula reinhardtii	**-	---	---	---	---	---	---	---
Navicula rhyncocephala	**-	+-+	---	+-+	---	+-+	---	---
Navicula slesvicensis	**-	---	---	+-+	---	+--	---	---
Navicula tripunctata	**-	---	---	+-+	---	+-+	---	+-+
Navicula trivialis	**-	+--	---	++-	---	+--	---	---
Navicula tuscula	**-	---	---	---	---	+--	---	+-+
Navicula veneta	**-	---	---	+-+	+-+	+--	---	---
Navicula viridula	**-	+-+	---	---	---	---	---	---
Neidium affine	**-	---	---	---	---	---	---	---
Neidium ampliatum	**-	---	---	---	---	---	---	---
Neidium binodis	**-	---	---	---	---	---	---	---
Neidium bisulcatum	**-	---	---	---	---	---	---	---
Neidium dubium	**-	--+	---	---	---	---	---	---
Nitzschia acicularis	**-	+--	---	+--	+-+	+-+	---	+-+
Nitzschia capitellata	**-	---	---	---	---	---	+-+	---
Nitzschia communis	**-	---	---	---	---	---	---	---
Nitzschia dissipata	**-	+++		+++	+++	+-+	---	+--
Nitzschia dubia	**-	---	---	---	---	---	+-+	+--
Nitzschia filiformis	**-	---	---	---	---	---	+-+	---
Nitzschia fruticosa	**-	---	---	---	---	---	---	---
Nitzschia gracilis	**-	---	---	---	---	---	---	---
Nitzschia heufleriana	**-	---	---	---	---	---	---	---
Nitzschia hungarica	**-	---	---	+-+	---	---	+--	---
Nitzschia inconspicua	**-	---	---	---	---	---	---	---
Nitzscha intermedia	**-	---	---	---	---	---	---	---
Nitzschia linearis	**-	+++	--+	-++	+++	+-+	+-+	---
Nitzschia microcephala	**-	---	---	---	---	---	---	---

Table 2b continued

Nitzschia palea	**-	+++	--+	+++	+++	+-+	+++	---
Nitzschia paleacea	**-	---	---	---	+-+	---	---	---
Nitzschia perminuta	**-	---	---	---	---	---	---	---
Nitzschia reversa	**-	---	---	---	---	---	+-+	---
Nitzschia sigmoidea	**-	---	---	---	---	---	---	---
Nitzschia tubicola	**-	---	---	---	---	---	---	+--
Nitzschia umbonata	**-	---	---	---	---	+-+	---	---
Pinnularia borealis	**-	+++	---	---	---	---	---	---
Pinnularia gibba	**-	---	---	---	---	---	---	---
Pinnularia hemiptera	**-	---	---	---	---	---	---	---
Pinnularia interrupta	**-	---	---	---	---	---	---	---
Pinnularia legumen	**-	---	---	---	---	---	---	---
Pinnularia major	**-	---	---	---	---	---	---	---
Pinnularia microstauron	**-	---	---	--+	++-	---	---	+--
Pinnularia nodosa	**-	---	---	---	---	---	---	---
Pinnularia rupestris	**-	---	---	---	---	---	---	---
Pinnularia subcapitata	**-	---	---	---	---	---	---	---
Pinnularia viridis	**-	---	---	+--	+--	---	---	--+
Rhoicosphaenia abbreviata	**+	+++	---	+++	+++	---	---	+++
Rhopalodia gibba	**-	---	---	---	---	---	---	---
Stauroneis anceps	**-	---	---	---	---	---	---	---
Stauroneis phoenicenteron	**-	---	---	---	---	---	---	+--
Stauroneis smithii	**-	---	---	---	---	---	---	---
Surirella angusta	**-	+-+	---	+++	+++	+-+	---	+-+
Surirella biserata	**-	---	---	---	---	---	---	---
Surirella brebissonii	**-	+++	--+	-++	+++	+++	+++	+++
Surirella gracilis	**-	---	---	---	---	---	---	+-+
Surirella linearis	**-	+--	---	-+-	+-+	+--	---	---
Surirella minuta	**-	--+	---	-+-	+-+	+++	---	---
Surirella ovalis	**-	--+	---	---	---	+-+	+++	+-+
Surirella splendida	**-	---	---	---	---	---	---	---
Surirella tenera	**-	---	---	---	---	+-+	---	+--
Tabellaria flocculosa	**-	---	---	---	---	---	---	---
Tetracyclus rupestris	**-	---	---	---	---	---	---	---

Table 2c: List of diatom species identified in 2007 in 8 sites located on the tributaries (**1**/spring; **2**/summer; **3**/ autumn; + the species was present; - the species was absent; ***** the site was not sampled).

Sampling site	T1	T2	T3	T4	T5	T6	T7	T8
Seasons	123	123	123	123	123	123	123	123
Achnanthes biasoletiana	---	---	---	---	---	---	---	---
Achnanthes bioretii	---	---	---	---	---	---	---	---
Achnanthes delicatula	---	---	---	---	---	---	+-+	---
Achnanthes helvetica	---	---	---	---	---	---	--+	---
Achnanthes hungarica	---	---	---	---	---	---	-++	+--
Achnanthes kryophila	---	---	---	---	---	---	---	---
Achnanthes lanceolata	+++	+++	+++	---	---	---	+++	---
Achnanthes minutissima	+++	+++	+++	---	---	+++	---	---
Achnanthes subatomoides	---	---	+++	---	---	---	---	---
Amphipleura pellucida	---	+-+	++-	---	---	---	---	---

Table 2c continued

Amphora lybica	---	---	---	---	---	---	--+	---
Amphora ovalis	---	---	---	---	---	---	+++	---
Amphora pediculus	+-+	---	---	---	---	+-+	+--	---
Amphora venetea	---	---	---	---	---	---	--+	---
Anomoeoneis vitrea	---	---	---	---	---	---	---	---
Aulacoseira granulata	---	---	---	---	---	---	--+	---
Bacillaria paradoxa	---	+--	---	---	---	---	--+	---
Caloneis amphisbaena	---	---	---	---	---	---	-+-	+-+
Caloneis silicula	---	---	---	---	---	---	-+-	---
Cocconeis disculus	+-+	---	+--	---	---	+++	---	---
Cocconeis neodiminuta	---	---	---	---	---	---	---	---
Cocconeis pediculus	---	+++	---	---	---	+++	+++	---
Cocconeis placentula	+++	+++	+++	---	---	+++	+++	---
Cyclotella iris	---	---	---	---	---	---	---	---
Cyclotella meneghineana	---	---	---	---	---	---	-+-	---
Cymatopleura elliptica	---	---	---	---	---	---	---	---
Cymatopleura solea	---	---	---	---	---	+--	--+	---
Cymbella affinis	---	---	+++	---	---	+++	+-+	---
Cymbella caespitosa	---	---	---	---	---	---	---	---
Cymbella cistula	---	---	+++	---	---	---	+--	---
Cymbella cuspidata	+-+	---	+-+	---	---	+-+	---	---
Cymbella gracilis	---	---	---	---	---	---	---	---
Cymbella helvetica	---	---	+-+	---	---	---	---	---
Cymbella lanceolata	---	---	+++	---	---	---	---	---
Cymbella mesiana	+--	---	+--	---	---	---	---	---
Cymbella minuta	+++	+++	+++	---	---	+++	+++	---
Cymbella naviculiformis	---	---	+--	---	---	---	---	---
Cymbella prostrata	---	---	---	---	---	---	+--	---
Cymbella silesiaca	---	+++	---	---	---	+++	+++	---
Cymbella simoensenii	---	---	---	---	---	---	---	---
Cymbella sinuata	+++	+++	+++	---	---	+++	---	---
Cymbella tumida	---	---	+-+	---	---	---	---	---
Cymbella tumidula	+-+	---	---	---	---	---	---	---
Cymbella turgidula	---	---	+-+	---	---	---	---	---
Diatoma anceps	---	---	---	---	---	---	---	---
Diatoma ehrenbergii	+--	---	+++	---	---	---	---	---
Diatoma elongatum	+--	---	---	---	---	---	---	---
Diatoma hyemalis	+++	---	+++	---	---	+++	---	---
Diatoma mesodon	+++	---	+++	---	---	---	---	---
Diatoma moniliformis	+++	---	---	---	---	---	---	---
Diatoma tenuis	+++	---	---	---	---	---	---	---
Diatoma vulgaris	+++	+++	+++	---	---	+++	---	---
Didymosphenia geminata	+--	---	+++	---	---	---	---	---
Diploneis parma	---	---	---	---	---	---	---	---
Epithemia adnata	---	---	---	---	---	---	---	---
Eunotia bilunaris	---	---	---	---	---	---	---	---
Eunotia exigua et var bidens	---	---	---	---	---	---	---	---
Eunotia minor	---	---	---	---	---	---	---	---

Table 2c continued

Eunotia tenella	---	---	---	---	---	---	---	---
Eunotia veneris	---	---	---	---	---	---	---	---
Fragilaria acus	---	---	---	---	---	---	---	---
Fragilaria arcus	+++	+++	+++	---	---	---	---	---
Fragilaria capucina et var. gracilis, var rumpens, var vaucheriae	+++	+++	+++	---	---	+++	+++	---
Fragilaria construens	---	---	---	---	---	---	---	---
Fragilaria crotonensis	---	---	---	---	---	---	---	---
Fragilaria pinnata	---	---	---	---	---	---	---	---
Fragilaria ulna	+++	+++	+++	---	---	+++	+++	---
Fragilaria virescens	---	---	---	---	---	---	---	---
Frustulia rhomboides var. saxonica	---	---	---	---	---	---	---	---
Frustulia vulgaris	---	---	---	---	---	---	---	---
Gomphonema acuminatum	---	---	---	---	+--	---	---	---
Gomphonema angustatum	+-+	---	---	---	+++	---	---	---
Gomphonema angustum	+--	+--	+-+	---	---	---	---	---
Gomphonema clavatum	---	---	---	---	---	---	---	---
Gomphonema gracile	---	---	---	---	---	---	---	---
Gomphonema minutum	---	---	---	---	---	+--	---	---
Gomphonema longiceps	+--	---	---	---	---	---	---	---
Gomphonema olivaceum et var. calcareum	+-+	---	+++	---	---	---	+++	---
Gomphonema parvulum	+++	+++	+++	---	---	+++	+++	+++
Gomphonema pseudoaugur	---	+-+	---	---	---	---	---	+--
Gomphonema pumilum	+--	+--	+-+	---	---	+++	---	---
Gomphonema tergestinum	---	+--	---	---	---	---	---	---
Gomphonema truncatum	---	---	+-+	---	---	---	---	---
Gyrosigma acuminatum	---	---	---	---	---	---	---	+--
Gyrosigma attenuatum	---	---	---	---	---	---	---	-+-
Gyrosigma nodiferum	---	---	---	---	---	---	---	+++
Gyrosigma scalproides	---	---	---	---	---	---	---	--+
Hantzschia amphioxys	---	+++	---	---	---	---	+++	+++
Melosira roseana	---	---	---	---	---	---	---	---
Melosira varians	---	---	---	---	---	---	--+	---
Meridion circulare	+++	+++	---	---	---	---	---	---
Navicula accomoda	---	---	---	---	---	---	---	+++
Navicula ambigua	---	---	---	---	---	---	---	+--
Navicula angusta	---	---	---	---	---	---	-+-	---
Navicula arvensis	---	---	---	---	---	---	---	---
Navicula atomus	---	---	---	---	---	---	---	---
Navicula bacillum	---	---	---	---	---	+--	---	---
Navicula capitata	---	---	---	---	---	---	---	+++
Navicula capitatoradiata	+-+	---	+--	---	---	---	+-+	---
Navicula cincta	+--	---	+++	---	---	+-+	---	---
Navicula cryptocephala	---	---	---	---	---	---	+++	---
Navicula cryptotenella	+--	---	+++	---	---	--+	-+-	---
Navicula cuspidata	---	---	---	---	---	---	---	+++
Navicula decussis	---	---	---	---	---	+--	---	---
Navicula digitatoradiata	---	---	---	---	---	---	---	---
Navicula elginensis	---	---	+--	---	---	--+	---	---
Navicula exigua	---	---	+--	---	---	---	---	---
Navicula goeppertiana	---	---	---	---	---	---	---	+++

Table 2c continued

Navicula gregaria	---	---	---	---	---	---	---	---
Navicula lanceolata	---	+++	+-+	---	---	+--	+++	---
Navicula menisculus	---	---	---	---	---	---	-+-	---
Navicula minima	---	---	---	---	---	---	---	---
Navicula minuscula	---	---	---	---	---	---	---	---
Navicula mutica	---	---	---	---	---	---	---	---
Navicula nivalis	---	---	---	---	---	---	---	---
Navicula oblonga	---	---	---	---	---	---	---	---
Navicula placentula	---	---	---	---	---	---	---	---
Navicula phyllepta	---	---	---	---	---	---	---	+--
Navicula pupulla	---	---	---	---	---	+--	---	---
Navicula radiosa	---	---	+-+	---	---	+-+	---	---
Navicula recens	---	---	---	---	---	---	+++	---
Navicula reinhardtii	+-+	---	---	---	---	---	---	---
Navicula rhyncocephala	---	+-+	---	---	---	---	---	---
Navicula slesvicensis	---	---	---	---	---	---	---	---
Navicula tripunctata	+-+	---	+-+	---	---	+++	+++	---
Navicula trivialis	---	---	---	---	---	---	---	---
Navicula tuscula	---	---	---	---	---	---	---	---
Navicula veneta	---	---	---	---	---	---	+-+	+--
Navicula viridula	---	---	---	---	---	+++	---	---
Neidium affine	---	---	---	---	---	---	---	---
Neidium ampliatum	---	---	---	---	---	---	---	---
Neidium binodis	---	---	---	---	---	---	-+-	---
Neidium bisulcatum	---	---	---	---	---	---	---	---
Neidium dubium	---	---	---	---	---	---	---	---
Nitzschia acicularis	---	---	---	---	---	+--	---	---
Nitzschia capitellata	---	---	---	---	---	---	---	+--
Nitzschia communis	---	+--	---	---	---	---	---	---
Nitzschia dissipata	---	---	+++	---	---	--+	+++	---
Nitzschia dubia	---	---	---	---	---	---	---	---
Nitzschia filiformis	---	---	---	---	---	---	---	---
Nitzschia fruticosa	---	---	---	---	---	---	---	+-+
Nitzschia gracilis	---	---	---	---	---	---	---	---
Nitzschia heufleriana	+-+	---	+++	---	---	---	---	---
Nitzschia hungarica	---	---	---	---	---	---	---	---
Nitzschia inconspicua	---	---	---	---	---	---	---	+-+
Nitzscha intermedia	---	---	---	---	---	---	---	---
Nitzschia linearis	+++	+-+	---	---	---	+--	+++	---
Nitzschia microcephala	---	---	---	---	---	---	---	---
Nitzschia palea	---	+++	+++	---	---	+++	+++	---
Nitzschia paleacea	---	---	---	---	---	---	---	---
Nitzschia perminuta	---	---	+--	---	---	---	---	---
Nitzschia reversa	---	---	---	---	---	---	---	+-+
Nitzschia sigmoidea	---	---	---	---	---	---	---	---
Nitzschia tubicola	---	---	---	---	---	---	---	---
Nitzschia umbonata	---	---	---	---	---	---	---	---
Pinnularia borealis	---	+--	+--	---	---	---	---	---

Table 2c continued

Pinnularia gibba	---	---	+--	---	---	---	---	---
Pinnularia hemiptera	---	---	---	---	---	---	---	---
Pinnularia interrupta	---	---	--+	---	---	---	---	---
Pinnularia legumen	---	---	---	---	---	---	---	---
Pinnularia major	---	---	--+	---	---	---	---	---
Pinnularia microstauron	---	---	+--	---	---	---	---	---
Pinnularia nodosa	---	---	---	---	---	---	---	---
Pinnularia rupestris	---	---	---	---	---	---	---	---
Pinnularia subcapitata	---	---	---	---	---	---	---	---
Pinnularia viridis	---	---	---	---	---	---	---	---
Rhoicosphaenia abbreviata	---	---	---	---	---	---	---	---
Rhopalodia gibba	---	---	---	---	---	---	---	---
Stauroneis anceps	---	---	---	---	---	---	---	---
Stauroneis phoenicenteron	---	---	---	---	---	---	---	---
Stauroneis smithii	---	---	---	---	---	---	-+-	---
Surirella angusta	+--	---	---	---	---	+--	---	---
Surirella biserata	---	---	---	---	---	---	---	---
Surirella brebissonii	---	---	---	---	---	---	+++	---
Surirella gracilis	---	---	---	---	---	---	---	---
Surirella linearis	---	---	---	---	---	---	---	---
Surirella minuta	---	---	---	---	---	---	-+-	+-+
Surirella ovalis	---	---	---	---	---	--+	---	+++
Surirella splendida	---	---	---	---	---	---	---	---
Surirella tenera	---	---	---	---	---	---	---	---
Tabellaria flocculosa	---	---	---	---	---	---	---	---
Tetracyclus rupestris	---	---	---	---	---	---	---	---

Most diatoms identified in the Arieş River course, but also on its main tributaries were cosmopolitan, eurybiont elements: *Achnanthes minutissima, Cocconeis placentula, Cymbella affinis*, *Cymbella minuta, Cymbella silesiaca, Cymbella sinuata, Diatoma vulgaris, Fragilaria capucina*, *Fragilaria ulna, Gomphonema parvulum, Nitzschia palea, Surirella brebissonii* etc. Almost all diatom species were benthic forms, except for the allochthonous planktonic species *Fragilaria acus* and *Fragilaria crotonensis* that came from the Mihoieşti former dam reservoir. Among the benthic species, most were epilithic elements, attached on river substratum (rocks, stones, boulders), like species belonging to the following genera: *Fragilaria, Gomphonema, Navicula, Didymosphenia* etc. Epipelic species were identified only on the lower river course, due to changes in substratum. They developed on the surface of mobile sediments like sand or mud: species belonging to *Caloneis, Gyrosigma* and *Cymatopleura* genera or some *Nitzschia* and *Navicula* species. Few epiphytic species were identified: *Meridion circulare*, *Epithemia adnata, Rhopalodia gibba* and some *Eunotia* species.

On the upper Arieş River course rheophilous species were found, living in waters with low temperature and high dissolved oxygen content: *Diatoma hyemalis, Diatoma mesodon, Meridion circulare, Achnanthes bioretii, Achnanthes kryophila, Achnanthes subatomoides* etc.

Regarding the pH values (Fig. 2), a high number of alkaliphilic and alkalibiont elements were found in the entire river basin area: *Cymbella cistula*, some *Amphora, Gomphonema, Navicula, Nitzschia, Surirella* species. However, acidophilic and acidobiont species appeared in the upper reaches of the river and downstream several pollution sources that caused decreases in pH values (sawdust from the Cîmpeni wood processing factory or outflows from the mining areas from Roşia Montană, Roşia Poieni, Baia de Arieş); species belonging to the following genera: *Eunotia, Pinnularia, Frustulia, Tabellaria, Neidium*.

Depending on water trophicity, on the upper reaches of the river oligotrophic or oligo-mesotrophic species were found: *Achnanthes bioretii, Achnanthes biasoletiana, Achnanthes helvetica, Cymbella gracilis, Eunotia exigua, Pinnularia subcapitata* etc. Eutrophic elements were found on passing downstream, species belonging to the genera: *Amphora, Fragilaria, Navicula, Nitzschia, Gyrosigma, Surirella* etc. Concerning saprobity levels indicated by diatom species (Marvan and Sladekova, 1978; Sladecek, 1973), a gradual degradation of water quality was observed from headwaters to mouth. The highest number of xenosaprobic, xeno-oligosaprobic, oligo- or β-mesosaprobic species was found in the upper stretches of the river, indicating clean waters: *Frustulia rhomboides* var. *saxonica, Tabellaria flocculosa, Cymbella gracilis, Cymbella mesiana, Cymbella lanceolata, Diatoma elongatum,* or species of *Eunotia*. Their number decreased gradually, so that in the lower river reaches, numerous species indicating critical saprobic levels were found (β - α mesosaprobic, α mesosaprobic, α meso-polisaprobic and polisaprobic), together with cosmopolitan ones: *Caloneis amphisbaena, Achnanthes hungarica, Diatoma tenuis, Fragilaria capucina* var. *vaucheriae, Navicula accomoda, Navicula goeppertiana, Navicula pupulla, Navicula slesvicensis, Navicula veneta, Nitzschia communis, Nitzschia hungarica* etc.

Considering other aspects of diatom indicator species, *Gomphonema olivaceum* var. *calcareum* was identified in river areas characterized by limestone substratum. Other species identified in the Arieş Basin area withstood high iron concentrations: *Surirella linearis, Pinnularia microstauron*; or high cupper concentrations: *Fragilaria virescens, Navicula viridula, Cymbella naviculiformis, Cymbella minuta, Gomphonema parvulum, Nitzschia palea.*

The dominant species with few exceptions were cosmopolitan elements like *Diatoma vulgaris, Cymbella minuta, Achnanthes minutissima* and *Fragilaria ulna* in the upper course; *Achnanthes minutissima, Fragilaria ulna* and *Fragilaria capucina* var. *vaucheriae* in the middle stretch. The swampy region near the river source (AR1) included acidophilic, acidobiont and xeno-oligosaprobic species like *Tabellaria flocculosa* or *Eunotia* sp. In the two sampling sites located in the lower river course, AR14 and AR15, the diatom community was dominated by species indicating critical saprobic levels like *Surirella* and *Nitzschia* species or epipelic forms (*Navicula* and *Gyrosigma* species).

A similar distribution was recorded on the tributaries, *Diatoma vulgaris, Achnanthes minutissima* and *Cymbella minuta* being the dominant species most of the times. The xeno-oligosaprobic species *Diatoma ehrenbergii* was most abundant in the Gîrda Seacă River. *Bacillaria paradoxa* and *Amphora pediculus*, species preferring nutrient rich waters, dominated in the Hăşdate River. Another cosmopolitan element dominated in the Valea Ocoliş River, *Cocconeis placentula*, next to *Achnanthes minutissima.* On the other hand, *Surirella* species dominated in the Racoşa River, indicating critical saprobic levels, together with *Nitzschia palea*, a cosmopolitan element preferring waters with high levels of organic matter.

Our results confirmed previous researches in the area (Péterfi and Momeu, 1984, 1985) and brought new data concerning the qualitative composition of benthic diatom community.

The benthic macroinvertebrate community

Stoneflies (Plecoptera) and mayflies (Ephemeroptera) were well represented not only on the main river course but also on its tributaries, the first including 10 genera and the second 11 genera. Ten caddisfly families (Trichoptera) were found on the river course while on the tributaries only five were identified. Beetles (Coleoptera) were represented by four families on the Arieş River course and by two families on the tributaries, while true flies (Diptera) had eight families on the main river and seven in the tributaries (Tab. 3).

The highest diversity of the macroinvertebrate community was observed in the upper river reaches, in the first six sampling sites (AR1 - AR6). Beginning with the seventh site - AR7 - upstream Cîmpeni, a drastic decrease of the number of Plecoptera genera occurred. At AR8 - downstream of the junction with the Abrud, the entire macroinvertebrate community was strongly affected by the Abrud River, a right tributary coming from the Roşia Montană mining area. In AR9 sampling site, Valea Lupşii, the macroinvertebrates community diversity increased, probably due to dilution. However, downstream the junction with other tributaries from other mining areas, the number of macroinvertebrate groups decreased drastically to five, each including low numbers of individuals. A similar situation was recorded in all the sampling sites located downstream, up to the Arieş River mouth, probably due to the severe impact of Turda and Cîmpia Turzii localities and their industrial platforms.

Leuctra sp. represented the most widely spread Plecoptera genus. It was identified in ten out of the 15 sampling sites located on the main river course and in four out of the eight sites situated on the main tributaries. The number of stonefly genera identified exceeded three only in five sampling sites from the main river course. In AR4 - Gîrda, 10 Plecoptera genera were found in all three sampling seasons. Concerning the tributaries, the difference between the unpolluted and polluted rivers was very clear. Six stonefly genera were identified in less affected rivers (T1 - the Gîrda Seacă, T2 - the Albac, T3 - the Arieşul Mic and T6 - the Valea Ocoliş) while in the other tributaries no Plecoptera genus was found.

Mayflies were well represented as concerns the number of genera identified in the 23 sampling sites (Tab. 3). On the main river course, the highest diversity of mayfly genera was recorded in AR4 - Gîrda, AR5 - upstream Albac and AR6 - downstream Albac, where nine out of 11 genera were present in all the sampling seasons. On the other hand, in AR8 - downstream the junction with the Abrud and AR15 - Luncani, no mayfly genera was identified. In the samples collected from the main tributaries, from the total number of 11 genera, the highest number was recorded in T1 - Gîrda Seacă, while in T4 - the Abrud, T5 - the Pârâul Şesei and T8 - Racoşa no genus was found. The most frequent genus was *Baëtis*. It was present in 13 out of the 15 sampling sites located on the main river course and in five out of the eight sites from the tributaries.

Family Hydropsychidae, order Trichoptera, was present in all the sites located on the main river course and in five out of the eight stations from the tributaries - except for the rivers coming from the mining regions (T4 - the Abrud and T5 - the Pârâul Şesei) and T8 - the Racoşa, coming from the industrial region of the Cîmpia Turzii locality. Families Limnephilidae, Rhyacophilidae and Polycentropodidae were identified in more than nine sites not only on the main river course but also on its tributaries. The highest taxonomical diversity of the Trichoptera group was recorded in AR3 - Arieşeni - village, where seven families were found. On the following tributaries: T1 - the Gîrda Seacă, T2 - the Albac and T3 - the Arieşul Mic, more than four families were collected.

Family Chironomidae, Diptera, was found in all sampling sites from the Arieş River course and from its main tributaries, except for the Pârâul Şesei - T5 and the Abrud - T4, two dead rivers from the point of view of the considered aquatic communities.

Beside family Chironomidae, the following Diptera families were also well represented: Limoniidae, Athericidae, Simuliidae and Ceratopogonidae. Oligochaeta was present at all sampling sites located on the main river and almost in all sampling seasons. They were also well represented on the sites situated on the tributaries, except for the Abrud (T4) and Pârâul Şesei (T5) where no organisms were found. Four Coleoptera families were identified; family Elminthidae was found at the highest number of sites. Dragonflies (Odonata) were represented by family Aeschnidae at AR1 and genera *Orthetrum* and *Calopterix* at T8. Only one genus was found belonging to aquatic Heteroptera: *Aphaelocheirus*, at AR6 (upstream Albac). Crustaceans were represented by family Gammaridae at 10 sampling sites and family Aselidae identified only at AR14. Gastropods were present at AR6 and AR7 on the main river course and at T3 on the tributaries with representatives belonging to family Ancylidae. *Dugesia* sp. (Turbellariata) was present at AR4, AR5 and T3. *Erpobdella* sp. (Hirudineae) was found at AR2, AR14 and T7, while *Sialis* sp. (Megaloptera) was identified at AR2, AR9, T3 and T6.

Table 3a: The macroinvertebrates taxa identified in the Arieş Basin in seven sampling sites from the main river course (**1**/spring 2007; **2**/summer 2007; **3**/autumn 2007; + the species was present; - the species was absent; * the site was not sampled).

Sampling sites	AR1	AR2	AR3	AR4	AR5	AR6	AR7
Seasons	123	123	123	123	123	123	123
TURBELARIA							
Dugesia	*--	---	---	+-+	--+	---	---
NEMATODA	*++	-++	--+	+--	--+	+-+	+--
GASTROPODA							
Ancylidae	*--	---	---	---	---	++-	-+-
HIRUDINEEA							
Erpobdella	*--	+--	---	---	---	---	---
OLIGOCHAETA	*++	+++	+++	+++	+++	+++	+++
HYDRACHNIDIA	*-+	+--	+++	+-+	+++	+-+	+++
CRUSTACEA							
Aselidae	*--	---	---	---	---	---	---
Gammaridae	*--	-+-	--+	---	--+	--+	+--
COLEOPTERA							
Dytiscidae	*++	-+-	---	---	---	---	---
Elminthidae	*--	-+-	+++	+-+	-++	-++	+++
Gyrinidae	*--	---	---	---	---	---	---
Hydrophilidae	*+-	---	---	---	---	---	---
DIPTERA							
Athericidae	*++	+++	+++	+++	+++	--+	+++
Blephariceridae	*--	---	+--	+--	++-	+--	---
Ceratopogonidae	*++	+--	+-+	+--	++-	+-+	++-
Chironomidae	*++	+++	+++	+++	+++	+++	+++
Empididae	*+-	---	---	---	+--	+--	---
Limoniidae	*--	+++	+++	+++	+++	+++	+++
Psychoididae	*--	-+-	---	--+	---	---	---
Simuliidae	*++	+--	-+-	+-+	+++	-++	---
EPHEMEROPTERA							
Baëtis	*++	+-+	+++	+++	+++	+++	++-
Caenis	*--	---	---	-+-	-+-	-+-	-+-
Ecdyonurus	*--	---	-++	+++	+++	+++	-++
Epeorus	*--	---	--+	-+-	-+-	--+	---

Table 3a continued

Ephemera	*--	---	---	--+	--+	--+	---
Ephemerella	*--	---	++-	+++	+++	++-	-+-
Habroleptoides	*+-	---	--+	+-+	+-+	---	---
Habrophlebia	*-+	-+-	---	---	---	+--	-+-
Paraleptophlebia	*--	---	---	---	---	---	---
Rhithrogena	*--	---	+-+	+-+	+-+	+-+	---
Torleya	*--	---	--+	+-+	+-+	+-+	+--
HETEROPTERA							
Aphelocheirus	*--	---	---	---	---	-+-	---
MEGALOPTERA							
Sialis	*--	-+-	---	---	---	---	---
ODONATA							
Aeschnidae	*-+	---	---	---	---	---	---
Calopteryx	*--	---	---	---	---	---	---
Orthetrum	*--	---	---	---	---	---	---
PLECOPTERA							
Amphinemura	*--	---	---	+-+	+--	---	---
Capnia	*--	---	---	---	---	---	---
Chloroperla	*--	---	--+	+--	+--	---	---
Dinocras	*--	---	---	+--	--+	---	---
Isoperla	*--	---	+-+	+-+	+-+	+-+	---
Leuctra	*++	+++	+++	+++	+++	+++	++-
Nemoura	*++	+++	--+	--+	--+	+--	---
Perla	*--	---	+++	+++	+-+	-++	---
Perlodes	*--	---	-++	--+	--+	---	---
Protonemura	*+-	---	--+	+--	+--	---	---
Rabdiopteryx	*--	---	---	---	---	---	---
Taeniopterys	*--	---	---	--+	---	---	---
TRICHOPTERA							
Beraeidae	*--	+--	--+	---	---	---	---
Brachycentridae	*--	--+	---	---	---	---	---
Goeridae	*--	---	--+	---	---	---	---
Hydropsychidae	*+-	+-+	-++	+-+	+++	-++	-+-
Leptoceridae	*--	---	---	+--	---	---	---
Limnephilidae	*++	++-	+++	+++	-++	++-	+--
Philopotamidae	*--	---	---	---	---	---	---
Polycentropodidae	*++	+++	+-+	---	+-+	--+	-+-
Rhyacophilidae	*++	-+-	+++	-++	+++	-++	++-
Sericostomatidae	*--	---	+--	++-	++-	-++	---

Table 3b: The macroinvertebrates taxa identified in the Arieş River basin in eight sampling sites from the main river course (**1**/spring 2007; **2**/summer 2007; **3**/autumn 2007; + the species was present; - the species was absent; * the site was not sampled).

Sampling sites	AR8	AR9	AR10	AR11	AR12	AR13	AR14	AR15
Seasons	123	123	123	123	123	123	123	123
TURBELIARIA								
Dugesia	**-	---	---	---	*-*	---	---	---
NEMATODA	**-	-++	---	---	*-*	---	+-+	---
GASTROPODA								
Ancylidae	**-	---	---	---	*-*	---	---	---

Table 3b continued

HIRUDINEEA								
Erpobdella	**-	---	---	---	*-*	---	-++	---
OLIGOCHAETA	**+	+++	+-+	+++	*+*	+++	+++	+-+
HYDRACHNIDIA	**-	+++	-++	-+-	*+*	-+-	-++	--+
CRUSTACEA								
Aselidae	**-	---	---	---	*-*	---	--+	---
Gammaridae	**-	+++	---	---	*-*	---	---	+--
COLEOPTERA								
Dytiscidae	**-	---	---	---	*-*	---	---	---
Elminthidae	**-	+-+	---	---	*+*	+++	+--	---
Gyrinidae	**-	---	---	--+	*-*	---	---	---
Hydrophilidae	**-	---	---	---	*-*	---	---	---
DIPTERA								
Athericidae	**+	+++	---	---	*+*	-+-	-++	---
Blephariceridae	**-	---	---	---	*-*	---	---	---
Ceratopogonidae	**-	-+-	+--	---	*-*	---	--+	---
Chironomidae	**+	+++	+--	-++	*+*	+++	+++	+-+
Empididae	**-	+++	---	---	*+*	---	---	---
Limoniidae	**+	-++	+--	-++		+-+	---	---
Psychoididae	**-	---	---	---	*-*	---	---	---
Simuliidae	**-	-++	---	---	*-*	---	---	---
EPHEMEROPTERA								
Baëtis	**-	+++	-+-	-++	*+*	+++	++-	---
Caenis	**-	-+-	---	---	*-*	--+	---	---
Ecdyonurus	**-	++-	---	---	*-*	---	---	---
Epeorus	**-	-+-	---	--+	*-*	---	---	---
Ephemera	**-	--+	---	---	*-*	---	---	---
Ephemerella	**-	-+-	---	---	*-*	---	---	---
Habroleptoides	**-	---	---	---	*-*	---	---	---
Habrophlebia	**-	---	---	---	*-*	---	---	---
Paraleptophlebia	**-	--+	---	---	*-*	---	---	---
Rhithrogena	**-	---	---	---	*-*	---	---	---
Torleya	**-	---	---	---	*-*	---	---	---
HETEROPTERA								
Aphelocheirus	**-	---	---	---	*-*	---	---	---
MEGALOPTERA								
Sialis	**-	++-	---	---	*-*	---	---	---
ODONATA								
Aeschnidae	**-	---	---	---	*-*	---	---	---
Calopteryx	**-	---	---	---	*-*	---	---	---
Orthetrum	**-	---	---	---	*-*	---	---	---
PLECOPTERA								
Amphinemura	**-	---	---	---	*-*	---	---	---
Capnia	**-	---	---	---	*-*	---	---	---
Chloroperla	**-	---	---	---	*-*	---	---	---
Dinocras	**-	---	---	---	*-*	---	---	---
Isoperla	**-	---	---	---	*-*	---	---	---
Leuctra	**-	-++	---	--+	*+*	---	---	---

Table 3b continued

Nemoura	**-	---	---	---	*-*	---	---	---
Perla	**-	---	---	---	*-*	---	---	---
Perlodes	**-	-+-	---	---	*-*	---	---	---
Protonemura	**-	---	---	---	*-*	---	---	---
Rabdiopteryx	**-	---	---	---	*-*	---	---	---
Taeniopterys	**-	---	---	---	*-*	---	---	---
TRICHOPTERA								
Beraeidae	**-	---	---	---	*-*	---	---	---
Brachycentridae	**-	---	---	---	*-*	---	---	---
Goeridae	**-	---	---	---	*-*	---	---	---
Hydropsychidae	**+	+++	+-+	-++	*+*	-++	+++	+-+
Leptoceridae	**-	---	---	---	*-*	---	---	---
Limnephilidae	**-	---	---	---	*+*	---	---	---
Philopotamidae	**-	--+	---	---	*-*	---	---	---
Polycentropodidae	**-	-+-	---	---	*-*	---	---	---
Rhyacophilidae	**+	+++	---	---	*-*	--+	---	---
Sericostomatidae	**-	--+	---	---	*-*	---	---	---

Table 3c: The macroinvertebrates taxa identified in the Arieş Basin in eight sites located on the main tributaries (**1**/spring 2007; **2**/summer 2007; **3**/autumn 2007; + the species was present; **-** the species was absent; ***** the site was not sampled).

Sampling sites	T1	T2	T3	T4	T5	T6	T7	T8
Seasons	123	123	123	123	123	123	123	123
TURBELIARIA								
Dugesia	---	---	-+-	---	---	---	---	---
NEMATODA	+--	+-	-+-	---	---	---	---	---
GASTROPODA								
Ancylidae	---	---	+++	---	---	---	---	---
HIRUDINEEA								
Erpobdella	---	---	---	---	---	---	-++	---
OLIGOCHAETA	+++	++-	+++	---	---	+++	+++	+++
HYDRACHNIDIA	-++	++	+++	---	---	++-	---	---
CRUSTACEA								
Aselidae	---	---	---	---	---	---	---	---
Gammaridae	---	---	++-	---	---	-++	+-+	---
COLEOPTERA								
Dytiscidae	-+-	---	---	---	---	---	-+-	---
Elminthidae	+++	++-	-+-	---	---	-++	-++	---
Gyrinidae	---	---	---	---	---	---	---	---
Hydrophilidae	---	---	---	---	---	---	---	---
DIPTERA								
Athericidae	+++	+--	+++	---	---	---	---	---
Blephariceridae	--+	+--	---	---	---	---	---	---
Ceratopogonidae	--+	---	+++	---	---	---	---	---
Chironomidae	+++	++-	+++	---	---	+++	+++	+++
Empididae	---	---	---	---	---	+--	+--	---
Limoniidae	+++	++-	+++	---	---	+++	++-	---
Psychoididae	---	---	---	---	---	---	---	---
Simuliidae	---	++-	++-	---	---	-+-	--+	---

Table 3c continued

EPHEMEROPTERA								
Baëtis	+++	++-	+++	---	---	+++	+++	---
Caenis	-+-	---	-+-	---	---	---	+++	---
Ecdyonurus	+++	---	+++	---	---	+++	+--	---
Epeorus	+--	+--	---	---	---	+-+	---	---
Ephemera	--+	---	+-+	---	---	--+	---	---
Ephemerella	-++	-+-	-+-	---	---	-+-	---	---
Habroleptoides	---	---	--+	---	---	--+	---	---
Habrophlebia	-++	+--	---	---	---	---	---	---
Paraleptophlebia	---	+--	---	---	---	---	---	---
Rhithrogena	+++	++-	--+	---	---	+-+	---	---
Torleya	+-+	---	+-+	---	---	---	---	---
HETEROPTERA								
Aphelocheirus	---	---	---	---	---	---	---	---
MEGALOPTERA								
Sialis	---	---	--+	---	---	--+	---	---
ODONATA								
Aeschnidae	---	---	---	---	---	---	---	---
Calopteryx	---	---	---	---	---	---	---	-++
Orthetrum	---	---	---	---	---	---	---	+++
PLECOPTERA								
Amphinemura	---	---	---	---	---	+--	---	---
Capnia	+--	-+-	---	---	---	--+	---	---
Chloroperla	+--	+--	+--	---	---	---	---	---
Dinocras	---	---	---	---	---	---	---	---
Isoperla	+-+	+--	+--	---	---	+-+	---	---
Leuctra	+++	++-	-+-	---	---	+++	---	---
Nemoura	---	---	--+	---	---	---	---	---
Perla	+++	++-	-+-	---	---	-++	---	---
Perlodes	--+	+--	--+	---	---	-+-	---	---
Protonemura	+--	+--	---	---	---	+--	---	---
Rabdiopteryx	---	+--	---	---	---	---	---	---
Taeniopterys	---	---	---	---	---	---	---	---
TRICHOPTERA								
Beraeidae	---	---	---	---	---	---	---	---
Brachycentridae	---	---	---	---	---	---	---	---
Goeridae	---	---	---	---	---	---	---	---
Hydropsychidae	--+	++-	+++	---	---	+++	+++	---
Leptoceridae	---	---	---	---	---	---	---	---
Limnephilidae	+++	++-	--+	---	---	-+-	-+-	---
Philopotamidae	---	---	---	---	---	---	---	---
Polycentropodidae	---	+--	++-	---	---	---	---	---
Rhyacophilidae	+++	+--	+++	---	---	+++	+--	---
Sericostomatidae	-++	---	+++	---	---	---	---	---

Ichthyofauna

21 fish species were identified in the Arieş Basin area (Tab. 4). Before 1960 (Bănărescu, 1964), prior to the massive human pressures occured in the area, 20 autochtonous native species occurred, characteristic to a clean river with high biodiversity values. After the year 2000 only 14 native species remained. Species characteristic to areas with high water

velocity and pebble riverbed disappeared (the longbarbel gudgeon or the Kessler's gudgeon). Moreover, species like the barbel, pike, vimba bream and the Danube streber also went extinct, probably due to heavy pollution occurred in the lower river course, but mostly near the Arieş River mouth. There, near the junction of the river with the Mureş, a new invasive species appeared - the Prussian carp.

Concerning the status of fish communities in the Arieş Basin area, in unaffected areas (upstream Cîmpeni) the values of fish abundance and biomass per 100 m^2 (Tab. 5) were good to medium, with an average of 5 - 10 ind./100 m^2 and a biomass of 50-100 g/100 m^2. On some tributaries, like the Gîrda Seacă River (T1) high values of abundance and biomass were recorded, indicating a well balanced ecosystem. On the other hand, in affected areas from the middle and lower river course (downstream Cîmpeni) drastic decreases of these ecological parameters occurred (Tab. 5). No fish were caught at Brăzăşti - AR10, downstream the junction of the Arieş with the Abrud - T4 and the Pârâul Şesei - T5, two highly impacted tributaries, where no fish were found either. In the lower Arieş River course, abundance values did not exceed 5 ind./100 m^2, but the average was about 1 - 2 ind./100 m^2. Biomass values per 100 m^2 were also lower compared with the ones recorded in the upper reaches, not exceeding 50 g/100 m^2 on the average. However, there were less affected tributaries like the Valea Ocoliş - T6 or Hăşdate - T7 that recorded higher abundance and biomass values, reaching up to 28 ind./100 m^2 and 2,456 g/100 m^2 at T7 for the Mediterranean barbel.

Table 4: List of fish species collected in the Arieş Basin area.

Family	Latin name	Common name	Status before 1960 (Bănărescu, 1964)	Status after 2005	Ecological status
Salmonidae	*Salmo fario* (Linnaeus, 1758)	trout	x	x	N
Thymollidae	*Thymallus thymallus* (Linnaeus, 1758)	grayling	x	x	N
Cyprinidae	*Babus barbus* (Linnaeus, 1758)	barbel	x	-	N
	Babus petenyi (Heckel, 1852)	Mediterranean barbel	x	x	N
	Rhodeus amarus (Bloch, 1782)	bitterling	x	-	N
	Gobio obtusirostris (Valencienaes, 1844)	gudgeon	x	x	N
	Rheogobio uranoscopus (Agassis, 1828)	longbarbel gudgeon	x	-	N
	Romanogobio kessleri (Dybowski, 1862)	Kessler's gudgeon	x	-	N
	Squalius cephalus (Linnaeus, 1758)	chub	x	x	N
	Phoxinus phoxinus (Linnaeus, 1758)	minnow	x	x	N
	Alburnoides bipunctatus (Bloch, 1782)	spirlin	x	x	N
	Alburnus alburnus (Linnaeus, 1758)	bleak	x	x	N

Table 4 continued

	Vimba carinata (Pallas, 1814)	vimba bream	x	-	N
	Chondrostoma nasus (Linnaeus, 1758)	undermouth	x	x	N
	Carassius gibelio (Bloch, 1782)	Prussian carp	-	x	I
Esocidae	*Esox lucius* (Linnaeus, 1758)	pike	x	-	N
Nemaicheilidae	*Orthrias barbatulus* (Linnaeus, 1758)	stone loach	x	x	N
Cobitidae	*Cobitis taenia* (Linnaeus, 1758)*	burbot	x	x	N
	Sabanejewia balcanica (Karaman, 1922)	spined loach	x	x	N
Percidae	*Zingel streber* (Siebold, 1962)	Danube streber	x	-	N
Cotidae	*Cottus gobio* (Linnaeus, 1758)	bullhead	x	x	N
TOTAL			20	14	

* *Cobitis taenia* syn. with *C. elongatoides* (Băcescu and Mayer, 1969); N - native species; I - invasive sp.

Table 5a: The number of individuals in 100 m^2 and the biomass in 100 m^2 (in brackets) per species and sampling sites in the Arieş Basin area during 2005 and 2007.

Sampling site	year	Trout	Grayling	Bullhead	Minnow	Spirlin	Med. barbel	Stome loach	Total
AR3 - Arieşeni village	2005	0.67 (55.67)	-	3.67 (48.67)	-	-	-	-	4.33 (104.34)
	2007	1.82 (45.50)	-	4.10 (50.00)	-	-	-	-	5.91 (95.50)
T1 - The Gârda Seacă	2007	6.46 (107.70)	2.15 (85.50)	10.46 (167.70)	-	-	-	0.31 (0.90)	19.38 (361.84)
AR4 - Gîrda	2005	0.30 (25.70)	0.30 (21.60)	1.30 (16.90)	-	-	0.10 (3.80)	-	2.00 (68.00)
AR5 - upstream Albac	2005	0.10 (7.30)	1.10 (28.30)	1.20 (8.60)	0.10 (0.50)	-	0.90 (62.30)	0.10 (0.50)	3.50 (107.50)
	2007	1.15 (16.73)	1.35 (7.50)	0.77 (5.77)	0.58 (3.46)	-	0.38 (15.00)	-	4.23 (48.46)
T2 - The Albac	2005	0.83 (37.50)	1.67 (227.08)	5.83 (49.17)	0.42 (0.42)	-	-	-	8.75 (314.17)
	2007	-	3.65 (146.96)	1.22 (9.04)	-	-	-	-	4.87 (156.00)
T3 - The Arieşul Mic	2007	-	2.32 (72.86)	4.64 (44.82)	6.25 (18.93)	-	2.68 (86.60)	0.36 (2.32)	16.25 (225.53)

Table 5a continued

AR7 - upstream Cîmpeni	2006	-	-	1.33 (12.67)	0.33 (1.50)	3.00 (36.33)	2.33 (32.00)	0.17 (1.33)	8.99 (282.99)
	2007	-	-	1.02 (9.49)	0.17 (0.17)	3.39 (25.76)	3.39 (55.59)	0.34 (1.86)	13.90 (213.21)
T4 - The Abrud	2007	-	-	-	-	-	-	-	-
T5 - The Pârâul Şesei	2007	-	-	-	-	-	-	-	-
AR 9 - Valea Lupşii	2007	-	-	-	-	1.11 (10.12)	1.85 (45.56)	-	5.42 (192.72)
AR10 - Brăzăşti	2006	-	-	-	-	-	-	-	-
	2007	-	-	-	-	-	-	-	-
T6 - The Ocoliş	2007	6.29 (38.86)	-	-	-	-	-	0.29 (3.14)	6.58 (42.00)
AR12 - Moldoveneşti	2006	-	-	-	2.12 (3.46)	0.10 (0.67)	0.38 (11.25)	-	8.38 (24.81)
	2007	-	-	-	-	0.17 (1.00)	1.00 (15.1 7)	0.17 (1.00)	4.17 (37.33)
T7 - The Hăşdate	2006	-	-	-	-	8.67 (42.00)	28.00 (2456.0)	1.33 (1.33)	49.34 (2773.3 3)
AR15 - Luncani	2006	-	-	-	-	-	-	-	1.22 (10.15)
	2007	-	-	-	-	-	0.43 (0.43)	-	4.27 (18.09)

Table 5b: The number of individuals in 100 m^2 and the biomass in 100 m^2 (in brackets) per species and sampling sites in the Arieş Basin area during 2005 and 2007.

Sampling site	year	Undermouth	Bleak	Chub	Gudgeon	Gold fish	Spined loach	Burbot	Total
AR3 - Arieşeni village	2005	-	-	-	-	-	-	-	4.33 (104.34)
	2007	-	-	-	-	-	-	-	5.91 (95.50)
T1 - Gârda Seacă	2007	-	-	-	-	-	-	-	19.38 (361.84)
AR4 - Gîrda	2005	-	-	-	-	-	-	-	2.00 (68.00)
AR5 - upstream Albac	2005	-	-	-	-	-	-	-	3.50 (107.50)
	2007	-	-	-	-	-	-	-	4.23 (48.46)
T2 - Albac	2005	-	-	-	-	-	-	-	8.75 (314.17)
	2007	-	-	-	-	-	-	-	4.87 (156.00)

Table 5b continued

T3 - Arieşul Mic	2007	-	-	-	-	-	-	-	16.25 (225.53)
AR7 - upstream	2006	1.33 (192.33)	-	0.33 (4.33)	0.17 (2.50)	-	-	-	8.99 (282.99)
Cîmpeni	2007	-	-	3.90 (101.02)	1.69 (19.32)	-	-	-	13.90 (213.21)
T4 - Abrud	2007	-	-	-	-	-	-	-	-
T5 - Pârâul Şesei	2007	-	-	-	-	-	-	-	-
AR 9 - Valea Lupşii	2007	0.12 (25.19)	-	2.22 (110.12)	0.12 (1.73)	-	-	-	5.42 (192.72)
AR10 -	2006	-	-	-	-	-	-	-	-
Brăzăşti	2007	-	-	-	-	-	-	-	-
T6 - The Ocoliş	2007	-	-	-	-	-	-	-	6.58 (42.00)
AR12 - Moldoveneşti	2006	-	0.1 (0.87)	5.48 (7.31)	0.10 (0.58)	0.10 (0.67)	-	-	8.38 (24.81)
	2007	0.83 (9.33)	-	1.50 (10.17)	0.33 (0.33)	-	-	0.17 (0.33)	4.17 (37.33)
T7 - The Hăşdate	2006	-	-	10.00 (264.67)	0.67 (2.00)	0.67 (7.33)	-	-	49.34 (2773.33)
AR15 - Luncani	2006	-	0.61 (3.79)	0.61 (6.36)	-	-	-	-	1.22 (10.15)
	2007	-	0.85 (1.70)	0.43 (2.13)	2.13 (13.62)	-	0.43 (0.21)	-	4.27 (18.09)

In the polluted regions, sensitive native species, intolerant to habitat degradation migrated towards the tributaries. A good example was the case of the Mediterranean barbel and the spirlin collected in the Hăşdate River mouth, where they recorded high abundance and biomass values. The fish community structure maintained its balance in unaffected or less affected areas - mostly in the upper basin, where native species dominated. The grayling region was perfectly preserved, with a well defined, self sustainable population. Before 1960 (Bănărescu, 1964), the undermouth occupied mostly the middle course of the Arieş River, the regions now destroyed due to human pressures (upstream and downstream AR10 - Brăzăşti). The undermouth, an intolerant and sensitive species, was replaced by the chub, that spread in the lower Arieş Basin area.

The figure 5 presents the number of taxa recorded at each sampling site in the Arieş Basin area for algal, macroinvertebrate and fish communities.

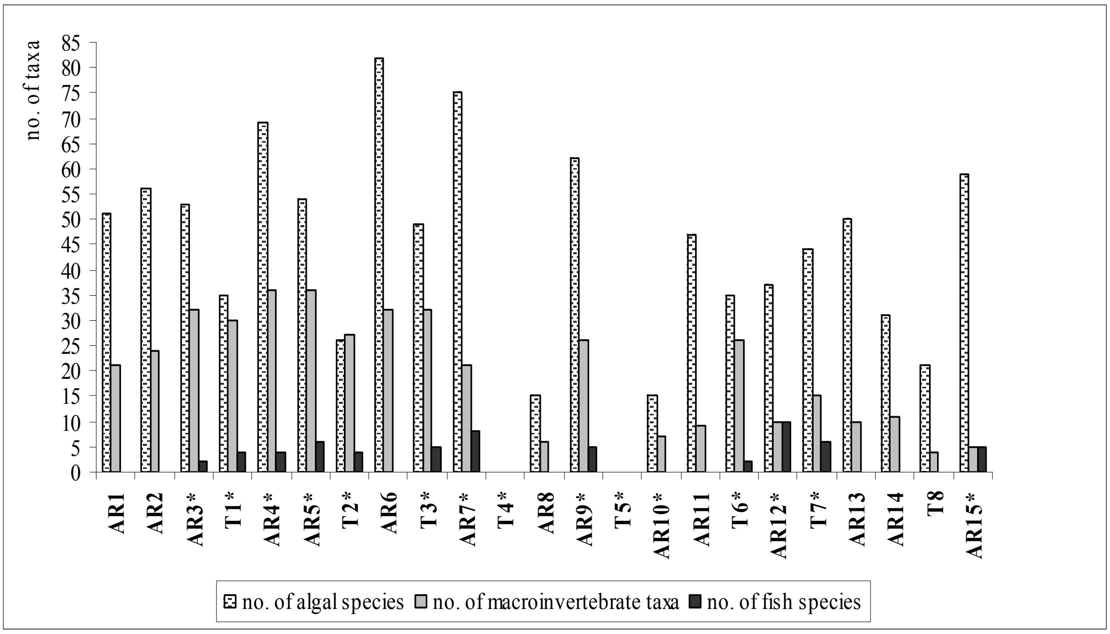

Figure 5: The number of algae, macroinvertebrate and fish taxa identified at the sampling sites from the Arieş Basin area (*- sites where fish were sampled as well).

As expected, the highest number of taxa at almost all sampling sites was recorded by the algal communities, followed by macroinvertebrates, because food webs in aquatic ecosystems have less predator species at the top - in this case fishes. Changes in taxa number from one part of the river to another were caused by changes in environmental factors but also by numerous forms of human impact existing in the entire river catchment area.

A relatively high algal and macroinvertebrate taxa number was recorded in the upper course of the Arieş River (sites AR1 - AR7). The middle stretch was highly impacted because of the outflows of the acid mining waters coming from Roşia Montană - Roşia Poieni - Baia de Arieş area, waste pits, domestic and industrial wastes, deforestation or ballast exploitation. Thus, at AR8, located downstream the junction of the Abrud with the main river, and at AR10, Brăzăşti, located downstream the Baia de Arieş mining area and downstream the junction with the Pârâul Şesei (T5) which discharged acid waters into the main river, the number of diatom and macroinvertebrate taxa decreased drastically (Fig. 5). Between the Abrud and Pârâul Şesei Stream mouths, the Arieş recovered, so at AR9 (Valea Lupşii) a higher number of taxa was identified (algae, macroinvertebrates and fishes). At the sampling sites located in the lower river course, algal and macroinvertebrate taxa varied in a similar way, recording lower values due to numerous ballast exploitation sites located in the main river bed, domestic and industrial wastes and numerous waste pits. However, at AR15 - Luncani, upstream the Arieş River mouth, 59 diatom species were recorded, most of which were cosmopolitan or high trophicity indicators (Fig. 5).

As concerns the main river tributaries, a high number of algal and macroinvertebrate taxa was recorded in the unaffected rivers: the Gîrda Seacă - T1, the Arieşul Mic - T3, the Valea Ocoliş - T6 and the Hăşdate - T7. T2 - the Albac River represented the only sampling site where macroinvertebrate taxa exceeded the number of algal species, probably due to domestic wastes or to the high quantities of sawdust deposits located on the banks or directly into the river. In the middle course, in two out of the four tributaries considered for this study no target taxa were identified, due to the highly acid mining waters and to the increased quantities of suspensions they carried: the Abrud (T4) and the Pârâul Şesei (T5). The Racoşa River (T8), located on the lower river catchment area was characterized by a particular substratum dominated by fine sediments, but also by strong pollution coming from the industrial area Cîmpia Turzii, leading to a low number of taxa.

A different situation was recorded in the variation of fish species number: there were fewer species in the upper regions compared to the lower reaches of the river, but those identified downstream were tolerant, eurybiont species. AR12 - Moldoveneşti represented the sampling site with the highest number of fish species caught (10), but they recorded only 1 - 2 ind./100 m^2 and 6 - 7 g/100 m^2 on the average. Moreover, the species with the highest abundance was the chub, known to be a cosmopolitan, eurybiont species.

The present study brought new information concerning the qualitative structure of algal, macroinvertebrate and fish populations from the Arieş Basin area, thus contributing to a better understanding of aquatic communities from the region.

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THE FACULTATIVE PARASITISM OF *CALLIPHORA VOMITORIA* (LINNÉ, 1758) ON *VIPERA BERUS* (LINNÉ, 1758) REPORTED FROM ARIEŞ RIVER BASIN (TRANSYLVANIA, ROMANIA)

*Ioan Valentin PETRESCU-MAG *, Bogdan GEORGESCU ***
and *Ruxandra Mălina PETRESCU-MAG ****

* Bioflux S. R. L., Ceahlău Street 54, Cluj-Napoca, Cluj County, Romania, RO-400488, zoobiomag2004@yahoo.com
** University of Agricultural Sciences and Veterinary Medicine of Cluj-Napoca, Faculty of Zootechny and Biotechnologies, Department of Ecology, Calea Mănăştur 3-5, Cluj-Napoca, Cluj County, Romania, RO-400372
*** "Babeş-Bolyai" University, Faculty of Environmental Sciences, Fântânele Street 30, Cluj-Napoca, Cluj County, Romania, RO-400294, pmalina2000@yahoo.com

KEYWORDS: Romania, Transylvania, Arieş River basin, *Calliphora vomitoria*, parasitic, facultative, *Vipera berus*.

ABSTRACT
The paper reports on the occurrence of a peculiar parasitic relation between a host species *Vipera berus* and a facultative parasite *Calliphora vomitoria* (reported from Arieş River Area, Transylvania, Romania, 2006). The *Calliphora vomitoria* species is able to inoculate living larvae in wet or vulnerable regions of an almost intact body, producing myiasis. This is the first record of myiasis in *Vipera berus* having as agent a member of genus *Calliphora*.

RÉSUMÉ: Le parasitisme facultatif de l'espèce *Calliphora vomitoria* sur *Vipera berus* enregistre dans la région du bassin hydrographique d'Arieş (Transylvanie, Roumanie).
L'article présente une relation parasitaire particulière observée sur l'hôte *Vipera berus*, ayant comme parasite facultatif le diptère *Calliphora vomitoria* (les échantillons biologiques étant collectés dans la région de l'Arieş, Transylvanie, Roumanie, en 2006). *Calliphora vomitoria* est capable d'inoculer des larves mobiles dans les parties moites ou vulnérables d'un corps animal presque intacte, engendrant la myiase. La présente étude est la première du genre à décrire une telle relation entre *Vipera berus* et un membre du genre *Calliphora.*

REZUMAT: Parazitismul facultativ al speciei *Calliphora vomitoria* pe *Vipera berus* înregistrat în zona bazinului râului Arieş (Transilvania, România).
Lucrarea relatează despre o relație parazitară aparte, observată la gazda *Vipera berus*, având ca parazit facultativ dipterul *Calliphora vomitoria* (probele biologice fiind recoltate din zona Arieşului, Transilvania, România, 2006). *Calliphora vomitoria* este capabilă să inoculeze larve mobile în regiunile umede sau vulnerabile ale unui corp animal aproape intact, producând miază. Studiul de față este primul în care se descrie o astfel de relație între *Vipera berus* şi un membru al genului *Calliphora*.

INTRODUCTION

Vipera berus is a native species in Romania having a wide range of distribution (Strugariu et al., 2008, 2009; Covaciu-Marcov et al., 2007, 2008; Gherghel et al., 2008a, b). The scope of the present paper is to report and describe a new parasitic relation from Romanian fauna, a case of facultative parasitism recorded in the Arieş River area during the year 2006.

In the last decades, many non-native animal taxa were introduced or found in many European countries (Kowarik, 2003; Falka et al., 2004; Iacob, 2008; Morar et al., 2008; Oltean et al., 2008), including Romania (Popa and Popa, 2005; Iacob and Petrescu-Mag, 2008; Gavriloaie, 2008; Gavriloaie et al., 2008; Petrescu-Mag et al., 2008; Mitroiu and Andriescu, 2008; Oltean et al., 2008; Popa et al., 2009; Malschi, 2009a, b; Pricop, 2009), and consequently the number of regional parasitic "first records" increased in Romania (Terinte et al., 2003; Dulceanu et al., 2003; Miron and Ivan, 2003; Morariu et al., 2005; Iacob et al., 2007; Cojocariu, 2007; Madeira de Carvalho et al., 2008; Oltean et al., 2008; Stavrescu-Bedivan and Aioanei, 2008). In some cases (also in the case which is presented here), both the host and the parasite are native to that country or area, but a new parasitic relation is reported (Yaman, 2008; Molnar, 2009).

Myiasis is the infestation of tissue with fly larvae and it is widespread in the tropics and subtropics of Americas and Africa. It occurs with significantly less frequency in most other world areas, including Europe. The infestation is most often subcutaneous and produces a furunculous or boil-like lesion, but is also known to occur in wounds and wet body cavities.

According to ethiological classification of myiasis-causing flies, there are: obligatory agents, facultative agents and accidental agents. From the first group we mention here: *Dermatobia hominis, Cordylobia anthropophaga, Oestrus ovis, Rhinoestrus purpureus, Gasterophilus intestinalis, Hypoderma bovis*, *Chrysomyia bezziana* and *Wohlfahrthia magnifica*. Flies of the family Sarcophagidae generally develop in decomposing tissue and they are considered facultative parasites. Their larvae parasitize wounds and other damaged tissues, and some species further invade living tissues adjacent to the wounds. Such flies are members of the genera: *Musca, Calliphora* and *Lucilia*. Accidental myasis also occurs when egg-stage flies are ingested on contaminated food or come in contact with the genitourinary tract area. This specific category includes some members of the families: Muscidae, Calliphoridae and Arcophagidae.

MATERIAL AND METHODS

In the present study, two infested individuals of *Vipera berus* were used and observed during the entire onthogenetic development of the dipter parasite. Six larvae, than pupae, and finally flies were retained for parasite species determination using the key of Lehrer (1972 - Fauna of Republic Socialist of Romania - Diptera, Calliphoridae).

The two vipers were collected during 2006, in summer, one from Băişoara locality (Cluj County) and other one from Arieş River area (nearby Turda locality, Cluj County), and they were kept in optimal conditions as described in Georgescu et al (2000).

In the early stages of parasitic development they were normal feed with white laboratory mice (*Mus musculus*) and one-day-old chicken (*Gallus domesticus*), and later the vipers were artificially feed with beef (weekly).

The wounds of the snakes were directly and macroscopically examined in laboratory, while the larvae, pupae and adult flies were directly examined under an ordinary binocular microscope.

DESCRIPTION AND EVOLUTION OF MYIASIS

At the moment of collection, the animals presented a recent moulted skin and small turgidities on the new skin surface (3 - 5 mm in diameter), looking like a pustular area (about 1 mm height). These small turgidities evolved in a few days to large boil-like lesions on the almost whole body lenght of the animals. Further and detailed examinations of the vipers were carefully made before we were able to give a correct diagnostic. After 1 - 2 weeks at a room temperature (18 - 20°C) the larvae were observed under the skin. After two weeks they penetrated deep in the body cavity, causing hard anguish and slow death of the host in about 2 - 3 weeks from the collection.

IDENTIFICATION OF THE PARASITE

Following the above mentioned key of flies determination, we found the parasite as being a member of the Family Calliphoridae, Subfamily Calliphorinae, species *Calliphora vomitoria* (Linnaeus, 1758). Sinonimes (less accepted): *Musca vomitoria* Linnaeus; *Calliphora fulvibarbis* Robneau-Desvoidy. Both chaetotaxia thorax (ac = 2 - 3 + 3, dc = 3 + 3, ia = 1 + 2, prs = 1, sa = 3 - 4, h = 4, ph = 3 - 5, n = 2, pa = 2, sc = 3 - 7 + 1 - 2, pp = 1, pst = 1, st = 2:1) and tibial chaetotaxia (t1: 1ad, 1pv; t2: 2-4ad, 2av; t3: 2-3ad, 2-3av, 3-4pd) of the adult fly were used in order to discriminate the species.

Two presumptions are yet available to explain the way the snakes were infested: direct infestation through the skin, or ingestion of larvae together with the prey. Having in view the superficial aspect of the initial wounds and their evolution, most likely the infestation began from outside after an oviposition of the larvae on the new, poor keratinized and vulnerable skin, immediately after the moult. This makes us conclude that the viviparous *Calliphora vomitoria* is a facultative agent of myiasis, while *Vipera berus* is a possible host for this fly. However, the facultative parasites are not very selective, that is why this first record makes sense to us: mammals (even humans) most likely are not excluded from trophic spectrum of this fly (see also Zumpt - undated -, or Leon 1908, both cited by Lehrer, 1972; Morariu et al., 2002).

CONCLUSIONS

Two presumptions are available to explain the way vipers were infested: first - direct infestation by flies, or - the second - larvae ingestion together with the dead prey. Having in view the superficial aspect of the initial wound and its evolution, most likely the infestation began from outside after an oviposition of the larvae on the new, poor keratinized and vulnerable skin, immediately after the moult. This makes us conclude that *Calliphora vomitoria* is a facultative agent of myiasis, while *Vipera berus* is a possible host for this fly. However, the facultative parasites are generally not very selective, that is why this first record makes sense to us: mammals most likely are not excluded from trophic spectrum of this fly. *Calliphora vomitoria* is able to inoculate living larvae in wet or vulnerable regions of an almost intact body, producing myiasis.

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TRANSYLVANIAN GIANT RABBIT ORIGINATES FROM ARIEŞ AND SOMEŞ AREAS (TRANSYLVANIA, ROMANIA)

*Ioan Valentin PETRESCU-MAG *, Ruxandra Mălina PETRESCU-MAG **, Miklos BOTHA* *** and *Ioan OROIAN* ****

* Bioflux S. R. L., Ceahlău Street 54, Cluj-Napoca, Cluj County, Romania, RO-400488, zoobiomag2004@yahoo.com
** "Babeş-Bolyai" University, Faculty of Environmental Sciences, Fântânele Street 30, Cluj-Napoca, Cluj County, Romania, RO-400294, pmalina2000@yahoo.com
*** Bioflux S. R. L., Ceahlău Street 54, Cluj-Napoca, Cluj County, Romania, RO-400488, miklosbotha@yahoo.com
**** University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Faculty of Agriculture, Department of Environmental Sciences, Calea Mănăştur 3-5, Cluj-Napoca, Cluj County, Romania, RO-400372, neluoroian@gmail.com

KEYWORDS: Romania, Transylvania, Arieş Basin area, Someş Basin area, new giant rabbit, Hymalaia gene, genetic improvement, first breed, first record, *Oryctolagus cuniculus*.

ABSTRACT

A new rabbit breed, *Oryctolagus cuniculus* (L.) is currently in forming: Transylvanian Giant Rabbit. According to the European standards rules for giant rabbit breeds, the body weight of Transilvanian Giant Rabbit will be of over 5.5 kg (there is no superior limit for its body weight). Yet, there is no other giant breed expressing the pointed black (Himalaya) colour pattern. All the rest of pointed black breeds are small or medium sized (for example the Himalaya breed or the California breed). California breed is the largest Himalayan so far, and the European standard of this breed foresees a body weight of maximum 4.5 kg.

RÉSUMÉ: Le Lapin Géant de Transylvanie originaire de la région d'Arieş et de Someş (Transylvanie, Roumanie).

Une nouvelle race de lapin *Oryctolagus cuniculus* (L.) est en train d'apparaître: le Lapin Géant de Transylvanie. Selon le règlement du standard européen des races géantes, la masse corporelle des lapins de cette race sera de plus de 5.5 kg (sans avoir une limite supérieure de ce paramètre). Jusqu'à présent, il n'y a pas de représentant des races géantes qui présente une distribution des couleurs de type Himalaya (à des extrémités noires). Toutes les races qui exhibent ce modèle sont de petite taille ou de taille moyenne (i.e. les races naines Himalayennes ou le Californien). Le Californien est le plus grand lapin a ce genre de jusqu'à présent mais le standard de cette race prévoit un poids maximale de 4.5 kg.

REZUMAT: Iepurele Uriaş de Transilvania de origine din zona Arieş şi Someş (Transilvania, România).

O nouă rasă de iepuri *Oryctolagus cuniculus* (L.) se află în curs de formare: Iepurele Uriaş de Transilvania. Conform prevederilor standardului european pentru rasele uriaşe, masa corporală a iepurilor din această rasă va fi de peste 5,5 kg (fără a exista o limită superioară a acestei valori). Până în prezent, nu există nici un reprezentant al raselor mari care să prezinte tiparul coloristic Himalaya (cu extremităţi negre). Toate rasele cu acest tipar sunt de talie mică sau mijlocie (spre exemplu rasele Himalaya şi California). Rasa California este cea mai mare rasa cu acest tip de coloraţie, dar standardul european prevede o greutate corporală maximă de 4,5 kg.

INTRODUCTION

Although Romania is a country with a good tradition for many animal husbandry branches - sheep (Coroian et al., 2009; Dărăban et al., 2009), cattle (Carşai, 2009), chicken (Pricop, 2006), swine (Păsărin and Stan, 2003), fish (Bud et al., 2009; Cocan, 2008; Grozea, 2007; Muscalu and Muscalu, 2009; Păsărin et al, 2004; Paşca et al., 2009), aquarium fish (Chiorean et al., 2009; Mag-Mureşan et al., 2004a, b; Molnar, 2008; Petrescu-Mag et al., 2008a, b, c; Petrescu-Mag, 2007a, b, 2008), bees (Mag et al., 2006), game (Ştefan et al., 2005), fur (Botha et al., 2007; Miclăuş et al., 2009a, b, c), dogs (Bud, 1993) and rabbits (Bud and Pop, 2005), there is no omologated Romanian rabbit breed yet. This is due to the fact that since the old times till present there was used in Romanian cuniculture a highly polymorphic rabbit, impossible to describe it from scientifically point of view, according to European Standards (2009). Although the genofond is a good one, especially that one from Transylvania (Petrescu-Mag, unpublished) there are too many colours, morphs, body sizes, ears lengths and forms to be able to describe a true Romanian breed of rabbits.

We were told that history of cuniculture in Romania was plenty of such failed attempts to create a first Romanian breed, eg. White of Cluj (now extinct - Miklos Botha, unpublished data). White of Cluj Breed Project started, but never ended. Unsatisfactory results were observed when they were tested in an intensive system of production (Dan Pop, personal communication). This rabbit strain was characterized by the mutant Viena gene (v) in homozygote form (vv), they were white coloured, blue eyed and medium sized.

Since 2008 the team consisting of Petrescu-Mag, Botha and Mălina Petrescu-Mag started to work to a new rabbit strain in order to develop a valuable Transylvanian Giant Rabbit (TGR) (the name in Romanian: Iepure Uriaş de Transilvania). This paper aims a preliminary and general presentation of TGR.

MATERIAL AND METHODS

During 2008 - 2009, Petrescu-Mag purchased over 20 specimens of polymorphic rabbit, originating from different hobbyists and farmers from Turda neighbourhoods (Cluj County, Romania). This material was characterized by a good fertility and a high resistance to diseases. A second acquisition was done in 2009 from Cluj-Napoca (Cluj-County, Romania), consisting in: California Rabbit (CR), English Spotted Rabbit (ESR), and German Giant Rabbit (GGR). This was the biological material used for the genetic improvement of the Turda lot. In the table 1 is presented the role of each of them in our improvement program.

The reproduction and genetic improvement developed in the first stages at the Bioflux S. R. L., Cluj-Napoca, and the breeding programe is presented in the figure 1. The native females were crossed with a California male from Timişoara (CR1) and many color patterns resulted in the offspring. The black females (H1) were retained in the effective. An ESR female was crossed with a CR male and resulted some black individuals (1/2 from the total) (H2 in Fig. 1). A GGR male from Cluj-Napoca (GGR1) was crossed with a CR from Hungary and resulted H3, which are dark steel coloured. These males were used in two crosses: one of them with H2 females and one of them with H1 females. The results: H4 and H5 have each of them four colour patterns: agouti, black, dark steel and Himalaya. None of Himalaya presented an intense black on the ears, nose, and feets, so that only black individuals will be retained in the genitors for future reproductions. We estimate H6 and H7 (end of 2010), both males and females, should be of two kinds: black and true Himalaya (intense pointed black, Fig. 2). The second will be the bud of a new breed, the first Romanian breed of rabbit in the history of Romanian cuniculture. Scientific materials necessary for national omologation are in preparation: they will underline mostly the productive performances of the new creation (data not here).

Table 1: The biological material used in TGR project.

Strain	Origins	Color pattern	Body weight at the sexual maturity (average)	Role in TGR program
Native	Turda neighborhoods (small commercial interests; poor chances to be transported from elsewhere)	Highly polymorphic (more than seven different phenotypes)	3.7 kg	1) Resistance and 2) Prolificacy to the new strain.
CR	Cluj-Napoca (some of them from Timişoara, Romania; others from Hungary)	Pointed black white (Himalaya pattern)	3.6 kg	1) Good skeletal and muscular habit, 2) a uniform color pattern 3) black body base colour.
ESR	Cluj-Napoca (parents: possible from Nitra, Slovakia)	White, spotted with black	5.8 kg	1) Improvement of the body size, 2) black body base color.
GGR	Cluj-Napoca (born in Braşov, Romania; others from Cluj-Napoca)	Agouti	7.5 kg	1) Improvement of the body size.

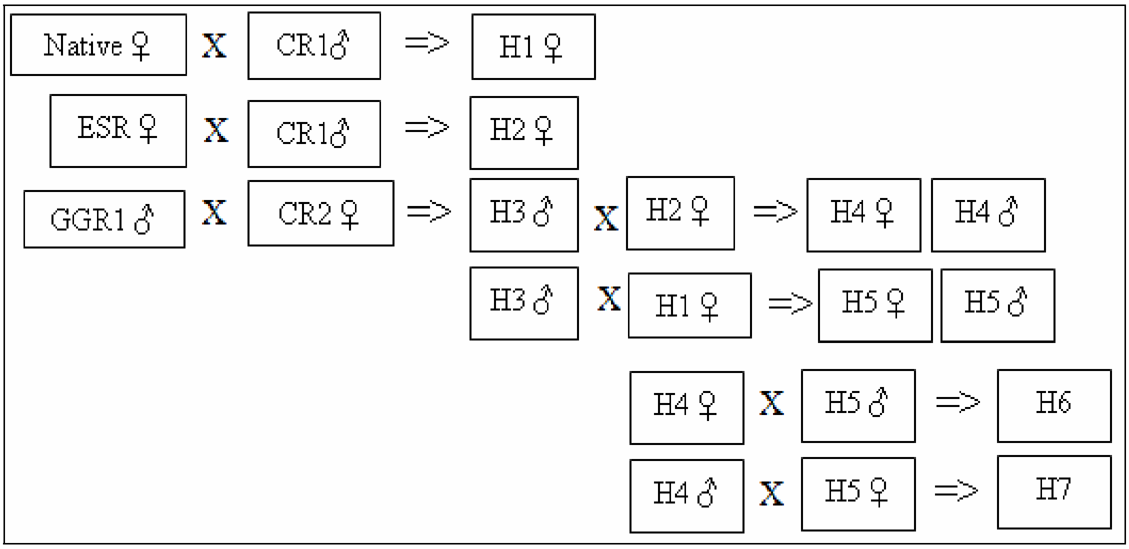

Figure 1: The TGR breeding programme 2008 - 2010, elaborated by Bioflux SRL (original).


Figure 2a: The pointed black colour pattern of Himalaya, California and TGR breeds (original).


Figure 2b: The pointed black colour pattern of Himalaya, California and TGR breeds (original).

RESULTS AND DISCUSSIONS

In the following table (Tab. 2) we shall describe, genetically, the genitors and the results: H1-H5, as well as the hypothetical result H6-H7. This description will include only the *C* and *A* loci. The *B, D, E, En, Du, V, W* and *Si* loci are omitted (details: Rabbit genetics 2009).

Table 2: The genotype of each color pattern obtained during creation of the TGR (*C* encode a full color development, c^h is the Himalaya gene, *A* encode the agouti pattern, *a* encode the self color/non-agouti).

Abreviation	Color pattern	Genotype	Observation
Native	Impossible to describe	Impossible to describe	Medium sized
CR	Pointed black white (Himalaya)	$c^hc^h\ aa$	Medium sized
ESR	White, spotted with black	*CC aa*	Giant
GGR	Agouti	*CC AA*	Giant
H1 - Only patterns of interest are considered.	Black	$Cc^h\ aa$	Medium sized
H2 - Only patterns of interest are considered.	Black	$Cc^h\ aa$	Medium sized
H3	Dark steel	Cc^hAa	Medium sized
H4	Agouti Dark steel Black Agouti Himalaya	Cc^hAa Cc^hAa $Cc^h\ aa$ $c^hc^h\ Aa$	Giant
H5	Agouti Dark steel Black Agouti Himalaya	Cc^hAa Cc^hAa $Cc^h\ aa$ $c^hc^h\ Aa$	Medium sized
H6 - Only patterns of interest are considered.	Pointed black white (Himalaya)	$c^hc^h\ aa$	Giant. Ideal color pattern for TGR
H7 - Only patterns of interest are considered.	Pointed black white (Himalaya)	$c^hc^h\ aa$	Giant. Ideal color pattern for TGR

CONCLUSIONS

Most of the giant rabbit breeds have some inconveniences such as: low fertility, vulnerability to diseases, low slaughter efficiency/ears too long, low muscular development in the first 3 - 4 months and others. We intend to eliminate these drawbacks in the new giant rabbit breed. According to the European Standards rules for giant rabbit breeds, the body weight of TGR will be of over 5.5 kg. There is no other giant breed expressing the Himalaya colour pattern. All other Himalaya breeds are small or medium sized (see Himalaya breed or California breed). California breed is the largest Himalayan so far, but the European standard of this breed foresees a body weight of 3.5 - 4.5 kg.

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ASPECTS OF TIMBER BUILDINGS DECAY - A CASE STUDY INDUCED BY THE ASSOCIATION OF THE ORGANISMS *SERPULA LACRYMANS, CONIOPHORA PUTEANA* AND *XESTOBIUM RUFOVILLOSUM*/ THE "AVRAM IANCU" MEMORIAL HOUSE (THE ARIEŞ BASIN AREA, TRANSYLVANIA, ROMANIA)

Livia BUCŞA * and *Corneliu BUCŞA* **

* "Lucian Blaga" University of Sibiu, Faculty of History and Patrimony "Nicolae Lupu", Department of Conservation - Restauration, Victoriei Boulevard 5 - 7, Sibiu, Sibiu County, Romania, RO-550024, livia.bucsa@yahoo.com, livia.bucsa@ulbsibiu.ro
** "Lucian Blaga" University of Sibiu, Faculty of Sciences, Department of Ecology and Environment Protection, Dr. Ioan Raţiu Street 5 - 7, Sibiu, Sibiu County, Romania, RO-550012, cornelbucsa@yahoo.com, cornel.bucsa@ulbsibiu.ro

KEYWORDS: Romania, Transylvania, wood decay, *Serpula lacrymans, Coniophora puteana, Xestobium rufovillosum*.

ABSTRACT

The paper presents a case study on biological decay found with the "*Avram Iancu*" Memorial House and the museum of Vidra de Sus, as a result of several negligences in their maintenance and inappropriate interventions to stop the attacks of the *Serpula lacrymans* fungus. All types of biological attacks are analysed, their extension, their generating causes, and recommended measures of extinction are suggested.

RÉSUMÉ: Aspects de la décomposition des bâtiments en bois - une étude de cas sur l'association des organismes *Serpula lacrymans*, *Coniophora puteana* et *Xestobium rufovillosum* / la Maison Mémoriale "Avram Iancu" (la région d'Arieş, Transylvanie, Roumanie).

Cet article présente une étude de cas sur la décomposition biologique identifiée dans la Maison Mémoriale "*Avram Iancu*" et le Musée de Vidra de Sus, en tant que résultat de quelques négligences dans la maintenance des bâtiments et des interventions inadéquates pour stopper les attaques du champignon *Serpula lacrymans*. Tous les types d'attaques biologiques ont été analysés, leur étendue, les causes de leur apparition et des mesures d'extinction ont été proposées.

REZUMAT: Aspecte privind degradările biologice ale construcţiilor din lemn - un studiu de caz determinat de asociaţia de organisme *Serpula lacrymans*, *Coniophora puteana* şi *Xestobium rufovillosum* / Casa memorială „Avram Iancu" (aria bazinului Arieş, Transilvania, România).

Lucrarea prezintă un studiu de caz privind degradările biologice care au apărut la Casa memorială „*Avram Iancu*" şi muzeul din Vidra de Sus ca urmare a neglijenţelor de întreţinere şi a intervenţiilor inadecvate de stopare a atacului ciupercii *Serpula lacrymans*. Sunt analizate tipurile de atacuri biologice, extinderea acestora, cauzele care le-au generat şi se propun măsurile de eradicare adecvate.

INTRODUCTION

Timber represented, in the geographical area of te Arieş River basin, like in all the mountainous regions of Transylvania, the main building stuff, until the mid-20th century. As long as they were properly maintained, the traditional timber buildings could be used by several generations and part of them have survived up to the present day.

As a result of infiltrations, negligence in maintenance or inappropriate interventions, the moisture of the timber allows an environment favourable to the development of biological agents, among which the fungi and the xylofagous insects are prevailing.

The decomposition of timber in the environment is a natural and complex biological process, in which the succession of the species is established by the substrate composition and moisture. With the timber used in building, the number of species participating in the decomposition process is quite reduced, as a result of a selection imposed by conditions specific to this anthropic habitat.

The list of Basidomycetes fungi species able to decay timber in building varies, according to different authors, between about 20 (Ridaut, 2004) and 45 species (Smith, 2006).

In the research studies made by us in a number of more than 500 timber buildings found in situ, 28 species of Basidyomycetes have been identified, and with the over 1,200 reconstructed sights in the open air museums in Romania, the number of species went up to 74 (Bucşa, 2009).

The research made to reveal the xylofagous coleoptera insects in the open air museum in Sibiu summed up 87 species belonging to 12 families (Bucşa, 2005).

Among certain species involved in this process, symbiotic relationship is likely to appear. Thus, some of the xylofagous insects cannot attack the timber which was not previously decomposed by certain species of fungi. In this respect, we have studied the occurrence and relationship between the xylofagous insects of the *Xestobium rufovillosum* and *Anobium punctatum* species and the fungi *Coniophora puteana, Serpula lacrymans, Donkioporia expansa, Fibroporia vaillanti*, etc. (Bucşa, 2004).

RESOURCES AND METHODS

The "*Avram Iancu*" Memorial House, situated in the village Vidra de Sus, is the house were the Romanian national hero of the 1848 Revolution was born and where he lived up to this event. Known under the name of "Craiul Munților" (Prince of the Mountains), he was a symbol of the Romanian fight for liberty and rights while under Austro-Hungarian Empire domination.

Iancu's house illustrates the traditional type of buildings in Țara Moților (County of the Mots) during the former half of the last century (Mărginean, 1993). It was built on a high stone socle, of beams from fir and spruce, stuck with clay and then whitewashed. The high roof is covered with spruce shingles (Fig. 1).

Inside, the two rooms (the fore room and the rear room) preserve the furniture and household devices, typical of a regional house.

In 1924, celebrating a century from Avram Iancu's birth, the "Astra" Society of Sibiu initiated the turn of the Memorial House to a museum. It was then that they took the decision of building outhouses, including a church and a school on the left and display spaces for the museum on the right. The museum side is L-shaped, connected to Iancu's house on the left. The building has a basement and a ground floor, with outer walls made of spruce beams and tile wrapping. On the sides looking to the courtyard, the building is guarded by a timber porch (Figs. 2 and 3).

Figure 1: The "*Avram Iancu*" Memorial House.

Figure 2: Display space for the museum.

Figure 3: Display space for the museum.

The museum contains a collection of folk art clothing specific to the area, items of household industry, and in the semi-basement there is a display of farming tools, wood carving tools and means of transport by which the inhabitants of the area, the Mots, used to carry their products throughout Romania (Fig. 4).

In 2006, having found advanced decay in the museum's spaces and their worsening by inappropriate interventions, The Restoration Project of the "*Avram Iancu*" Memorial Museum was implemented and we were required to make the biological expertise of the buildings.

The paper presents the results of the research and observations made at the museum, the causes of the biological decay and the measures to eradicate it. It is a relevant case study of the consequences of negligence and lack of competence over the state of a building.

RESULTS AND DISCUSSIONS

The results of the observations will be presented separately for each of the two buildings known as **Iancu's House** and the **Astra Building**.

Iancu's House

Few deficiences were found outside, of which the following can be mentioned:

- the initial foundation was wrapped in a concrete socle;
- on the Southern side, at the joining of the house and the church, the rain-pipe flows at the basis of the foundation damping the contiguous wall (Fig. 5);
- at the joining of the wrapping between Iancu's House and the Astra Building, on both sides, the lines of striction and the drains are stuck with fir needles, dry twigs and soil, and moss and weeds grow in the drains (Fig. 5);
- the test made on this side, at the base beam level, revealed that it was made of spruce and was covered by the concrete socle. The sample timber drawn was damp and highly degraded by a fungic attack, in the form of prismatic brown rot and galleries of xylofagous insects, produced by the *Xestobium rufovillosum* species.

Figure 4: Folk art collection.

Figure 5: Rain-pipe flows damping the contiguous wall.

The inside inspection, made at the basement level, revealed several aspects of biodegradation. The first room was attacked by a quite strong and old fungic decay, both at the level of the wood and of the brickwork. The northern wall was covered with fungic fruiting bodies, quite extended and aged, belonging to the *Coniophora puteana* species, "the cellar fungus" (Figs. 6 and 7).

Figure 6: The first room, fungic fruiting bodies, quite extended and aged.

Figure 7: The first room, fungic fruiting bodies, quite extended and aged.

The upper Southern wall presented aged fruiting bodies of the *Serpula lacrymans* species, which was also extended to the timber plank.

The main beam has an aged fruiting bodies of *Serpula lacrymans* on the end to the fore room (Fig. 8). The opposite end was broken and the decomposed wood, under the form of prismatic brown rot was left in the brickwork. The end which was mechanically cross sectioned at a previous intervention was held by props and the timber in the cross section was brown-coloured and cracked in multiple places, as a result of the fungic decay (Fig. 9).

The rest of the longitudinal beams were also sectioned, doubled and supported by props. Some of the floor planks were replaced when the beams were cross sectioned.

Figure 8: The main beam, an aged fruiting bodies of *Serpula lacrymans* and the timber, in the cross section, decayd by fungi.

Figure 9: The main beam, an aged fruiting bodies of *Serpula lacrymans* and the timber, in the cross section, decayd by fungi.

The Astra Building

The following problems were found during the outer inspection of the houses on the right, the sides to the South, West and North:

- the drain was distorted and the water flowing through it sprayed the foundation and the timber parapet of the porch, on which colonies of green algae developed. The rain-pipes flow in the immediate vecinity of the foundation;
- the foundation in front of the annexe building of the lavatory is damp and has colonies of green algae;
- in front of the basement window, the brickwork is damp by the waters leaking from the distorted drain;
- the timber wall is marked, at the level of the bottom beans, by flight holes and xylofagous insects galleries, produced by the *Hylotrupes bajulus* (Fig. 10).

Figure 10: *Hylotrupes bajulus* flight holes and galleries.

Figure 11: Fresh fruiting bodies of the *Serpula lacrymans.*

The inner inspection of the basement, in the exhibition rooms, revealed serious problems of biodegradation.

The first room on the southern side had high ascending moisture on all the walls. The plaster was stained and swollen at the level of the floor.

The second room, on the western side, is also marked by high ascending moisture with all its walls. Behind the display panels, the moisture is even more pregnant, as a result of poor ventilation.

The eastern wall of the room, between beams no. 10 and no. 11 of the floor, had fruiting bodies of the *Coniophora puteana* fungus, and between beams no. 13 and no. 16 there are visible marks of old and fresh fruiting bodies of the *Serpula lacrymans* (Fig. 11).

The beams of the floor over the basement, between no. 7 and no. 19, have their eastern side ends decayed, on various lengths, between 0.50 and 1.50 m, by a powerful attack of the *Serpula lacrymans* fungus. Some of the beams were doubled, others were supported with props, and others got their wood rotten inside and could collapse.

In the corner next to room no. 3, a fresh fruiting bodies of the *Serpula lacrymans* fungus has developed.

Room no. 3 is marked by ascending moisture of the walls and the beams of the floor are new.

Room no. 4 also presents high ascending moisture of all its walls. Behind the display panels, the moisture is much more pregnant. Traces of rain infiltrations in the chimney are visible in front of the stoves.

The Ground Floor

The porch, in its access area, presents rain infiltrations coming from the tin throat, in the corner next to Iancu's House.

The Spread of the Fungic Attack

The basement space situated in Iancu's House is violently affected by a fungic attack, produced by the *Serpula lacrymans* and the *Coniophora puteana* fungi. According to our observations, we can now appreciate the extension of the attack as follows:

- Iancu's House - all the beams of the floor and the floor over the second room and the porch, as well as, assumingly, over the first room, which was not available;
- all the brickwork in the basement;
- the Astra Building, all the beams of the floor in room no. 2;
- the wall on the eastern side.

In order to get fully acquainted to the extension of the attack, it is necessary to have the basement space cleared up, the plaster from the façade walls and the southern part of Iancu's House removed, as well as from the southern wall in the basement of The Astra Building.

These operations can only be possible after closing the museum and storing the exhibits in an appropriate space.

The Causes of the Biological Attacks

The main cause of a biological attack emergence is the high level of moisture of the support.

The outer inspection revealed part of the sources nourishing the ascending moisture in the basement, which are as follows:

- the rain waters discharged by the drains and the rain-pipes, at the basis of the socles;

- the stagnation of the rain water in the museum courtyard;
- the tread level of the courtyard, much lower than the road in front of the building;
- the high level of precipitations in the area.

The lack of a heating system in the museum spaces and, implicitly, the relative moisture of the air to values over 75% is another factor which contributes to the incresed value of the timber moisture.

The fungic attack is old but active and according to the cross sections and replacements made on the floor beams, one might conclude that attempts have been made to stop the attack. The procedures were executed without specialized consultancy and without appropriate treatments, for which reason the attack reappeared and extended, covering part of the basement space in the Astra Building.

The Eradication of the Attack

The removal of the exhibits stored in the basement of Iancu's House to other spaces, not before being disinfected. We suggest a general treatment of disinfection in the basement spaces affected by *Serpula lacrymans* and later, cleaning the exhibits and treating them by brushing them with a fungic-insecticide solution.

The order of the eradication procedures is the following:

- extraction of the whole part of timber attacked by the *Serpula lacrymans* and the *Coniophora puteana*;
- cross sectioning of partially attacked elements, at 0.5 m from the visible attacked area;
- burning off these materials in a close and appropriate space, away from danger of incense;
- removing away the plaster from the affected walls;
- jointing the brickwork and persistently burning with open flame;
- treating the brickwork with a special solution of Diffuzit M, by spraying it twice;
- repairing all the infiltration sources and insuring an appropriate ventilation for these spaces.

The final measures will be decided after an accurate and thorough acquaintance of the revealed situation after the suggested detachments and the freeing up of the basement space.

The attack of *Serpula lacrymans* syn. *Merulius lacrymans*, popularly known as "house sponge" is the most dangerous of all the fungic attacks, as it needs special eradication measures, according to the ongoing standards (Standards of Preventing and Fighting the "Dry rot" with the Wood Essences Used in Building, 1963, CSCAS, INCET. Bucureşti).

Failing to obey these measures can lead to the recurrence of the attack.

The eradication measures are to be supervised by a professional biologist.

In the case of the attacks caused by the other species of fungi identified: *Conoiphora puteana*, popularly known as "the cellar fungus", doesn't need any special eradication measures. In this case, the timber is to be replaced or cross sectioned at the decayed area which is openly visible. The attack of this species stops when timber moisture falls below 16%.

The new timber used for replacements is to be of high quality, dried under 17% and should be preventively treated with an insecto-fungicide solution.

The xylofagous insects attacks were produced by *Xestobium rufovillosum, Anobium punctatum* and *Hylotrupes bajulus*. Some of these attacks are no longer active and there is no need of treatments with insecticide solutions in these areas.

We have suggested the elements that need replacement, but the general designer and the antrepreneur will take the final decisions, putting together the outcomes of all the studies and possibilities of joining.

CONCLUSIONS

Avram Iancu is a symbol of the Romanian fight for independence, and his Memorial House is a pilgrimage sight for all the Romanians, that is why it is difficult to understand how the maintenance problems of these buildings have been neglected for years on end. These negligences and the lack of competence in the attempt to stop the attack of the *Serpula lacrymans* led to its spreading on a much wider surface, thus putting in collapse danger the structure of the floors.

The present day state of the decay produced by the advanced biological attacks, particularly those caused by the *Serpula lacrymans* and *Coniophora puteana* fungi, can be remedied only by special eradication measures. These measures are components of a general restauration project of the houses and we are confident that the funds necessary to an urgent start of the procedures will be allotted.

The project needs to include proposals for a heating system and maintenance responsibilities in the future.

The delay of the procedures can lead to the extension of the attack and the increase of the eradication costs.

Keeping the personnel in the village museums and the memorial houses informed about the consequences deriving from negligences regarding the maintenance of the buildings can contribute to the prevention of several biological attacks having serious consequences over the preservation state of cultural goods.

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