THE CHILIA-PARDINA SECTOR EVOLUTION BASED ON SATELLITE IMAGERY AND CARTOGRAPHIC DOCUMENTS

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KEYWORDS: Pardina-Chilia sector, cartographic documents, old maps, satellite imagery.

ABSTRACT

Historical and archaeological studies, conducted in the Danube Delta, have provided the opportunity to discover a series of cartographic documents related to this area.

From all of these, those related to the Pardina-Chilia sector proved to be of great significance. These maps provide many elements that clarify the evolution of the delta along the Sulina and Chilia arms in different historical periods. Within this paper, based on cartographic documents and satellite imagery, we study different aspects related to the geomorphological and hydrographic evolution of the Pardina-Chilia sector. Using this data we aimed to identify how the Danube Delta evolved between Sulina and Chilia phases and how in the frame of Pardina-Chilia sector the network of channels were developed.

REZUMAT: Analiza evoluției sectorului Pardina-Chilia pe baza documentelor cartografice și a imaginilor satelitare.

Studiile istorice și arheologice, realizate în zona Deltei Dunării, s-au concretizat prin descoperirea unei serii de documente cartografice legate de această zonă. Dintre acestea, de o mare importanță s-au dovedit cele legate de sectorul Pardina-Chilia, deoarece furnizează multe elemente ce clarifică evoluția Deltei Dunării de-a lungul brațelor Sulina și Chilia, în diferite perioade istorice. În cadrul acestui studiu s-au urmărit aspecte legate de evoluţia geomorfologică şi hidrografică a sectorului Pardina-Chilia pe baza unor documente cartografice şi imagini satelitare. Prin utilizarea acestor date s-a urmărit identificarea modului în care a evoluat Delta Dunării între fazele Sulina şi Chilia, precum şi modul în care s-a dezvoltat reţeaua de canale în cadrul sectorului Pardina-Chilia.

RÉSUMÉN: El sector de evolución Chilia-Pardina basado en imágenes de satélite y documentos de cartografía.

Estudios históricos y arqueológicos conducidos en el Delta del Danubio han proporcionado la oportunidad de descubrir una serie de documentos cartográficos relacionados a esta área. A partir de ello, los documentos relacionados con el área de Pardina-Chilia evidenciaron una gran significancia. Estos mapas proporcionaron muchos elementos que aclaran la evolución del Delta a lo largo de los brazos de Sulina y Chilia en diferentes periodos históricos. Dentro de este artículo, basado en los documentos cartográficos e imágenes de satélite, nosotros estudiamos diferentes aspectos relacionados a la geomorfología y evolución hidrográfica del área Pardina-Chilia. Utilizando esos datos, nuestro objetivo fue identificar como el Delta del Danubio evolucionó entre las fases Sulina y Chilia, y como en el marco del área de Pardina-Chilia la red de canales fueron desarrollados.

INTRODUCTION

The Chilia-Pardina sector evolution was studied on the basis of several cartographic documents related to the area. However, the historical cartographic documents performed on different time periods in many cases are not easy to interpret. Currently, the cartographic materials are difficult to correlate with current data as they are older.

The purpose of this study was to analyze, from a hydrological and geomorphological point of view, the evolution of the Chilia-Pardina sector. But the moment when this area was filled with sediment raises many questions.

The oldest cartographic material that could be georeferenced to an acceptable level was the Ptolemy map that has been created in the year 160 AD.

The old cartographic data were correlated with those obtained from satellite images Landsat 7 (L7) Enhanced Thematic Mapper Plus (ETM+).

Based on data from historical maps and the satellite images, a spatial distribution of network channels was established. These data were processed in GIS/SIG dedicated applications.

MATERIAL AND METHODS

Within this paper we used digital data (data that are not available commercially in many cases) and scientific studies from different sources, they are as follows:

- Landsat 7 (L7) Enhanced Thematic Mapper Plus (ETM+);
- Ptolemy map from 160 AD- reproduction after Nicolae Panin and Willem Overmars (2012);
- Austrian maps (1910) and Soviet maps 1:100000 redesigned Stereo70, from http://www.geo-spatial.org;
- The various old specific cartographic materials from Old Maps Online (www.oldmapsonline.org/).

The satellite images were processed in their turn depending on needs. The Landsat images were assembled for each spectral band separately and then the satellite images from three bands were combined together.

The old cartographic materials were georeferenced on QGIS in projection system Stereo 70 version from 2008.

RESULTS AND DISCUSSION

The evolution and the current geomorphology of the Danube Delta are the result of the interaction between the river and the sea during the Holocene period.

The Chila-Pardina sector is located in the north north-west region of the Danube Delta between Chilia and Sulina branches.

Between 1985-1987 the Pardina area underwent extensive dam and drainage works, which actually owes its current aspect to (Fig. 1).

On the Danube Delta, the Roman Period is characterized by two main stages, namely Early Roman Period and Late Roman Period. Within the Early Roman Period, traces of fortified settlements appear in the upper Danube, particularly in the Noviodunum Fortress (Isaccea) area. The first fortified settlement from Noviodunum was raised on an embankment located with 25-30 m North of the late Roman period and approximately 40 m north of the current bank line.

However, all these data indicate a change of Danube flow at the end of the Early Roman Period, which probably led to the development of the Delta along the Chilia Branch.

In maps made by Ptolemy in 160 AD, the Chilia Delta is half formed, and the Thiagola Lake is marked between Chilia Levee and Letea Sandbank (Fig. 2).

After the year 160, the Chilia Pardina sector grows as a wetland into the Danube Delta (Figs. 3, 4 and 5).

The studied evolution sector is marked by four main stages (Tab. 1), which are: Paleo-Chilia Delta (Fig. 2), holm of Chilia Branch (Figs. 3 and 4), wetland (Fig. 5) and agricultural polder (Fig. 1).

Table 1: The evolution of Chila-Pardina sector.

Stages	Periods	Observations
Paleo-Chilia Delta	600 B.Chr.-160 A.Chr.	lagoon sedimentation phase
Holm of Chilia Branch	160-1910	secondary branches throughout the area
Wetland	1910-1985	many canals and lakes
Agricultural polder	1985-present	area undergoing renaturation

Correlating the Russian map made in 1804 with Austrian maps made in 1910, a number of main channels that start from Chilia Branch and lead to a channel that passes through the western part of the Chilia Levee are highlighted. The size of these channels and their relative position to the map from 1804 (and the name of holm record on the Austrian map) make us assume that these channels would be at the beginning of the secondary branch of Chilia Branch (Fig. 6).

The correlation of the maps made into the old USSR time with the Russian map from 1804 not only strengthened this idea, but also offered clues on the evolution of the sediments' deposition process (Fig. 7). This process was developed on the west-south-west to north north-east range.

Figure 1: Chilia-Pardina Sector on Landsat 7 (L7) Enhanced Thematic Mapper Plus (ETM+), with green are the high wet areas and the low ones are in red.

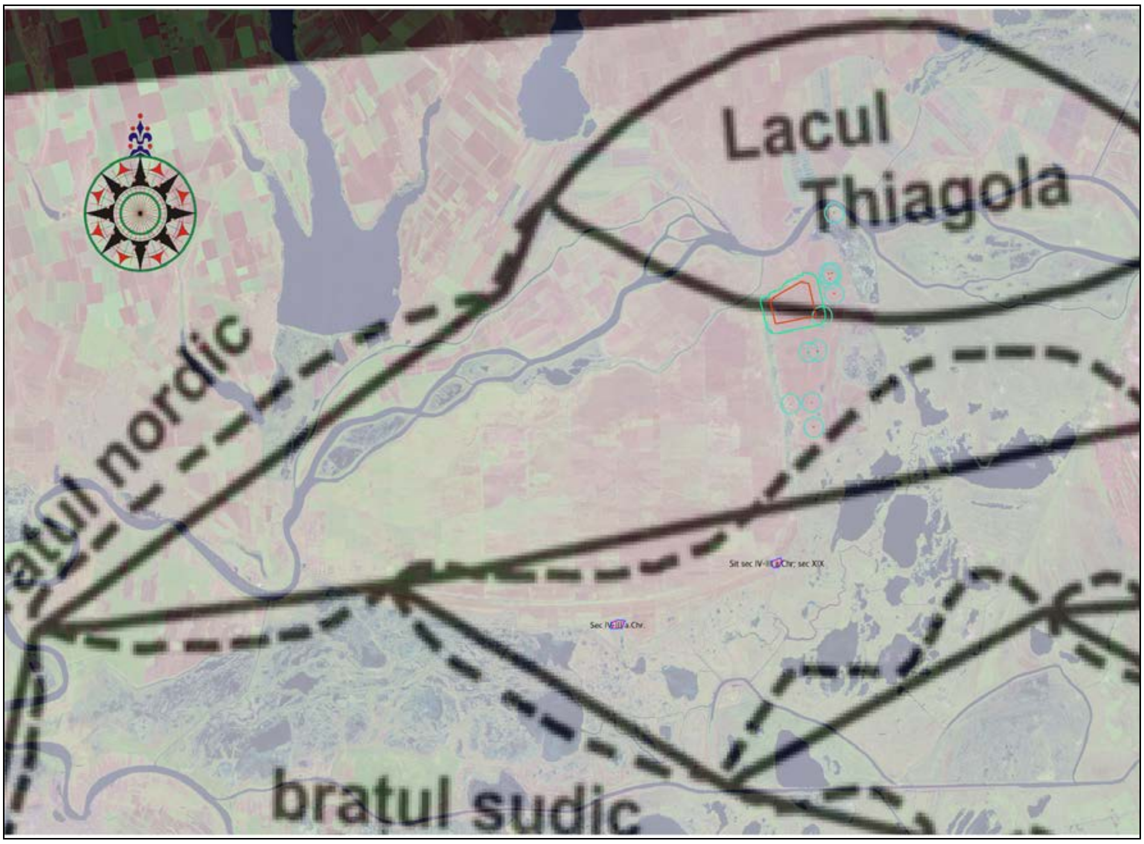

Figure 2: Chilia-Pardina Sector on Landsat 7 (L7) Enhanced Thematic Mapper Plus (ETM+) and Ptolemy map from 160 AD.

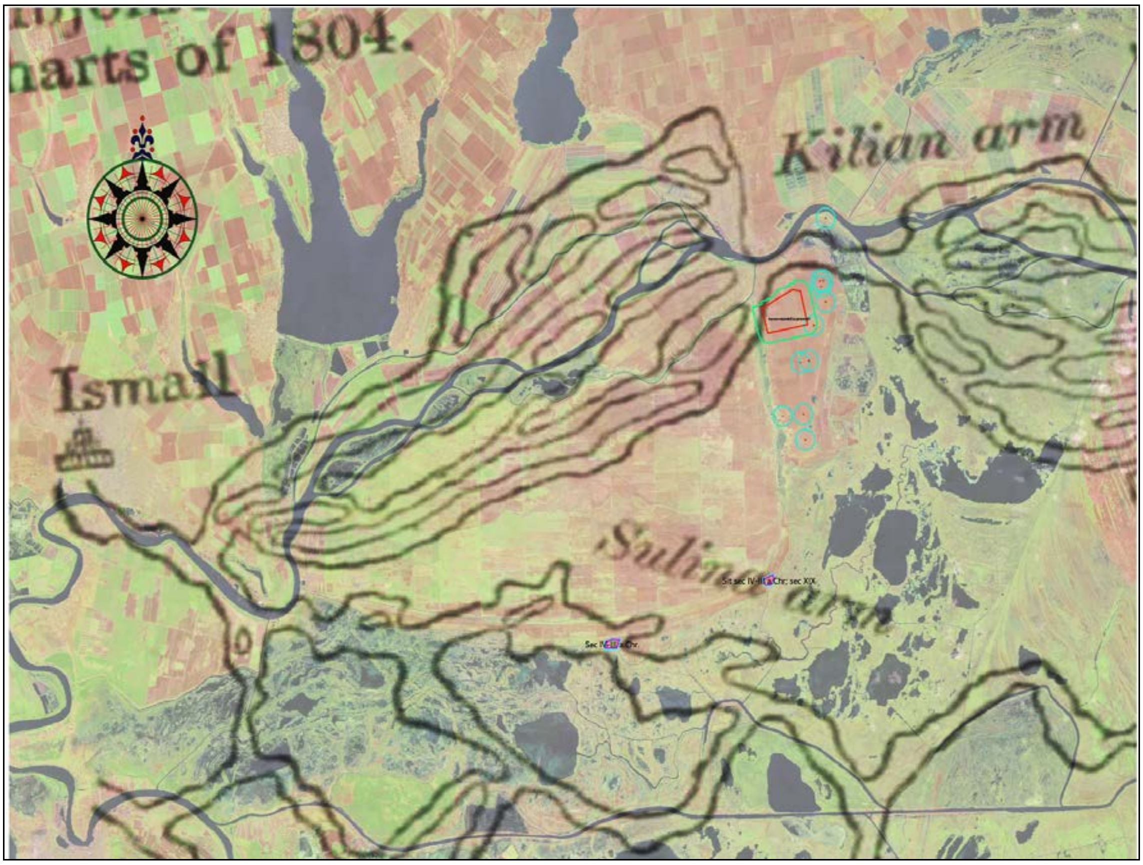

Figure 3: Chilia-Pardina Sector on Landsat 7 (L7) Enhanced Thematic Mapper Plus (ETM+) and Russian map made in 1804.

Figure 4: Chilia-Pardina Sector on Landsat 7 (L7) Enhanced Thematic Mapper Plus (ETM+) and Austrian maps (1910).


Figure 5: Chilia-Pardina Sector on Landsat 7 (L7) Enhanced Thematic Mapper Plus (ETM+) and Soviet maps 1:100000.

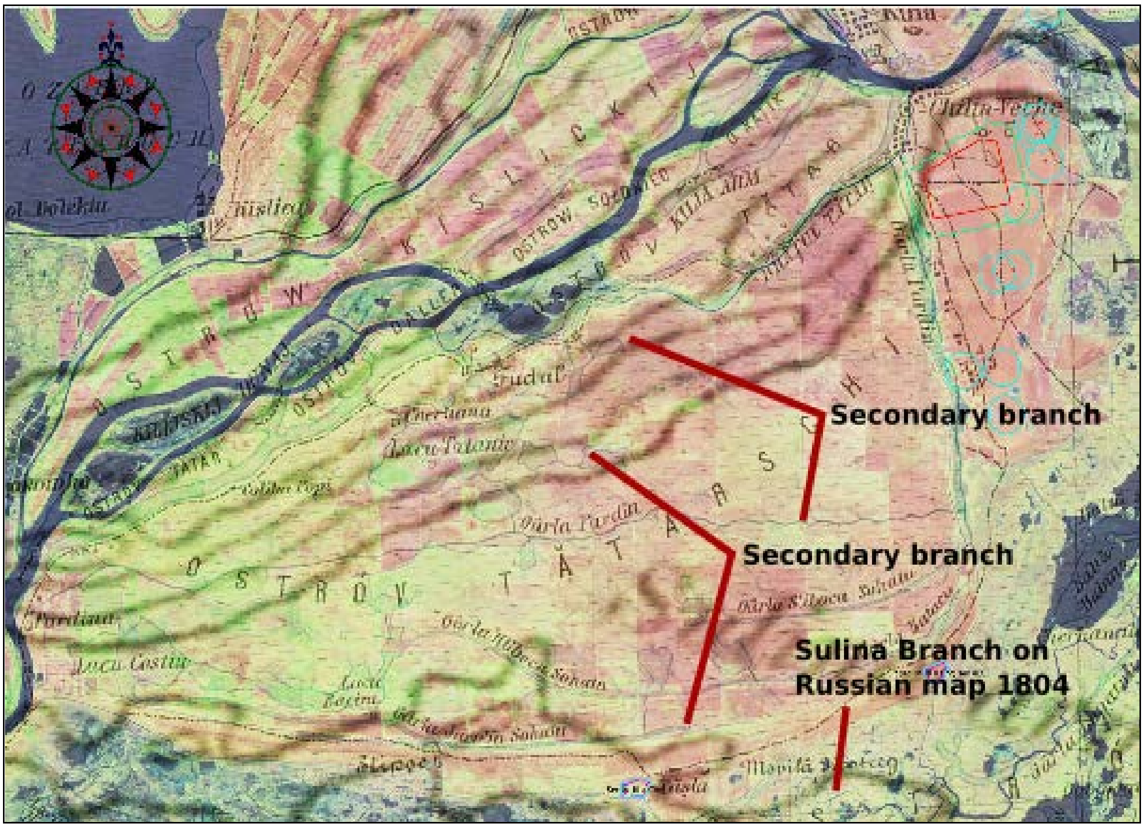

Figure 6: Correlation between the Russian map made in 1804 and Austrian maps made in 1910.

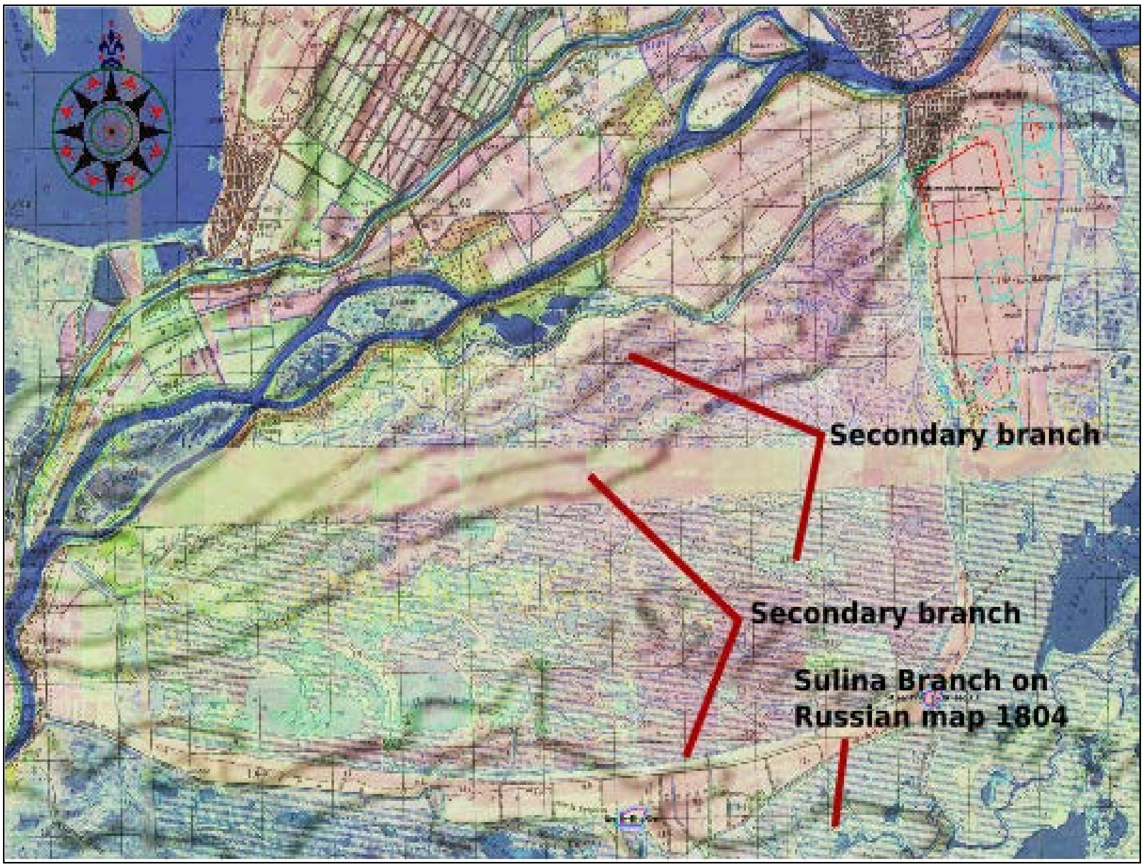

Figure 7: Correlation between the Russian map made in 1804 and Soviet maps 1:100000.

CONCLUSIONS

Although similar studies have been conducted in the Danube Delta, it is difficult to find correlations between the different cartographic data as the interpretation was difficult. There are always new interpretations depending on the materials used.

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LANDSCAPE AND/OR LANDSAFT IN ECOLOGICAL VISION

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KEYWORDS: landscape, landscape ecology, landschaft, systemic levels, terms, definition.

ABSTRACT

In scientific research is work based on clearly defined terms.

Unfortunately, nowadays, to define a well-determined biogeographic zone with precise local characteristics, both in nature and the activities and culture of the local population, the term "landscape" is used, the meaning of which is far too general and vague which can lead to confusion.

Therefore, for professionals studying these types of complexes we propose a more precise, previously-used term; the "landschaft".

This paper specifies the main characteristics and major themes currently utilized by landschaft ecologists.

REZUMAT: Peisajul şi/sau landşaftul în viziune ecologică.

În cercetarea ştiinţifică se lucrează numai cu termeni foarte clar definiţi.

Din păcate acum, pentru a defini o zonă biogeografică bine delimitată, cu specific local precis, care se manifestă atât în natură cât şi în activitatea şi cultura populaţiei locale, se foloseşte termenul de „peisaj", al cărui sens este mult prea general şi vag, deci care poate crea confuzii.

De aceea, pentru specialiştii care studiază aceste complexe, se propune utilizarea unui termen precis, folosit anterior, cel de „landşaft".

Sunt precizate caracteristicile principale și temele majore abordate în prezent de ecologi ai landşaftului.

ZUSAMMENFASSUNG: Landschaft in ökologischer Vision.

In der wissenschaftlichen Forschung arbeitet man nur mit ökologisch klar definierten Begriffen.

Leider verwendet man heute in der Fachliteratur zur Definierung eines biogeographisch gut abgegrenzten Gebietes mit genauen lokalen Eigenheiten, die sich sowohl in der Natur als auch in der Tätigkeit und der Kultur der lokalen Bevölkerung abzeichnen, den Begriff „paysage", dessen Sinn viel zu allgemein und zu vage ist und dementsprechend zu Konfusionen führen kann.

Daher wird für die Fachleute, die sich mit der Erforschung derartiger Komplexe befassen, die Verwendung eines präzisierten, vorher in der Fachliteratur verwendeten Begriffes „Landschaft" vorgeschlagen.

In vorliegender Arbeit werden die Hauptkennzeichen und umfassenden Themenbereiche der von Ökologen derzeit behandelten Landschaften klar umrissen.

INTRODUCTION

Following the history of ecology, and based on applied principles of systems theory, the study of level organization of ecological systems is indicated with: population level (autecology and synecology), ecosystemic level (ecosystems), over-ecosystemic level (ecobioms and ecosphere) (Godeanu, 2013), to the present day with consideration of its future evolution (Fig. 1).

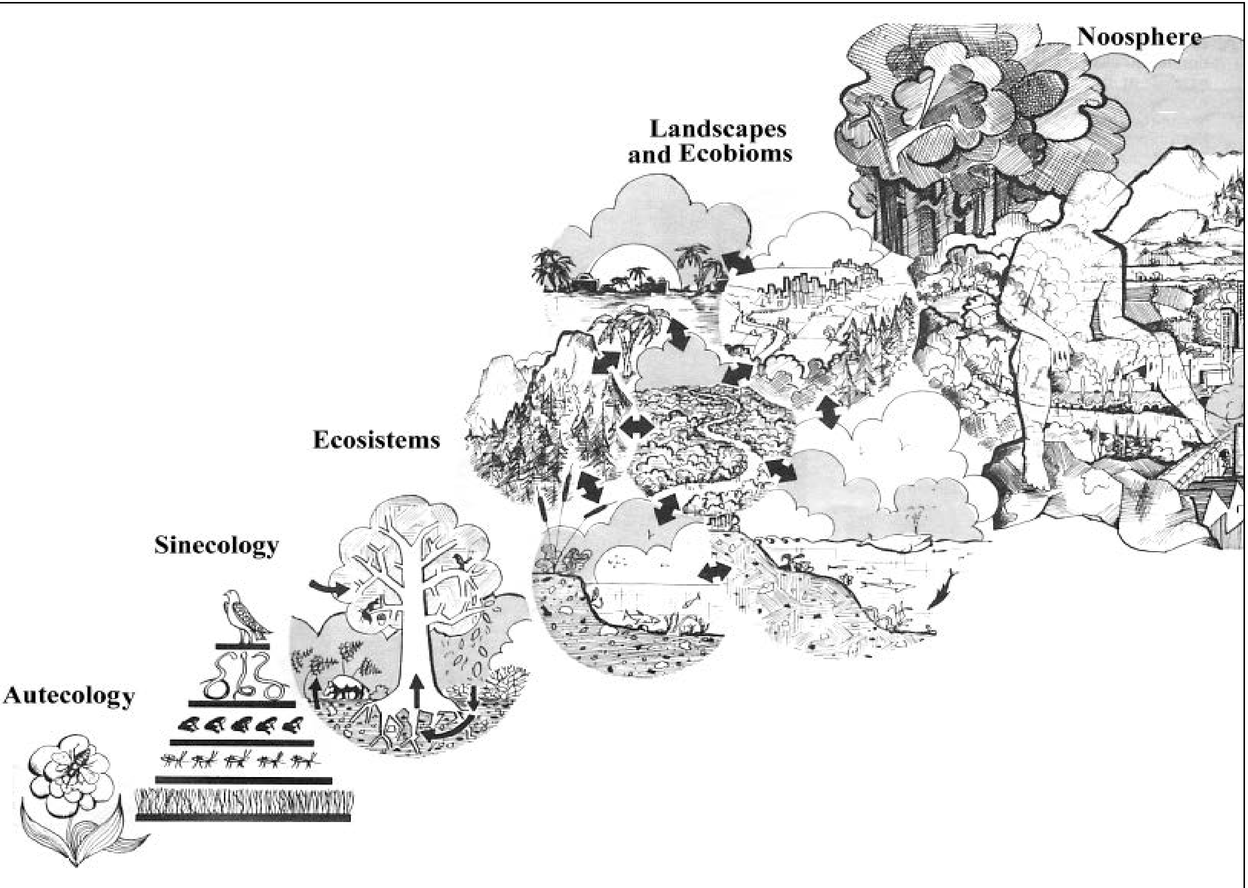

Figure 1: Stages of evolution ecology (Di Castri, 1981) – modified.

In the ecosystemic levels, the sublevels could be described as the following: forest ecosystems, meadows, forest swamps, rocky areas or in river deltas, the mix of temporary mini-ecosystems/ecosystems appearing after water withdrawal, after a flood or flash flood and that cannot be considered real ecosystems. These subecosystems are not particularly stable and, from a functional point of view, they are subordinated to the general characteristics of the ecosystems they pertain to.

In this situation, there are ecological formations which can be positioned on a supraecosystemic level of the systemic organization, but under the ecobiomic ecosystem formations there is a great variety of forms, each with individual and distinct characteristics, but without a character of universality (as true systemic levels), and being somewhat similar with the notions of synusia, consortium or merocoenosis, are being increasingly studied. These are the terms “paysages” (in French), “Landschaft” (in German), “landscapes” (in English) or „peisaje” (in Romanian).

Because of different approaches and studies there is a lot of misunderstanding regarding the specific definition and characterization of these particular ecological terms.

MATERIAL AND METHODS

At first glance, in the various dictionaries, the terms "landschaft", "landscape", "paysage", "peisagio", "peisaj", etc., appear to be the same thing, but the application of a specific term (for a better understanding of the practical notion) is a big ecological problem. Currently, in Romania, geographers prefer the term "peisaj" taken from French and adapted to Romanian. But, at this point, problems began since the term is too large and variously employed; it is used by people from various fields in very different ways, so its use in ecology can create great confusion. The term is employed in expressions such as natural and artificial landscape, about rural, agricultural and urban landscape, about touristic, alpine, historic, cultural, political landscape, etc. If we follow the definition of the terms "landscape" and "landschaft" from various dictionaries, the differences between the two terms clearly appear:

A. In the Explanatory Dictionary of the Romanian language (DEX, 1998) the term of landscape is explained as follows:

Peisaj: peisaje, s. n. – **1.** Part of nature forming an artistic complex and which is caught in a single view; image of any territory, resulting from the combination of natural and anthropic factors. **2.** Kind of painting or graphics which represent landscapes from nature; a picture, a photo representing a landscape. **3.** Description, representation of nature in literary work, descriptive literary composition. From fr. paysage, it. paesagio.

B. In the English dictionary "English free online dictionary" the "landscape" is defined as follows:

1. An expanse of scenery that can be seen in a single view: *a desert landscape*.

2. A picture depicting a scenery expanse.

3. The branch of art dealing with the representation of natural scenery.

4. The aspect of the land characteristic of a particular region: *a bleak New England winter landscape.*

5. Grounds that have been landscaped: *like the house especially for its landscape*.

6. An extensive mental view; an interior prospect: "*They occupy the whole landscape of my thought*".

C. In "Merriam Webster" British dictionary, the "landscape" is presented as having the following meanings:

1. A picture that show a natural scene of land or the countryside.

2. An area of land that has a particular quality or appearance.

3. A particular area of activity.

D. In the German dictionary duden.de "Landschaft" is presented as below:

1. hinsichtlich des äußeren Erscheinungsbildes (der Gestalt des Bodens, des Bewuchses, der Bebauung, Besiedelung o. Ä.) in bestimmter Weise geprägter Teil, Bereich der Erdoberfläche; Gebiet der Erde, das sich durch charakteristische äußere Merkmale von anderen Gegenden unterscheidet

2. Beispiele:

- eine karge, öde, baumlose, steppenartige, gebirgige, malerische, liebliche Landschaft
- die spanische Landschaft,
- der moderne Bau passt gut in diese Landschaft,
- in übertragener Bedeutung: die [innen]politische Landschaft (Situation) hat sich geändert.

The European Landscape Convention 2000 considered that "landscape meant an area as perceived by people, whose character is the result of the action and interaction of natural and/or human factors".

According to Wikipedia.ro, the current concept of "landscape" is fairly new. Before being the object of artistic or architectural representations, a "landscape" means a land, a region – portion of the national territory – with a clearly defined identity, a place for living and working for local people belonging to that specific region.

For geographers, the first scientists who perceived it as a special scientific entity, the "landscape" is a geographic region that is distinguished from others by certain geographical, climatic, geological, biological, and cultural characteristics, including the population of this region with their habitat and economic, cultural and social activities.

For ecologists, "landscape" is "a geographic unit relatively well defined, which has certain geomorphological, hydrological and biological characteristics, composed from a variety of natural and anthropogenic ecosystems that has a common historical evolution and is characterised by interconnected flows of substance, energy and information" (Bavaru et al., 2007; Godeanu, 2013) (Fig. 2).

It is hard to clearly distinguish a territory with specific characters from the notions mentioned above, so in our opinion it would be better to have, in Romanian, a term to be used only in Ecology and Geography. To minimize confusion with its meaning in other fields, we proposed several years ago (Bavaru et al., 2007) the use of the term "landschaft", which, mentioned previously, was used in the past in our country instead of the presently used term – "peisaj"/"landscape" (I also proposed the term „Țară" be used in different areas of the country; Țara Făgăraşului, Țara Pădurenilor, Țara Zarandului, but is difficult to translate and correlate with similar terms in other languages).

Figure 2: A landschaft fragment image in the south of Apold Village (Transylvania, Romania) (foto Erika Schneider-Binder).

RESULTS AND DISCUSSION

Following these definitions, we see that using the generic term “peisaj”/“landscape” in scientific contexts can cause confusion. What is the landscape? From what point of view do we approach it in ecology? How do you differentiate it from other terms?

In Romanian ecology literature, the foreign terms have been preserved in the scientific vocabulary due to their repeated use, nevertheless always employing the same meaning. This is the case of terms such as: ecosystem, turnover, productivity, production, habitat, noosphere, etc.

All sciences work with clear concepts and scientists give them the same meaning. From our point of view, the current “peisaj”/“landscape” term is too general and can create misperceptions. Why not use a special term for this type of complex ecological system, a term borrowed from foreign specialized literature that can be romanised and accepted simultaneously by geographers, biologists, ecologists, ethnologists and other scientists with concerns in the same field of study? In this case, how about “landscape”? And how about “landschaft”?

Up to the end of World War II, geographers used “peisaj”/“landscape”, the term “landschaft” (in its romanised form „landşaft”), a term which is still used in German and Russian languages with a special, narrow, and very clear meaning.

Since the middle of the last century, and especially during the past three or four decades, the landschaft ecology has seen extraordinary development starting with German and American geographers. During the last two decades many treaties in this area (Bastian and Schreiber1999; Bastian and Steinhardt, 2002; Turner et al., 1993, 2001; Green et al., 2006; Wiens et al., 2006) were published, culminating with the emergence of a specialized periodical, the “Landscape ecology”, increasingly more popular in the scientific world.

In the beginning, the landschaft ecology had a predominantly local and regional descriptive characteristic, but gradually approached functional, historical, international and prospective elements.

The study of the landschaft is an interdisciplinary research field with a pronounced practical character aim (Turner et al., 1993, 2005; Godeanu, 2013):

- Good management of environmental services;
- Reduction/improvement of human impacts;
- Optimizing the relationships between the natural environment and the human-modified environment.

Presently, the landschaft ecology is oriented by the German school (Bastian and Steinhardt, 2002) in three major directions:

- Morphological: the study of territory and plant associations physiognomy (the so-called Geology);
- Holistic: the study of local interacting factors (the so-called geoecosystem);
- Causative: deterministic vision of geosystems’ structure and function.

The American school has a number of different, but complementary approaches (Turner, 2005):

- Ecology of spatial configuration of human scale;
- The study focuses on natural landschafts;
- The study of fragmentation of natural ecosystems, the role of corridors among this fragments, research of ecotones areas;
- The study of interactions among different types of ecosystems (especially those dominant) of the different types of ecosystems;
- The management of environment at level of landschaft;
- Finding practical applications of this type of research.

More details on theoretical and applied aspects of landschaft ecology can be found in the Romanian book „Ecologie aplicată”/“Applied Ecology” (Godeanu, 2013).

Bavaru et al. (2007) consider that “the landschaft ecology is the science that studies and ameliorates the interrelations between environmental processes and certain ecosystems. It takes place at different spatial scales, at organizational, political and scientific levels. The Landschaft Ecology is an interdisciplinary domain of ecology which integrates biophysical and analytical approaches in humanistic and holistic perspective from natural and social sciences”.

My opinion as an ecologist is that landschaft ecology is “the particular domain of the Ecology that studies the interaction between different ecosystems – natural, anthropic or manmade – located on a relatively uniform or homogeneously evolving territory and integrating in space and time the relationships between them, thereby causing a specificity of local economic, social, cultural and interhuman relations”.

In our vision, the landschaft has the following characteristics: geographical characteristics; climatic characteristics; pedological characteristics; hydrographic characteristics; biological characteristics; ecological characteristics; socio-human characteristics, there are specific to various activities (economic, historical, cultural, ethnographic, folklore, etc.).

The landschaft ecology taps in to three major themes (Green et al., 2006; Turner, 2005; Godeanu, 2013, modified):

1. The structure: describing of different types of ecosystems and their fragments, corridors of connection between them and the matrix of dominant ecosystems, borders and ecotone zones between different types of ecosystems.
2. Functioning: of all of ecological systems that are part of a landschaft regardless of their origin, changing their biotic components, the influence of the migratory biota to the ecological systems that penetrate them, the role of ecotone biodiversity areas in the preservation of ecosystem fragments, the production of different types of ecosystems, substance, energy and information flows in ecosystems, determine the principal ecosystem drive of the ecological processes composing the landschaft.
3. Changes: taking place in space and time, weight and role of ecosystems fragments in the functioning of different types of landschafts, ecosystems dominant role, rebalance and speed of succession arising from the imbalances caused by humans.

The landschaft ecology should highlight the following main features of a landscape concerning their functionality and persistence in space and time:

- Uniqueness: given by the combination of local specific ecological elements;
- Heterogeneity: ecosystem components are different and each one possesses its specific characteristics;
- Functionality: each ecological system has its own activities;
- Dynamics of ecological processes: the landschaft is a result of continuously combining the specificities of each type of ecosystem through interaction between their particular functions, interactions that change in time;
- Hierarchy: organization and cooperation of ecological systems composing the landschaft in ensuring a good functioning, such as stated by the principles of the systemic theory;

- Self-regulation: a landschaft has a certain stability and it is characterised by a stable general structure, and the manner of functioning of its components working in a particularly complicated way;
- Physiognomy: each landschaft has its own characteristics that depend on the dominant characteristics of certain components;
- The historical character: as a result of its evolution under the influence of different anthropogenic impacts and quantitative and technical development of human society populating that landschaft.
- Informational character: the landschaft is an open system that receives and sends information from biotic and abiotic factors, and currently receive more information from humankind.

CONCLUSIONS

We consider that the evidence discloses substantial justification for the need to establish a special term for „peisaj"/"landscape"/"landschaft" (or whatever we call it), but that it is a strict and clear scientific ecological term, comparable to terms such "ecosystem", "habitat" or "noosphere", and which all experts will understand as the same term. Therefore, we chose to use the term taken from the German language, the landschaft, and its romanised form of „landşaft".

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WARMING PHENOMENA AND THE HEAT WAVES FROM THE WARM SEASON OF THE YEAR IN DEPRESSION OF SIBIU (ROMANIA)

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KEYWORDS: temperature, heat waves, drought, Sibiu Depression, Romania.

ABSTRACT

In the last decades climate warming and a great frequency and high intensity of thermal risk such as heat waves have been registered. Air temperature is the parameter that defines the warming phenomenon and the heat waves. Analysis of statistical data string from the Sibiu meteorological station for a fairly long period of time (1970-2014) gave us the opportunity to highlight thermal phenomena of warming, especially the heat waves and the frequency which occurred in the warm season of the year. Warmest representative years were highlighted: 1994, 2007 and 2012, the last being the year in which absolute maximum temperature were recorded from the observed period (38.9°C on 25 August 2012). In the last 15 years, the frequency of 30-35°C of temperature occurrence was about 41% and in 6% of cases the thermal threshold of 35°C was exceeded. In this situation the occurrence probability of positive extreme temperatures exceeding 30°C at Sibiu is about 50% in the warm season. This forecast is useful to the authorities for taking measures for the prevention and mitigation of the heat effects.

REZUMAT: Fenomenul de încălzire şi valurile de căldură din sezonul cald al anului în Depresiunea Sibiului (România).

În ultimele decenii se remarcă o încălzire a climei şi o frecvenţă ridicată a unor riscuri termice de mare intensitate, cum sunt valurile de căldură. Temperatura aerului redă fenomenul de încălzire şi valurile de căldură. Analiza şirului de date statistice la staţia meteorologică Sibiu, pentru o perioadă destul de lungă de timp (1970-2014), ne-a dat posibilitatea evidenţierii fenomenelor termice de încălzire, dar mai ales a valurilor de căldură şi a frecvenţei cu care acestea s-au produs în sezonul cald al anului. S-au evidenţiat ani călduroşi reprezentativi: 1994, 2007 și 2012, ultimul fiind şi anul în care s-a înregistrat temperatura maximă absolută din perioada analizată (38,9^{o}C în 25 august 2012). Frecvenţa de producere a temperaturilor de 30-35^{o}C în sezonul cald al anului în ultimii 15 ani a fost de circa 41% şi în 6% din cazuri a fost depăşit pragul termic de 35^{o}C. În această situaţie probabilitatea de producere la Sibiu a unor temperaturi extreme pozitive care depăşesc 30^{o}C este de circa 50%. Această prognoză este utilă autorităţilor pentru luarea unor măsuri de prevenţie şi diminuare a efectelor caniculei.

ZUSAMMENFASSUNG: Erwärmungsphänomene und Hitzewellen während des Sommers in der Senke von Sibiu/Hermannstadt (Rumänien).

In den letzten Jahrzehnten wurde eine Klimaerwärmung und eine immer größere Frequenz und Intensität thermischer Risiken wie Hitzewellen festgestellt. Die Luftemperatur ist der Parameter, der das Phänomen der Erwärmung und der Hitzewellen widerspiegelt wiedergibt. Die Analyse der Reihe statistischer Daten der Wetterstation Sibiu/Hermannstadt für einen relativ langen Zeitraum (1970-2014) ermöglichte es, die thermischen Phänomene der Erwärmung hervorzuheben, vor allem aber die Hitzewellen und die Häufigkeit, in mit der sie während der Sommerzeit auftraten, festzuhalten. Repräsentative warme Jahre 1994, 2007 und 2012 wurden hervorgehoben, wobei in letzterem am 25 August 2012 mit 38,9°C die absoluten Höchstwerte der analysierten Datenreihe gemessen wurden. Die Häufigkeit der Entwicklung von Temperaturen zwischen 30-35°C während der warmen Jahreszeit in den letzten 15 Jahren betrug etwa 41% und in 6% der Fälle wurde die thermische Schwelle von 35°C überschritten. In diese Falle beträgt die Wahrscheinlichkeit der Entwicklung Temperaturen über 30°C in Hermannstadt etwa 50%. Diese Prognose ist für die Behörden von Nutzen, die für Vorsorgemaßnahmen und solche zur Verminderung der Auswirkungen der Hitze zuständig sind.

INTRODUCTION

In the last decades, worldwide, more and more frequent and more and more intense natural weather and climate phenomena were recorded (IPCC, 2007; Meehl and Tebaldi, 2004). All countries from Europe and, of course, Romania, were affected by excessive heating phenomena, which had known an extraordinary increase in the decade between 2000 and 2010 (Klein Tank and Können, 2003; Luterbacher et al., 2004; Klein Tank et al., 2005). These phenomena occur mainly in the hot season of the year, but they may occur in the cold one, too (Bogdan, 1993; Bogdan and Niculescu, 1999; Moldovan, 2003; Croitoru et al., 2012; Klein Tank and Können, 2003).

The studies on daily temperature values indicate for Europe the presence of the heating phenomena during 1979-1999, with unprecedented increases in the rate of warming in summer due to increasing of the extreme positive values. The European trend for the period between 1976 and 1999 indicate an increase of temperature per decade with an average of 0.43^{o}C, with regional differences of 0.09-0.77^{o}C. The highest increases were in Central, Western and Northern Europe, and the lowest for Eastern Europe (Klein Tank and Können, 2003).

In Romania, the heating phenomenon is marked by the increase of the temperature with an average of 0.3^{o}C (Cuculeanu, 2003; Ivanovici et al., 2003). The studies have been conducted based on the analysis of long strings of data and indicate also regional and seasonal differences. The strongest warming has occurred in the Eastern part of the country with continental influences and was more nuanced in the other regions due to the relief configuration and the influence of the Carpathians (Bogdan and Marinică, 2007). The most accentuated warming was recorded in the urban – industrial regions due to the dominance of artificial active surfaces and pollution (Klein Tank et al., 2005). The temperature increase was about +0.8^{o}C at Bucharest, Constanţa and Roman and about +0.7^{o}C at Baia Mare (***). The strongest warming was remarked in winter (+1.9^{o}C at Bucharest), in spring (+1.1-1.4^{o}C) and less in summer (Săraru, 2005).

The warming phenomenon was also highlighted for the Sibiu Depression (Ciulache, 1997; Costea, 2011). In this geographical area for the years between 1970 and 2000 the average temperatures were higher in the winter and lower in the summer, but also higher in the sub-mountainous hills and lower on the bottom of the depression. Also, maximum temperatures registered at the Sibiu meteorological station were lower and minimum ones were higher, and 1999-2000 were the years of warming onset due to heat waves subsequently reported between 2000 and 2012.

The heat waves are weather-climate phenomena of thermal risk generated by the advection of the dry tropical air masses (Bogdan and Niculescu, 1999; Moldovan, 2003; Marinică, 2003). The tropical circulation has a reduced occurrence in Romania (15%) compared to the other types (western 45%, polar 30%), but it has obvious effects on our country by producing the strong warming phenomena and heat waves, especially in the warm season of the year and producing absolute maximum temperatures, of tropical days, of hot days, but also of hot nights.

These phenomena occur mainly in the case of continental tropical air advections from Northern Africa towards high latitudes which determine through thermal transfer, regardless of seasons, a very warm and dry weather; in summer it induces hot days accompanied by drought. These phenomena of thermal risk occur mainly in the summer, also in the case of the tropical hot humid air advection, air mass dried by humidity due to the action of continental anticyclone developed in the South-Eastern Europe, South-Eastern of Asia, in the Balkan Peninsula or in the North-Western Africa (Bogdan and Niculescu, 1999; Moldovan, 2003; Webster et al., 2005).

The atmospheric circulation blocking has an important role, too, in producing of thermal risks in the warm season of the year. This is the result of the expansion and stagnation of the North-African anticyclone ridge for a long time above Europe, and also above our country, and by the formation and maintenance at the Earth surface of a high atmospheric pressure field (Bogdan and Marinică, 2007). Such air circulation in the summer of 2003, all over Europe, very high positive extreme temperatures (positive anomalies) and the hottest days from the Western and Northern European countries (IPCC, 2007; Della-Marta et al., 2007; García-Herrera et al., 2010).

In the conditions of repeating and persistence of these types of atmospheric circulation, in Romania, and of course in the Sibiu Depression which was chosen as a case study, absolute temperatures which exceed 30^{o}C can be recorded in May-September interval, with a higher frequency in July and August. The warming phenomenon of the Earth Surface is intensified by insolation and through terrestrial radiation is increasing the air heating from the vicinity of the topographical surface, generating extreme positive temperatures. However, the frequency of these actions is higher in the Carpathians periphery lowlands, due to the opening of this area towards the Southern Circulation and also due to the role of the Southern Carpathians as orographic barrier (Bogdan and Marinică, 2007; Bordei, 2008). The Transylvanian Depression has a sheltered position towards these factors, which reduces the number of hot days and the values of maximum absolute temperatures compared with other regions (Ciulache, 1997; Bordei, 2008).

The climatic characteristics of interest area

The Sibiu Depression is situated in the Southern part of the Transylvania Depression, at the bottom of Cindrel and Lotru mountains. The position is almost central in Romania, and the strong influence of Western air masses determine the temperate-continental moderate climate of this depression, with average year temperature which vary around 8.7^{o}C (multiannual average calculated at Sibiu meteorological station since 1851 until 2000) and medium amounts of precipitations of about 650 mm/year (multiannual average calculated for the same period) (Ciulache, 1997; Costea, 2011).

The relief is, by far, one of the most important factors which influences the climate in the geographical space of the Sibiu Depression. The sub-mountainous position alongside the concave shape of this area, as well as the closure towards North, East and West through plateau hills with low altitudes, determines the particular climate features of this depression. All of these are influenced by the invasion or by the persistence of the air mass with different thermal and humidity characteristics. The ocean influences which dominate due to Western atmospheric circulation have a role in moderating the warming and also the descendant movement of the air from mountains slopes, reduces the incidence of heat waves (Bogdan and Niculescu, 1999). However, in the conditions of the persistence of anticyclonic regime, the position at the shelter of the orographic barrier of Southern Carpathians, makes that the warm air masses (humid or dry) carried by the Southern – South-Western circulation gets into Sibiu Depression poor in humidity.

The descendants of the air on the northern slopes of Cindrel Mountains generates föehn effect that amplifies the warming phenomenon generated by the anticyclone activity and causes excessive heating periods in the warm season of the year, especially in spring (Ciulache, 1997; Bogdan, 1993; Costea, 2011).

The reduced surface of forest areas, the high degree of urbanization and the atmospheric calm which dominates in average over 60% of cases during the year, are factors which emphasize the heat waves, maintain the event duration and influence the production of extreme positive temperatures.

METHODOLOGY

The characterisation of thermal regime was done on the basis of data (1970-2014) obtained from the Sibiu meteorological station (420 m), which was found to be the representative station for this depression area.

The analysis relies on the average values of air temperature and on the positive extreme values. The heat waves were highlighted based on: the positive deviations of the annual average temperatures from the multi-annual average temperature, the annual and monthly average of maximum temperatures, the positive deviations of the averages of maximum temperatures from the multi-annual maximum temperatures, the positive deviations of the monthly average temperatures in the hottest years from the multi-annual monthly average, maximum temperatures and the number of days in which the temperatures exceed thermal thresholds (tropical T ≥ 30°C; hot T ≥ 35°C).

RESULTS AND DISCUSSION

The warming trend is evidenced by the increase of the average annual temperature of the air. The annual average temperature analysis reveals oscillations from one year to another with a slight growth trend of this parameter in the last 15 years after the model of a second order polynomial equations (Fig. 1). This trend is significant in case of the analysis of five years sliding averages (R^2 is 0.86) and 10 years sliding averages (R^2 is 0.95) (Fig. 2). Non-periodic air temperature variations are highlighting small cycles of 3-5 years with different air masses circulations that had determined values below the multi-annual average (8.78°C) and higher values towards it. The lowest annual average temperature was of 7.6°C in 1985, and the highest was of 10.8°C in 2014. On this background of non-periodic variability, figure 1 and 2 show two main cycles: the first was cooler (1970-1992) and the second was warmer (1999-2014). The interval from 1994 to 2000 is making the transition between the two. The trend of air temperature increases in Sibiu in the last 15 years is caused on the one hand by the dominance of the southern air movement and by the blocking circulation that causes extreme positive values. Secondly, the high degree of urbanization (artificiality of active surfaces) increases the insolation phenomenon and air overheating through terrestrial radiation intensification.

Warmest years are highlighted by positive annual average temperature deviations from the multiannual average. The increase in air temperature over the multiannual average indicates positive thermal anomalies (Bogdan and Marinică, 2007). The graph of annual average temperature deviations from the multiannual average in the Sibiu Depression points to different intensities of warming phenomenon (positive deviation between 0.01°C and 2.01°C) and to the warmest representative year 1994, as well as the intervals 1999-2003 and 2007-2014 (Fig. 3).

Noteworthy is the isolated relative position of 1994 (annual average temperature of 10°C and deviation of +1.21°C) when the warming was due to a heat wave recorded in the warm season of the year (from July to September), when the entire Romanian territory was under the influence of very hot and dry north-African origin air masses (Bogdan and Niculescu, 1999). The graph of monthly average deviations of 1994 compared to monthly multiannual averages indicates the continuity of the warming phenomenon from July to September with a maximum intensity in September (the maximum deviation of +4.21°C) (Fig. 5, 1994). Whithin that year there was a recorded massive warming phenomena as a result of exceeding the 30°C thermal threshold over 25 days (tropical days). From May to October a total of 97 summer days were recorded. (T ≥ 25°C, with exceedings of this value in three days in October). We also note the continuity of warming in the interval between 1999-2014, excluding 2004, 2005, 2006 and 2011, when, despite the fact that the deviations were negative, the temperatures decrease was however not significant compared to the increases.

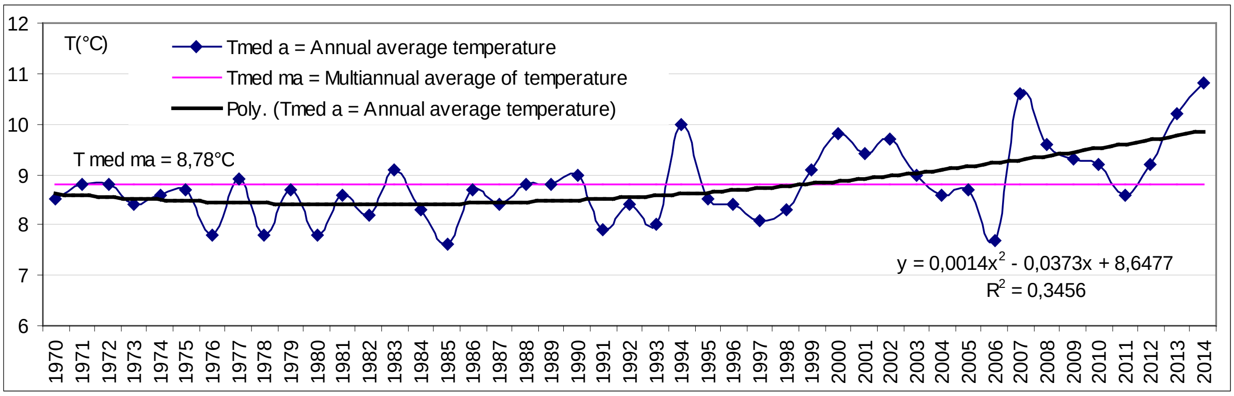

Figure 1: Non-periodic variability of annual average temperature and the warming trend.

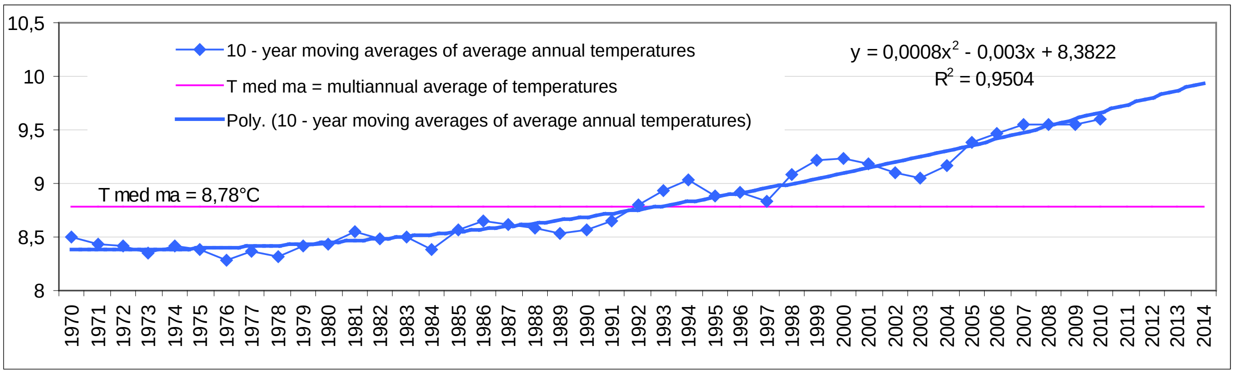

Figure 2: Warming trend highlighted by 10 years sliding average of annual mean temperature.

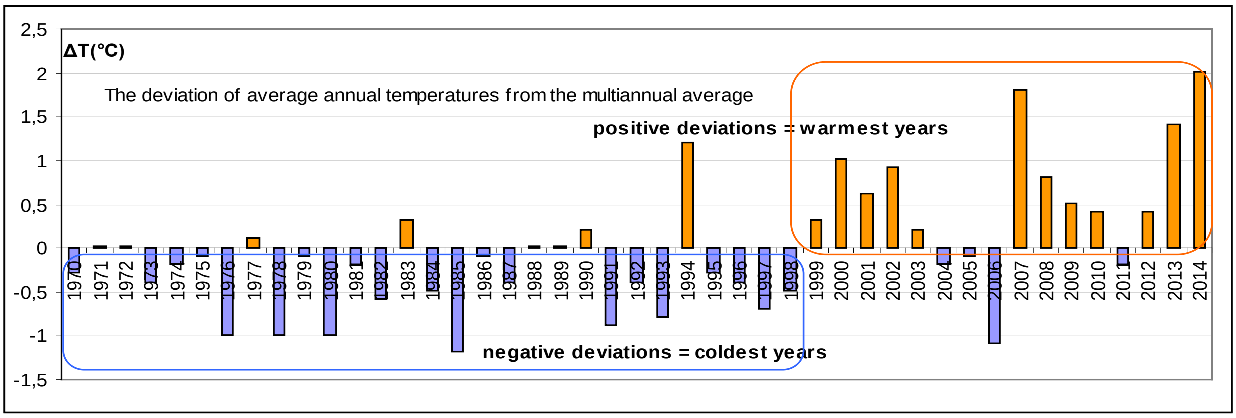

Figure 3: The annual average temperature deviation (ΔT)
from the multiannual average temperature.

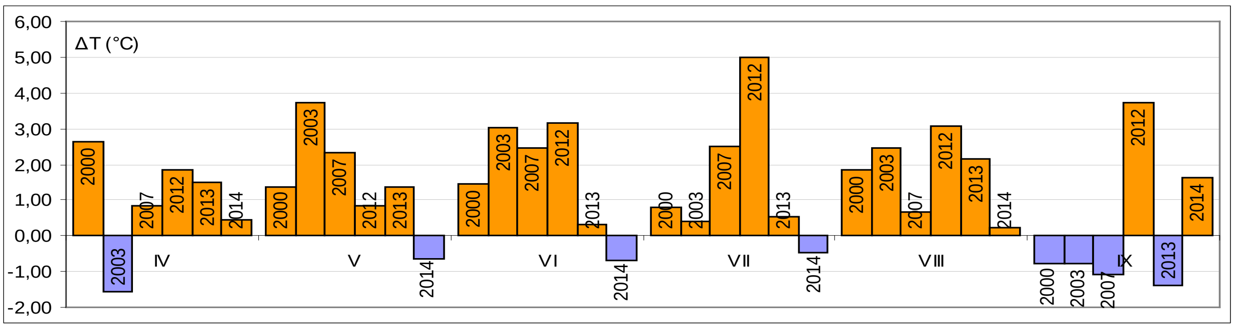

Figure 4: Monthly average temperature deviation from the multiannual monthly average for the warmest season in the representative warmest years.

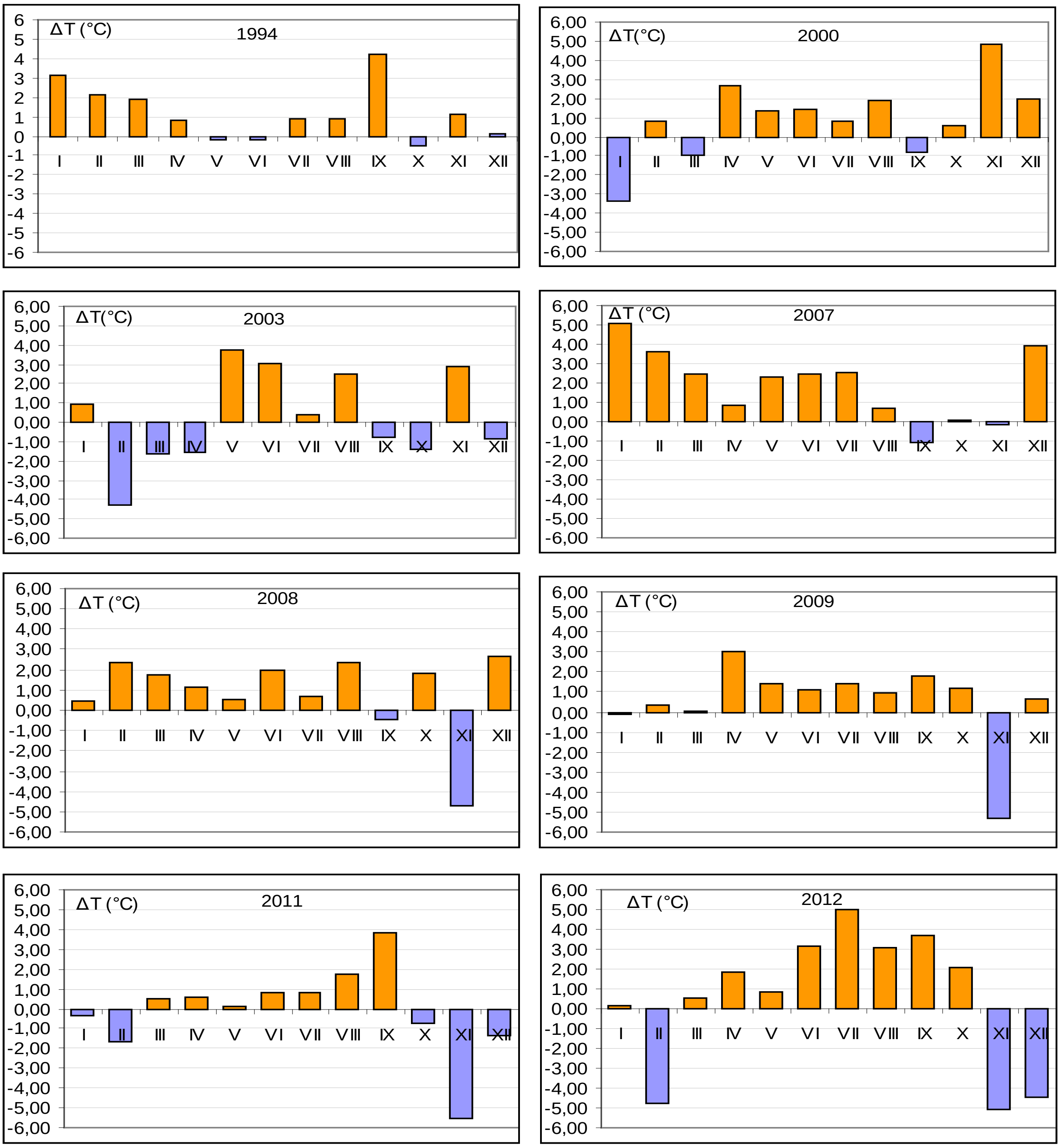

Figure 5: Monthly average temperature anomaly from the multiannual monthly average (1970-2014) in representative years for warming phenomenon during the warm season or all year round.

Large deviations occurred in 2007 (T annual average of 10.6°C and deviation of +1.81°C) and in 2014 (the largest T annual average of 10.8°C and the largest deviation + 2.01°C were registered) (Fig. 3).

Although 2014 was the hottest year, the warming phenomenon has not occurred in the warm season, but in winter. In the warm season monthly averages recorded negative anomalies in May, June, July (–0.5 to –0.7°C) and insignificant positive deviations in April and August (+0.2 – +0.5°C) (Figs. 4 and 5, 2014).

The representative years for warming in the warm season of the year were: 2000, 2003, 2007, 2008, 2009, 2001, 2012, and 2013 (Figs. 4 and 5). Positive thermal anomalies in the warm season of the year ranged between +0.5°C to +5°C, the largest deviations being recorded in different years: +3.05 in April 2009, +3.75 in May 2003, +3.14 in June 2012, +5.01 in July 2012 (the last value was the highest average temperature anomaly of summer in the observations string), +3.06 in August 2012 and +3.81 in September 2011 (Tab. 1).

Table 1: Monthly average temperature anomaly (°C) compared to the multiannual monthly average (1970-2014) for Sibiu in the warm season in the last 15 years representative for the warming phenomenon; source: processed data.

Year	IV	V	VI	VII	VIII	IX
1999	0.45	–0.75	1.14	1.21	0.16	1.21
2000	2.65	1.35	1.44	0.81	1.86	–0.79
2001	0.25	0.85	–1.36	0.71	0.96	–0.69
2002	–0.55	2.45	1.34	1.41	–0.44	–0.79
2003	–1.55	3.75	3.04	0.41	2.46	–0.79
2004	0.65	–1.25	0.24	0.31	–0.04	–0.69
2005	–0.15	0.65	–0.76	–0.19	–0.44	0.51
2006	1.25	–0.55	–0.26	0.91	–0.54	0.21
2007	0.85	2.35	2.44	2.51	0.66	–1.09
2008	1.15	0.55	1.94	0.71	2.36	–0.49
2009	3.05	1.45	1.14	1.41	0.96	1.81
2010	0.65	0.75	1.24	1.41	1.76	0.11
2011	0.55	0.15	0.84	0.81	1.76	3.81
2012	1.85	0.85	3.14	5.01	3.06	3.71
2013	1.50	1.39	0.30	0.54	2.16	–1.38
2014	0.47	–0.62	–0.69	–0.49	0.23	1.61
Max	**3.05**	**3.75**	**3.14**	**5.01**	**3.06**	**3.81**
Min	**–1.55**	**–1.25**	**–1.36**	**–0.49**	**–0.54**	**–1.38**
warming intensity		0-1°C		2.01 –		> 4°C
		1.01 –		3.01 –		

At the country level, 2007 was the second warmest year in the last 15 years, when the average thermal ranges of the country has been exceeded in average with 1.6-2°C. Increasing thermal ranges were determined by the positive deviations registration between +3.5 to +5°C in winter, continued with positive deviations of more than +2°C in the spring and summer. Exception were the months of April and August, when climatologically norm was exceeded by less than +1°C, but this reduction of deviations and negative deviations recorded in autumn failed to offset very large deviations from the first half of year (Fig. 5, 2007). Heat waves that hit Romania on 24 July 2007 were due to penetration of very warm tropical air masses from northern Africa, which has crossed the Balkan Peninsula from the southwest and reached up above the Carpathians. The influence of this air mass was felt in Sibiu, where it led to an increases of maximum temperature. The average of maximum temperatures was 29.7 in July and the absolute maximum temperature in the analyzed period was 38.3°C, which was recorded on that day. In the neighbouring Carpathian area the heat also determined previous thermal maximum exceeding (the absolute maximum temperature reached 24.8°C at Bâlea meteorological station and 28.4°C at Parâng meteorological station) (Bogdan, 2008).

Although 2014 was the warmest year and the second after that followed was 2007, in regards to the warming years cycle with heating in the warm season, the year 2012 stands out due to the intensity and continuity of this phenomenon. Massive warming in 2012 occurred in July but was preceded and continued by heating phenomena that have occurred throughout the spring, summer, and autumn. Deviations of the monthly average temperatures from the normal were positive, ranging between +1 and +5^{o}C (July), indicating high intensity of warming. In four consecutive months there have been deviations greater than +3^{o}C (June, July, August, and September). The phenomenon has extended also in October, when a positive deviation of +2.09°C was recorded, which was the second most important positive anomaly for October since 2001 from all of the analyzed observations string (Fig. 5, 2012; Tab. 1).

In 2012 the highest average values of maximum temperature of all analyzed data were recorded: in July (32.1°C), August (30.4°C) and September (26.6^{o}C). Also on the 25th of August 2012 the absolute maximum temperature for this month was recorded; it was of 38.9°C, and it was produced by a heat wave associated to the tropical air movements. On October 1st, 2012 the absolute maximum temperature for this month was recorded for the entire range of data; it was of 31.7°C.

Figure 5 and table 1 also show, for the last 15 years, that the warming phenomenon started in the cold season (2007, 2008, 2009) and continued with high intensity in spring (April, May), with the same intensity (2003, 2007) or with lower intensity in the next months (2000, 2009). The growth of temperatures in April-May has consequences both localy and on the regional level, causing sudden melting of the snow in the mountain area of Cibin River basin that increases the risk to flooding.

The continuity of warming and its intensification during the months of warm seasons causes strong evaporation, dryness and even drought (1994, 2000, 2003, and 2012). Pequi climographs indicate for the representative warmest years the sudden occurrence of the warming phenomena associated with the deficit or the surplus of precipitations (Higgins et al., 1999; Trömel and Schönwiese, 2007). The sudden decrease of rainfall amount from one month to another amplifies the thermal stress produced by heat waves by generating dryness and drought: August-September 1994 and 2012, May-June 2007 and 2012 (Fig. 6). In the last 20 years simultaneous and opposite meteo-climatic phenomena were recorded: the temperature increases were accompanied by decreases of precipitation amount in 1994, 2000-2003 interval, in 2011 and 2012. The rainfall deficit was of –108.7 mm in 1994, –251.8 mm in 2000, –180.8 mm in 2003, –163 mm in 2011 and of –1,173 mm in 2012. Although 2007 was a year with a surplus of precipitations, nevertheless in June and July an important deficit has been recorded (Busuioc et al., 2007). In Sibiu, and also in Romania, June is the rainiest month of the year and in June 2007 at the Sibiu station the rainfall recorded ½ of the monthly average amount, and also in July ¾ of the monthly average amount was recorded.

As negative consequences in such prolonged situations we mention: air dryness, drought in soil, vegetation and crops compromising through drying, groundwater migration to deep, strong evaporation and the deep cracks formation in the substrata, and in areas with more intense pastoral activity, as submountainous hills and plateau hills at the Sibiu Depression limit, land degradation occurs (Meehl et al., 2000; Jentsch and Beierkuhnlein, 2008).

In the conditions of anticyclone persistence, especially under the influence of very warm air invasion from the southern part of the continent (continental air or tropical hot air) in the space of the Sibiu Depression, heat waves occur during the summer accompanied by absolute maximum temperatures which often exceed 30ºC, the increase in the number of days with characteristic temperatures (summer days with T ≥ 25ºC, tropical days with T ≥ 30ºC).

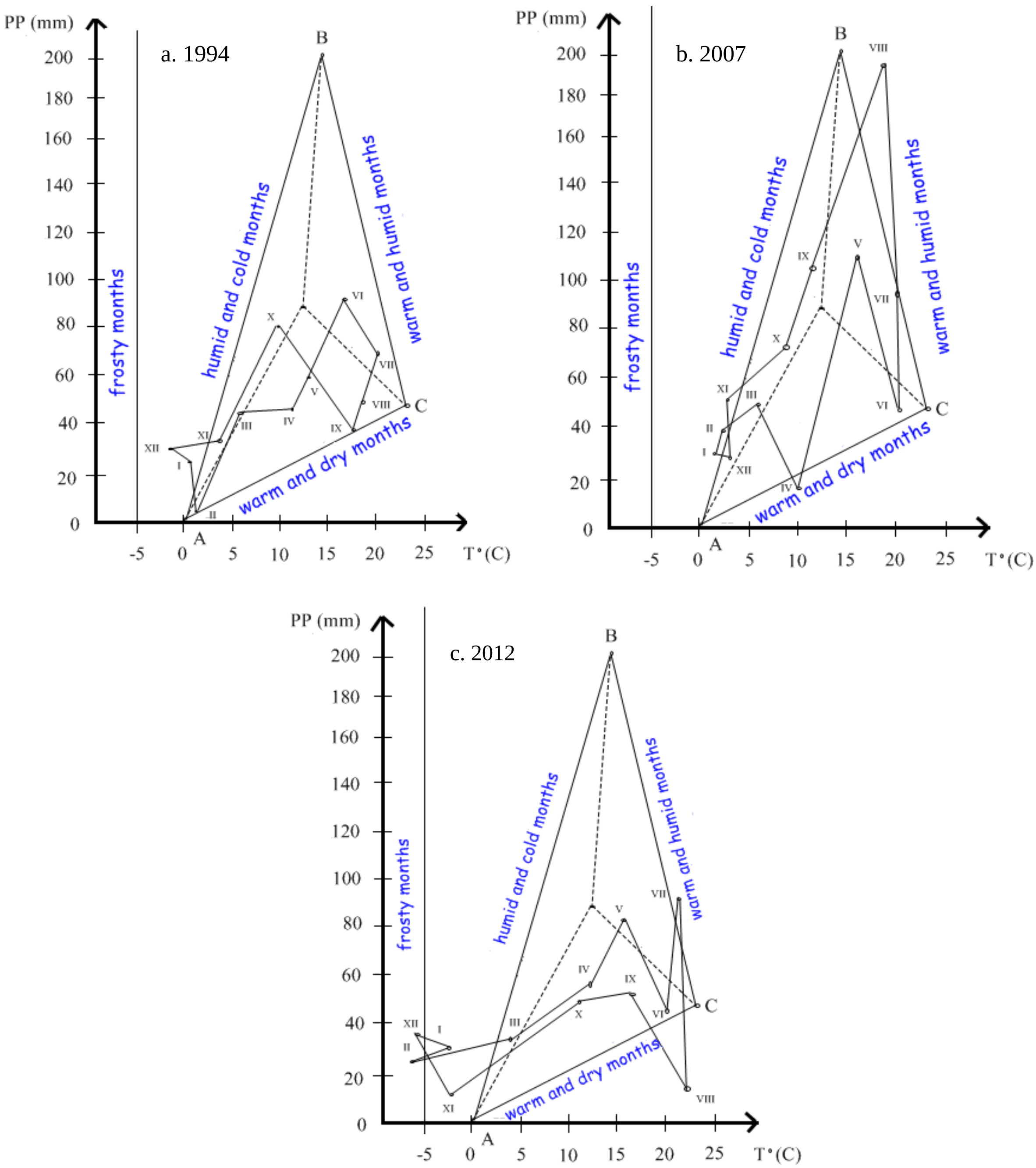

Figure 6: Pequi climographs in different representative years for warming phenomenon.

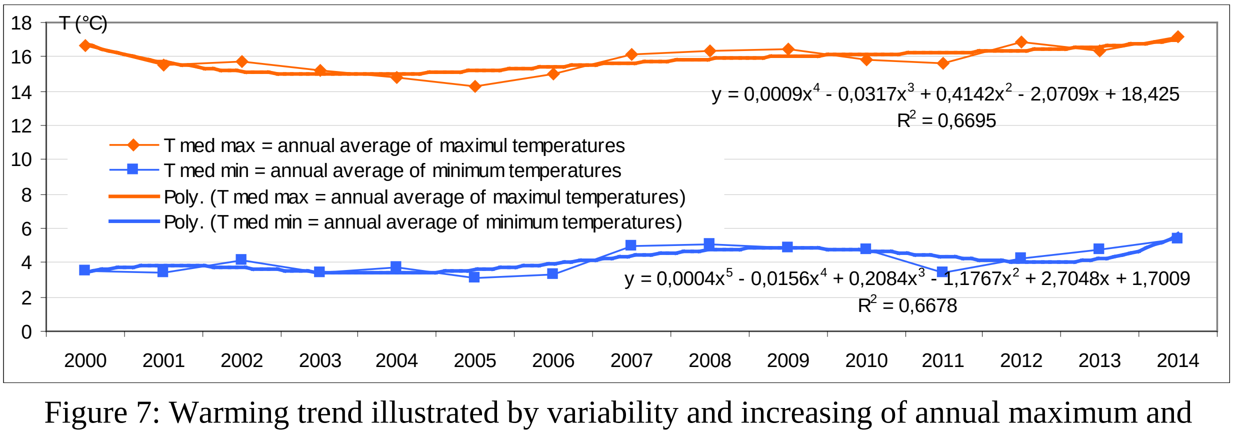

Figure 7: Warming trend illustrated by variability and increasing of annual maximum and minimum temperature averages, evidenced through the 4th and 5th order polynomial equations.

Warming trend of the last 15 years is evidenced by the increase of the maximum and minimum temperature averages. Years with heat waves are highlighted by the deviation of the maximum and minimum annual average (Ciulache, 1997, 1980; Ciulache and Cismaru, 2000).

The minimum temperature average deviations are positive and growing for the same period, except in 2011, and they are higher than the deviation of maximum temperature averages. The averages of maximum temperatures are rising and have positive deviations between +0.3 and +1.5ºC for the interval 2007 and 2014, with the exception of 2010 and 2011 (Figs. 7 and 8).

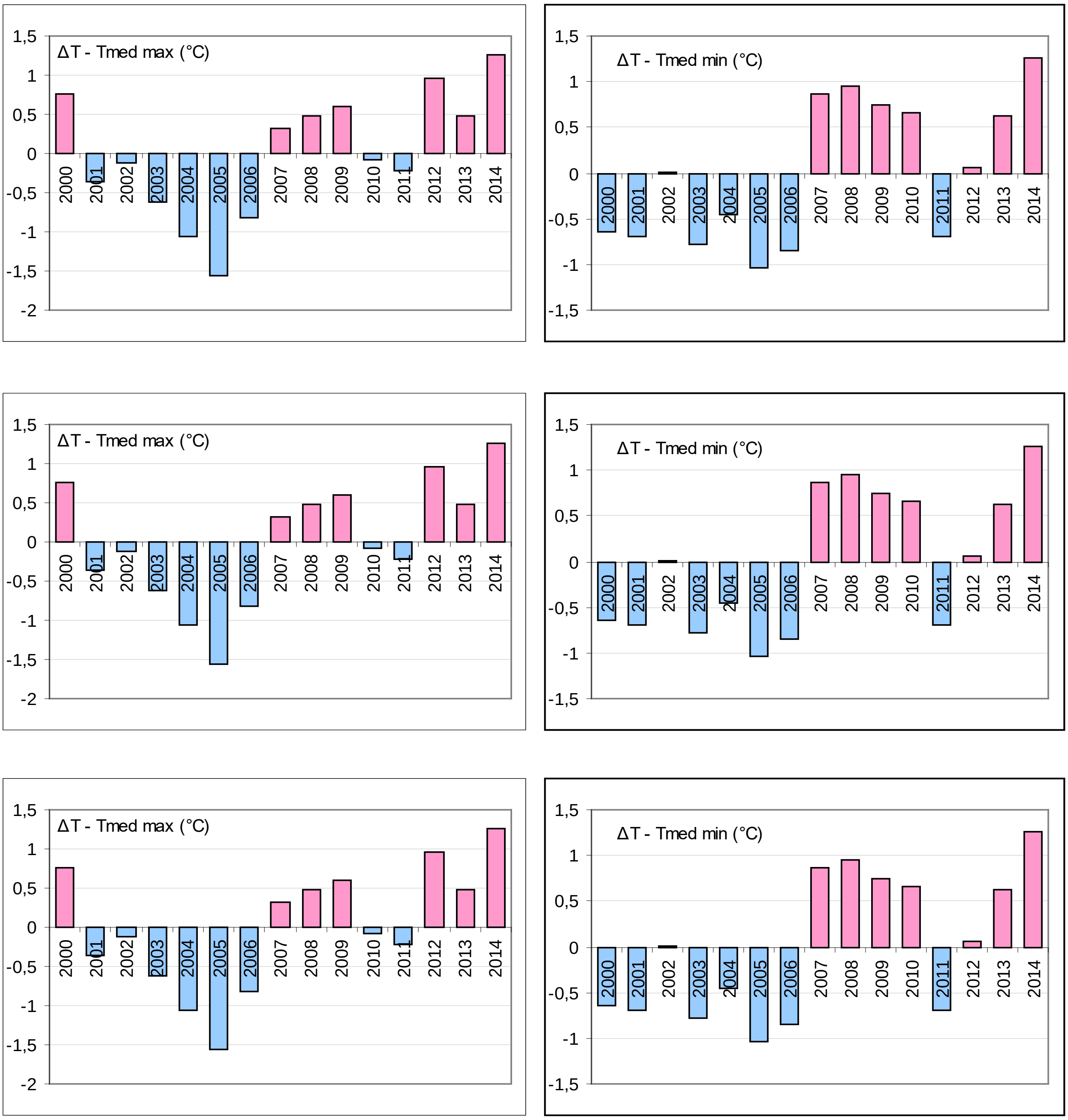

Figure 8: The annual average deviations of maximum and minimum average temperature at Sibiu.

The absolute maximum temperature was 39.5°C on the 7th of September 1946, but between 1970 and 2014 the maximum was 38.9°C and occurred on the 25th of August, 2012.

The thermal maxims recorded in Sibiu exceeded frequently the value of 30ºC (Ciulache, 1980), for the whole interval standing out regularly achieving and exceeding these values in July and August, but they can occur, also, in May, June, September or even in October (Fig. 9).

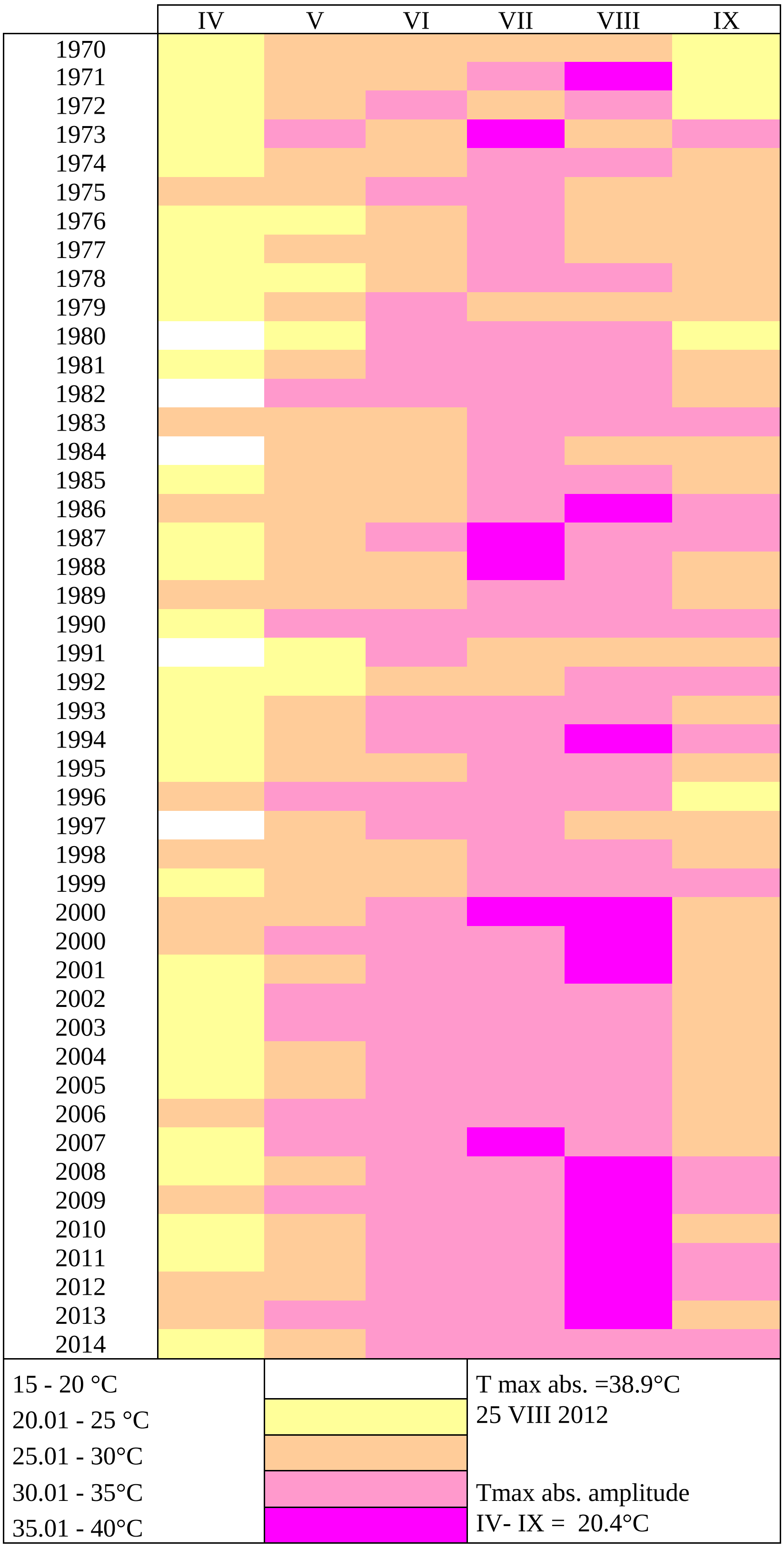

Figure 9: Distribution of absolute maximum temperatures on ranges.

Table 2: The monthly absolute maximum temperatures during the warm season and annual maximum from Sibiu between 1970 and 2014; source: Sibiu meteorological station.

Sibiu	IV	V	VI	VII	VIII	IX	Annual value
T max. abs	29.8	32.2	34.8	38.3	38.9	33.6	38.9
Day	27/2013	24/2006	11/2001	24/2007	25/2012	7/2008	25 VIII 2012

Table 3: Frequency of absolute maximum temperatures during the warm season of the year at Sibiu between 1970 and 2014; source: processed data.

	Temperature ranges									
	15-20°C		20.01-25°C		25.01-30°C		30.01-35°C		35.01-40°C	
	No.	%	No.	%	No.	%	No.	%	No.	%
IV	5	11	29	63	12	26	-	-	-	-
V	-	-	5	11	30	65	11	24	-	-
VI	-	-	-	-	17	37	29	63	-	-
VII	-	-	-	-	5	11	36	78	5	11
VIII	-	-	-	-	9	20	25	54	12	26
IX	-	-	5	11	28	61	13	28	-	-
Total/period/ T range	5	1.81	39	14.13	101	36.6	114	41.31	17	6.15
Occurrence probability	100%		98.19%		84.06%		47.46%		6.15%	

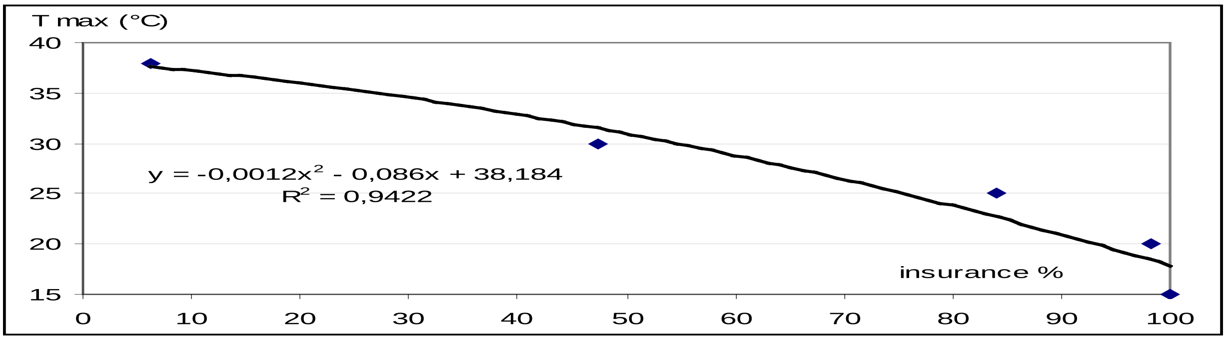

Figure 10: Insurance curve of absolute maximum temperatures occurrence in Sibiu.

Table 4: Insurance percentage in case of maximum temperatures occurrence.

Sibiu	The insurance of maximum temperature occurrence %								
	10	20	30	40	50	60	70	80	90
T. max °C	37°C	36.0	37.5	33.0	31.0	28.7	26.4	23.5	21.0

Between 2000 and 2014 what stands as remarkable are the continuity of massive warming and the producing of absolute maximum temperatures above the 30°C threshold both from year to year and during the year from month to month during the summer month's, with the debut in spring or translational occurrence towards all the autumn months of the year.

Table 2 shows the absolute maximum temperatures recorded during the warm season of the year throughout the period of observation. The frequency of maximum temperatures from different value classes is shown in table 3, being over 50% for the range of 30-35°C in June, July and August (Tab. 3). Massive warmings occur as a result of exceeding the heat threshold (T ≥ 35°C) in July (11% of cases) and August (26% of cases).

After analyzing the data trends of the absolute maximum temperature, the insurance curve occurrence of such values was plotted and the probability of occurrence during the warm season of extreme positive value was determined (Tab. 4; Fig. 10). Massive heating from warm season of the year are highlighted by the high number of tropical days.

At the Sibiu meteorological station, the average number of tropical days is of 13.8 days throughout the analyzed period, and of 22 days for the last 15 years.

There have been years when the number of tropical days was between 20 and 25 days: 25 days in 1987 and 1994, 24 days in 2010, 23 days in 2007, 2008, 2011, 22 days in 1992 and 1993, etc. Of all analyzed string the year stands out is 2000 with 36 tropical days and 2012 with the highest number of tropical days, 58 days.

The frequency of tropical days is high in July and August, but these were recorded even in May (three tropical days in May 2003) and October (two tropical days in October 2012).

The maximum number of tropical days in July was recorded in 2012 (26 days) and in August 1992 (21 days). It should be noted the last 15 years with a large number of tropical days are in July and August (Tab. 5).

Table 5: Number of tropical days between 2000 and 2014 (T ≥ 30^{o}C); Source: Sibiu meteorological station.

Year	V	VI	VII	VIII	IX	X	Total
2000		11	11	13			36
2001		2	5	5			12
2002	1	5	9				15
2003	3	10	7	11			31
2004			9	5			14
2005			5	2			7
2006	1	6	10	4			21
2007		2	17	4			23
2008		3	6	10	4		23
2009		5	7	3	1		16
2010		6	9	9			24
2011		2	12	5	4		23
2012		9	26	14	7	2	58
2013		6	3	11			20
2014		2	1	4			7
Max no.	3/2003	11/2000	26/2012	14/2012	7/2012	2/2012	Average no. =

CONCLUSIONS

Analyzing the data from the meteorological station in Sibiu, we can conclude the following characteristics of warming and heat waves from the warm season of the year:

– the strongest warming phenomenon occurred in the last 15 years (2000-2014 interval);

– positive deviations of temperature with values ranging between 2-5°C are characteristic to the monthly averages of the warmest years;

– warming phenomena are highlighted by increasing maximum temperature averages and minimum temperature averages;

– the months with the highest frequency of warming phenomenon are July and August, highlighted by the large number of tropical days and heat thermal threshold supplies;

– the most massive warming from the warm season in the observation period does not occur in the most warming years (1994, 2007, 2014) but in 2012, when a record number of tropical days (58) were recorded and the absolute maximum temperature of the observations period (38.9 °C on 25 August 2012) were registered, with 0.6°C lower than the record value of maximum temperature recorded on September 7, 1946;

– heat waves are often simultaneous with precipitations deficit, and when coupled together they are generating complex risks like dryness and drought;

– the occurrence probability of temperatures that exceeds 30°C increased as a result of the high frequency of phenomena in recent years, which was about 50%.

The conducted analysis reveals the meteo-climatic risk of warming phenomena from the warm season of the year. These risks are triggering a chain of associated risks, on physical-geographical components, such as dryness and drought, degradation of vegetation, loss of land productivity, etc.

On the other hand heat waves through the duration of the event, intensity and their frequency has negative effect on the human body leading to lower thermal comfort and even large medical problems or loss of life, i.e. summer 2003 in Western Europe (IPCC, 2007; García-Herrera et al., 2010). Predictive models, the monitoring of weather conditions and weather warnings are extremely important actions in risk management triggered by heat waves.

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THE SMALL ALMOND (*PRUNUS TENELLA* BATSCH.) SHRUBBERY ON HILLS OF THE SOUTHERN TRANSYLVANIAN TABLELAND (ROMANIA)

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KEYWORDS: xero-termophilous scrub, forest steppe elements, woodland fringes, habitat types 40A0* and 40C0*.

ABSTRACT

Dwarf or Steppe Almond (*Prunus tenella* Batsch, *Amygdalus nana* L.), denotes some characteristic scrub communities on the fringes of xero-thermophilous oak forests, located on the upper part of South-, South-Western- and South-east-facing hill slopes of the Transylvanian Tableland. Towards the front of the slopes these communities are commonly interlinked with xero-thermophilous tall herbaceous forest fringes and steppic grasslands characterized by *Stipa* species. Dwarf Almond bushes are analysed from an ecological and phyto-coenological point of view and discussed in the context of the priority habitat types 40A0* Subcontinental peri-Pannonic scrub and 40C0* Pontic-Sarmatic deciduous thickets, as Dwarf Almond is a species that characterizes similar plant communities in both habitat types. As the Dwarf Almond scrub habitat is not only of great interest from a bio-geographical and phyto-historical point of view, but also as habitat of European Community interest, special attention should to be paid to its protection and management.

REZUMAT: Tufărișuri de migdal pitic (*Prunus tenella* Batsch.) pe colinele Podișului Transilvaniei de sud (România).

Migdalul pitic (*Prunus tenella* Batsch, *Amygdalus nana* L.) edifică comunităţi de tufărişuri caracteristice la marginea pădurilor xero-termofile de stejar în partea superioră a pantelor expuse spre sud, sud-vest şi sud-est din sudul Podişului Transilvaniei. Se întrepătrund înspre partea frontală, deschisă a pantelor de obicei, cu borduri xero-termofile de buruienişuri xeroterme şi pajişti de colilie. În lucrarea prezentată, tufărişurile de migdal pitic sunt analizate din punct de vedere ecologic şi fitocenologic, fiind discutate apoi în contextul tipurilor de habitat prioritare 40A0* Tufărişuri subcontinentale peripanonice şi 40C0* Tufărişuri caducifoliate ponto-sarmatice, migdalul pitic edificând comunităţi similare în ambele tipuri de habitate. Tufărişurile de migdal pitic fiind importante din punct de vedere biogeografic şi fito-istoric, dar şi ca habitat de interes comunitar, conservarea şi managmentul lor necesită o deosebită atenţie.

ZUSAMMENFASSUNG: Zwergmandel (*Prunus tenella* Batsch.) Gebüsche auf Hängen im Hochland Südsiebenbürgens (Rumänien).

Die Zwergmandel (*Prunus tenella* Batsch, *Amygdalus nana* L.) bildet charakteristische Mantel-Gebüsche xero-thermophiler Eichenwälder an der Oberkante südlich, südöstlich und sudwestlich exponierter Hänge im Hochland Süd-Siebenbürgens. Zum Offenland hin sind sie eng mit xero-thermophilen Steppen-Hochstauden- und teils mit Federgrasfluren verzahnt. Das Zwergmandelgebüsch wird in der Folge aus ökologischer und phyto-coenologischer Sicht analysiert und im Kontext der prioritären Habitattypen 40A0* Subkontinentale peri-pannonische Gebüsche und 40C0* Pontisch-sarmatische Gebüsche, dargestellt, da die Art ähnliche Gesellschaften aufbaut, die jeweils den genannten Habitatytpen zugeordnet sind. Als Gebüschformationen von großer biogeographischer und phytohistorischer Bedeutung, ist der nachhaltigen Sicherung dieser Lebensräume besondere Aufmerksamkeit zu schenken.

INTRODUCTION

Dwarf or Steppe Almond (*Prunus tenella* Batsch, *Amygdalus nana* L., *Prunus nana* (L.) Stokes) is an Euro-Asiatic continental, xero-thermophilous to sub-thermophilous species with a sporadic distribution in Romania from the steppic zone to the level of oak forests in hilly areas (Ciocârlan, 2009). It occurs as isolated shrubs in grasslands, and as continuous scrub formations on the fringes of forests and in forest clearings (Sârbu et al., 2013; Schneider-Binder, 1983; Schneider, 1992). According to Sanda et al. (2008) the phytocoenoses of *Prunus tenella* develop for the most part on sunny, South-facing hill slopes and rarely as fringes of forests. This last manifestation must be regarded only in strong relation to the fact that in the forest-steppe zone such type of communities became very rare due to cutting forests and scrubland and transformation of the natural habitats into agricultural lands. For this reason the natural distribution along ecological gradients is disturbed and mostly less representative. In this area the Dwarf Almond develops also by secondary expansion on to sites of former forest steppe (Burduja et al., 1971). But considering the South-facing hills of the Transylvanian Tableland, well conserved sites can be observed sheltering Dwarf Almond shrub communities as fringes of woodlands, and being part of a hill slope profile – on the upper front part of hill slopes – where the vegetation is distributed along ecological gradients from the top to the foot of the hills, strongly dependent on aspect, slope inclination, soil conditions and related temperatures (Schneider-Binder, 1983; Schneider, 1992). Elsewhere one can observe that the Dwarf Almond shrubs form mosaic groups within steppe grasslands of the Stipion lessingianae alliance and other forest-steppe elements, or with plant groups of rupicolous Pannonic grasslands (Danciu, 1970).

According to the habitats classification of the Interpretation Manual of European Union habitats (EUR 28, 2013) and the Romanian Manual (Gafta and Monford, 2008) the Dwarf Almond bushes are included in the priority habitat type 40A0 * Subcontinental peri-Pannonic scrub together with a number of other shrubbery associations. At the same time, Dwarf Almond is mentioned as a characteristic species also for another shrubbery habitat type, that of 40C0 *Ponto-Sarmatic deciduous thickets. According to the Romanian habitat classification (Doniţă et al., 2005) the Dwarf Almond bush association is given as R3131 Pontic-Pannonic Scrub of Dwarf Almond (*Amygdalus nana*) distributed in the Northern and Southern Moldova region Tablelands (Podişurile Moldovei de Nord, Podişurile Moldovei de Sud), the Tableland of Northern and Southern Dobrogea (Podişul Dobrogei de Nord, Podişul Dobrogei de Sud), the Mostiştea Bărăgan area, the foothills of Olteţ (Piemontul Olteţului), the "Câmpia" Transilvaniei (Northern part of the Transylvanian Tableland), the Făgăraş, Braşov and Sibiu depressions; in these mentioned regions the phytocoenoses occur in the steppe and/or the oak forest zone. The situation in the last three mentioned – the Depressions of Braşov, Făgăraş and Sibiu – refers to hill slopes on the border of the Depressions and not to the Depressions themselves, as these are more or less flat areas, lacking the appropriate site conditions for the Dwarf Almond scrub.

The question is, whether the Dwarf Almond shrubs mentioned from the Transylvanian Tableland area and those of the Moldavian and Dobrogean Tablelands have to be included within the same habitat type, Peri-Pannonic scrub, or separated into two different types of habitats: Peri-Pannonic scrub habitats for those of Transylvania, and Ponto-Sarmatic deciduous thickets for those of Moldova, Muntenia, Oltenia and Dobrogea; or to enlarge the Peri-Pannonic habitat type, changing its name from Peri-Pannonic to that of the Ponto-Pannonian habitat type.

Another principal question concerns the phytocoenological units mentioned in the Interpretation Manual (EUR 28, 2013) as also being included near the Dwarf Almond scrub of the Peri-Pannonic scrub habitat type, as they are only more or less similar in structure, but quite different with respect to their ecological requirements and general geographical distribution. Considering these facts, the objective of this paper is to contribute to the further knowledge of the Dwarf Almond phytocoenoses of the Southern Transylvanian Tableland, to compare them with phytocoenoses known from other regions of Romania, to discuss the Dwarf Almond habitat subtype in the context of the habitat types 40A0* and 40C0*, and to clarify its belonging to the mentioned habitat type.

MATERIAL AND METHODS

During specific field research over several decades in the area of the Transylvanian Tableland, in particular in its Southern part between the Târnava Mare and the Olt Rivers, the Dwarf Almond (*Prunus tenella*) scrub has been studied in close relation to the xero-thermic steppic grasslands vegetation on South-facing hill slopes. The author's older samples (Schneider-Binder, 1972) have been analysed and compared with newer samples (2000, 2007, 2015) from the same hilly area of Guşteriţa/Hammersdorf – municipality of Sibiu/Hermannstadt, hills near the villages Roșia/Rotberg, Vurpăr/Burgberg on the Southern border of the Transylvanian Tableland (namely Podişul Vurpărului) and the communes of Șeica Mare/Markt-Schelken, Agârbiciu/Arbegen, both on slopes of the Visa Valley near to the mouth into the Târnava Mare River.

The phytocoenological samples were taken according to the method of Braun-Blanquet (1964) with the seven degree scale of abundance-dominance values for the degree of cover. The size of sampling area was 25 m^2 (5 m x 5 m) with some exceptions. For following the distribution along ecological gradients, also the side by side method of sampling has been used.

Comparative studies have been undertaken between Dwarf Almond communities from different localities to assess whether the phytocoenoses are in a more or less stable state or undergoing major changes. In order to show similarities and differences between Dwarf Almond scrub communities from different regions of Romania, samples of phytocoenoses of the association Amygdaletum nanae/Prunetum tenellae published in a number of scientific papers have been used for comparison. They were included in a synthetic table with frequency values (I-V). The nomenclature of the species listed in the tables follows Ciocârlan (2009), Drăgulescu (2010) and Sârbu et al. (2013).

RESULTS AND DISCUSSION

The scrub characterized by Dwarf Almond (*Prunus tenella, Amygdalus nana*) in Southern Transylvania was known as a distinct shrub community from the mid-19th century, by naturalists of the Transylvanian Society for Natural Sciences (Herbarium M. Fuss; Fuss, 1866; Fuss, 1867). The first mention as an association according to phytocoenological nomenclature was as Prunetum nanae n. n. (Borza, 1931). Later the association Prunetum tenellae Soó 1951 (Syn. Prunetum nanae Borza 1931 n.n.) has been described, with eight samples of different xerothermic area around Cluj (Soó, 1951; Chifu et al., 2014). The distribution of Dwarf Almond bushes in the Transylvanian Tableland follows approximately the border of the forest steppe level (Csürös, 1963) i.e. the forest steppe zone as it is delineated according to Paşcovschi and Doniţă (1967). This border reaches up on to the slopes of the Mureş Valley and through the corridor of Târnava Mare River and Visa Valley nearly to the border of the Transylvanian Tableland to the Depressions of Sibiu and Făgăraş (Schneider-Binder, 1972, 1983;

Schneider, 1992). As well, Dwarf Almond shrubs inhabit steep rocky slopes on the edge of Baraolt Mountains and Apuseni Mountains (Danciu, 1970; Brînzan, 2013).

The most frequent occurences of Dwarf Almond scrub in Southern Transylvania are associated with fringes of thermophilous oak forests charcterized by Downy oak (*Quercus pubescens*), Manna or Flowering ash (*Fraxinus ornus*), Sessile oak (*Quercus petraea*) and thermophilous shrub species, for example in some areas (Sibiu-Guşteriţa/Hammersdorf) there is European steppe cherry *Cerasus fruticosa* (Schneider-Binder, 1972, 2009). The shrubs are accompanied on the open part of the slope by tall herbaceous fringes of *Aster oleifolius*, locally with *Peucedanum tauricum*, or *P. cervaria*, *P. oreoselinum* and *Dictamnus albus*, which in their turn are interlocking with open steppic grasslands of *Stipa pulcherrima*. Such succession can be still observed in many places in Southern Transylvania, such as at Şeica Mare, Agârbiciu, Roşia, Şura-Mare/slope of Şerbuţa Valley, but there are also many places where the natural succession along ecological gradients has been disturbed. The old data combined with the new research have enabled us to understand how the structures and the disposition of phytocoenoses along ecological gradients on South-facing hills have been in the past (Tab. 1).

Figure 1: *Prunus tenella* on a South-facing exposed hill slope near to the village Roșia/Rotberg, Sibiu County (Photo: Eckbert Schneider).

On the Southern border of its geographical distribution in the Transylvanian Tableland, the Dwarf Almond shrubbery phytocoenoses were mentioned from the second part of the 19th century as existing in some of places mentioned at that time, as we have stated, until the present (Roşia, Vupăr, Guşteriţa, Şura Mare and Şeica Mare) (Fig. 1). In other sites they have disappeared together with the forest from the top of the hills, due to human interventions, as for example on the Southern slope of Zakelsberg between Şura-Mare/Groß-Scheuern and Slimnic/Stolzenburg (Schneider-Binder, 1983), the area included in the Natura 2000 site 93: Steppic islands nearby Slimnic. In some areas Dwarf Almond patches are distributed in xerothermic grasslands, as for example at Şeica Mare area, identifying forest fringes, but also interlocking and entering in the local feather-grass community.

In other areas of former (secondary) steppe grasslands "Târfla Dealului" and "Dosul Făgetului" near Făgăraş on slopes of the Southern border of the Transylvanian Tableland where sheep grazing has ceased, Dwarf Almond occupies a large area (Roman, 1994).

Table 1: Comparison of the historical with actual situation on each of the sites studied with succession of plant communities on the upper part of hill slopes of the Transylvanian Tableland; SuM = Şura Mare, Ro = Roşia, Vu = Vurpăr, Gu = Guşteriţa, Sei = Şeica Mare, Ag = Agârbiciu, all in Sibiu County.

Locality	SuM	SuM	Ro	Ro	Vu	Vu	Gu	Gu	Sei	Sei	Ag	Ag
	Hist	Act.	Hist	Act	Hist	Act	Hist	Act	Hist	Act	Hist	Act
Thermophilous oak forest	+	-	+	+	+	±	+	±	+	+	+	+
Amygdaletum nanae	+	-	+	+	+	+	+	+	+	+	+	+
Fringe of *Aster oleifolius*	+	±	–	–	–	–	–	–	+	+	+	+
Fringe of *Aster oleifolius* and *Peuced. tauric.*	–	–	–	–	–	–	–	–	+	+	+	+
Dictamnus and *Peucedanum cervaria oreoselinum*	–	–	–	–	+	+	–	–	–	–	–	–
Stipetum pulcherrimae and Amygdalus	–	–	–	–	–	–	+	+	–	–	+	+
Stipetum pulcherrimae	+	+	+	+	+	+	+	+	+	+	+	+

Comparing the phytocoenoses from the area of Visa Valley (Şeica Mare and Agârbiciu) with those of Roşia and Vurpăr near to the Hârtibaciu Valley, one group of samples is similar to the other.

In both are present species of Prunion, Prunetalia and Rhamno-Prunetea, followed by characteristic species of the alliances Stipion lessingianae, Festucion valesiacae, Cirsio-Brachypodion, the order Festucetalia and the class Festuco-Brometea. Another group with lower values is represented by species of tall herbaceous fringes of Class Trifolio-Geranietea and species of the Class Quercetea pubescenti-petreae. But there are as well some regional differences due to the number and frequency of xerothermic steppe species of the Stipion lessingianae alliance, such as *Aster oleifolius, Peucedanum tauricum* and *Vinca herbacea*, present only in the samples from the Visa Valley (Tab. 2, 1-5). Relevant as well is the greater number of species of the alliance Festucion and the order Festucetalia, many of them such as *Allium flavum, Iris pumila, Euphorbia seguieriana, Kengia (Diplachne) serotina, Adonis vernalis* and *Astragalus dasyanthus* occur only in the samples from the Visa Valley area.

This fact can be explained by climatic differences between the sites of the Visa Valley and those near to the Hârtibaciu Valley. Both cases represent edaphically conditioned forest steppe areas on slopes of high inclination, related high insolation and soil conditions.

Table 2: Prunetum tenellae Soó 1951 with samples from hills of Southern Transylvania (Sibiu County); 1-5 from slopes of the Visa Valley and 6-10 from Roșia and Vurpăr close to the Hârtibaciu Valley.

Number of columns	1	2	3	4	5		6	7	8	9	10	
Slope aspect	SW	SW	S	SE	SE		S	S	S	S	S	
Position on the hill slope	ups	ups	ups	ups	ups		ups	ups	ups	ups	ups	
Inclination of slope	10	30	30	45	45		40	40	45	45	40	
Cover %	1	80	75	75	70		85	80	85	75	75	
Locality	Sei	Sei	Sei	Ag	Ag		Vu	Vu	Ro	Ro	Ro	
Association						F						F
Prunus tenella	4	2	3	2	3	V	4	4	4	3	4	V
Prunion, Prunetalia, Rhamno-Prunetea												
Crataegus monogyna	+	+	.	+	.	III	+	.	+	+	+	IV
Ligustrum vulgare	1	+	+	+	.	IV	.	.	+	+	+	III
Prunus spinosa	1	.	.	.	.	I	.	.	.	+	1	II
Viburnum lantana	+	.	+	.	.	II	.	.	.	.	.	-
Rosa spinosissima	+	.	.	.	.	I	.	.	.	.	.	-
Cornus sanguinea	.	.	.	.	.	-	.	+	+	+	+	IV
Rhamnus saxatilis ssp. *tinctorius*	.	.	.	.	.	-	.	.	+	+	+	III
Evonymus verrucosa	.	.	.	.	.	-	.	.	+	+	.	II
Rhamnus cathartica	.	.	.	.	.	-	.	.	+	.	.	I
Stipion lessingianae												
Aster oleifolius (= villosus)	+	2	1	+	1	V	.	.	.	.	.	-
Peucedanum tauricum	+	+	+	.	+	IV	.	.	.	.	.	-
Vinca herbacea	+	+	+	+	+	V	.	.	.	+	+	II
Stipa pulcherrima	.	1	1	.	+	III	.	.	+	2	2	III
Salvia nutans	.	+	.	.	.	I	.	.	.	.	.	-
Hypericum elegans	.	.	.	.	.	–	+	.	.	.	.	I
Cephalaria uralensis	.	.	+	.	+	II	.	.	.	+	+	II
Crambe tataria	.	.	.	.		-	2	1	.	.	.	II
Cirsio-Brachypodion												
Brachypodium pinnatum	1	.	.	.	.	I	.	.	.	.	.	-
Dorycnium herbaceum	.	1	1	+	+	IV	.	.	.	+	+	II

Table 2 (continued): Prunetum tenellae Soó 1951 with samples from hills of Southern Transylvania (Sibiu County); 1-5 from slopes of the Visa Valley and 6-10 from Roșia and Vurpăr close to the Hârtibaciu Valley.

Number of columns	1	2	3	4	5		6	7	8	9	10	
Slope aspect	SW	SW	S	SE	SE		S	S	S	S	S	
Position on the hill slope	ups	ups	ups	ups	ups		ups	ups	ups	ups	ups	
Inclination of slope	10	30	30	45	45		40	40	45	45	40	
Cover %	1	80	75	75	70		85	80	85	75	75	
Locality	Sei	Sei	Sei	Ag	Ag		Vu	Vu	Ro	Ro	Ro	
Fragaria viridis	+	.	+	.	.	II	+	+	1	.	.	III
Inula ensifolia	.	.	.	.	2	I	+	+	.	+	.	III
Polygala major	.	.	.	.	.	-	.	+	.	.	.	I
Festucion valesiacae- Festucetalia												
Verbascum phoeniceum	.	+	+	+	+	IV	+	+	+	+	+	V
Elymus hispidus	.	3	2	3	2	IV	2	3	3	.	2	IV
Thymus pannonicus	.	2	+	2	+	IV	2	+	.	+	+	IV
Stachys recta	.	.	+	.	+	II	+	+	+	+	+	V
Festuca valesiaca	.	+	+	.	.	II	+	+	.	.	+	III
Campanula sibirica	.	+	+	+	+	IV	+	.	.	+	.	II
Centaurea micranthos	.	+	.	.	.	I	.	.	.	+	+	II
Jurinea mollis	.	+	.	.	.	I	.	.	.	+	+	II
Cytisus austriacus	.	+	.	+	.	II	+	.	.	.	.	I
Aster amellus	.	+	.	+	.	II	.	.	.	+	.	I
Seseli pallasii	.	+	.	+	.	II	.	.	+	1	.	II
Nonea pulla	.	+	.	+	.	II	.	+	.	.	.	I
Allium flavum	.	+	+	.	+	III	.	.	.	.	.	-
Iris pumila	.	+	+	.	+	III	.	.	.	.	.	-
Kengia (=Diplachne) serotina	+	1	1	.	1	IV	.	.	.	.	.	-
Euphorbia seguieriana	+	+	+	+	.	IV	.	.	.	.	.	-
Adonis vernalis	+	+	+	.	.	III	.	.	.	.	.	-
Astragalus dasyanthus	.	+	.	+	.	II	.	.	.	.	.	-
Stipa capillata	.	.	+	.	.	I	.	.	.	.	.	-
Iris aphylla ssp. *hungarica*	.	.	.	.	.	–	.	.	2	+	1	III
Achillea setacea	.	.	.	.	.	–	.	.	+	.	.	I
Silene buploeuroides	.	.	.	.		–	.	.	+	.	.	I
Festuco-Brometea												
Euphorbia cyparissias	+	+	+	+	+	V	+	.	.	.	+	II
Medicago falcata	+	1	+	1	+	V	.	+	+	+	.	III
Teucrium chamaedrys	+	+	1	.	+	IV	1	2	+	.	.	III
Falcaria sioides	+	+	+	.	+	IV	+	.	+	+	+	IV
Artemisia campestris	.	+	+	+	+	IV	+	.	.	+	1	III
Hypericum perforatum	.	+	+	+	+	IV	.	+	+	+	.	III
Asperula cynanchica	.	+	+	+	+	IV	+	.	+	+	.	III
Tragopogon dubius	+	+	+	.	+	IV	.	.	.	.	+	I

Table 2 (continued): Prunetum tenellae Soó 1951 with samples from hills of Southern Transylvania (Sibiu County); 1-5 from slopes of the Visa Valley and 6-10 from Roșia and Vurpăr close to the Hârtibaciu Valley.

Number of columns	1	2	3	4	5		6	7	8	9	10	
Slope aspect	SW	SW	S	SE	SE		S	S	S	S	S	
Position on the hill slope	ups	ups	ups	ups	ups		ups	ups	ups	ups	ups	
Inclination of slope	10	30	30	45	45		40	40	45	45	40	
Cover %	1	80	75	75	70		85	80	85	75	75	
Locality	Sei	Sei	Sei	Ag	Ag		Vu	Vu	Ro	Ro	Ro	
Bupleurum falcatum	.	+	.	+	.	II	+	+	.	+	+	IV
Aster linosyris	.	+	+	.	1	III	.	.	+	+	+	III
Botriochloa ischaemum	.	+	+	.	1	III	.	+	.	2	.	II
Linaria genistifolia	.	+	+	.	+	III	.	.	.	+	+	II
Eryngium campestre	+	+	+	.	.	III	.	.	.	+	.	I
Carex humilis	+	.	1	.	.	II	.	+	+	.	.	II
Veronica spicata	.	.	+	.	+	II	+	.	.	.	.	I
Salvia pratensis	.	+	+	.	.	II	.	.	.	+	.	I
Melica ciliata	.	.	+	.	.	I	.	.	+	.	.	I
Seseli annuum	.	.	.	+	.	I	.	.	.	+	.	I
Poa angustifolia	.	+	.	.	.	I	.	+	.	.	.	I
Astragalus onobrychis	.	+	.	.	.	I	.	.	.	.	.	-
Potentilla arenaria	.	.	+	.	.	I	.	.	.	.	.	-
Galium glaucum	.	.	.	.	.	–	.	.	+	+	+	III
Thalictrum minus	.	.	.	.		–	+	+	+	.	.	III
Phleum montanum	.	.	.	.	.	–	+	.	.	+	.	II
Astragalus monspessulanus	.	.	.	.	.	–	+	+	.	.	.	II
Carex praecox				.		–	+	+	.	.	.	II
Potentilla recta	.	.	.	.		–	+	+	.	.	.	II
Teucrium montanum	.	.	.	.	.	–	+	+	.	.	.	II
Trifolio-Geranietea, Origanietalia				.								
Clinopodium vulgare	+	+	.	.	.	II	.	.	+	.	.	I
Asparagus officinalis	.	+	.	.	.	I	+	+	.	+	+	IV
Inula conyza	.	+	.	+	.	II	.	.	.	.	.	-
Coronilla varia	.	.	+	.	+	II	.	.	.	.	.	-
Dictamnus albus	.	.	.	.	+	I	.	.	.	.	.	-
Campanula bononiensis	.	.	.	.	+	I	+	.	.	.	.	II
Veronica austriaca ssp. jaquinii	.	.	.	.		–	+	+	.	.	.	II
Origanum vulgare	.	.	.	.	.	–	.	+	.	+	.	II
Agrimonia eupatoria	.	.	.	.	.	–	.	+	+	.	.	II
Peucedanum cervaria	.	.	.	.	.	–	+	+	.	.	.	II
Geranium sanguineum	.	.	.	.	.	–	.	+	+	.	.	I
Viola hirta	.	.	.	.	.	–	.	.	+	.	.	I
Quercetalia pubescentis, Quercetea pubescentis-petreae												
Sedum telephium ssp. *maximum*	.	+	.	.	.	I	+	+	+	.	+	IV
Quercus robur, reg.	.	+	+	.	.	II	.	.	.	.	+	I

Table 2 (continued): Prunetum tenellae Soó 1951 with samples from hills of Southern Transylvania (Sibiu County); 1-5 from slopes of the Visa Valley and 6-10 from Roșia and Vurpăr close to the Hârtibaciu Valley.

Number of columns	1	2	3	4	5		6	7	8	9	10	
Slope aspect	SW	SW	S	SE	SE		S	S	S	S	S	
Position on the hill slope	ups	ups	ups	ups	ups		ups	ups	ups	ups	ups	
Inclination of slope	10	30	30	45	45		40	40	45	45	40	
Cover %	1	80	75	75	70		85	80	85	75	75	
Locality	Sei	Sei	Sei	Ag	Ag		Vu	Vu	Ro	Ro	Ro	
Quercus petraea	.	.	.	.	+	I	.	.	+	.	.	I
Fraxinus ornus	2	+	.	.	.	II	.	.	2	.	.	I
Quercus pubescens	.	+	.	+	+	III	.	.	.	.	.	-
Salvia nemorosa	.	.	.	.	.	–	+	+	+	.	.	III
Pyrus pyraster	.	.	.	.	.	–	+	.	.	.	.	I
Other species												
Polygonatum verticillatum	.	+	.	+	.	II	.	.	.	.	.	-
Echinops sphaerocephalus	.	+	.	+	.	II	+	.	.	.	.	I
Convolvulus arvensis	.	.	+	.	+	II	.	.	.	.	.	-
Fagopyrum convolvulus	.	.	+	.	+	II	.	.	.	.	.	-
Camelina microcarpa	.	.	.	.	.	–	+	+	.	.	.	II
Daucus carota	.	.	.	.	.	–	+	+	.	.	.	II
Valerianella locusta	.	.	.	.	.	–	+	+	.	.	.	II
Plantago lanceolata	.	.	.	.	.	–	+	+	.	.	.	II
Viola arvensis	.	.	.	.	.	–	+	.	+	.	.	II
Rapistrum perenne	.	.	.	.	.	–	2	+	.	.	.	II
Galium mollugo	.	.	.	.	.	–	+	+	.	.	.	II

Species noted with "I" in one column: 3: *Knautia arvensis*; 6: *Achillea millefolium, Acinos arvensis, Arenaria serpyllifolia, Alyssum alyssoides, Centaurea scabiosa, Gentiana cruciata, Lepidium draba, Lithospermum arvense, Myosotis stricta (micrantha), Medicago minima, Poa pratensis, Potentilla argentea, Salvia verticillata;* 7: *Crepis setosa, Echinops sphaerocephalus, Lathyrus tuberosus, Lotus corniculatus;* 8: *Dianthus carthusianorum, Turritis glabra, Verbascum lychnitis*; 9: *Centaurea atropurpurea, Euphorbia virgata, Inula helenium;* 10: *Pinus sylvestris (*juv.*).*

Abbreviations in the table: Sei = Şeica Mare/Marktschelken, Ag = Agârbiciu/Arbegen (Sibiu County) – both on the left slopes of the Visa Valley; Vu = Vurpăr/Burgberg, Ro = Roşia/Rotberg (all Sibiu County); ups = upper part of the slope.

The Dwarf Almond bushes are included in the priority habitat type 40A0 Subcontinental peri-Pannonic scrub together with a number of other scrub and bush communities which fit more or less together according to their structure, but very different one from the other from a phytocoenological as well as an ecological point of view, and also their origin and geographical distribution.

Comparing only the association Alno incanae-Syringetum josikaeae (Borza, 1965) Raţiu et al. 1984 with a different ecology, distribution and phytocoenological affinity to the habitat type 91E0 subtype Alnion incanae (44.2) being part of an alluvial ecosystem, it is possible to see, how heterogeneous is the habitat type 40A0. From the point of view of the structure and geographical distribution the shibliac-type bush communities Syringo-Carpinion orientalis Jakucs 1959 and Syringo – Genistetum radiatae Maloş 1972 exceed largely the Pannonian basin and its surrounding area and have a more Mediterranean than continental character. Also, the distribution of Prunetum tenellae Soó 1951 exceeds considerably the peri-Pannonic area. Considering these facts we should raise the question as to whether the inclusion of such different types of scrub and shrubbery formations in the habitat type 40A0 is justified.

At the same time we have to ask the question about overlap of the habitat type 40A0* Subcontinental peri-Pannonic scrub and the habitat type 40C0* Ponto-Sarmatic deciduous thickets, as both include Dwarf Almond phytocoenoses and are both strongly interlocked with the habitat type 62C0* Ponto-Sarmatic steppe, including associations from the alliances Stipion lessingianae, Artemisio-Kochion and Festucion valesiacae, which occurs in the wooded steppe zone of the Pontic and Sarmatic regions and adjacent area and in resticted patches also in the forest steppe area of the Transylvanian Tableland (Csürös, 1963; Pascovşchi and Doniţă, 1967). If we compare the synthetic data with frequency values of the Dwarf Almond scrub from different regions of Transylvania and also those from Moldova (Tab. 3), it becomes clear that there are some differences concerning the status of the geographical variants. But in general the Dwarf Almond scrub communities from the Transylvanian Tableland and those of Moldova (Chifu et al., 2006) have to be included in the same unit of habitat type; they are similar and no characteristic and differential species of the phytocoenoses of Moldova can be stated on the basis of the comparative synthetic table. Only *Acer campestre* has the highest frequency in the samples from Moldova (Tab. 3, column 1). Even the Dwarf Almond bushes from the Dobrogea are included in the same habitat type (Doniţă et al., 2005), considering that the differences are only on the level of geographical variants. But for these scrub formations from the Northern and Southern Tableland of Dobrogea unfortunately no samples or synthetic tables are available.

In each case the naming of the habitat type 40A0 as peri-Pannonic scrub is less adequate for the unit as the name of Ponto-Pannonian shrubbery of Dwarf Almond (*Amygdalus nana*) given by Doniţă et al. (2005).

According to Brînzan (2013) the composition of the Dwarf Almond shrubs from the Dobrogea region are different from those of the Western part of the country, as many species, such as *Thymus zygoides*, *Koeleria lobata*, *Convolvulus cantabrica*, *Campanula romanica* and *Dianthus dobrogensis*, are distributed only in this part of the country. But these species can be considered as geographically differential species.

A differentiation of the Dwarf Almond scrublands of the country can be made only by comparing the associations described from the different regions. Including all samples from the whole country in one synthetic column (Chifu et al., 2014) cannot reflect the existing diversity of regional variants. Even between the Dwarf Almond phytocoenoses occurring in different sites of the Southern Transylvanian Tableland such as those from Visa Valley, on the hills of Sibiu/Guşteriţa, or those close to the Hârtibaci Valley and of the Râpa Roşi area near Sebeş Alba, visible differences can be seen (Tab. 2 and 3). The last one from Râpa Roşie site mentioned, on the border of the Secaş Tableland, has been described under the name Prunetum tenellae Soó 1951 var. sebesiense (Borza, 1959).

Table 3: Comparison of Small Almond associations (on the base of frequency values) from different parts of the country; synthetic table.

Number of columns	1	2	3	4	5	6	7	8
Locality	Mo	Cj	Vai	Gu	Vi	Ha	Fa	Bar
Number of samples included	15	8	6	6	5	5	5	13
Association								
Amygdalus nana	V	V	V	V	V	V	V	V
Prunion spinosae, Prunetalia								
Cerasus fruticosa	–	–	–	I	–	–	–	–
Viburnum lantana	–	–	–	–	II	–	–	–
Ligustrum vulgare	II	–	I	I	IV	III	I	–
Prunus spinosa	III	–	III	II	I	II	–	II
Rhamno-Prunetea								
Acer campestre	IV	–	–	I	–	–	–	–
Cornus sanguinea	I	–	–	–	–	IV	–	–
Crataegus monogyna	IV	II	III	I	III	IV	II	II
Rhamnus cathartica	I	–	–	I	–	I	–	–
Rosa canina	III	–	II	I	–	–	I	–
Rhamnus saxatilis ssp. tinctorius	I	–	–	–	–	III	–	II
Rosa gallica	I	II	–	–	–	–	III	
Evonymus verrucosa	–	–	–	–	–	II	–	–
Geum urbanum	II	–	–	–	–	–	–	–
Stipion lessingianae								
Aster oleifolius (=Aster villosus)	–	–	–	–	V	–	–	–
Peucedanum tauricum	–	–	–	–	IV	–	–	–
Vinca herbacea	–	II	–	V	V	II	–	–
Stipa pulcherrima	–	I	–	I	III	III	–	III
Cephalaria uralensis	–	I	II	–	II	II	–	–
Salvia nutans	–	II	–	–	I	–	–	III
Hypericum elegans	I	–	–	I	–	I	–	–
Viola collina	–	–	III	II	–	–	–	–
Stipa capillata	I	–	III	–	I	–	–	–
Stipa lessingiana	I	III	–	–	–	–	–	–
Crambe tataria	–	III	–	–	–	II	–	–
Salvia transsilvanica	–	–	–	–	–	–	III	–
Nepeta nuda	II	I	–	–	–	–	–	II
Allium denudatum (ammophilum)	–	–	II	–	–	–	–	–
Cirsio-Brachypodion								
Dorycnium herbaceum	I	IV	III	I	IV	II	–	–
Fragaria viridis	I	II	III	I	II	III	IV	IV
Inula ensifolia	II	II	V	–	I	III	–	–
Brachypodium pinnatum	I	I	–	–	I	–	–	–
Polygala major	–	I	–	–	–	I	–	–
Festucion valesiacae-Festucetalia								
Elymus hispidus	III	III	V	V	IV	IV	–	I
Stachys recta	III	–	V	III	II	V	–	IV
Festuca valesiaca	III	–	–	III	II	III	–	IV
Campanula sibirica	I	I	II	II	IV	II	II	II
Centaurea stoebe ssp. australis	I	-	I	II	I	II	–	III
Carex humilis	I	II	III	–	II	II	–	III
Verbascum phoeniceum	–	–	–	V	IV	V	–	–

Table 3 (continued): Comparison of Small Almond associations (on the basis of frequency values) from different parts of the country; synthetic table.

Number of columns	1	2	3	4	5	6	7	8
Locality	Mo	Cj	Vai	Gu	Vi	Ha	Fa	Bar
Number of samples included	15	8	6	6	5	5	5	13
Thymus pannonicus	–	–	–	I	IV	IV	–	I
Festuca rupicola	I	I	III	–	–	–	–	–
Jurinea mollis	–	I	–	I	I	II	–	I
Nonea pulla	–	I	–	I	II	I	–	I
Cytisus austriacus	I	–	–	–	II	I	–	I
Cytisus albus	–	II	–	–	–	–	–	–
Adonis vernalis	I	IV	–	–	III	–	–	II
Aster amellus	–	–	–	III	II	I	–	I
Seseli pallasii	–	–	–	–	II	II	–	–
Silene bupleuroides	–	–	–	I	–	I	–	–
Anchus barrelieri	I	I	–	–	–	–	–	I
Leontodon crispus ssp.crispus	–	I	–	II	–	–	–	I
Centaurea stoebe ssp.stoebe	–	II	II	–	–	–	–	–
Iris aphylla ssp. hungarica	–	I	–	–	–	III	–	–
Allium paniculatum ssp. fuscum	–	I	–	–	–	–	II	–
Veronica orchidea	–	–	V	–	–	–	–	II
Kengia (=Diplachne) serotina	–	–	–	–	IV	–	–	I
Allium flavum	–	–	–	–	III	–	–	–
Iris pumila	–	–		I	III	–	–	–
Achillea setacea	–	–	–	–	–	I	–	III
Euphorbia seguieriana	–	–	–	–	IV	–	–	–
Astragalus dasyanthus	–	–	–	–	II	–	–	–
Festuco-Brometea								
Teucrium chamaedrys	III	III	V	IV	IV	III	–	V
Medicago falcata	II	II	II	I	V	III	–	III
Falcaria sioides	I	III	–	III	IV	IV	IV	III
Thalictrum minus	II	I	I	II	–	III	IV	IV
Potentilla recta	I	I	III	III	–	II	–	III
Poa angustifolia	III	II	–	II	I	I	–	III
Eryngium campestre	I	I	III	I	III	I	–	-
Euphorbia cyparissias	–	III	V	IV	V	II	–	IV
Hypericum perforatum	I	II	II	IV	IV	III	–	II
Asperula cynanchica	I	I	V	II	IV	III	–	II
Dichantium ischaemum	I	I	III	I	–	–	–	III
Bupleurum falcatum	–	–	-	I	II	IV	IV	I
Artemisia campestris	–	–	II	IV	IV	III	II	I
Astragalus onobrychis	–	–	–	I	I	–	II	–
Aster linosyris	–	II	–	I	III	III	–	–
Potentilla arenaria	–	I	III	–	I	–	–	I
Galium glaucum	–	IV	–	–	–	III	–	V
Melica ciliata	I	–	–	I	I	I	–	–
Tragopogon dubius	–	–	–	–	IV	I	–	–
Linaria genistifolia	–	–	I	–	III	II	–	–
Veronica spicata	–	–	–	–	II	I	–	–
Salvia pratensis	–	I	–	–	II	I	–	II

Table 3 (continued): Comparison of Small Almond associations (on the basis of frequency values) from different parts of the country. Synthetic table.

Number of columns Locality	1 Mo	2 Cj	3 Vai	4 Gu	5 Vi	6 Ha	7 Fa	8 Bar
Number of samples included	15	8	6	6	5	5	5	13
Seseli annuum	–	–	–	–	I	I	–	–
Astragalus monspessulanus	–	III	II	–	–	II	–	–
Phleum montanum	–	I	–	II	–	II	–	V
Carex praecox	–	–	–	–	–	II	–	II
Melica transsilvanica	I	–	–	–	–	–	–	II
Alyssum alyssoides	–	–	III	IV	–	I	–	III
Allium sphaerocephalon	–	–	–	–	–	I	–	IV
Arenaria serpyllifolia	–	–	–	II	–	I	–	II
Achillea collina	I	–	III	I	–	–	–	–
Galium verum	II	II	–	–	–	–	–	I
Teucrium montanum	I	–	V	–	–	–	–	I
Acinos arvensis	–	–	III	–	–	I	–	–
Koeleria macrantha	I	I	–	III	–	–	–	II
Artemisia pontica	–	–	III	–	–	–	–	–
Achillea seidlii (pannonica)	I	II	–	–	I	–	–	–
Scabiosa ochroleuca	I	–	II	–	–	–	–	–
Thymus glabrescens	–	–	II	–	–	–	–	I
Isatis tinctoria	–	–	–	–	–	–	III	–
Cephalaria radiata	–	I	–	–	–	–	I	–
Geranion sanguinei	–	–	–	–	–	–	–	–
Geranium sanguineum	–	–	–	–	–	I	–	IV
Phlomis tuberosa	I	I	–	–	–	–	III	V
Peucedanum cervaria	I	–	–	–	–	II	–	–
Iris variegata	I	I	–	–	–	–	–	–
Vincetoxicum hirundinaria	I	–	–	–	–	–	–	II
Inula hirta	–	–	–	–	–	–	–	II
Origanietalia								
Agrimonia eupatoria	I	I	–	II	–	II	–	–
Asparagus officinalis	I	I	III	IV	II	IV	–	–
Origanum vulgare	I	–	–	–	–	II	–	I
Clinopodium vulgare	I	–	IV	II	II	I	–	–
Lavathera thuringiaca	I	–	–	–	–	-	II	II
Trifolio-Geranietea								
Coronilla varia	II	–	I	II	II	–	II	II
Dictamnus albus	I	I	III	–	I	–	–	IV
Inula conyza	–	–	–	–	II	–	–	–
Campanula bononiensis	–	–	–	–	I	II	–	–
Vicia tenuifolia	–	–	–	IV	–	–	–	I
Veronica austriaca	II	–	–	–	–	II	–	–
Viola hirta	I	I	–	–	–	I	–	–
Quercetea pubescentis s.l.								
Lithospermum purpureo-coeruleum	I	–	–	I	–	–	–	–
Quercus pubescens	–	–	–	–	III	–	–	–
Quercus petraea	–	–	–	–	II	I	–	–

Table 3 (continued): Comparison of Small Almond associations (on the basis of frequency values) from different parts of the country. Synthetic table.

Number of columns	1	2	3	4	5	6	7	8
Locality	Mo	Cj	Vai	Gu	Vi	Ha	Fa	Bar
Number of samples included	15	8	6	6	5	5	5	13
Quercus virgiliana	–	–	–	–	–	–	II	–
Salvia nemorosa	III	–	V	–	–	III	–	–
Sedum maximum	–	I	III	III	I	IV	II	II
Pyrus pyraster	–	I	I	–	–	I	–	–
Potentilla thuringiaca	–	I	–	–	–	–	–	II
Molinio-Arrhenatheretea								
Achillea millefolium	I	–	–	–	–	I	–	–
Daucus carota	I	–	III	–	–	–	–	II
Elymus repens	III	I	–	I	–	–	–	IV
Knautia arvensis	I	–	–	II	–	–	–	–
Plantago lanceolata	I	–	I	II	–	–	–	–
Dactylis glomerata	II	–	–	–	–	–	–	–
Galium mollugo	–	–	–	I	–	–	–	II
Plantago media	–	–	–	II	–	–	–	I
Other accompaining species								
Bromus inermis	I	–	–	–	–	–	–	II
Bromus arvensis	–	–	–	II	–	–	–	–
Crepis setosa	–	–	–	II	–	–	–	–
Poa compressa	I	–	II	–	–	–	–	–
Salvia verticillata	I	–	I	I	–	–	–	I
Artemisia absinthium	I	–	–	III	–	–	–	II
Artemisia vulgaris	I	–	–	I	–	–	–	–
Ballota nigra	I	–	–	I	–	–	–	–
Calamagrostis epigeijos	I	II	–	–	–	–	–	I
Galium aparine	–	–	–	II	–	–	–	I
Valerianella dentata	–	–	–	I	–	–	–	I
Myosotis arvensis	–	–	–	–	–	–	–	II
Helianthemum num.ssp.obscurum	–	–	–	–	–	–	–	III
Quercus robur	–	–	–	I	–	–	–	I
Lappula echinata	–	–	–	II	–	–	–	III
Anthemis tinctoria	–	–	–	–	–	–	–	II
Tragopogon dubius	–	–	–	II	–	–	–	–
Polygonatum verticillatum	–	–	–	–	II	–	–	–
Verbascum blattaria	–	–	–	–	–	–	III	–
Carduus candicans	–	–	–	–	–	–	II	–
Bromus commutatus	–	–	–	–	–	–	–	II
Melilotus officinalis	–	I	V	–	–	–	–	–
Linum tenuifolium	–	–	II	–	–	–	–	–
Thalictrum aquilegifolium	–	–	II	–	–	–	–	–
Brassica elongata	–	I	II	–	–	–	–	–

Species present only in one column with frequency “I “are not included **Mo** = Moldova (Valea lui David, Mititelu et al, 1969; Dealul Perchiu, Burduja et al. 1971; Vulturica-Popricani, Burduja et al. 1976; Ceornohal Reservation, Horeanu and Horeanu, 1981; Nature reserve Breana-Roşcani, Sîrbu et al., 1995, Nature Reserve Gârboavele-Galaţi, Sârbu et al., 1997); **Cj** = sites near Cluj (Soó 1951), **Vai** = Vaidacuta/Mureş County (Şuteu 1975), **Gu** = Guşterita/Sibiu (Schneider-Binder, 1972); **Vi** = Visa Valley (Schneider-Binder actual data of this paper, Tab. 2), **Ha** = sites near Hârtibaciu valley – Roşia and Vurpăr (Schneider-Binder data of this paper, Tab. 2), **Fa** = near Făgăraş at “Tâfla Dealului” and “Dosul Făgetului” (Roman, 1994), **Bar** = Southern part of Baraolt Mountains (Danciu, 1970).

CONCLUSIONS

In the studied area of the Transylvanian Tableland, well-structured Dwarf Almond shrub communities have been found and monitored over a longer period. It can be stated that these scrub areas – comparing them with older data – present a relatively stable floristic composition and structure, which is characterized by high biodiversity. It is a typical forest fringe community with a clear zonation in a shore of coenoses distributed along ecological gradients. In the sites studied we can presume that the Dwarf Almond bushes comprise part of a complex of edaphically conditioned forest steppe patches, strongly related to the restricted extent of Ponto-Sarmatic steppe associations of the Stipion lessinginae alliance (habitat type 62C0) that exist in the area.

Due to human intervention in the landscape the Dwarf Almond scrub has become rare and has disappeared in some places where it existed until a few decades ago. As they have become so rare, they require special conservation attention, and are now being included in the Natura 2000 network in the frame of the priority habitat type 40A0.

Dwarf Almond scrub is distributed in the continental and the steppe bio-region of Romania, the phytocoenoses from both bio-regions being similar to one another. Differences seen in some localities are at the level of geographical variants. More detailed studies are needed to elucidate the clear distribution limits of these variants.

Peri-pannonic scrub, as the name for this community, corresponds only with a part of the sites where the Dwarf Almond scrub occurs, with the more appropriate name being Pontic-Pannonic scrub, as the identifying species are mostly Eurasian-continental, Pontic-Pannonic and Pontic-Balcanic floristic elements with a distribution over a larger area. In each case, however, these Dwarf Almond communities are of biogeographical and phyto-historical interest and require more attention in the context of the European network of sites of community interest.

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CONSIDERATIONS REGARDING THE ROCKY HABITATS OF THE ROMANIAN CARPATHIANS

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KEYWORDS: Romania, saxicolous habitats, characteristics, typology, floristic structure, field data sheet, chorology.

ABSTRACT

This paper examines Romania's saxicolous habitats, in terms of structural types and bio-geographical sub-types, and their floristic and phyto-coenological characteristics, as well as the chorology of the Romanian Carpathians and adjacent areas. Six structural types of saxicolous habitats are highlighted (three being scree/detritus, two rocky slopes, one skeletal soils) and twelve bio-geographical sub-types (of which six are alpine, five continental, one steppic). The rock habitats in Romania are found for the most part in the alpine bio-region (the Carpathian range), some in the continental region (in gorges along rivers that reach the sub-mountainous, even the hill level) and most exceptionally in the steppe region (Măcin Mountains in North of Dobrudja; Canaraua Fetei in South of Dobrudja). Those habitats are fragmented and small in size; most are extremely inaccessible and thus enjoy a favourable state of preservation. In the description of samples being analysed, the field data sheet given below was employed.

REZUMAT: Considerații asupra habitatelor saxicole din Carpații României.

Lucrarea analizează habitatele saxicole din România pe tipuri structurale şi subtipuri biogeografice, particularităţile lor, caracteristicile floristice şi fitocenologice şi corologia în Carpaţii româneşti şi la periferia acestora. Sunt evidenţiate şase tipuri structurale de habitate saxicole (trei de grohotişuri, două de fisuri de stânci/versanţi stâncoşi şi unul de soluri scheletice) şi 12 subtipuri biogeografice (şase alpine, cinci continentale şi unul stepic). Habitatele de stâncării din România sunt localizate preponderent în bioregiunea alpină (lanţul carpatic), puţin în cea continentală (în chei cu râuri care intră până în etajul submontan şi chiar colinar) şi parţial în cea stepică (Munţii Măcin în nordul Dobrogei, Canaraua Fetei în sudul Dobrogei). Sunt fragmentate, de mici dimensiuni şi marea majoritate, sunt inaccesibile şi au o stare de conservare favorabilă. Pentru descrierea eşantioanelor cercetate s-a folosit fişa de teren inserată în lucrare.

ZUSAMMENFASSUNG: Betrachtungen zu den Felshabitaten der Karpaten Rumäniens.

In vorliegender Arbeit werden die Felslebensräume Rumäniens nach Strukturtypen und biogeographischen Subtypen, die floristischen und phytocoenologischen Charakteristika sowie die Chorologie in den rumänischen Karpaten und in deren Randgebieten analysiert. Es werden sechs Strukturtypen von Felshabitaten hervorgehoben und zwar drei Geröll-, zwei Felsspalten-und ein Skelettboden-Habitattyp sowie 12 biogeographische Subtypen, davon sechs alpine, fünf kontinentale und einer der Steppe. Die Felslebensräume Rumäniens kommen vorwiegend in der alpinen Bioregion der Karpaten vor, weniger in der kontinentalen, vor allem in Schluchten, die bis in die submontane und sogar bis in die kolline Stufe reichen. Zuweilen sind sie auch in der Steppen-Bioregion (Macin-Gebirge, Canaraua Fetei Schlucht in der Süddobrogea) anzutreffen. Sie kommen fragmentarisch vor, haben eine geringe Flächenausdehnung, sind größtenteils unzugänglich und weisen einen guten Erhaltungszustand auf. Für die Beschreibung der einzelnen Untersuchungsflächen wurde ein im methodischen Teil der Arbeit vorgestelltes Formblatt verwendet.

INTRODUCTION

Saxicolous habitats share a number of features, of which we shall mention the most important. Rock habitats in Romania lie mostly in the alpine bio-region (the Carpathian range), a few in the continental region (in gorges along rivers that reach the sub-mountaneous, even the hill level) and most exceptionally in the steppe region (Măcin Mountains in North of Dobrudja; Canaraua Fetei in South of Dobrudja); such habitats consist of scree/detritus and rocky slopes. As a rule, they are rather difficult or impossible to reach, therefore one cannot study them closely; conversely, the human impact – deterioration, destruction – is diminished. In other words, these have been preserved unaltered for centuries (particularly in the case of high-altitude habitats). Most saxicolous habitats enjoy a favourable state of preservation. Another particular feature is their fragmentary nature: they frequently cover 1-10 m^2 – such as a fissure, a ledge, a stretch of detritus. Also, they have poor plant species cover of and are hard to find or identify as such.

There are six types of saxicolous habitats in Romania: one in the alpine bio-geographical region, four in the alpine and continental regions, and one in the alpine, continental and steppe regions (Tab. 1).

Table 1: Romania saxicolous habitats, with denominations, codes and bio-geographical regions.

No.	Codes of habitats	Names of habitats	Biogeographic regions
1.	8110	Siliceous scree of the montane to snow levels (Androsacetalia alpinae and Galeopsidetalia)	ALP
2	8120	Calcareous and calcshist screes of the montane to alpine levels (Thlaspietea rotundifolii)	ALP, CON
3.	8160	* Medio-European calcareous scree of hill and montane levels	ALP, CON
4.	8210	Calcareous rocky slopes with chasmophytic vegetation (Potentilletalia caulescentis)	ALP, CON
5. .	8220	Siliceous rocky slopes with chasmophytic vegetation	ALP, CON
6.	8230	Siliceous rock with pioneer vegetation of the Sedo-Scleranthion or of the Sedo-albi-Veronicion dillenii	ALP, CON, STE

MATERIAL AND METHODS

In order to identify the saxicolous habitats of Romania, the bibliography attached was employed, and trips to most mountain massifs in the Carpathians were made, especially in the years 2012-2015.

For each type of habitat, the plant associations and the typical species have been established, for the sake of easy identification in the field. In other words, the floristic and phyto-coenological composition of every habitat has been determined.

A field data sheet was created, in which information was noted concerning location, geo-morphology, geology, phyto-coenology, disturbance factors, etc.

Much of the information in this paper was obtained via the author's work as an expert in the project "Monitoring of the state of preservation of Romanian species and habitats, Habitats Directive", funded by Programul Operaţional Sectorial Mediu (POS Mediu), Axa prioritară 4, SMIS-CSNR 17655.

RESULTS AND DISCUSSION

Using the specialised bibliography, a description was created for every type of saxicolous habitat, based on the relevant floristic and phyto-coenological composition (see below).

8110 Siliceous scree of the montane to snow levels (Androsacetalia alpinae and Galeopsidetalia)

Characteristic species:

Vascular cryptogams and phanerogams: *Androsace chamaejasme, Athyrium distentifolium, Festuca picta, Geum reptans, Luzula alpinopilosa, Minuartia sedoides, Oxyria digyna, Poa laxa, Ranunculus glacialis, Saxifraga bryoides, Saxifraga cymosa, Saxifraga carpathica, Saxifraga oppositifolia, Saxifraga moschata, Senecio carniolicus, Silene acaulis, Veronica baumgarteni*, etc.

Mosses: *Polytrichum alpinum, Polytrichum piliferum, Polytrichum sexangulare, Rhacomitrium lanuginosum*.

Lichens: *Cladonia* ssp., *Lecidea* ssp., *Rhizocarpon* ssp., *Umbilicaria* ssp., *Solorina crocea, Stereocaulon alpinum, Thamnolia vermicularis.*

Associations:

Festucetum pictae Krajina, 1933 (syn.: Festuco pictae-Senecionetum carniolicae Lungu and Boşcaiu 1981), Poo contractae-Oxyrietum digynae Horvat et al. 1937 (syn. as. Oxyria digyna with Geum (Sieversia) reptans Puşcaru et al. 1956, as. Oxyria digyna with Poa nyárádyana (Simon n.n.) Csűrös, 1957), Saxifragetum carpathicae-cymosae Coldea (1986) 1990, Saxifrago bryoidis-Silenetum acaulis Boşcaiu et al., 1977, Saxifrago carpathicae-Oxyrietum digynae Pawł et al., 1928, (syn.: Oxyrietum digynae auct. rom. non. Br.-Bl. 1926), Sileno acaulis-Minuartietum sedoidis Puşcaru et al., 1956, Veronico baumgartenii-Saxifragetum bryoidis Boşcaiu et al., 1977.

8120 Calcareous and calcareous schist screes of the montane to alpine levels (Thlaspietea rotundifolii)

Characteristic species:

Vascular cryptogams and phanerogams: *Acinos alpinus (Calamintha baumgarteni), Arabis alpina, Cardaminopsis neglecta, Cerastium arvense* ssp. *calcicolum (C. arvense* ssp. *molle), Cerastium lerchenfeldianum, Cerastium transsilvanicum, Cystopteris alpina, Doronicum carpaticum, Doronicum columnae, Erytrichum nanum, Festuca violacea, Galium lucidum, Galium anisophyllum, Geranium macrorhizum, Linaria alpina, Papaver pyrenaicum* ssp. *corona sancti-stephani, Parietaria officinalis Pritzelago alpina, Rumex scutatus, Saxifraga aizoides, Saxifraga moschata, Sedum fabaria, Teucrium montanum, Thymus comosus* and *Viola alpina*, etc.

Mosses: *Dicranum* sp., *Encalypta ciliata, Leskeela nervosa, Syntrichia montana*

Lichens: *Alectoria ochroleuca, Thamnolia vermicularis.*

Associations:

Acino-Galietum anisophylli Beldie 1967 (syn. as. Calamintha baumgartenii with Galium anisophyllum Beldie 1967), Cardaminopsio neglectae-Papaveretum Coldea and Pânzaru 1986 (Papavero-Festucetum violaceae Beldie 1967), Cerastio calcicolae-Saxifragetum moschatae Coldea (1986) 1990, Cerastio lerchenfeldiani-Papaveretum Boşcaiu et al. 1977 (syn. Papavereto-Cystopteridetum Csűrös et al. 1956, Papavero-Linarietum alpinae Puşcaru et al. 1956, as. Papaver pyrenaicum with Viola alpina Puşcaru et al. 1981), Cerastio transsilvanici-Galietum lucidi Boşcaiu et al. 1996; Doronico columnae-Rumicetum scutati Boşcaiu 1977 (syn.: Rumicetum scutatii auct. rom.), Galio-Hirundinarietum Dihoru 1975 (syn. Vincetoxicetum officinalis Schwick 1944 p.p.), Parietarietum officinalis Csűrös 1958, Saxifragetum moschatae-aizoidis Boşcaiu 1971, Sedo fabariae-Geranietum macrorrhizi Boşcaiu and Täuber 1977, Thymo comosi-Galietum albi Sanda and Popescu 1999 (syn. Thymetum comosi Pop and Hodişan 1963, Galietum erecti Pop and Hodişan 1964, Teucrietum montani Csűrös 1958).

8160 * Medio-European calcareous scree of hill and montane levels

Characteristic species:

Vascular cryptogams and phanerogams: *Achnatherum calamagrostis, Acinos arvensis, Anthericum ramosum, Asplenium (Phyllitis) scolopendrium, Calamagrostis varia, Cardaminopsis arenosa, Carduus defloratus, Chaenorhinum minus, Cystopteris fragilis, Galeopsis angustifolia, Galeopsis ladanum, Geranium robertianum, Gymnocarpium robertianum, Melica ciliata, Rumex scutatus, Teucrium botrys, Vincetoxicum hirundinaria*, etc.

Mosses: *Abietinella abietina, Barbilophozia barbata, Campylium chrysophyllum, Ctenidium molluscum, Ditrichum flexicaule, Encalypta streptocarpa, Grimmia pulvinata, Homalothecium sericeum, Orthotrichum anomalum, Rhytidium rugosum, Schistidium apocarpum, Tortella tortuosa*.

Lichens: *Aspicilla (Lecanora) calcarea, Aspicilla (Lecanora) contorta, Caloplaca saxicola, Caloplaca variabilis, Candelariella aurella, Cladonia pocillum (Cladonia pyxidata* var. *pocillum), Cladonia rangiformis, Lecanora albescens, Peltigera praetexata, Peltigera rufescens, Verrucaria nigrescens*.

Associations:

Achnatheretum calamagrostis Br.-Bl. 1918, Gymnocarpietum robertianae Kaiser 1926 (syn. Dryopteridetum robertianae (Kuhn 1937) Tüxen 1937, Thymo marginati-Phegopteridetum robertianae Csűrös and Csűrös Káptalan 1966).

8210 Calcareous rocky slopes with chasmophytic vegetation (Potentilletalia caulescentis)

Characteristic species:

Vascular cryptogams and phanerogams: *Achillea schurii, Alyssum montanum, Androsace lactea, Artemisia eriantha (Artemisia petrosa), Asplenium ruta-muraria, Asplenium trichomanes, Asplenium viride, Asplenium lepidum, Asplenium scolopendrium (Phyllitis scolopendrium), Biscutella laevigata, Campanula carpatica, Campanula crassipes, Campanula cochlearifolia, Ceterach officinarum, Cystopteris fragilis, Draba aizoides, Draba dorneri, Draba haynaldii, Draba kotschyi, Draba lasiocarpa, Draba stellata* ssp. *simonkaiana, Edraianthus kitaibelii, Erysimum crepidifolium, Festuca pallens, Gypsophila petraea, Hieracium bifidum, Hieracium glaucinum, Hieracium schmidtii, Kernera saxatilis, Poa rehmanii, Saxifraga cuneifolia, Saxifraga luteo-viridis, Saxifraga marginata* ssp. *rocheliana, Saxifraga moschata, Saxifraga mutata* ssp. *demissa, Sedum dasyphyllum, Sesleria filiifolia, Sesleria varia, Silene petraea, Silene zawadski, Thymus pucherrimus, Valeriana sambucifolia*, etc.

Mosses: *Anomodon viticulosus, Ctenidium molluscum, Distichum capillaceum, Encalypta streptocarpa, Grimma orbicularis, Grimma tergestina, Gymnostomum aeruginosum, Homalothecium lutescens, Homalothecium sericeum, Metzgeria conjugata, Neckera crispa, Porella (Madotheca) platyphylla, Scapania aspera, Seligeria calcarea, Tortella inclinata, Zygodon viridissimum*.

Lichens: *Aspicillia (Lecanora) calcarea, Aspicilia (Lecanora) contorta, Buellia epipolia, Caloplaca decipiens, Caloplaca saxicola (Caloplaca murorum), Caloplaca teicholyta, Collema auriforme (Collema auriculatum), Collema tenax, Dermatocarpon miniatum, Lecanora albescens, Lecanora campestris (Lecanora subfusca* var. *campestris), Lecanora dispersa, Leptogium lichenoides, Placynthium nigrum, Protoblastenia rupestris, Verrucaria nigriscens*.

Associations:

Achilleo schurii-Campanuletum cochleariifoliae Fink 1977, Artemisio petrosae-Gypsophiletum petraeae Puşcaru et al. 1956, Asplenietum trichomanis-rutae-murariae Kuhn 1937, Tüxen 1937 (syn. Tortulo-Asplenietum Tüxen 1937), Asplenio-Ceterachetum Vives 1964, Asplenio-Cystopteridetum fragilis Oberd. (1936) 1949, Asplenio quadrivalenti-Poëtum nemoralis Soó ex Gergely et al. 1966, Asplenio-Schivereckietum podolicae Mititelu et al. 1971, Asplenio-Silenetum petraeae Boşcaiu 1971, Campanuletum crassipedis Borza ex Schneider-Binder et al. 1970, Ctenidio-Polypodietum Jurko and Peciar 1963; Drabo lasiocarpae-Ceterachetum (Schneider-Binder 1969) Peia 1978, Saxifrago demissae-Gypsophiletum petraeae Boşcaiu and Täuber 1977, Saxifrago luteo-viridis-Silenetum zawadzkii Pawł and Walas 1949, Saxifrago moschatae-Drabetum kotschyi Puşcaru et al. 1956, Saxifrago rochelianae-Gypsophiletum petraeae Boşcaiu et al. 1977, Sileno zawadzkii-Caricetum rupestris Täuber 1987, Thymo pulcherrimi-Poëtum rehmanii Coldea (1986) 1990.

8220 Silceous rocky slopes with chasmophytic vegetation

Characteristic species:

Vascular cryptogams and phanerogams*: Asplenium adiantum-nigrum, Asplenium cuneifolium, Asplenium septentrionale, Asplenium trichomanes, Dianthus henteri, Jovibarba heuffelii (Sempervivum heuffelii), Polypodium vulgare, Potentilla haynaldiana, Rhodiola rosea (Sedum roseum), Saxifraga pedemontana* ssp. *cymosa, Sedum telephium, Senecio glaberrimus, Silene dinarica, Silene lerchenfeldiana, Symphyandra wanneri, Veronica bachofeni, Woodsia alpina, Woodsia ilvensis,* etc.

Mosses: *Amphidium mougeotii, Andreaea rupestris, Barbilophozia barbata, Barbilophozia lycopodioides, Bartramia pomiformis, Batramia ithyphylla, Bartramia halleriana, Bazzania trilobata, Diplophyllum albicans, Frullania tamarisci, Grimmia laevigata, Grimmia montana, Grimmia trichophylla, Hedwigia ciliata, Paraleucobryum longifolium, Rhacomitrium heterostichum, Rhacomitrium sudeticum, Schistostega pennata.*

Lichens: *Acarospora fuscata, Candelariella vitellina, Chrysothrix chlorina, Diploschistes scruposus, Lasallia pustulata, Lecanora polytropha, Lecidea (Lecanora) confluens, Lecidea fuscoatra, Lepraria incana, Parmelia conspersa, Parmelia saxatilis, Pertusaria corallina, Protoparmelia (Parmelia) badia, Rhizocarpon alpicolum, Rhizocarpon geographicum, Rhizocarpon obscuratum, Tephromela atra, Umbillicaria cylindrica, Umbillicaria deusta, Umbillicaria hirsuta, Umbilicaria polyphylla.*

Associations:

Asplenietum septentrionalis-adianti-nigri Oberd. 1938, Asplenietum septentrionalis Schwick 1944, Asplenio trichomanis-Poëtum nemoralis Boşcaiu 1971, Diantho henteri-Silenetum lerchenfeldianae Stancu 2000, Hypno-Polypodietum Jurko and Peciar 1963, Sempervivetum heuffelii Schneider-Binder 1969, Senecio glaberrimi-Silenetum lerchenfeldianae Boşcaiu et al. 1977, Silenetum dinaricae Schneider-Binder and Voik 1976, Sileno lerchenfeldianae-Potentilletum haynaldianae (Horvat et al. 1937) Simon 1958, Woodsio ilvensis-Asplenietum septentrionalis Tüxen 1937 (inclusive subas. dianthetosum henteri (Schneider-Binder 1972) Drăgulescu 1988).

8230 Siliceous rock with pioneer vegetation of the Sedo-Scleranthion or of the Sedo-albi-Veronicion dillenii

Characteristic species:

Vascular cryptogams and phanerogams: *Aira caryophyllea, Allium montanum, Anthericum liliago, Arenaria serpyllifolia, Artemisia campestris, Cerastium brachypetalum, Cerastium glutinosum, Cerastium pumilum, Cerastium semidecandrum, Erophila verna (Draba verna), Festuca pallens, Festuca rupicola, Filago arvensis, Gagea bohemica, Gagea saxatilis, Galium pumilum, Hieracium pilosella, Holosteum umbellatum, Jovibarba heuffelii (Sempervivum heuffelii), Lactuca perennis, Myosotis ramosissima, Myosotis stricta, Petrorhagia prolifera, Potentilla argentea, Rumex acetosella, Saxifraga tridactylites, Scleranthus perennis, Scleranthus polycarpos, Sedum acre, Sedum album, Sedum annuum, Sedum rupestre, Sedum sexangulare, Sempervivum montanum, Silene nutans, Silene rupestris, Silene viscaria, Thymus pulegioides, Trifolium arvense, Trifolium striatum, Veronica dilenii, Veronica fruticans, Veronica verna, Vulpia myuros,* etc.

Mosses: *hythecium albicans, Ceratodon purpureus, Grimmia ssp., Hedwigia ciliata, Pleuridium subulatum, Polytrichum piliferum, Ptilidium ciliare, Rhytidium rugosum, Riccia ciliifera, Tortula muralis, Tortula ruraliformis (Tortula ruralis* ssp. *ruraliformis).*

Lichens: *Cetraria aculeata (Cornicullaria tenuissima), Cladonia foliacea, Cladonia furcata, Cladonia gracilis, Cladonia pyxidata, Parmelia omphalodes, Parmelia saxatilis, Peltigera praetexata, Peltigera rufescens.*

Associations:

Polytricho piliferi-Scleranthetum perennis Moravec 1967, Sileno rupestris-Sedetum annuui Oberd. 1957, Vulpio-Airetum capillaris Paucă 1941.

Samples of saxicolous habitats have been identified in almost all the mountain massifs in Romania (Tab. 2).

Table 2: The chorology of saxicolous habitats – considering bio-geographical and mountain massifs.

No.	Saxicolous habitats	Biogeographic regions	Chorology
1.	8110 Siliceous scree of the montane to snow levels (Androsacetalia alpinae and Galeopsidetalia)	ALP	Maramureş Mountains (Farcău Mountain), Ţibleş Mountains (Arcer Peak and Ţibleş Peak), Mountains Rodnei (Anieşu Mare, Galaţiu, Pietrosu Mare, Puzdra Peak and Rebra Peak), Suhard Mountain, Ciucaş Mountain, Bucegi Mountains (Bucşoiu, Caraiman, Coştila and Omu peaks), Făgăraş Mountains (Arpăşel, Bâlea, Capra, Negoiu Peak), Cozia Mountain, Cindrel Mountains (Iezeru Mare, Iezeru Mic), Căpăţânei Mountains (Vânturariţa and Vioreanu peaks), Parâng Mountains (Câlcescu, Coasta lui Rus, Gruiu and Mândra peaks), Mehedinţi Mountains (Gaura Mohorului), Retezat Mountains (Bucura, Custura and Peleaga peaks, Pietrele), Vâlcan Mountains (Oslea), Ţarcu-Godeanu-Cernei Mountains (Cleanţul Ilovei, Groapa Bistrei, Obârşia Hidegului, Ţarcu Peak), Apuseni Mountains (Cepelor Valley, Vlădeasa Peak).
2.	8120 Calcareous and calcshist screes of the montane to alpine levels (Thlaspietea rotundifolii)	ALP	Rarău-Giumalău Mountains (Rarău Peak), Rodna Mountains (Ineu, Negoiescu Mare and Pietrosu peaks), Bicaz Gorges, Siriu Mountains (Siriu Peak), Ciucaş Mountains (Ciucaş Peak), Bucegi Mountains (Creasta Bucura, Omu Peak), Leaota Mountains (Cheii Gorges, Dâmboviţei Gorges), Piatra Craiului Mountains (Crăpăturii Valley, Marele Grohotiş, Piatra Craiului Mică), Piatra Mare, Mountain, Postăvaru Mountain, Făgăraş Mountains (Arpăşel, Doamnei Valley, Netedu Peak), Lotru Mountains (Căprăreţ Valley, Lotrioarei Valley, Târnovu Mare Mountain), Buila-Vânturariţa Mountains, Retezat Mountains (Piatra Iorgovanului, Piule), Ţarcu-Godeanu-Cernei Mountains (Ciuceava Mare, Gura Zlata, Ţarcu Peak), Apuseni Mountains (Boga Valley), Trascău Mountains (Bedeleu Mountain, Feneşului Valley, Întregalde Gorges), Gilău Mountains (Muntele Mare, Râmeţ Gorges), Bihor Mountains (Bulzeşti Gorges, Sighiştelului Valley), Metaliferi Mountains (Crăciuneşti Gorges), Pădurea Craiului Mountains (Crişului Repede Defile, Iad Valley).
3.	8120 Calcareous and calcshist screes of the montane to alpine levels (Thlaspietea rotundifolii)	CON	Tălmaciu-Podul Olt, Ţarcu-Godeanu-Cernei Mountains (Bedinei Gorge, Bela Reca Valley, Cernei Valley at Bobot), Caraşului Gorges, Porţile de Fier, Turzii Gorges, Vadu Crişului.

Table 2 (continued): The chorology of saxicolous habitats – considering bio-geographical and mountain massifs.

No.	Saxicolous habitats	Biogeographic regions	Chorology
4.	8160 * Medio-European calcareous scree of hill and montane levels	ALP	Leaota Mountains (Cheii Gorges, Dâmboviţei Gorges Ghimbavului Gorges), Cernei Mountains (Curmătura Paltina), Bihor Mountains (Vidra-Avram Iancu).
5.	8160 * Medio-European calcareous scree of hill and montane levels	CON	Cernei Valley (Bedinei Gorge, Prisăcinei Gorge).
6.	8210 Calcareous rocky slopes with chasmophytic vegetation (Potentilletalia caulescentis)	ALP	Rarău-Giumalău Mountains (Pietrele Doamnei), Ţibleş Mountains (Arsu Mountain), Rodnei Mountains (Corongiş Peak Piatra Rea, Pietrosu Peak), Ceahlău Peak, Suhard Mountain, Bicazului Gorges, Hăşmaşu Mare Mountain, Vrancei Mountains (Tişiţei Gorges), Bistriţei Aurii Valley, Trotuşului Valley, Ciucaş Mountains (Tigăile, Piroşca), Bucegi Mountains (Lespezi, Jepii Mici), Piatra Craiului Mountains (Piatra Craiului Mică, Şaua Crăpăturii), Piatra Mare Mountain, Postăvaru Mountain, Leaota Mountain, Iezer-Păpuşa Mountains (Cheii Gorges, Ghimbavului Gorges), Făgăraş Mountains (Arpăşel, Avrig Lake, Ciortea Peak, Jgheabul Văros, Podragului Valley at Turnuri), Lotrului Mountains (Târnovu Mare), Buila-Vânturariţa Mountains (Bistriţei Gorges), Retezat Mountains (Piatra Iorgovanului, Piule), Ţarcu, Godeanu-Cernei Mountains (Arjana Peak, Cleanţul Ilovei, Custura Gropii Bistrei, Obârşia Hidegului), Mehedinţi Mountains (Piatra Cloşanilor), Apuseni Mountains (Piatra Bulzului, Piatra Singuratică), Trascău Mountains (Galdei Valley, Piatra Ceţii).
7.	8210 Calcareous rocky slopes with chasmophytic vegetation (Potentilletalia caulescentis)	CON	Stânca Ştefăneşti, Cernei Mountains (Băile Herculane, Bedinei Gorge, Drăstănicului Gorge, Priscăcinei Gorge), Mehedinţi Mountains (Ţesnei Valley), Buila-Vânturariţa Mountains (Bistriţei Gorges), Aninei Mountains (Caraşului Gorges), Almăjului Mountains (Cazanele Dunării), Porţile de Fier, Apuseni Mountains (Aiudului Gorges, Avram Iancu, Baldovin in Bulzeşti Valley, Băcâia, Cibului Gorges, Crişului Repede Defile, Măzii Gorges, Turzii Gorges), Pădurea Craiului Mountains (Albioarei Gorges, Şuncuiuş in Mişid Valley).

Table 2 (continued): The chorology of saxicolous habitats – considering bio-geographical and mountain massifs.

No.	Saxicolous habitats	Biogeographic regions	Chorology
8.	8220 Siliceous rocky slopes with chasmophytic vegetation	ALP	Gutâi Mountains, Rodnei Mountains, Călimani Mountains (Haitii Valley), Vrancei Mountains (Tişiţei Gorges), Nemira Mountains, Siriu Mountain (Colţii Balei), Piatra Craiului Mountains (Dâmbovicioarei Gorges, Prăpăstiile Zărneştilor), Iezer-Păpuşa Mountains (Ghimbavului Gorges, Peştera Urşilor), Leaota Mountains, Mountains Făgăraş (Suru Peak on Fruntea Moaşei, Şerbota Valley), Cozia Mountains (Cozia Peak), Parâng Mountains, Cindrel Mountains (Dealu Grosu, Fundu Râului, Râul Mare), Căpăţânii Mountains (Buila, Vânturariţa), Lotru Mountains (Călineşti Valley, Masa Verde, Lotrioara Valley, Căprăreţ Valley), Sebeşului Mountains (Oaşa at Stăvilar, Tărtărău, Tău), Retezat Mountains (Faţa Retezatului, Gemenele), Ţarcu-Godeanu Mountains (Custura Mătaniei, Piga Peak), Apuseni Mountains (Vlădeasa in Drăganului Valley), Gilău Mountains (Râmeţului Valley, Scăriţa-Belioara), Bihor Mountains (Ordâncuşei Gorges), Trascău Mountains (Feneşului Gorges), Codru-Moma and Metaliferi mountains, Pădurea Craiului Mountains (Crişului Repede Defile, Iadului Valley).
9.	8220 Siliceous rocky slopes with chasmophytic vegetation	CON	Cozia Mountains (Călineşti Valley, Cozia Peak), Turnu Roşu Defile at Fântâna Împăratului), Orlat, Boiţa in Olt Defile, Eşelniţa, Mraconia, Porţile de Fier, Apuseni Mountains (Băcâia Gorges, Cibului Gorges, Crişului Repede Defile, Curături, Feneşului Gorges, Iadului Valley, Mada Gorges, Ordâncuşei Gorges, Râmeţului Valley, Vadu Crişului).
10.	8230 Siliceous rock with pioneer vegetation of the Sedo-Scleranthion or of the Sedo-albi-Veronicion dillenii	ALP	Maramureşului Mountains (Cisla Valley), Mehedinţi Mountains (Ţesnei Valley), Codru-Moma Mountains, Plopiş Mountains.
11.	8230 Siliceous rock with pioneer vegetation of the Sedo-Scleranthion or of the Sedo-albi-Veronicion dillenii	CON	Băile Herculane, Cazanele Mari, Dunării Defile, Dubova, Eşelniţa Valley – Mraconiei Valley, Plavişeviţa, Sviniţa-Tricule, Mountains Locvei, Apuseni Mountains (Turzii Gorge).

Table 2 (continued): The chorology of saxicolous habitats – considering bio-geographical and mountain massifs.

No.	Saxicolous habitats	Biogeographic regions	Chorology
12.	8230 Siliceous rock with pioneer vegetation of the Sedo-Scleranthion or of the Sedo-albi-Veronicion dillenii	STE	Măcin Mountains (Cheia, Greci)

CONCLUSIONS

In Romania, there are six structural types of saxicolous habitats: three being scree/detritus-based, two rock-fissure/rocky slopes, and one skeletal soils. If their bio-geographical distribution is taken into account, twelve sub-types result: six being alpine, five continental, and one steppic.

It should be specified that from around 50 associations of screes and of rocky slopes mentioned from the Romanian Carpathians more than a third are rare or endemic. These are, for example:

– in the habitat type 8110 Siliceous screes of the montane to snow levels (Androsacetalia alpinae and Galeopsidetalia) the associations: Saxifragetum carpathicae-cymosae Coldea (1986) 1990, Saxifrago bryoidis-Silenetum acaulis Boşcaiu et al. 1977 and Veronico baumgartenii-Saxifragetum bryoidis Boşcaiu et al. 1977;

– in the habitat type 8120 Calcareous and calcareous schist screes of the montane to alpine levels (Thlaspietea rotundifolii) the associations: Cardaminopsio neglectae-Papaveretum Coldea et Pânzaru 1986 and Cerastio lerchenfeldiani-Papaveretum Boşcaiu et al. 1977;

– in the habitat type 8160* Medio-European calcareous screes of hill and montane levels the association: Achnatheretum calamagrostis Br.-Bl. 1918;

– in the habitat type 8210 Calcareous rocky slopes with chasmophytic vegetation (Potentilletalia caulescentis) the associations: Achilleo schurii-Campanuletum cochleariifoliae Fink 1977, Asplenio-Schivereckietum podolicae Mititelu et al. 1971, Asplenio-Silenetum petraeae Boşcaiu 1971, Campanuletum crassipedis Borza ex Schneider-Binder et al. 1970, Drabo lasiocarpae-Ceterachetum (Schneider-Binder 1969) Peia 1978, Saxifrago demissae-Gypsophiletum petraeae Boşcaiu and Täuber 1977, Saxifrago moschatae-Drabetum kotschyi Puşcaru et al. 1956, Saxifrago rochelianae-Gypsophiletum petraeae Boşcaiu et al. 1977, Sileno zawadzkii-Caricetum rupestris Täuber 1987 and Thymo pulcherrimi-Poëtum rehmanii Coldea (1986) 1990;

– in the habitat type 8220 Siliceous rocky slopes with chasmophytic vegetation the associations: Diantho henteri-Silenetum lerchenfeldianae Stancu 2000, Senecio glaberrimi-Silenetum lerchenfeldianae Boşcaiu et al. 1977, Sileno lerchenfeldianae-Potentilletum haynaldianae (Horvat et al. 1937) Simon 1958 and Woodsio ilvensis-Asplenietum septentrionalis Tüxen 1937 (inclusiv subas. dianthetosum henteri (Schneider-Binder 1972) Drăgulescu 1988).

The rare or endemic associations mentioned highlight the particularity of rocky habitats and their specific biodiversity in the Carpathian mountains, being of great interest from the point of view of phyto-geography.

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LAND SNAIL COMMUNITIES FROM CHEILE OLTEŢULUI NATURE RESERVE

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KEYWORDS: land snail fauna, biodiversity, conservation, Cheile Olteţului, Polovragi, Southern Carpathians, Romania.

ABSTRACT

A number of 48 land snail species were identified, 45 of which have been recorded in the riparian area and 28 in the forest. The land snail community from the riparian areas is dominated by the following species: *Carychium tridentatum, Spaeleodiscus triarius, Alopia hildegarde, Granaria frumentum, Faustina faustina,* while the beech forest is populated mostly by species such as: *Aegopinella pura, Laciniaria pseudostabilis, Vitraea transsilvanica, Carychium tridentatum* and *Monachoides vicinus.* The considerably highest diversity found in the riparian area is due to the diversity of habitat conditions and to the presence of shelters. Also, the proximity of the river and the small distance between the limestone walls facilitate keeping the moisture in the area. Among the species of conservative interest we are underlining the presence of *Alopia hildegarde*, an endemic species present only in this nature reserve; as well as *Drobacia banatica*, a species officially listed in the Annex II of EU Habitats Directive.

REZUMAT: Comunităţi de gastropode terestre din Parcul Natural Cheile Olteţului.

Au fost identificate 48 specii de gastropode terestre, dintre care 45 specii sunt prezente în zona ripariană şi 28 în zona forestieră. Comunitatea de gastropode terestre din zona ripariană este dominată de către *Carychium tridentatum, Spaeleodiscus triarius, Alopia hildegarde, Granaria frumentum* şi *Faustina faustina,* în timp ce pădurea de fag este populată în primul rând de către *Aegopinella pura, Laciniaria pseudostabilis, Vitraea transsilvanica, Carychium tridentatum* şi *Monachoides vicinus.* Diversitatea considerabil mai mare găsită în zona ripariană se datorează diversităţii condiţiilor de habitat şi prezenţei adăposturilor. De asemenea, vecinătatea râului şi distanţa redusă dintre versanţi favorizează păstrarea umidităţii în această zonă. Printre speciile de interes conservativ identificate în zona de referinţă menţionăm *Alopia hildegarde*, endemit al zonei calcaroase străbătută de râul Olteţ şi *Drobacia banatica*, specie listată în Anexa II a Directivei Habitate.

RÉSUMÉ: Communautés de gastéropodes terrestres de la Réserve naturelle Cheile Olteţului.

48 espèces de gastéropodes terrestres ont été identifiées, parmi lesquelles 45 espèces sont présentes dans la région riveraine, et 28 dans la forêt. La communauté des gastéropodes terrestres de la région riveraine est dominée par *Carychium tridentatum, Spaeleodiscus triarius, Alopia hildegarde, Granaria frumentum, Faustina faustina,* tandis que la forêt de hêtres est peuplée principalement par *Aegopinella pura, Laciniaria pseudostabilis, Vitraea transsilvanica, Carychium tridentatum* et *Monachoides vicinus.* La diversité la plus importante que l'on retrouve dans la zone riveraine est due à la diversité des conditions d'habitat et à la présence d'abris. La proximité de la rivière et la distance réduite entre les pentes favorisent également la rétention d'eau. Parmi les espèces d'intérêt conservatif on mentionne, *Alopia hildegarde,* endémique locale, et *Drobacia banatica,* espèce de l'Annexe II de la Directive Habitats.

INTRODUCTION

In karst areas, the diversity of the relief and the nature of substrate offer a variety of shelters and favourable conditions for the presence of land snails. It is generally accepted that the calcareous habitats in these locations harbour a large diversity of land snails and offer the needed amount of calcium for their shells and eggs (Kerney and Cameron, 1979; Nekola, 1999; Horsák, 2006). In limestone gorges, the combination of the two most important requirements for land snails, calcium and water, favour the development of these animals and generate highly diverse communities and/or large populations.

The Olteţului Gorges are located at the limit of two mountains in the Southern Romanian Carpathians, the Parâng and Căpăţânii Mountains. The water of the Olteţ River has dug deep into the Jurassic limestone, one of the steepest, narrowest and spectacular gorges in Europe. The valley in this gorges is about three km long, 30-50 m large, and limited by vertical limestone walls frequently above 100 m high (Posea, 1982). The karst area crossed by Olteţ River has 46 caves, among them Polovragi Cave is one of the longest in Romania with 9,171 m (Grigore, 1989). The gorges and the Polovragi Cave are part of the same protected area, included in Nordul Gorjului de Est Natura 2000 Site. The information regarding the land snails in the area is poor and dates back over fifty years. Most of the references are included in the monograph of the Romanian gastropods (Grossu, 1981, 1983, 1986, 1987), but also in several older works (Bielz, 1867; Kimakowicz, 1883, 1884, 1890, 1894). Some information can also be found in the M. v. Kimakowicz collection from the Natural History Museum of Sibiu. As for most of the common species, not all of their localities are given; this information is generally not suitable for comparison with the present situation, except some rare species which benefit of more accurate information regarding their past distribution.

The present paper aims to make a contribution to the assessment of biodiversity in a protected area, Cheile Olteţului Nature Reserve, in order to complete the information for an effective management plan.

MATERIAL AND METHODS

Semi quantitative samples were taken in 2013 and 2014, in two types of habitats: the beech forest that surrounds the gorges and the riparian area inside the gorges where both forest habitats and limestone rocks were considered.

A number of 15 sampling points were selected (eight in the riparian area and seven in the forest), and a standardized effort method was used in each sampling point in order to estimate the land snail community structure through species' relative abundance (Pokryszko and Cameron, 2005). Snails were collected from plots of 100 m^2, by two people for one hour. Additionally, 20 l of leaf litter was sieved. In the absence of leaf litter, about 4 l of topsoil was collected. The soil and litter samples were then sorted in order to complete the species list along with the minute species. Due to the fact that on calcareous substrate the shells generally have high persistence, only the living snails and fresh empty shells were considered.

The location of the studied gorges and the sampling area is presented in figure 1.

RESULTS AND DISCUSSION

In the researched area, a total of 48 land snail species were recorded (Tab. 1), among them 46 species were present in the sampling points inside the gorges, and 32 species in the beech forest surrounding the gorges.

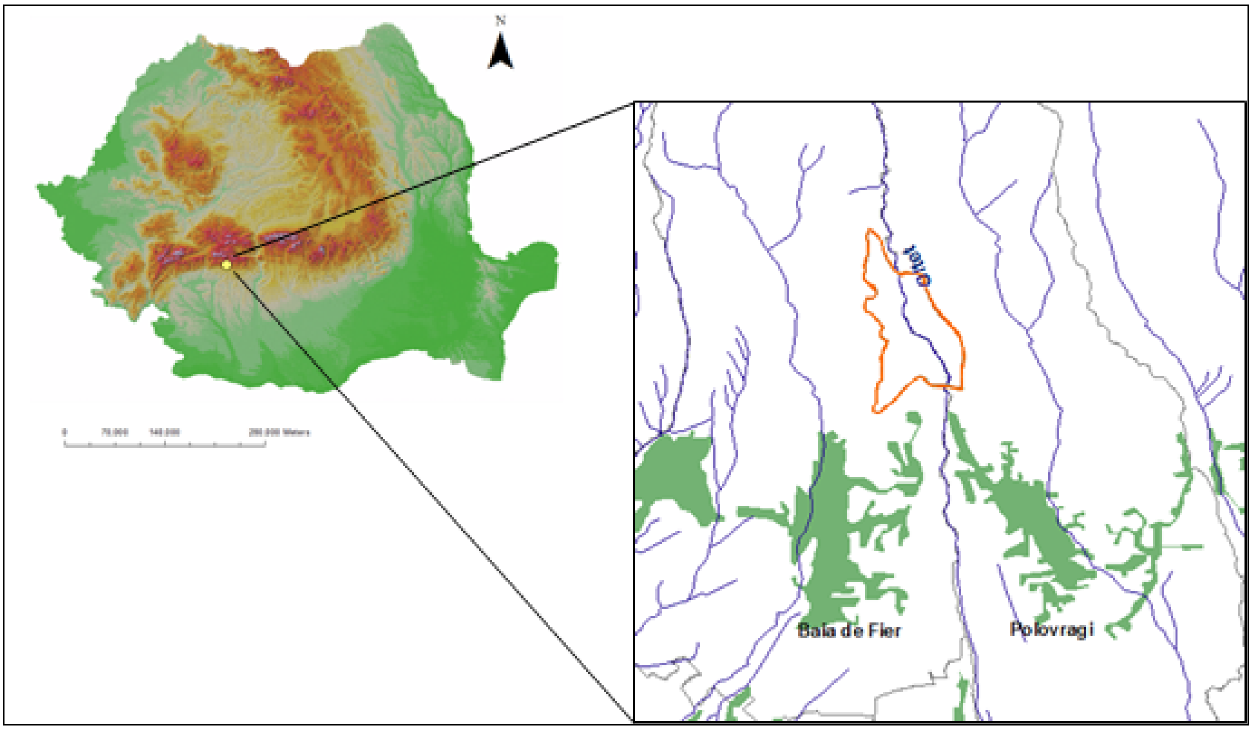

Figure 1: Location of Olteţului Gorges (Cheile Olteţului Nature Reserve), and the sampling area.

List of land snail species identified in Cheile Olteţului Nature Reserve

1. *Platyla banatica* (Rossmässler, 1842) – both habitats; in the soil litter;

2. *Platyla polita* (Hartmann, 1840) – inside the gorges; soil and in soil litter; less common than *P. banatica*;

3. *Carychium (Saraphia) tridentatum* (Risso, 1826) – both habitats; common species with large ecological amplitude, found in leaf litter;

4. *Cochlicopa lubricella* (Porro, 1838) – inside the gorges; prefers dry and warm habitats, found between rocks;

5. *Vallonia costata* (Müller, 1774) – inside the gorges; prefers dry habitats on calcareous substrate, found on limestone rocks;

6. *Vallonia excentrica* Sterki, 1893 – inside the gorges; found only on limestone rocks;

7. *Orcula jetschini* (Kimakowicz, 1883) – the only *Orcula* species from Romania, distributed in the Banat region, western Transylvania (including Crişana) and northern Oltenia; only two empty shells were found in the forest above the gorges.

8. *Sphyradium doliolum* (Bruguière, 1792) – both habitats; common species on limestone;

9. *Agardhiella parreyssi armata* (Clessin, 1887) – inside the gorges; subterranean species, living in the cracks of limestone rocks, in the soil, between small pieces of stones, among roots, difficult to find; the species was found in Romania at Motru Sec, in the north-western part of Oltenia (Grossu, 1987); only one shell was found at the base of a limestone wall;

10. *Spelaeodiscus triarius* (Rossmässler, 1839) – both habitats; commonly found on limestone, especially on rocky substratum, between stones;

11. *Acanthinula aculeata* (Müller, 1774) – both habitats; a common species in the forests, found in soil litter;

12. *Pyramidula pusilla* Gittenberger and Bank, 1996 – confined to calcareous habitat, found between the rock crevices, and in accumulations at the basis of limestone walls only inside the gorges;

13. *Chondrina arcadica* (Reinhardt, 1881) – inside the gorges; found on rock rubble;

14. *Granaria frumentum* (Draparnaud, 1801) – inside the gorges; on rock rubble and limestone walls, on sunny slopes;

15. *Columella edentula* (Draparnaud, 1805) – inside the gorges; moist habitats on calcareous substrate;

16. *Pupilla sterrii* (Forster, 1840) – found in dry sunny slopes, between stones, inside the gorges;

17. *Vertigo pygmaea* (Draparnaud, 1801) – in the leaf litter, inside the gorges;

18. *Merdigera obscura* (Müller, 1774) – found under the leaf litter and under the stones inside the gorges;

19. *Alopia hildegardae* (Brandt, 1961) – inside the gorges; one of the endemic *Alopia* species, described and confined to the Olteţului Gorges; the species was found only in one sampling point located inside the gorges, in large numbers;

20. *Cochlodina laminata* (Montagu, 1803) – both habitats; common species in forests, shrubs, on the soil, in leaf litter, logs and decayed woody debris;

21. *Cochlodina (Paracochlodina) orthostoma* (Menke, 1828) – inside the gorges¸ in humid and shady rocky habitats;

22. *Ruthenica filograna* (Rossmässler, 1836) – a common species found in ground litter from both habitats;

23. *Clausilia dubia* Draparnaud, 1805 – found in ground litter and on wet limestone walls, inside the gorges;

24. *Laciniaria pseudostabilis* (Westerlund, 1901) – inside the gorges;

25. *Laciniaria plicata* (Draparnaud, 1801) – between rocks and leaf litter inside the gorges;

26. *Alinda (Alinda) biplicata biplicata* (Montagu, 1803) – common in leaf litter and between rocks in both habitats;

27. *Alinda (Pseudalinda) fallax* (*Rossmässler*, 1836) – found in the leaf litter, only in the forest;

28. *Alinda (Pseudalinda) stabilis* (L. Pfeiffer, 1847) – found in decayed wood near the water stream sector, inside the gorges;

29. *Alinda (Pseudalinda) viridana* (Rossmässler, 1836) – under the leaf litter, only in the forest;

30. *Vestia turgida* (Rossmässler, 1836) – under the leaf litter, only in the forest;

31. *Bulgarica (Strigilecula) cana* (Held, 1836) – both habitats, under the rocks and in the leaf litter;

32. *Punctum (Punctum) pygmaeum* (Draparnaud, 1801) – in the leaf and soil litter, both habitats;

33. *Discus (Gonyodiscus) perspectives* (Megerle von Mühlfeld, 1816) – both habitats; deciduous forests, under the stones, in leaf litter;

34. *Vitrea crystallina* (Müller, 1774) – both habitats, in the leaf and soil litter;

35. *Vitrea diaphana* (Studer, 1820) – both habitats, in rock rubble from forested slopes;

36. *Vitrea transsylvanica* (Clessin, 1877) – both habitats, in the leaf litter;

37. *Euconulus (Euconulus) fulvus* (Müller, 1774) – both habitats, in the leaf litter;

38. *Oxychilus depressus* (Sterki, 1880) – inside the gorges, between the stones and in the soil litter;

39. *Aegopinella pura* (Alder, 1830) – both habitats, in soil and leaf litter;

40. *Vitrina pellucida* (Müller, 1774) – both habitats, common species in the soil and leaf litter;

41. *Fruticicola fruticum* (Müller, 1774) – in humid areas with dense herbaceous vegetation inside the gorges;

42. *Monachoides incarnatus* (Müller, 1774) – in the leaf litter of both habitats;

43. *Monachoides vicinus* (Rossmassler, 1842) – in the leaf litter of both habitats;

44. *Perforatella dibothrion* (M. Von Kimakowicz, 1884) – in the leaf litter and under the decayed wood, inside the gorges;

45. *Drobacia banatica* (Rossmässler, 1838) – in humid areas, with abundant vegetation, both habitats;

46. *Faustina faustina* (Rossmässler, 1853) – common species, found in humid rocky places, inside the gorges;

47. *Isognomostoma isognomostomos* (Schroter, 1784) – present in forested areas, in leaf litter, both habitats;

48. *Helix (Helix) pomatia* Linnaeus, 1758 – both habitats.

According to these results, among the identified species 45 were present in the area inside the gorges, and 32 in the beech forest. Due to the fact that the sampling points in the riparian area were selected in forested places, near the river, or close to the limestone wall, we considered the two sampling areas as two distinct habitats. Four species were recorded via only empty shells (Tab. 1), *Platyla polita, Orcula jetschini, Pupilla sterrii*, and *Vertigo pygmaea.*

The diversity in the riparian areas is considerable higher than in the beech forest, due to the diversity of microhabitats, habitat conditions and the presence of shelters. So, the presence of the water stream, the abundant vegetation and the narrow valley bordered by high limestone walls, favour the conservation of humidity. The rock crevices, the accumulation of rocks at the base of the cliffs, and the rocky substrate of the riparian forest, offer a multitude of shelters where the snails can withdraw during unfavourable conditions.

The land snail community in the beech forest is dominated by: *Aegopinella pura, Laciniaria pseudostabilis, Vitraea transsilvanica, Carychium tridentatum*, and *Monachoides vicinus*, while in the riparian area the most abundant species are: *Alopia hildegarde, Carychium tridentatum, Faustina faustina, Spaeleodiscus triarius*, and *Granaria frumentum.*

Although *Alopia hilderade* species has one of the highest abundance values in the riparian area, this is due to the presence of a large number of individuals in a single sampling point. This type of distribution makes these endemic species much more vulnerable to human induced disturbance. *Alopia hildegarde* species lives only in the limestone area crossed by the Olteț River; therefore this species conservation in the area is extremely important.

Therfore, the species' diversity is relatively high considering the Nature reserve has only 150 ha surface, in fact surrounding the three km long gorges. The number of species present here is almost the same as that reported for Porțile de Fier Nature Park (Gheoca, 2014), but the abundance is significantly lower than usual in limestone areas from western Romania (Cameron et al., 2015). Species that usually develop large populations of hundreds of individuals, *Granaria frumentum, Chondrina arcadica, Pyramudula pusilla, Spaeleodiscus triarius*, and *Vallonia excentrica,* are present here, but only in small numbers (Fig. 2).

Table 1: The relative abundance of land snail species. The * mark represent the species where only empty shells were found.

No.	Species	Forest A%	Inside the gorges A%
1.	*Platyla banatica*	1.88235	1.961
2.	*Platyla polita* *	0	0.178
3.	*Carychium tridentatum*	**4.70588**	**10.695**
4.	*Cochlicopa lubricella*	0	1.248
5.	*Vallonia costata*	0	1.961
6.	*Vallonia excentrica*	0	2.496
7.	*Orcula jetschini* *	0.47059	0
8.	*Sphyradium doliolium*	1.41176	1.783
9.	*Agardhiella armata*	0	0.178
10.	*Spelaeodicus triarius*	3.52941	**9.091**
11.	*Acanthinula aculeata*	3.29412	**4.456**

Table 1 (continued): The relative abundance of land snail species. The * mark represent the species where only empty shells were found.

No.	Species	Forest A%	Inside the gorges A%
12.	*Pyramidula rupestris*	0	0.535
13.	*Chondrina arcadica*	0	1.248
14.	*Granaria frumentum*	0	**4.456**
15.	*Columella edentula*	0	0.535
16.	*Pupilla sterrii* *	0	0.535
17.	*Vertigo pygmaea* *	0	0.178
18.	*Merdigera obscura*	0	0.535
19.	*Alopia hildegardae*	0	**9.269**
20.	*Cochlodina laminata*	4	0.357
21.	*Cochlodina orthostoma*	0	0.357
22.	*Ruthenica filograna*	0.47059	0.357
23.	*Clausilia dubia*	0	0.713
24.	*Laciniaria pseudostabilis*	**14.8235**	**4.456**
25.	*Laciniaria plicata*	3.05882	0.178
26.	*Alinda biplicata*	3.05882	2.139
27.	*Alinda fallax*	0.23529	0
28.	*Alinda stabilis*	0	0.535
29.	*Alinda viridana*	**4.47059**	0
30.	*Vestia turgida*	1.86706	0.713
31.	*Bulgarica cana*	1.87647	1.070
32.	*Punctum pygmaeum*	2.11765	3.209
33.	*Discus perspectivus*	1.17647	1.961
34.	*Vitrea crystallina*	0.94118	1.783
35.	*Vitrea diaphana*	10.1176	3.922
36.	*Vitrea transsylvanica*	**4.23529**	0.535
37.	*Euconulus fulvus*	2.11765	0.891
38.	*Oxychilus depressus*	0	0.357
39.	*Aegopinella pura*	**12.2353**	3.387
40.	*Vitrina pellucida*	**6.11412**	1.426
41.	*Fruticicola fruticum*	0	2.674
42.	*Monachoides incarnatus*	2.35294	0.178
43.	*Monachoides vicinus*	**5.88235**	0.891
44.	*Perforatella dibothrion*	0	0.357
45.	*Drobacia banatica*	1.64706	3.209
46.	*Faustina faustina*	0	8.556
47.	*Isognomostoma isognomostomos*	0.70588	0.357
48.	*Helix pomatia*	1.17647	4.100

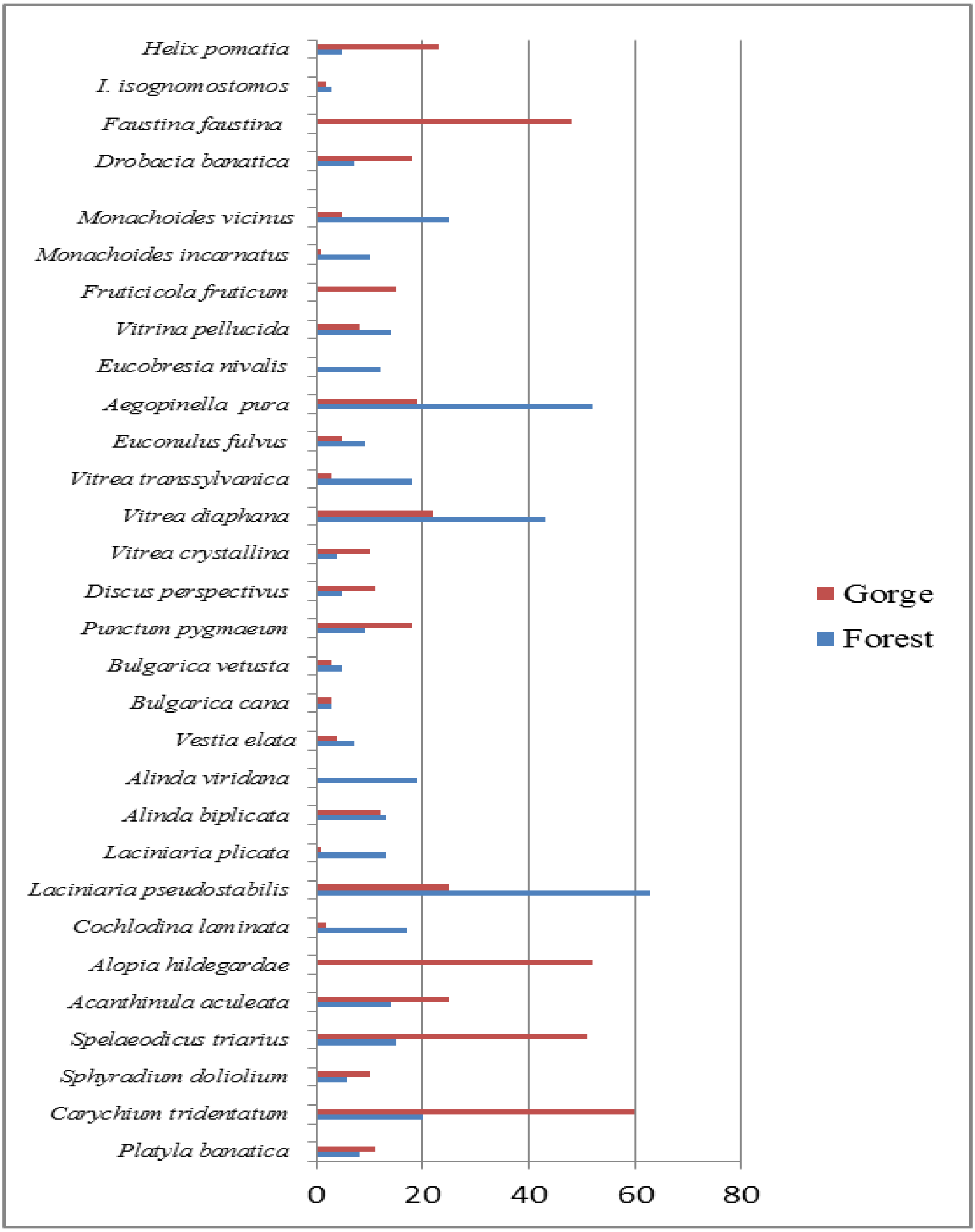

Figure 2: Abundance of the most common species in the two habitats.

CONCLUSIONS

Cheile Olteţului Nature Reserve harbours a diverse land snail fauna. The particular nature of the land snail community is most likely due to microclimatic conditions. Most of the land snails that are usually abundant on limestone rocks are thermophilous species; while here the narrow valley and the height of the limestone walls reduce the insolation and modify the classical structure of the land snail communities. Among the 48 identified land snail species, 45 are present in the riparian area and 28 are in the forest. The land snail community from the riparian areas is dominated by *Carychium tridentatum, Spaeleodiscus triarius*, *Alopia hildegarde, Granaria frumentum* and *Faustina faustina*, while the beech forest is populated mostly by *Aegopinella pura, Laciniaria pseudostabilis*, *Vitraea transsilvanica*, *Carychium tridentatum* and *Monachoides vicinus*. The considerably higher diversity found in the riparian area is due to the diversity of habitat conditions and the presence of shelters. Also, the proximity of the river and the small distance between the limestone walls facilitate moisture being retained in the area. Among the species of conservative interest are: *Alopia hildegarde*, an endemic species present only here, and *Drobacia banatica*, listed in Annex II of the EU Habitats Directive. The river valleys are important corridors for the dissemination of snails and so it is the case for *Drobacia banatica*, whose distribution is directly related to waterbeds; as the species is found in humid and moderately humid woodlands. Present mostly in Transylvania, Crişana and Banat, its occurrence in the southern part of the Carpathic arch is confined to some river valleys, but not beyond the Subcarpathians. Therefore, the preservation of these marginal populations is important for the species' conservation.

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DRAGONFLIES (INSECTA, ODONATA) IN TIMIȘ COUNTY (BANAT, ROMANIA), A GENERAL VIEW OF DISTRIBUTION

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KEYWORDS: Romania, Timiş County, Odonata, diversity, *Coenagrion ornatum*, *Gomphus flavipes*, *Ophiogomphus cecilia*, *Lestes parvidens*, *Coenagrion scitulum*, *Anax parthenope*, *Somatochlora meridionalis*, *Sympetrum depressiusculum*, *Sympetrum pedemontanum*.

ABSTRACT

This paper is a synthesis of more than 10 years of research in Timiș County.

Research started in 1999 and continued with some periods of interruption until 2015.

The research was comprised of more than one thousand entries in a database of more than 100 toponyms and resulted in the knowledge that the area hosted 45 species of dragonflies.

From these 45 species, nine are of more interest, being species of conservation interest (Natura 2000 species) (*Coenagrion ornatum*, *Gomphus flavipes* and *Ophiogomphus cecilia*) or rarer species in Romanian fauna (*Lestes parvidens*, *Coenagrion scitulum*, *Anax parthenope*, *Somatochlora meridionalis*, *Sympetrum depressiusculum* and *Sympetrum pedemontanum*).

REZUMAT: Libelulele (Insecta, Odonata) din județul Timiș (Banat, Romania), vedere generală asupra distribuţiei.

Această lucrare este o sinteză a peste 10 ani de cercetări realizate în județul Timiș.

Cercetările au început în anul 1999 și au continuat cu unele întreruperi până în 2015.

Aceste cercetări totalizează peste o mie de intrări în baza de date dintr-un număr de peste 100 de toponime și au ca rezultat prezența în zona cercetată a 45 de specii de libelule.

Dintre aceste 45 de specii nouă sunt mai interesante fiind specii de interes conservativ (specii comunitare) (*Coenagrion ornatum*, *Gomphus flavipes* și *Ophiogomphus cecilia*) sau specii mai rare în fauna României (*Lestes parvidens*, *Coenagrion scitulum*, *Anax parthenope*, *Somatochlora meridionalis*, *Sympetrum depressiusculum* și *Sympetrum pedemontanum*).

RÉSUMÉ: Les libellules (Insecta, Odonata) dans département de Timiş (Banat, Roumanie), un état des lieux de leur distribution.

Cet article est une synthèse de plus de dix années de recherche dans le département de Timiş.

Les travaux ont commencé en 1999 et ont été continuées avec quelques interruptions jusqu' en 2015.

Elles ont compris plus de mille entrées dans la base de données de plus d'une centaine des toponymes, d'ici en résultant que la zone abrite 45 espèces de libellules.

De ces 45 espèces, neuf sont plus intéressantes, parce qu' elles sont des espèces communitaires (Espèces Natura 2000) (*Coenagrion ornatum*, *Gomphus flavipes* et *Ophiogomphus cecilia*) ou sont des espèces plutot rares dan la faune de la Roumanie (*Lestes parvidens*, *Coenagrion scitulum*, *Anax parthenope*, *Somatochlora meridionalis*, *Sympetrum depressiusculum* et *Sympetrum pedemontanum*).

INTRODUCTION

Dragonfly fauna from Timiș County is more or less unknown with only four papers that deal with this region and its surroundings, being published previously: Bulimar in 1984 (five species mentioned from the county), Beutler in 1988 (four species), Stănescu in 2005 (33 species), Manci in 2005 (35 species) and Manci in 2006 (10 species).

We hope that this paper will shed more light on the distribution of this insect group in Romania.

MATERIAL AND METHODS

Odonata species were observed, photographed, but rarely collected in the studied area starting from 1999 (Fig. 1).

Observations in the field were made with the help of a small pair of binoculars and photos taken in the field with various cameras. Voucher specimens were collected with an entomological net and specimens were treated with acetone before being collected in envelopes. Exuviae were collected by hand from vegetation and kept dry on pins. The collected specimens are stored in a personal collection. For this paper mostly data about the adults found was used.

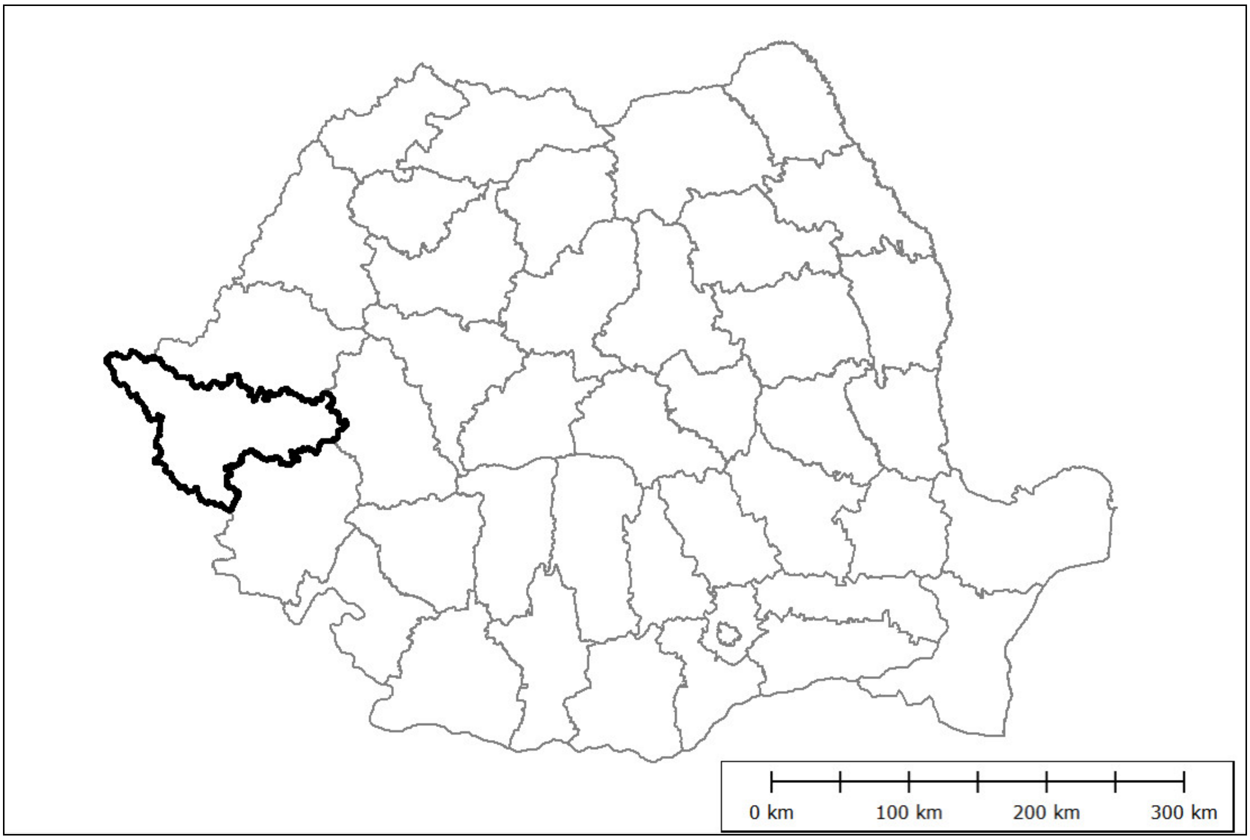

Figure 1: Map of Romania, with bold line marking the studied area.

Some data collected (via photos) by Ardelean A., Ardelean C. and Pârvulescu L. was used too. Complete details which comprise of date, number of specimens, conditions, habitat data, GPS coordinates, collector, and others, are stored in databases at http://dragonfly.nature4stock.com and/or https://kladia.info/klados/.

Taxonomic names, classification and order of taxon are based on Dijkstra (2006).

Maps for each species were created using a network of 5x5 km of UTM squares and elements of reference were added (main water courses and a few big cities) (Fig. 2).

On the map, own data are marked with a blue circle, other published data with a yellow circle, and the own and other authors data are marked with a split blue/yellow circle.

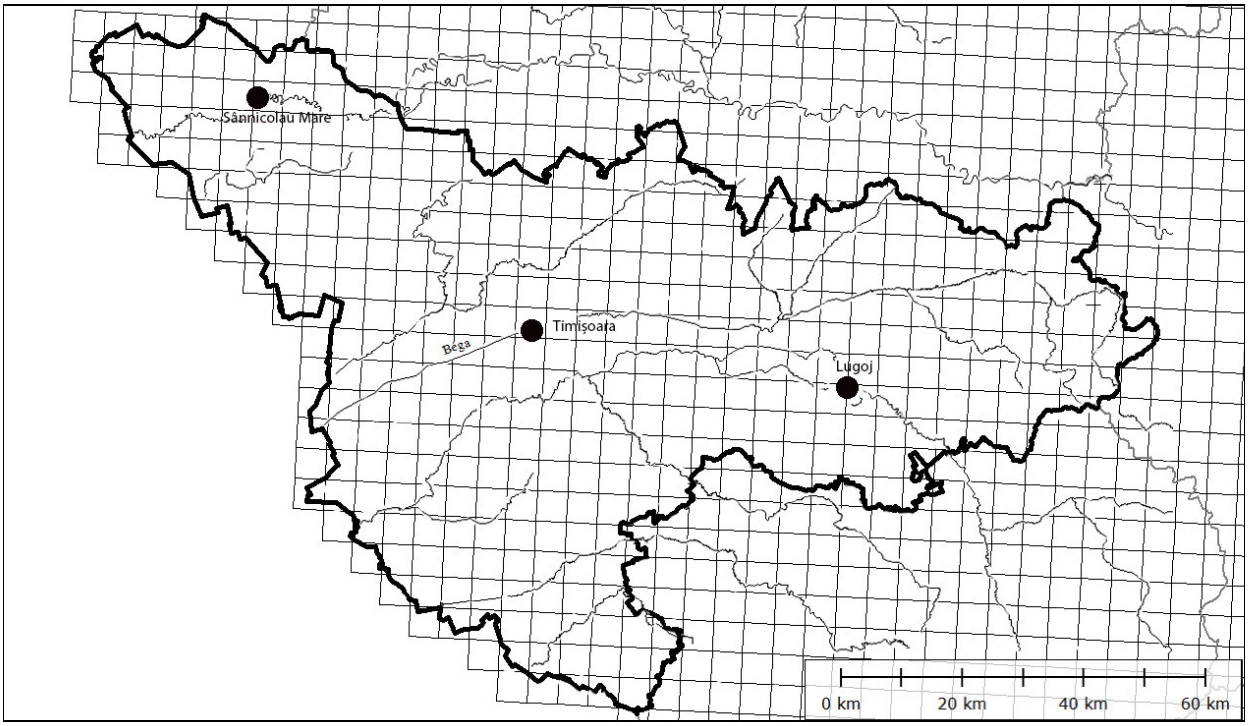

Figure 2: Map of studied area, with 5x5 km UTM squares, major rivers and major localities.

RESULTS AND DISCUSSION

As a result of this work, 45 species are now known and for each species a map was created. In the following pages, each species is listed with dates and localities; a critical text has been added to some of the species. Also, a list of toponyms is listed.

Calopterygidae are presented with 2 species in the area − both being common species in suitable habitats.

Calopteryx splendens (Harris, 1782) (Fig. 3): Balint − 14.VII.2005; Bazoşu Nou − 16.V.2004, 6.VI.2004, 18.VI.2004; Bărăteaz − 3.VII.2004; Becicherecu Mic − 12.VI.2005; Beregsău Mare − 12.VI.2005; Beregsău Mic − 12.VI.2005; Biled − 12.VI.2005; Bistra Forest − 3.VIII.2004, 15.V.2010; Bobda − 12.VI.2005; Brestovăţ − 28.VI.2004; Cebza − 25.VII.2004; Cenad − 15.VI.2005; Cenei − 12.VI.2005; Chevereş Forest − 14.V.2004; Coştei − 14.VII.2005; Covaci − 12.VI.2005; Curtea − 20.VIII.2003; Dragşina − 14.V.2004, 17.V.2004; Dudeştii Vechi − 13.VI.2005; Foeni − 25.VII.2004; Gad − 25.VII.2004; Gătaia − 6.VII.2007; Găvojdia − 14.VII.2005; Ghiroda Nouă − 22.VII.1999 (1 ♀ collected); Grăniceri − 25.VII.2004; Igriş − 15.VI.2005; Jebel − 25.VII.2004; Leucuşesti − 14.VII.2005; Liebling Lake − 6.VII.2007; Lighed Forest − 25.VII.2004; Lugoj − 14.VII.2005; Otelec − 12.VI.2005; Parţa − 25.VII.2004; Pădurea Verde − 31.V.1999 (1 ♂ collected), 10.VI.1999 (1 ♂ collected), 18.VII.1999 (1 ♂ collected), 6.VI.2000 (1 ♀ collected), 21.V.2004, 15.VI.2004, 13.V.2005, 21.V.2005, 3.V.2009; Peciu Nou − 25.VII.2004; Periam − 27.VI.2015; Pişchia Forest − 9.VI.2004 (2 ♀ collected); Remetea Mare − 16.V.2004, 2.VII.2007; Rudna − 25.VII.2004; Satchinez − 3.VIII.2003, 23.VIII.2003, 1.V.2004, 15.V.2004, 3.VII.2004; Sânandrei − 12.VI.2005; Sânmihaiu Român − 12.VI.2005; Timişoara − 22.VI.1987 (Beutler, 1988); Tomnatic − 13.VI.2005; Topolovăţul Mare − 14.VII.2005; Uivar − 12.VI.2005; Unip Forest − 25.VII.2004.

Calopteryx virgo (Linnaeus, 1758) (Fig. 4): Barna − 19.VII.2013; Bulza − 23.VII.2013; Bunea Mare − 24.VII.2013; Bunea Mică − 24.VII.2013; Cladova − 25.VII.2013; Colonia Fabricii − 20.VIII.2003; Coşava − 22.VII.2013; Crivina − 19.VII.2013; Crivina de Sus − 22.VII.2013; Curtea − 20.VIII.2003; Drinova − 19.VII.2013; Dubeşti −

25.VII.2013; Fărășești − 21.VII.2013; Fârdea − 20.VII.2013; Gladna Montană − 20.VII.2013; Gladna Română − 20.VII.2013; Groși − 23.VII.2013; Hânzești − 20.VII.2013; Homojdia − 22.VII.2013; Jdioara − 18.VII.2013; Lățunaș − 10.VII.2013; Luncanii de Jos − 21.VII.2013; Luncanii de Sus − 19.VIII.2003; Nădrag − 19.VII.2013; Nemeșești − 23.VII.2013; Ohaba Lungă − 25.VII.2013; Ohaba Română − 25.VII.2013; Pădurani − 24.VII.2013; Pietroasa − 22.VII.2013; Pogănești − 19.VII.2013; Poieni − 22.VII.2013; Sălciua − 12.VII.2013; Sintești − 23.VII.2013; Surduc Lake − 20.VII.2013; Temerești − 24.VII.2013; Tomești − 21.VII.2013.

Lestidae are present with six species from two genera. From these, five species belong to *Lestes* − one of them *Lestes parvidens* being one of the more interesting species − and *Sympecma* with one species.

Lestes sponsa (Hansemann, 1823) (Fig. 5): Charlottenburg − 26.VII.2008 (1 ♀ collected); Cheveresș Forest − 14.VIII.2005; Lighed Forest − 1.IX.2005; Pădurea Verde − 21.VI.2000 (1 ♀ collected); Pișchia Forest − 9.VI.2004; Rudna − 1.IX.2005; Satchinez − 19.VIII.2006.

Lestes dryas Kirby, 1890 (Fig. 6): Bistra Forest − 6.VI.2006; Cheveresș Forest − 14.VIII.2005; Lighed Forest − 25.VII.2004; Pădurea Verde − 10.VI.1999 (3 ♂ and 2 ♀ collected), 18.VII.1999 (1 ♂ collected), 2.VI.2000 (1 ♂ and 1 ♀ collected); Rudna − 25.VII.2004.

Lestes barbarus (Fabricius, 1798) (Fig. 7): Becicherecu Mic − 12.VI.2005; Biled − 12.VI.2005; Bistra Forest − 2.VI.1999 (1 ♂ and 1 ♀ collected), 6.VI.2006; Cheveresș Forest − 14.VIII.2005; Covaci − 12.VI.2005; Dudeștii Vechi − 13.VI.2005; Grăniceri − 25.VII.2004; Jebel − 25.VII.2004; Jimbolia − 13.VI.2005; Lighed Forest − 25.VII.2004; Pădurea Verde − 10.VI.1999 (3 ♀ collected); Peciu Nou − 25.VII.2004; Pișchia Forest − 9.VI.2004; Rudna − 25.VII.2004; Satchinez − 3.VIII.2003, 23.VIII.2003, 3.VII.2004, 19.VIII.2006 (1 ♂ and 1 ♀ collected); Sânandrei − 12.VI.2005; Timișoara − 22.VI.1987 (Beutler, 1988); Timișoara (irrigation canal Agronomie) − 2.VIII.2003; Tomnatic − 13.VI.2005; Unip Forest − 25.VII.2004.

Lestes virens (Charpentier, 1825) (Fig. 8): Becicherecu Mic − 12.VI.2005; Bistra Forest − 6.VI.2006; Charlottenburg − 26.VII.2008 (1 ♂ and 1 ♀ collected); Cheveresș Forest − 14.VIII.2005; Grăniceri − 25.VII.2004; Jimbolia − 13.VI.2005; Lighed Forest − 25.VII.2004; Pădurea Verde − 15.VI.2004; Peciu Nou − 25.VII.2004; Rudna − 25.VII.2004; Satchinez − 3.VIII.2003; Sânandrei − 12.VI.2005; Timișoara (irrigation canal Agronomie) − 2.VIII.2003.

Lestes parvidens Artobolevskii, 1929 (Fig. 9): Bistra Forest − 6.IX.2003, 8.IX.2006 (4 ♀ collected); Cheveresș Forest − 14.VIII.2005; Dragșina − 14.VIII.2005; Lighed Forest − 1.IX.2005; Pădurea Verde − 10.VI.1999 (1 ♂ collected), 10.IX.1999 (6 ♂ and 1 ♀ collected), 2.IX.2006 (4 ♂ collected); Remetea Mare − 8.IX.2006 (1 ♂ collected); Rudna − 1.IX.2005; Satchinez − 19.VIII.2006 (1 ♂ and 1 ♀ collected), 8.X.2006. This taxon was described originally as a subspecies of *Lestes viridis* from Crimea, and between the 1980's and 1990's. It became evident that it is much more widespread, being found in large parts of Italy and Balcanic Peninsula (Dijkstra, 2006). Some authors still retain the taxon only under the name of *Lestes viridis* (Askew, 2004). *Lestes parvidens* and *L. viridis* are the subject of debate of whether they should be treated under the genus *Chalcolestes* (Dijkstra, 2006). This species was previously treated as *Lestes viridis* (Vander Linden, 1825) in Manci, 2005. It is likely that other papers/specimens from Romania that are published under this name are in reality *Lestes parvidens*. It is not a rare species in the area and it can even locally be an abundant species. All records of *Lestes viridis* from Romania should be checked against *Lestes parvidens* to see exactly the distribution of these two species in Romania.

Sympecma fusca (Vander Linden, 1820) (Fig. 10): Bacova − 5.IX.1999 (1 ♂ collected); Bărăteaz − 9.IX.2003, 9.IV.2006; Bencecu de Jos (forest) − 30.IV.2004; Bistra Forest − 3.VIII.2004, 8.IX.2006 (1 ♂ and 1 ♀ collected); Blajova − 7.IV.2005; Charlottenburg − 26.VII.2008 (1 ♂ collected); Chevereș Forest − 14.VIII.2005; Dragșina − 17.V.2004; Dumbrăvița Lake − 28.IX.2003, 5.IV.2006; Gad − 4.IV.2004; Ghiroda Nouă − 17.III.2004; Giulvăz − 11.IV.2006; Foeni − 18.III.2005, 11.IV.2006; Lighed Forest − 25.VII.2004; Murani Lake − 30.IV.2004; Pădurea Verde − 10.IX.1999 (1 ♂ and 2 ♀ collected), 21.III.2004, 31.III.2004, 29.IV.2004, 5.IV.2006, 2.IX.2006 (1 ♂ and 1 ♀ collected); Rudna − 4.IV.2004, 8.IV.2004, 18.IV.2004 (2 ♂ and 1 ♀ collected), 10.iv.2005; Satchinez − 9.IX.2003, 4.IV.2004, 3.VII.2004, 4.IV.2006, 15.IV.2006, 19.III.2007; Săcălaz − 8.IV.2010; Șag − 12.VIII.2007; Tapia − 7.IV.2005; Timișoara (irrigation canal Agronomie) − 2.VIII.2003.

Coenagrionidae are present with eight species from four genera. From these species, *Coenagrion ornatum* and *Coenagrion scitulum* are of main interest.

Ischnura elegans (Vander Linden, 1820) (Fig. 11): Bazoșu Nou − 16.V.2004, 6.VI.2004; Bărăteaz − 3.VII.2004; Becicherecu Mic − 12.VI.2005; Bistra Forest − 3.VIII.2004, 5.VI.2006; Brestovăț − 28.VI.2004; Cenad − 15.VI.2005; Diniaș − 10.V.2004; Chevereș Forest − 14.V.2004; Dragșina − 14.V.2004, 17.V.2004; Foeni − 25.VII.2004; Gad − 25.VII.2004; Gătaia − 6.VII.2007; Giarmata Mare − 18.VIII.2006 (1 ♂ collected); Ghiroda Nouă − 22.VII.1999 (1 ♂ collected); Grăniceri − 25.VII.2004; Igriș − 15.VI.2005; Jimbolia − 13.VI.2005; Liebling Lake − 6.VII.2007; Lighed Forest − 25.VII.2004; Pădurea Verde − 21.V.2004, 15.VI.2004, 13.V.2005, 21.V.2005, 3.V.2009; Peciu Nou − 25.VII.2004; Periam − 27.VI.2015; Pișchia Forest − 9.VI.2004; Remetea Mare − 16.V.2004, 6.VI.2004 (1 ♀ collected), 2.VII.2007; Rudna − 25.VII.2004; Satchinez − 1983 (Bulimar, 1984), 3.VIII.2003, 23.VIII.2003, 1.V.2004, 15.V.2004, 3.VIII.2004, 19.VIII.2006 (1 ♂ collected); Săcălaz (Beregsău Rivulet) − 13.V.2005; Sânandrei − 15.V.2006; Surduc Lake − 20.VII.2013; Timișoara (irrigation canal Agronomie) − 2.VIII.2003.

Ischnura pumilio (Charpentier, 1825) (Fig. 12): Bărăteaz − 3.VII.2004; Becicherecu Mic − 12.VI.2005; Dragșina − 17.V.2004; Giarmata Mare − 18.VIII.2006 (1 ♂ collected); Pădurea Verde − 13.V.2005 (1 ♀ collected; Peciu Nou − 25.VII.2004; Rudna − 25.VII.2004; Satchinez − 1983 (Bulimar, 1984), 3.VII.2004, 19.VIII.2006 (1 ♂ collected); Săcălaz − 12.VI.2005.

Coenagrion pulchellum (Vander Linden, 1825) (Fig. 13): Bazoșu Nou − 6.VI.2004; Becicherecu Mic − 12.VI.2005; Bistra Forest − 3.VIII.2004, 5.V.2007, 15.V.2010; Brestovăț − 28.VI.2004; Charlottenburg − 26.VII.2008 (1 ♂ collected); Cenad − 15.VI.2005; Chevereș Forest − 14.VIII.2005; Denta − 25.VII.2004; Diniaș − 10.V.2004; Dragșina − 14.V.2004, 17.V.2004; Dumbrăvița Lake − 7.VI.2000 (1 ♂ collected); Foeni − 25.VII.2004; Gad − 25.VII.2004; Ghiroda Nouă − 22.VII.1999 (1 ♂ collected); Giroc Forest − 9.V.2010; Grăniceri − 25.VII.2004; Igriș − 15.VI.2005; Jdioara − 18.VII.2013; Jimbolia − 13.VI.2005; Liebling Lake − 6.VII.2007; Murani Lake − 30.IV.2004; Pădurea Verde − 18.VII.1999 (1 ♀ collected), 2.VI.2000 (2 ♂ collected), 21.V.2004, 13.V.2005 (1 ♂and 3 ♀ collected), 21.V.2005; Pișchia Forest − 9.VI.2004; Remetea Mare − 2.VII.2007; Rudna − 25.VII.2004; Satchinez − 1983 (Bulimar, 1984), 1.V.2004, 15.V.2004, 3.VII.2004, 4.VII.2006, 23.V.2010; Sânandrei − 15.V.2006; Săcălaz (Beregsău Rivulet) − 13.V.2005; Surduc Lake − 20.VII.2013; Timișoara (irrigation canal Agronomie) − 2.VIII.2003. Attention should be paid when recording this species, mainly in the case of the females because many of them have a coloration form similar at first sight to *Ischnura elegans*. Specimens from the area look very rare, like the one illustrated in Dijkstra, 2006.

Coenagrion puella (Linnaeus, 1758) (Fig. 14): Bărăteaz − 3.VII.2004;

Becicherecu Mic − 12.VI.2005; Bencecu de Jos (forest) − 30.IV.2004; Brestovăț − 28.VI.2004; Bistra Forest − 6.VI.2006, 2.VII.2007; Cenad − 15.VI.2005; Diniaș − 10.V.2004; Chevereș Forest − 14.VIII.2005; Dragșina − 14.V.2004, 17.V.2004; Dumbravița Lake - 7.VI.2000 (1 ♂ collected); Gătaia − 6.VII.2007; Grăniceri − 25.VII.2004; Jdioara − 18.VII.2013; Jimbolia − 13.VI.2005; Liebling Lake − 6.VII.2007; Murani Lake − 30.IV.2004; Pădurea Verde − 31.V.1999 (2 ♂ collected); 18.VII.1999 (1 ♂ collected); 2.VI.2000 (1 ♂ and 1 ♀ collected); 21.V.2004, 15.VI.2004, 13.V.2005, 3.V.2009; Peciu Nou − 25.VII.2004; Pișchia Forest − 9.VI.2004; Remetea Mare − 2.VII.2007; Rudna − 25.VII.2004; Satchinez − 1983 (Bulimar, 1984), 15.V.2004; Săcălaz (Beregsău Rivulet) − 13.V.2005; Surduc Lake − 20.VII.2013; Șag − 12.VIII.2007; Timișoara − 22.VI.1987 (Beutler, 1988); Timișoara (irrigation canal Agronomie) − 2.VIII.2003.

Coenagrion ornatum (Selys, 1850) (Fig. 15): Chevereș Forest − 25.VI.2004; Dragșina − 25.VI.2004; Jimbolia − 13.VI.2005; Lighed Forest − 25.VII.2004; Pădurea Verde − 15.VI.2004; Pișchia Forest − 9.VI.2004 (1 ♂ collected); Rudna − 25.VII.2004; Satchinez − 3.VII.2004. This is an important species from the area, from a conservation point of view, being a Natura 2000 species. This species is not rare in the area, but very local as it appears to colonise the habitats created in running areas of the dam where the substrate is partly or totally made from concrete or wet canals that end up with a lot of stone in substrate; that area being in parallel with adjacent train tracks or at points where the train tracks pass over via small bridges.

Coenagrion scitulum (Fonscolombe, 1838) (Fig. 16): Charlottenburg − 6.VI.2000 (1 ♂ collected); Dumbravița Lake − 7.VI.2000 (1 ♀ collected); Pădurea Verde − 21.V.2005. It appears to be a rare and very local species in the area and Romania too.

Erythromma viridulum (Charpentier, 1840 (Fig. 17): Becicherecu Mic − 12.VI.2005; Bistra Forest − 3.VIII.2004, 2.VII.2007; Chevereș Forest − 14.V.2004; Dragșina − 17.V.2004; Dumbravița Lake − 7.VI.2000 (1 ♂ and 1 ♀ collected), 20.VI.2008; Gătaia − 6.VII.2007; Ghiroda − 6.IX.2003; Ghiroda Nouă − 22.VII.1999 (2 ♂ collected), 22.VI.2000 (1 ♂ collected); Grăniceri − 25.VII.2004; Ivanda − 6.VII.2007; Jimbolia − 13.VI.2005; Liebling Lake − 6.VII.2007; Pădurea Verde − 2.VI.2000 (1 ♂ collected); Pișchia Forest − 9.VI.2004; Remetea Mare − 2.VII.2007; Rudna − 25.VII.2004; Satchinez − 19.VIII.2006; Săcălaz − 12.VI.2005.

Pyrrhosoma nymphula (Sulzer, 1776) (Fig. 18): Bencecu de Jos (forest) − 30.IV.2004; Bistra Forest − 2.VI.1999 (1 ♂ collected), 5.V.2007; Chevereș Forest − 14.V.2004; Pădurea Verde − 21.V.2004, 13.V.2005; Satchinez − 1.V.2004.

Platycnemididae are present with one common species in the area.

Platycnemis pennipes (Pallas, 1771) (Fig. 19): Bazoșu Nou − 16.V.2004, 6.VI.2004, 18.VI.2004; Bărăteaz − 3.VII.2004; Becicherecu Mic − 12.VI.2005; Bistra Forest − 3.VIII.2004, 17.V.2009; Brestovăț − 28.VI.2004; Cenad − 15.VI.2005; Charlottenburg − 10.IX.1999 (1 ♂ collected), 26.VII.2008 (1 ♂ collected); Chevereș Forest − 14.V.2004; Dragșina − 17.V.2004; Gătaia − 6.VII.2007; Giroc Forest − 17.VI.2009; Grăniceri − 25.VII.2004; Hodoni − 12.VI.2005; Igriș − 15.VI.2005; Jimbolia − 13.VI.2005; Luncanii de Sus − 19.VIII.2003; Murani Lake − 21.VII.1999 (1 ♀ collected); Pădurea Verde − 29.IV.2004, 21.V.2004, 15.VI.2004, 13.V.2005, 21.V.2005; Peciu Nou − 25.VII.2004; Periam − 27.VI.2015; Pișchia Forest − 21.VII.1999 (1 ♂ collected), 9.VI.2004 (2 ♂ collected); Remetea Mare − 16.V.2004, 6.VI.2004, 18.VI.2004, 8.IX.2006, 2.VII.2007; Rudna − 25.VII.2004; Satchinez − 1983 (Bulimar, 1984), 3.VIII.2003, 23.VIII.2003, 15.V.2004, 3.VII.2004, 19.VIII.2006 (1 ♂ collected); Săcălaz (Beregsău Rivulet) − 13.V.2005; Sânandrei − 12.VI.2005; Timișoara − 22.VI.1987 (Beutler, 1988); Timișoara (irrigation canal Agronomie) − 2.VIII.2003.

Aeshnidae are present with seven species from three genera. From these seven species, *Anax parthenope* appear to be very rare in the studied area.

Aeshna mixta Latreille, 1805 (Fig. 20): Bacova − 5.IX.1999; Bărăteaz − 9.IX.2003; Bistra Forest − 3.VIII.2004, 8.IX.2006; Cenad − 15.VI.2005; Chevereș Forest − 14.VIII.2005; Chizătău − 11.IX.2006; Criciova − 10.IX.2006; Curtea − 19.VIII.2003; Dragșina − 14.VIII.2005; Dumbrăvița Lake − 28.IX.2003; Găvojdia − 10.IX.2006; Ghiroda Nouă − 8.IX.2006; Giroc Forest − 3.X.2010; Igriș − 15.VI.2005; Leucușesti − 11.IX.2006; Lighed Forest − 1.IX.2005; Lugoj − 10.IX.2006; Luncanii de Sus − 19.VIII.2003; Nădrag − 29.IX.1999 (3 ♂ collected); Pădurea Verde − 10.IX.1999 (1 ♂ and 2 ♀ collected), 2.IX.2006 (4 ♂ and 1 ♀ collected); Peciu Nou − 25.VII.2004; Satchinez − 3.VIII.2003, 23.VIII.2003, 8.X.2006; Remetea Mare − 8.IX.2006 (1 ♂ collected); Rudna − 1.IX.2005; Șag − 12.VIII.2007; Timișoara − 28.VIII.2006; Timișoara (irrigation canal Agronomie) − 2.VIII.2003; Uivar − 27.IX.2006.

Aeshna affinis Vander Linden, 1820 (Fig. 21): Bărăteaz − 3.VII.2004; Becicherecu Mic − 12.VI.2005; Bistra Forest − 22.VII.1999 (1 ♂ collected), 3.VIII.2004, 2.VII.2007; Brestovăț − 28.VI.2004; Cărani − 20.VI.2005; Cenad − 15.VI.2005; Charlottenburg: − 26.VII.2008 (1 ♂ collected); Coștei − 14.VII.2005; Foeni − 25.VII.2004; Gad − 25.VII.2004; Gătaia − 6.VII.2007; Ghiroda Nouă − 22.VII.1999 (2 ♂ collected); Herneacova − 28.VI.2004; Hodoni − 12.VI.2005; Igriș − 15.VI.2005; Jimbolia − 13.VI.2005; Liebling Lake − 6.VII.2007; Lighed Forest − 25.VII.2004; Pădurea Verde − 18.VII.1999 (2 ♂ and 1 ♀ collected), 15.VI.2004; Peciu Nou − 25.VII.2004; Periam − 27.VI.2015; Sângeorge − 13.VI.1999 (2 ♂ collected); Pișchia Forest − 9.VI.2004; Rudna − 25.VII.2004; Satchinez − 3.VII.2004; Săcălaz − 12.VI.2005; Surduc Lake − 20.VII.2013; Șag − 21.VI.2005.

Aeshna isoceles (Müller, 1767) (Fig. 22): Bărăteaz − 3.VII.2004; Becicherecu Mic − 12.VI.2005; Beregsău Mare − 12.VI.2005; Bistra Forest − 15.V.2010; Dumbrăvița Lake − 20.VI.2008; Ghiroda Nouă − 22.VII.1999; Gătaia − 6.VII.2007; Liebling − 28.VI.2015; Pădurea Verde − 22.VII.1999 (1 ♂ collected), 21.V.2005, 3.V.2009; Periam − 27.VI.2015; Remetea Mare − 2.VII.2007; Sacoșu Turcesc − 28.VI.20015; Satchinez − 3.VIII.2003; Timișoara − 22.VII.1999.

Aeshna cyanea (Müller, 1764) (Fig. 23): Bistra Forest − 3.VIII.2004; Criciova − 10.IX.2006; Curtea − 19.VIII.2003; Luncanii de Sus − 19.VIII.2003; Nădrag − 29.IX.1999 (2 ♂ collected).

Anax imperator Leach, 1815 (Fig. 24): Bazoșu Nou − 6.VI.2004; Bărăteaz − 3.VII.2004; Becicherecu Mic − 12.VI.2005; Beregsău Mare − 12.VI.2005; Bistra Forest − 3.VIII.2004; Brestovăț − 28.VI.2004; Cărani − 20.VI.2005; Cenad − 15.VI.2005; Charlottenburg − 26.VII.2008; Chevereș Forest − 14.V.2004; Coștei − 14.VII.2005; Dragșina − 14.V.2004; Foeni − 25.VII.2004; Gad − 25.VII.2004; Gătaia − 6.VII.2007; Ghiroda Nouă − 22.VII.1999; Grăniceri − 25.VII.2004; Ianova − 28.VI.2004; Igriș − 15.VI.2005; Ivanda − 6.VII.2007; Jimbolia − 13.VI.2005; Herneacova − 28.VI.2004; Hodoni − 20.VI.2005; Liebling Lake − 6.VII.2007; Pădurea Verde − 21.V.2004, 15.VI.2004, 21.V.2005; Periam − 27.VI.2015; Pișchia Forest − 9.VI.2004; Remetea Mare − 2.VII.2007; Rudna − 25.VII.2004; Sacoșu Turcesc − 28.VI.20015; Satchinez − 3.VIII.2003, 3.VII.2004; Săcălaz - 12.VI.2005; Sânandrei − 12.VI.2005; Surduc Lake − 20.VII.2013; Șag − 21.VI.2005; Timișoara − 3.VI.2010; Timișoara (irrigation canal Agronomie) − 2.VIII.2003; Tomnatic − 13.VI.2005; Topolovățul Mare − 14.VII.2005; Uivar − 12.VI.2005.

Anax parthenope (Selys, 1839) (Fig. 25): Satchinez − 3.VIII.2003, 23.VIII.2003. This is a very common species in the Danube Delta, but it seems to be much more uncommon or even rare in the rest of the country.

Brachytron pratense (Müller, 1764) (Fig. 26): Bărăteaz − 15.V.2004; Bencecu de

Jos (forest) − 30.IV.2004; Bistra Forest − 15.V.2010; Chevereș Forest − 14.V.2004; Diniaș − 29.V.2010; Dragșina − 14.V.2004; Pădurea Verde − 2.VI.2000 (1 ♂ collected), 21.V.2004, 13.V.2005, 5.V.2006, 3.V.2009 (1 ♀ collected); Rudna − 18.IV.2004; Satchinez − 1.V.2004, 15.V.2004, 30.IV.2007; Șag − 21.VI.2005.

Gomphidae are present with four species from three genera. From these four species two are of particular interest (*Gomphus flavipes* and *Ophiogomphus cecilia*) being Natura 2000 species.

Gomphus vulgatissimus (Linnaeus, 1758) (Fig. 27): Albina − 7.V.2006; Bazoșu Nou − 16.V.2004, 6.VI.2004, 18.VI.2004; Bărăteaz − 3.VII.2004; Becicherecu Mic − 12.VI.2005; Bencecu de Jos (forest) - 30.IV.2004; Beregsău Mare − 12.VI.2005; Brestovăț − 28.VI.2004; Bistra Forest − 5.V.2007, 17.V.2009; Cenad − 15.VI.2005; Chevereș Forest − 14.V.2004, 17.V.2005; Coștei − 14.VII.2005; Dragșina − 14.V.2004, 17.V.2005 (1 ♂ collected); Foeni − 25.VII.2004; Gad − 25.VII.2004; Gătaia − 6.VII.2007; Ghiroda Nouă − 30.V.2001 (1 ♂ collected), 5.V.2007; Giroc Forest − 9.V.2010; Grăniceri − 25.VII.2004; Igriș − 15.VI.2005; Jdioara − 18.VII.2013; Pădurea Verde − 10.VI.1999 (1 ♂ collected), 21.V.2004, 15.VI.2004, 21.V.2005 (1 ♀ collected), 3.V.2009; Periam − 27.VI.2015; Pișchia Forest − 9.VI.2004; Remetea Mare − 16.V.2004, 6.VI.2004; Rudna − 25.VII.2004; Sacoșu Turcesc − 28.VI.20015; Satchinez − 15.V.2004, 3.VII.2004; Săcălaz − 12.VI.2005; Sânandrei − 12.VI.2005; Sângeorge − 13.VI.1999 (1 ♀ collected); Surduc Lake − 20.VII.2013; Șag − 21.VI.2005; Topolovățul Mare − 14.VII.2005; Uivar − 12.VI.2005; Utvin − 21.V.2005.

Gomphus flavipes (Charpentier, 1825) (Fig. 28): Bistra Forest − 3.VIII.2004; Cenad − 15.VI.2005; Chevereș Forest − 14.VIII.2005; Dragșina − 14.VIII.2005; Ghiroda Nouă − 22.VII.1999 (1 ♀ collected); Igriș − 15.VI.2005; Pădurea Verde − 10.VI.1999 (1 ♂ collected); Periam − 27.VI.2015; Pișchia Forest − 9.VI.2004; Remetea Mare − 2.VII.2007; Rudna − 25.VII.2004; Satchinez − 3.VII.2004; Săcălaz − 12.VI.2005; Sânandrei − 12.VI.2005; Sângeorge − 13.VI.1999 (1 ♀ collected); Șag − 21.VI.2005. This is a local species found near rivers and is of particular interest as it is a Natura 2000 species, but ommited in Romanian legislation.

Ophiogomphus cecilia (Fourcroy, 1785) (Fig. 29): Bazoșu Nou − 6.VI.2004; Lățunaș − 10.VII.2013; Peciu Nou − 25.VII.2004; Remetea Mare − 6.VI.2004 (1 ♂ collected); Satchinez − 3.VIII.2003; Săcălaz − 12.VI.2005; Sângeorge − 13.VI.1999 (1 ♀ collected). Another species that is found locally near rivers and is of particular interest from a conservation point of view as it is a Natura 2000 species.

Onychogomphus forcipatus (Linnaeus, 1758) (Fig. 30): Barna − 19.VII.2013; Cladova − 25.VII.2013; Crivina − 19.VII.2013; Făget − 25.VII.2013; Fârdea − 20.VII.2013; Jdioara − 18.VII.2013; Lățunaș − 10.VII.2013; Luncanii de Sus − 19.VIII.2003; Margina − 25.VII.2013; Nădrag − 19.VII.2013; Răchita − 25.VII.2013; Sălciua Nouă − 12.VII.2013; Surduc Lake − 20.VII.2013.

Cordulegastridae are present with one common species in the area.

Cordulegaster bidentata Selys, 1843 (Fig. 31): Lățunaș − 10.VII.2013; Luncanii de Sus − 19.VIII.2003 (1 ♂ collected); Nădrag − 29.IX.1999 (1 ♀ collected).

Corduliidae are present with two species from two genera in the area. One species appears to be rare in the studied area.

Cordulia aenea (Linnaeus, 1758) (Fig. 32): Bărăteaz − 3.VII.2004; Becicherecu Mic − 12.VI.2005; Bistra Forest − 2.VI.1999 (1 ♂ collected), 5.V.2007; Chevereș Forest − 14.V.2004; Dragșina − 14.V.2004; Dumbrăvița Lake − 5.V.2006; Ghiroda Nouă − 30.V.2001 (1 ♀ collected); Murani Lake − 30.IV.2004; Pădurea Verde − 29.IV.2004, 21.V.2004; Rudna − 25.VII.2004; Sacoșu Turcesc − 28.VI.20015; Satchinez − 1.V.2004, 15.V.2004; Săcălaz − 12.VI.2005; Sânandrei − 15.V.2006; Șag − 21.VI.2005.

Somatochlora meridionalis Nielsen, 1935 (Fig. 33): Bencecu de Jos (forest) − 9.VI.2004; Bistra Forest − 2.VI.1999; Pădurea Verde − 2.VI.2000 (1 ♂ and 2 ♀ collected), 6.VI.2000 (1 ♂ collected), 21.V.2004, 15.VI.2004, 13.V.2005; Pişchia Forest − 9.VI.2004. This is an uncommon species in the studied area with a debated status. Some authors considered it to be only a subspecies of *Somatochlora metallica* (Askew, 2004) and treated as a full species here and by others (Dijkstra, 2006). In Romania, it appears to be a clear separation between the two also on ecological demands: *Somatochlora meridionalis* being found only near small and shaded running waters (mostly at low altitude); and *Somatochlora metallica* being found only at an altitude in habitats with standing waters. All old data published in/from Romania needs to be reviewed.

Libellulidae are present with 14 species from four genera in the researched area. Species appear to be uncommon in the studied area and one of these (*Sympetrum depressiusculum*) has recorded a steep decline.

Libellula quadrimaculata Linnaeus, 1758 (Fig. 34): Bistra Forest − 6.VI.2006; Ghiroda Nouă − 7.V.2001 (1 ♂ collected); Murani Lake − 30.IV.2004; Pădurea Verde − 29.IV.2004, 21.V.2004; Satchinez − 1.V.2004; Sânandrei − 15.V.2006.

Libellula depressa Linnaeus, 1758 (Fig. 35): Bazoşu Nou − 16.V.2004; Bărăteaz − 3.VII.2004; Becicherecu Mic − 12.VI.2005; Beregsău Mare − 12.VI.2005; Bencecu de Jos (forest) − 30.IV.2004; Bistra Forest − 5.V.2007, 15.V.2010; Brestovăţ − 28.VI.2004; Buziaş − 18.V.2008; Cărani − 20.VI.2005; Cenad − 15.VI.2005; Charlottenburg − 26.VII.2008 (1 ♀ collected); Chevotereş Forest − 14.V.2004 (1 ♀ collected); Coştei − 14.VII.2005; Diniaş − 10.V.2004; Dragşina − 14.V.2004; Foeni − 25.VII.2004; Gad − 25.VII.2004; Gătaia − 6.VII.2007; Grăniceri − 25.VII.2004; Ianova − 28.VI.2004; Igriş − 15.VI.2005; Jdioara − 18.VII.2013; Jimbolia − 13.VI.2005; Herneacova − 28.VI.2004; Hodoni − 20.VI.2005; Liebling Lake − 6.VII.2007; Murani Lake − 30.IV.2004; Pădurea Verde − 6.VI.2000 (1 ♂ collected), 21.V.2004, 15.VI.2004, 13.V.2005, 21.V.2005 (2 ♀ collected), 5.V.2006, 3.V.2009; Peciu Nou − 25.VII.2004; Periam − 27.VI.2015; Pişchia Forest − 9.VI.2004 (1 ♀ collected); Remetea Mare − 2.VII.2007; Rudna − 25.VII.2004; Sacoşu Turcesc − 28.VI.20015; Satchinez − 3.VIII.2003, 23.VIII.2003, 1.V.2004, 15.V.2004, 3.VII.2004; Săcălaz (Beregsău Rivulet) − 13.V.2005; Sânandrei − 15.V.2006; Surduc Lake − 20.VII.2013; Şag − 21.VI.2005; Timişoara (irrigation canal Agronomie) − 2.VIII.2003; Timişoara (Freidorf) − 2.V.2009; Tomnatic − 13.VI.2005; Topolovăţul Mare − 14.VII.2005; Uivar − 12.VI.2005.

Libelula fulva Müller, 1764 (Fig. 36): Bazoşu Nou − 16.V.2004, 6.VI.2004, 18.VI.2004; Bărăteaz − 3.VII.2004; Bencecu de Jos (in the near forest) − 30.IV.2004; Bistra Forest − 5.V.2007; Brestovăţ − 28.VI.2004; Chevereş Forest − 14.V.2004 (1 ♀ collected); Dragşina − 14.V.2004 (2 ♂ collected); Giroc − 4.V.2011; Pădurea Verde − 10.IX.1999 (1 ♀ collected), 2.VI.2000 (1 ♂ collected), 6.VI.2000 (1 ♀ collected), 15.VI.2004, 13.V.2005, 21.V.2005 (1 ♂ and 1 ♀ collected), 3.V.2009; Periam − 27.VI.2015; Pişchia Forest − 9.VI.2004; Remetea Mare − 16.V.2004, 2.VII.2007; Rudna − 25.VII.2004; Sacoşu Turcesc − 28.VI.20015; Satchinez − 15.V.2004.

Orthetrum cancellatum (Linnaeus, 1758) (Fig. 37): Bărăteaz − 3.VII.2004; Bistra Forest − 3.VIII.2004, 2.VI.2007; Cenad − 15.VI.2005; Chevereş Forest − 14.V.2004; Dragşina − 14.V.2004; Gătaia − 6.VII.2007; Igriş − 15.VI.2005; Liebling Lake − 6.VII.2007; Pădurea Verde − 10.VI.1999 (1 ♂ collected), 21.V.2005 (1 ♀ collected), 3.V.2009; Periam − 27.VI.2015; Pişchia Forest − 29.V.1999 (1 ♂ collected), 9.VI.2004; Remetea Mare − 6.VI.2004 (1 ♂ collected); Satchinez − 3.VII.2004; Şag − 21.VI.2005; Timişoara (irrigation canal Agronomie) − 2.VIII.2003.

Orthetrum albistylum (Selys, 1848) (Fig. 38): Bistra Forest − 5.V.2007; Dumbravița Lake − 6.VI.2000 (1 ♀ collected); Ghiroda Nouă − 22.VII.1999; Jimbolia − 13.VI.2005; Herneacova − 28.VI.2004; Liebling Lake − 6.VII.2007; Pădurea Verde − 10.VI.1999 (1 ♀ collected), 2.VI.2000 (1 ♀ collected), 3.V.2009; Pișchia Forest − 29.V.1999 (1 ♂ collected); Remetea Mare − 2.VII.2007; Rudna − 25.VII.2004; Sacoșu Turcesc − 28.VI.20015; Satchinez − 3.VII.2004.

Orthetrum coerulescens (Fabricius, 1798) (Fig. 39): Bistra Forest − 3.VIII.2004; Ghiroda Nouă − 22.VII.1999 (3 ♂ and 1 ♀ collected), 3.VIII.2004; Liebling Lake − 6.VII.2007; Pădurea Verde − 18.VII.1999 (1 ♀ collected), 15.VI.2004; Remetea Mare − 2.VII.2007; Rudna − 25.VII.2004; Sacoșu Turcesc − 28.VI.20015; Satchinez − 3.VII.2004; Sângeorge − 13.VI.1999 (1 ♀ collected); Timișoara (irrigation canal Agronomie) − 2.VIII.2003. Specimens that looks very good for *Orthetrum coerulescens ancep*s can be found in the area.

Orthetrum brunneum (Fonscolombe, 1837 (Fig. 40): Buziaș − 1.VIII.2007; Charlottenburg − 26.VII.2008 (1 ♀ collected); Giarmata Mare − 18.VIII.2006 (1 ♂ collected); Ghiroda Nouă − 22.VII.1999; Pădurea Verde − 18.VII.1999; Pișchia Forest − 9.VI.2004 (1 ♂ collected); Rudna − 25.VII.2004; Satchinez − 3.VIII.2003.

Sympetrum pedemontanum (Müller in Allioni, 1766) (Fig. 41): Ghiroda Nouă − 22.VII.1999 (2 ♂ collected). Appears to be a rare species in the area with only one known colony.

Sympetrum sanguineum (Müller, 1764) (Fig. 42): Bărăteaz − 3.VII.2004; Bistra Forest − 6.IX.2003, 3.VIII.2004, 8.IX.2006; Charlottenburg − 26.VII.2008 (1 ♂ and 1 ♀ collected); Gătaia − 6.VII.2007; Giarmata Mare − 18.VIII.2006 (1 ♂ collected); Giroc Forest − 3.VII.2011; Liebling Lake − 6.VII.2007; Nădrag − 29.IX.1999 (1 ♂ collected); Pădurea Verde − 21.VI.1999 (4 ♂ and 1 ♀ collected), 18.VII.1999 (3 ♂ and 2 ♀ collected); Pișchia Forest − 21.VII.1999 (1 ♂ collected); Remetea Mare − 8.IX.2006 (1 ♀ collected), 2.VII.2007; Rudna − 25.VII.2004; Sacoșu Turcesc − 28.VI.20015; Satchinez − 3.VIII.2003, 3.VII.2004, 19.VIII.2006 (1 ♂ and 1 ♀ collected); Timișoara (Freidorf) − 28.VI.2006, 22.VII.2007, 30.VII.2007; Timișoara (irrigation canal Agronomie) − 2.VIII.2003.

Sympetrum depressiusculum (Selys, 1841) (Fig. 43): Satchinez − 19.VIII.2006. This species appears to be rare in the area, being seen only one time in one location. The species appears to be very rare in Romania. If we compare the new data with the old data, the population decline of the species at a national level is more than 90%.

Sympetrum striolatum (Charpentier, 1840) (Fig. 44): Bărăteaz − 8.XI.2003; Bistra Forest − 3.VIII.2004, 8.IX.2006 (3 ♀ collected); Cenad − 15.VI.2005; Chevereș Forest − 14.VIII.2005; Dragșina − 14.VIII.2005; Dumbrăvița Lake − 28.IX.2003, 7.X.2007; Gătaia − 6.VII.2007; Igriș − 15.VI.2005; Lighed Forest − 1.IX.2005; Luncanii de Sus − 19.VIII.2003; Pădurea Verde − 10.IX.1999 (1 ♀ collected), 2.IX.2006 (1 ♂ and 2 ♀ collected); Remetea Mare − 8.IX.2006; Rudna − 1.IX.2005; Satchinez − 3.VIII.2003, 23.VIII.2003, 8.X.2006, 4.XI.2008; Timișoara (irrigation canal Agronomie) − 2.VIII.2003.

Sympetrum vulgatum (Linnaeus, 1758) (Fig. 45): Satchinez − 8.X.2006.

Sympetrum meridionale (Selys, 1841) (Fig. 46): Bărăteaz − 3.VII.2004; Bistra Forest − 8.IX.2006 (1 ♀ collected), 3.VIII.2004; Charlottenburg − 26.VII.2008; Dumbrăvița Lake − 28.IX.2003; Ghiroda Nouă − 6.IX.2003; Giarmata Mare − 18.VIII.2006 (1 ♂ collected); Pădurea Verde − 21.VI.1999 (1 ♂ and 1 ♀ collected), 18.VII.1999 (1 ♀ collected), 2.IX.2006 (1 ♀ collected); Peciu Nou − 25.VII.2004; Satchinez − 3.VIII.2003, 23.VIII.2003, 3.VII.2004, 19.VIII.2006 (2 ♂ collected); Timișoara (Freidorf) − 9.X.2007; Timișoara (irrigation canal Agronomie) − 2.VIII.2003.

Crocothemis erythraea (Brullé, 1832) (Fig. 47): Bazoşu Nou − 18.VI.2004; Bărăteaz − 3.VII.2004; Bistra Forest − 3.VIII.2004, 2.VI.2007; Cenad − 15.VI.2005; Dumbravița Lake − 6.VI.2000 (1 ♂ collected), 7.VI.2000 (1 ♂ collected); Gătaia − 6.VII.2007; Ghiroda Nouă − 22.VII.1999 (3 ♂ collected); Igriș − 15.VI.2005; Liebling Lake − 6.VII.2007; Murani Lake − 30.IV.2004; Pădurea Verde − 10.VI.1999 (1 ♀ collected), 15.VI.2004; Periam − 27.VI.2015; Remetea Mare − 2.VII.2007; Rudna − 25.VII.2004; Sacoşu Turcesc − 28.VI.20015; Satchinez − 3.VIII.2003, 3.VII.2004, 4.VII.2006; Sânandrei − 3.VII.2004; Şag − 21.VI.2005; Timişoara (irrigation canal Agronomie) − 2.VIII.2003; Timişoara (Freidorf) − 30.VII.2007.

The full list of toponyms (in alphabeticcal order): Albina, Bacova, Balint, Barna, Bărăteaz, Bazoşu Nou, Bencecu de Jos, Beregsău Mare, Beregsău Mic, Bistra Forest, Blajova, Bobda, Brestovăț, Bulza, Bunea Mare, Bunea Mică, Buziaș, Cărani, Cebza, Cenad, Cenei, Charlottenburg (Şarlota), Cheveres Forest, Chizătău, Cladova, Colonia Fabricii, Coşava, Coştei, Criciova, Crivina, Crivina de Sus, Curtea, Denta, Diniaş, Dragşina, Drinova, Dubeşti, Dumbrăvița Lake, Făget, Fărăşeşti, Fârdea, Foeni, Gad, Gătaia, Găvojdia, Giarmata Mare, Giroc Forest, Giulvăz, Ghiroda, Ghiroda Nouă, Gladna Montană, Gladna Română, Grăniceri, Groşi, Hănzeşti, Herneacova, Hodoni, Homojdia, Ianova, Igriş, Ivanda, Jdioara, Jebel, Jimbolia, Lăţunaş, Leucuşeşti, Liebling Lake, Lighed Forest, Lugoj, Luncanii de Jos, Luncanii de Sus, Margina, Murani Lake, Nădrag, Nemeşeşti, Parța, Pădurani, Pădurea Verde, Peciu Nou, Periam, Pietroasa, Pişchia Forest, Poganeşti, Poieni, Ohaba Lungă, Ohaba Română, Otelec, Răchita, Remetea Mare, Rudna, Satchinez, Săcălaz (Beregsău Rivulet), Sălciua Nouă, Sânandrei, Sângeorge, Sânmihaiu Român, Sinteşti, Surduc Lake, Şag, Tapia, Temereşti, Timişoara (irrigation canal Agronomie), Timişoara (Freidorf), Tomeşti, Uivar, Unip Forest and Utvin (a total of 107 toponyms).

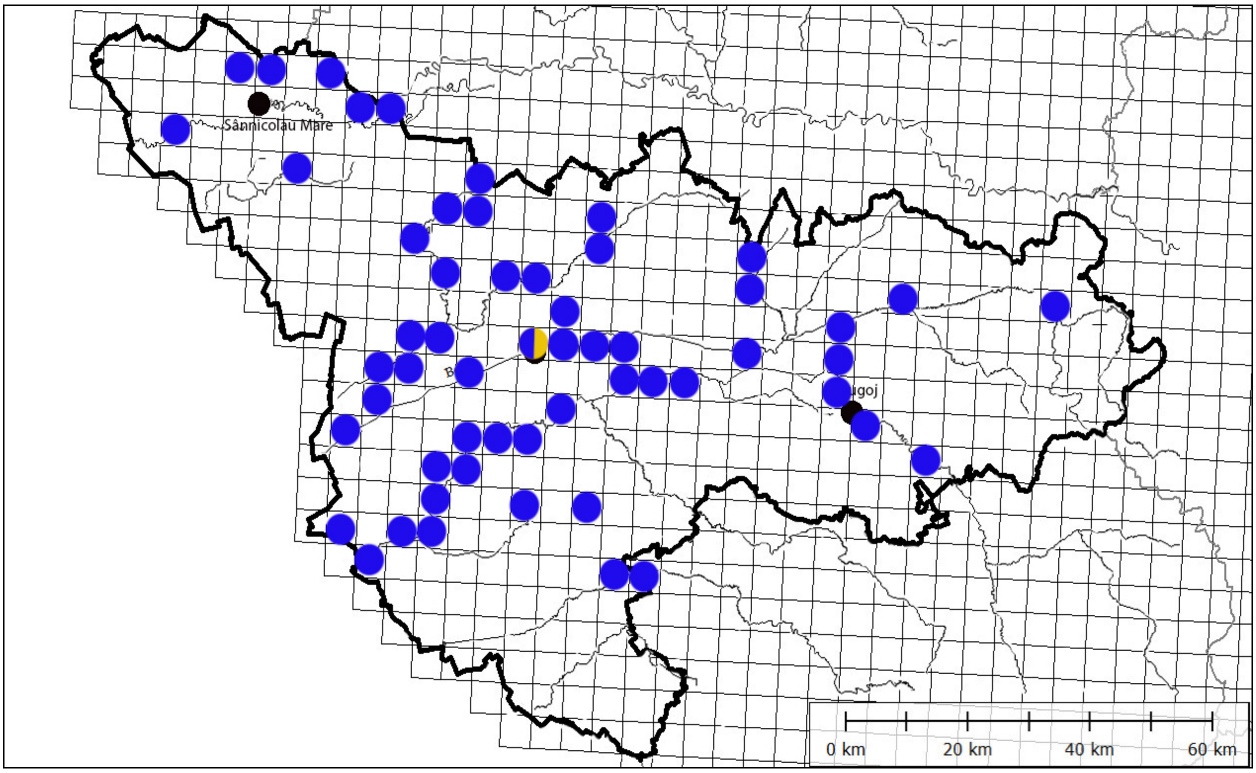

Figure 3: Distribution of *Calopteryx splendens* (Harris, 1782) in Timiş County.

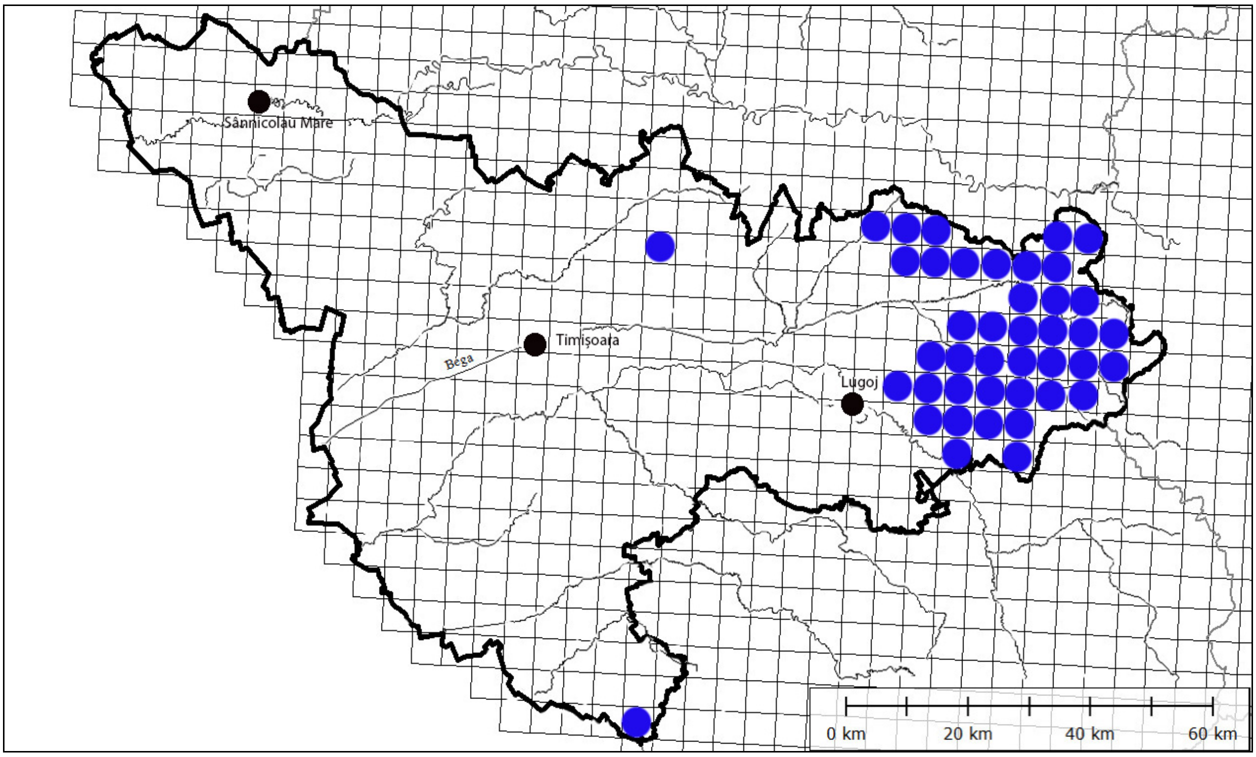

Figure 4: Distribution of *Calopteryx virgo* (Linnaeus, 1758) in Timiș County.

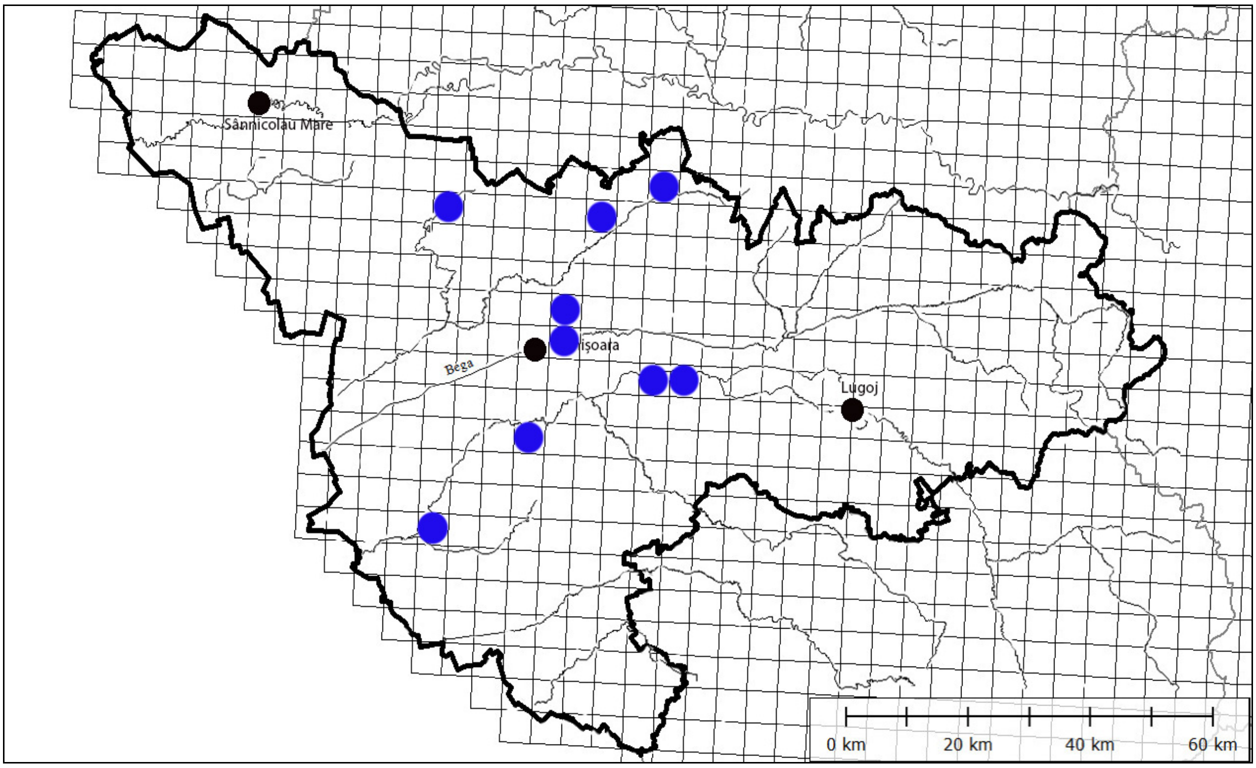

Figure 5: Distribution of *Lestes sponsa* (Hansemann, 1823) in Timiș County.

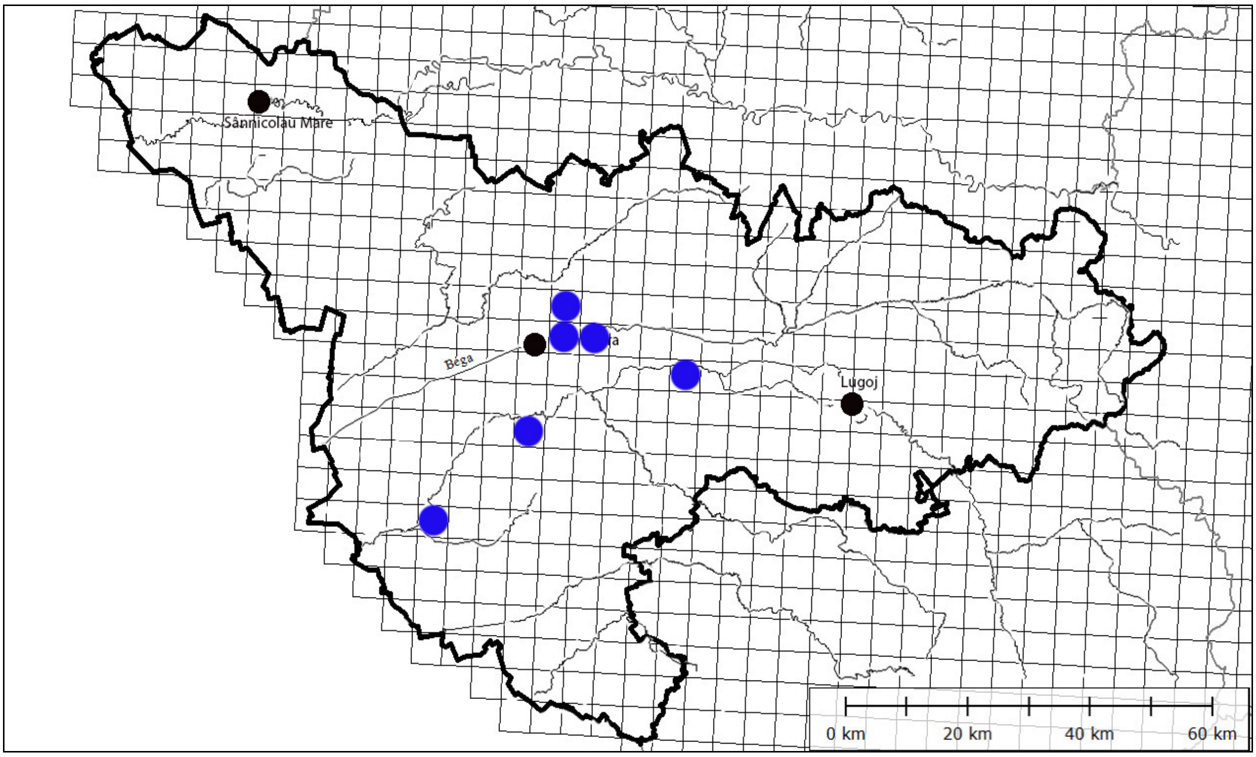

Figure 6: Distribution of *Lestes dryas* Kirby, 1890
in Timiș County.

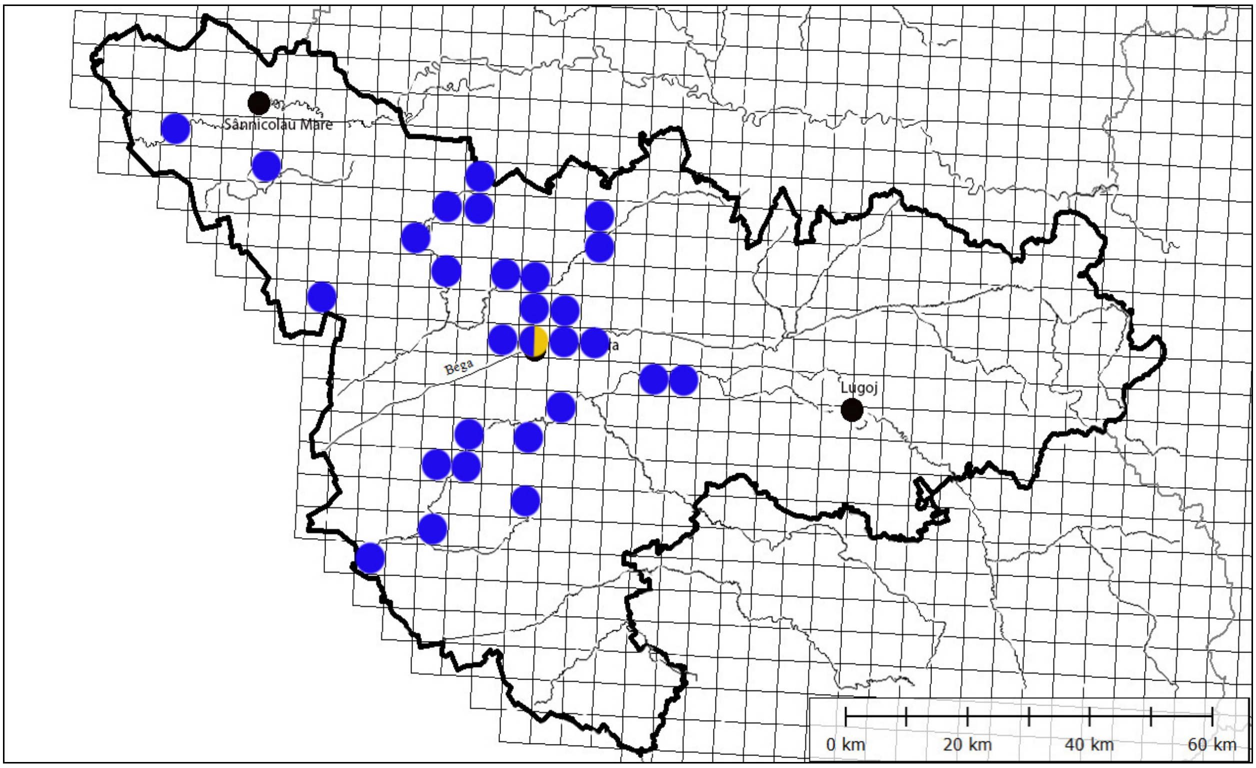

Figure 7: Distribution of *Lestes barbarus* (Fabricius, 1798)
in Timiș County.

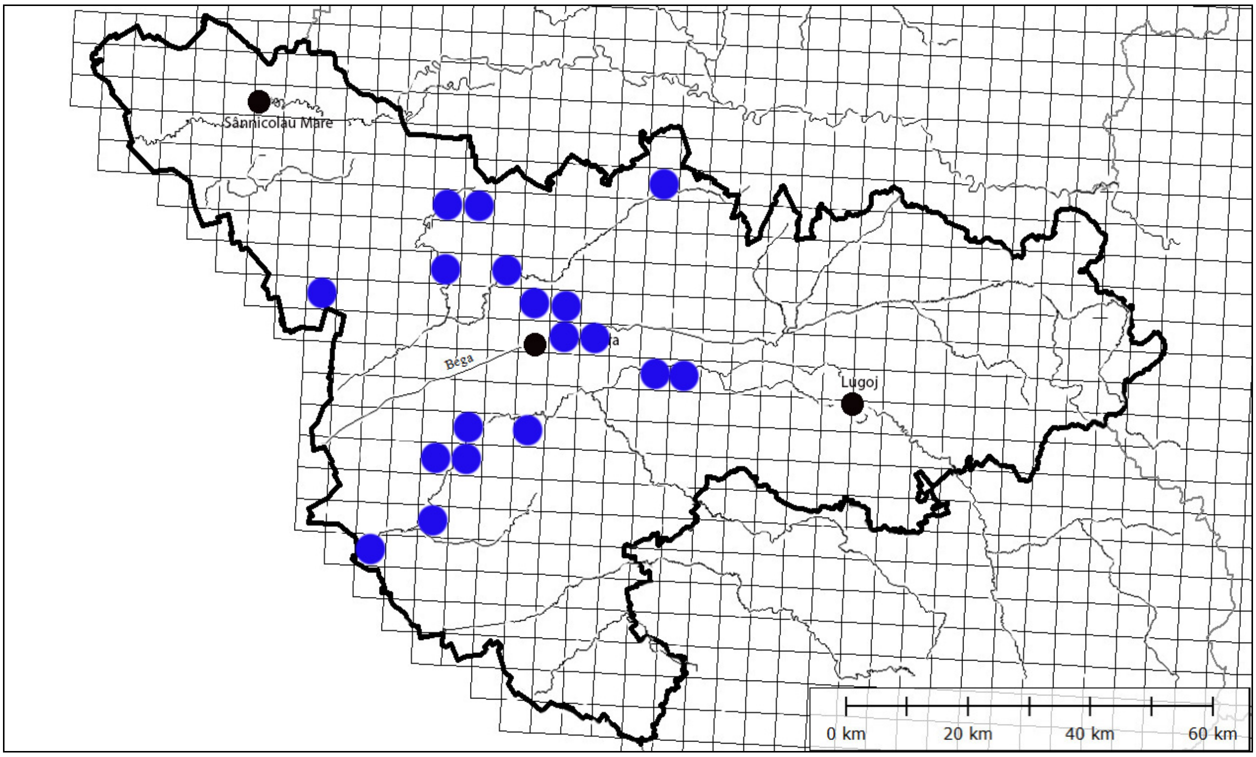

Figure 8: Distribution of *Lestes virens* (Charpentier, 1825)
in Timiș County

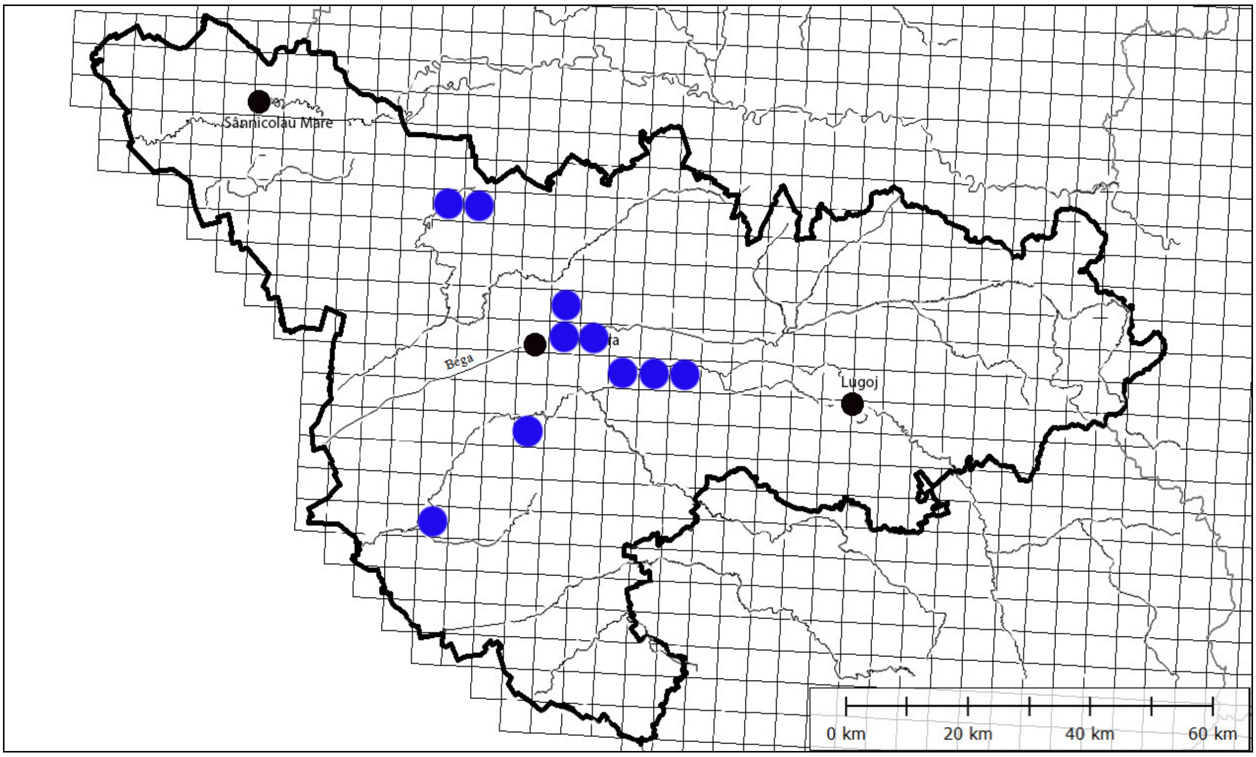

Figure 9: Distribution of *Lestes parvindes* Artobolevskii, 1929
in Timiș County.

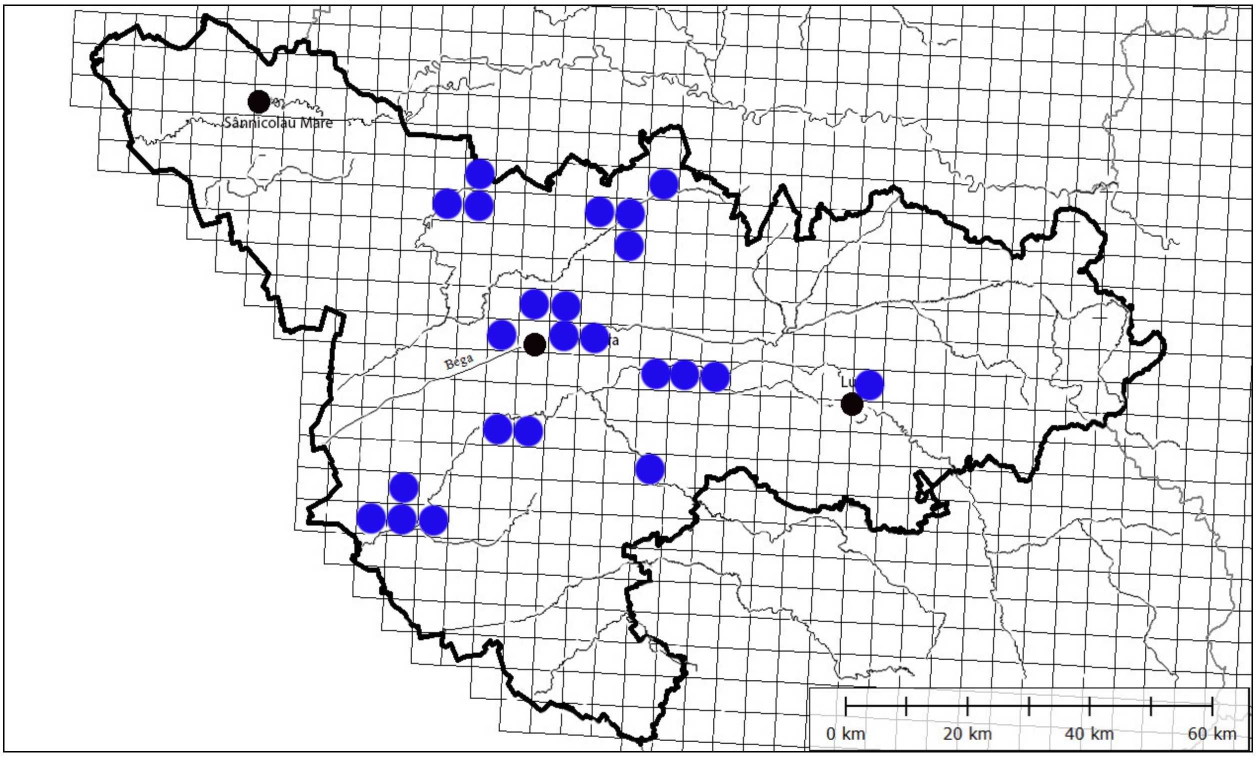

Figure 10: Distribution of *Sympecma fusca* (Vander Linden, 1820) in Timiş County.

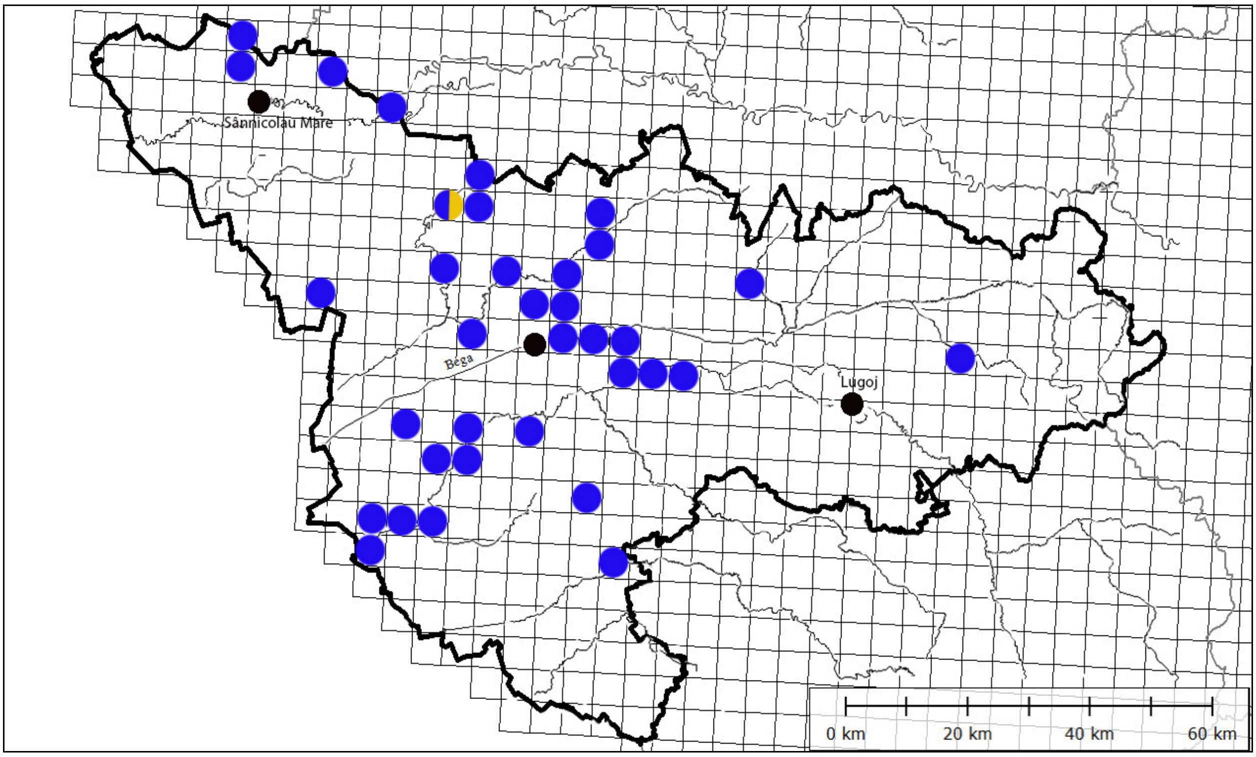

Figure 11: Distribution of *Ischnura elegans* (Vander Linden, 1820) in Timiş County.

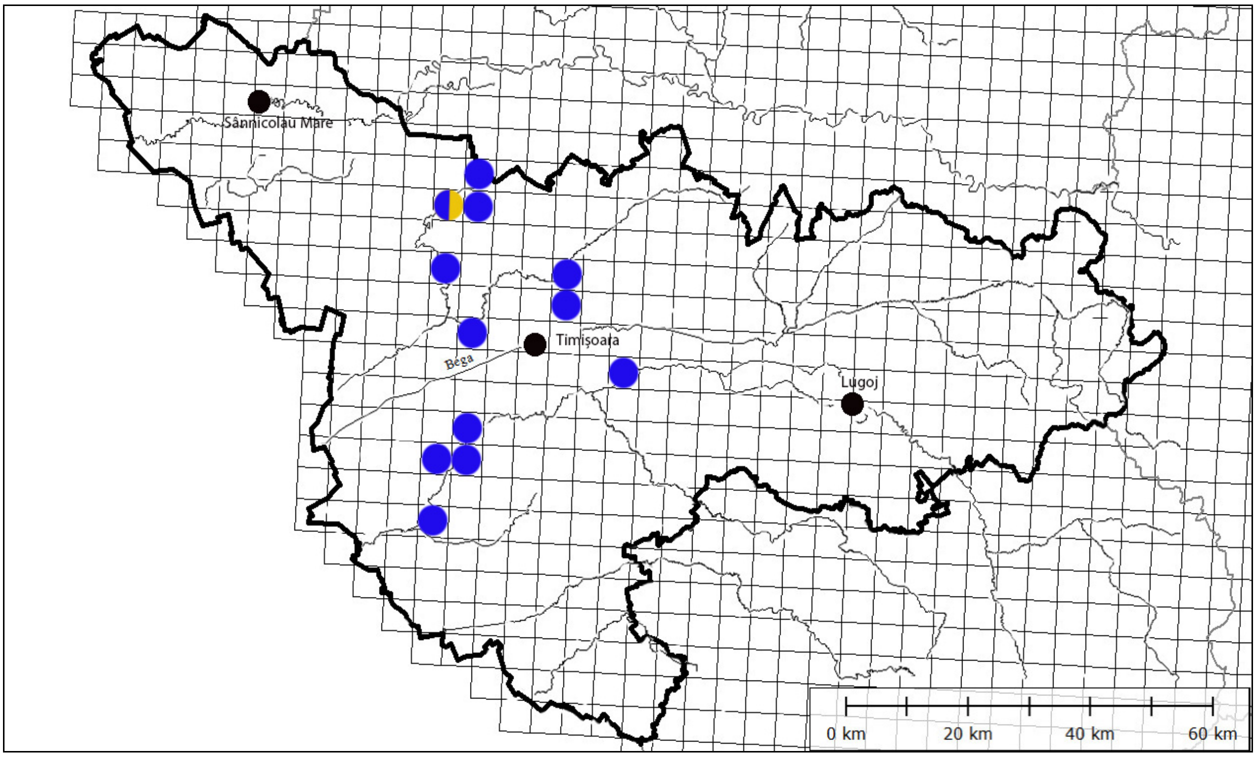

Figure 12: Distribution of *Ischnura pumilio* (Charpentier, 1825) in Timiș County.

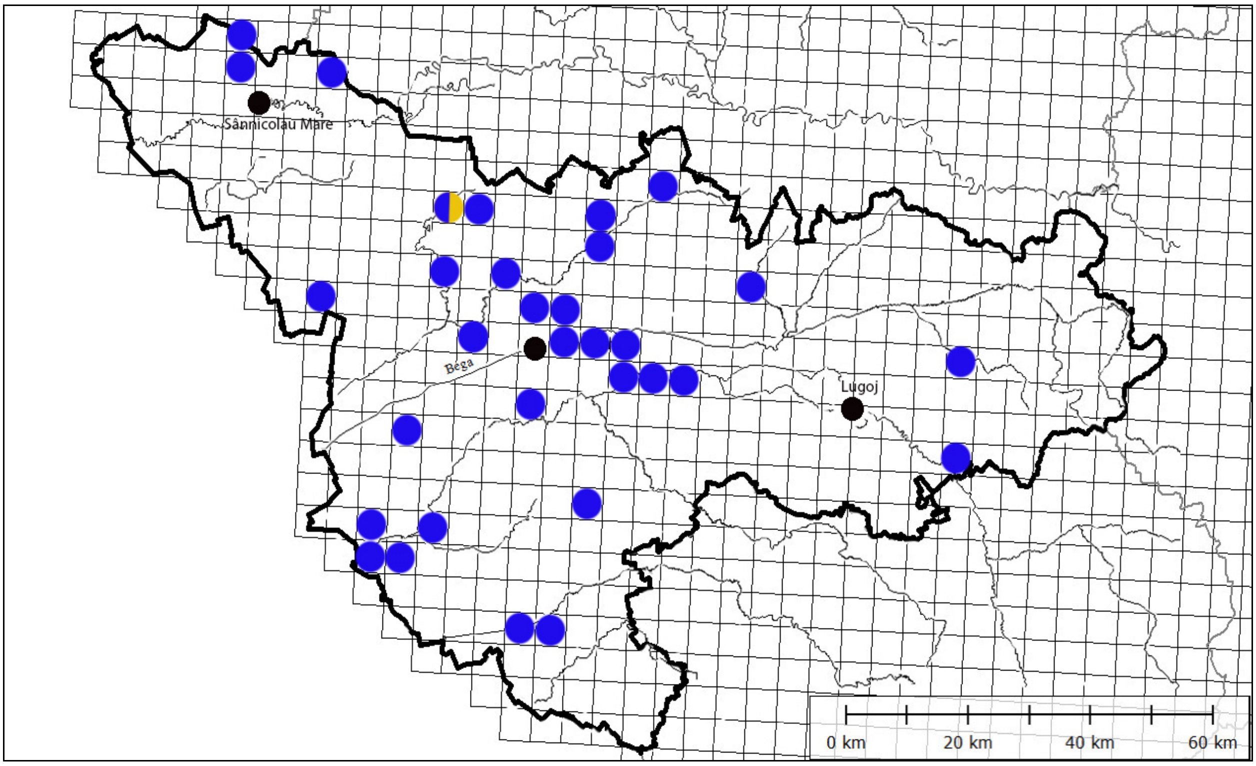

Figure 13: Distribution of *Coenagrion pulchellum* (Vander Linden, 1825) in Timiș County.

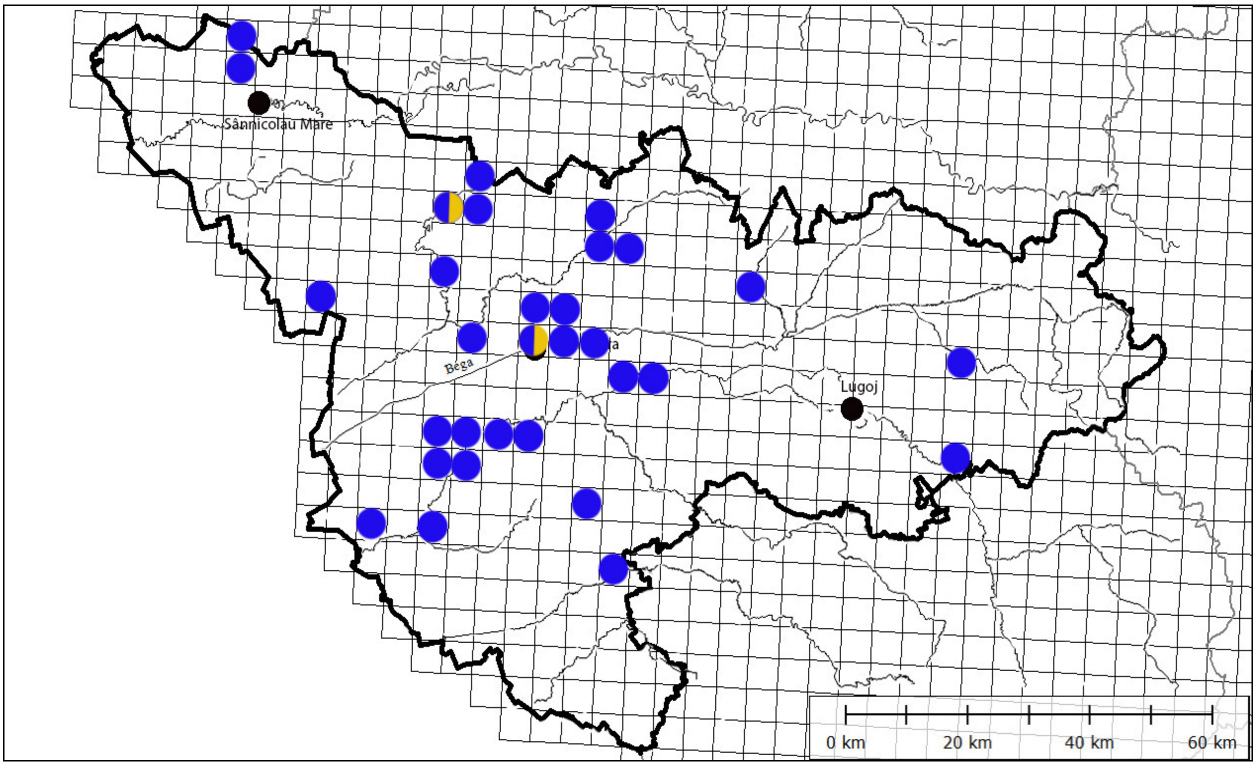

Figure 14: Distribution of *Coenagrion puella* (Linnaeus, 1758) in Timiș County.

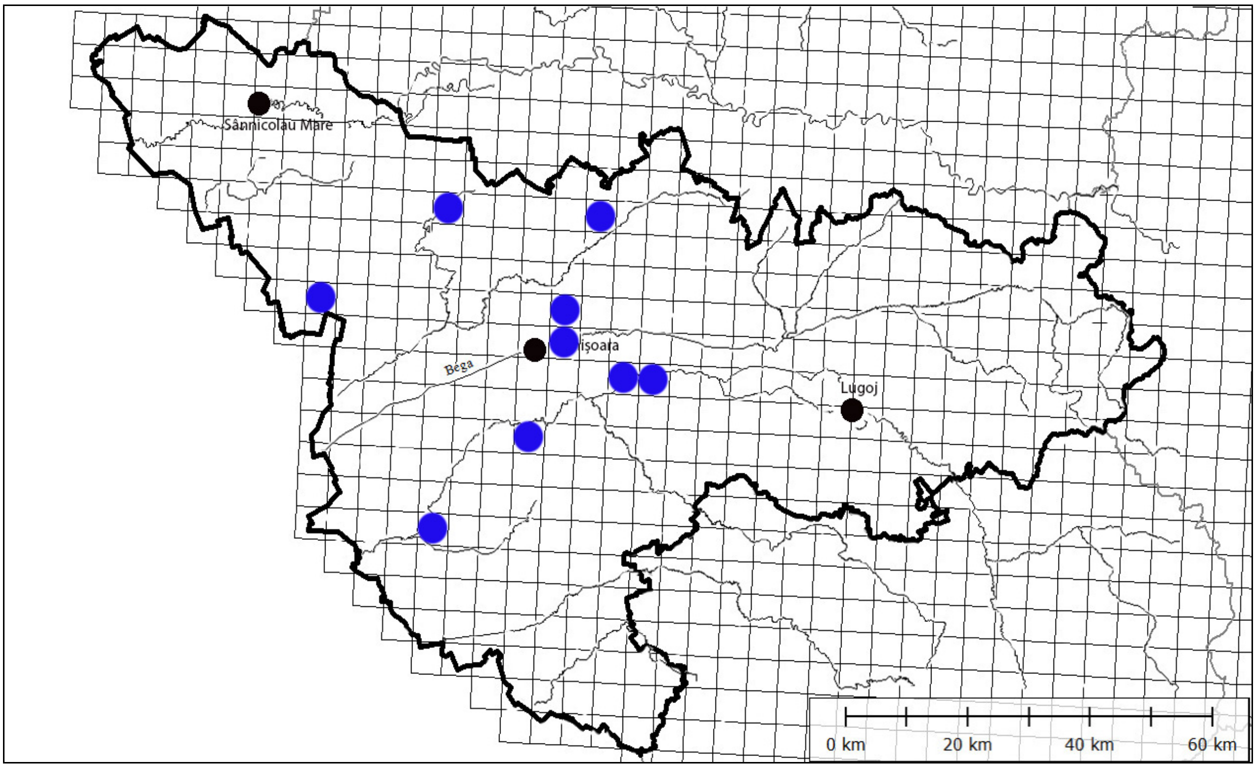

Figure 15: Distribution of *Coenagrion ornatum* (Selys, 1850) in Timiș County.

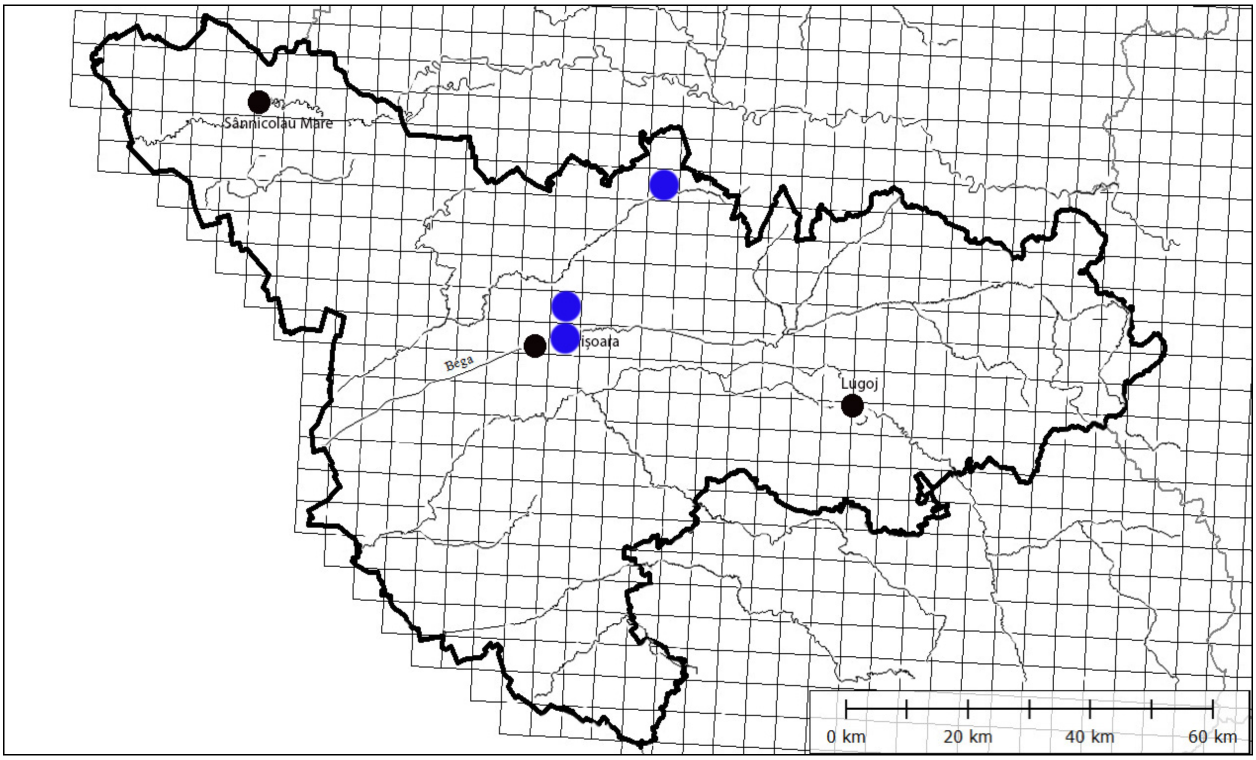

Figure 16: Distribution of *Coenagrion scitulum* (Fonscolombe, 1838) in Timiș County.

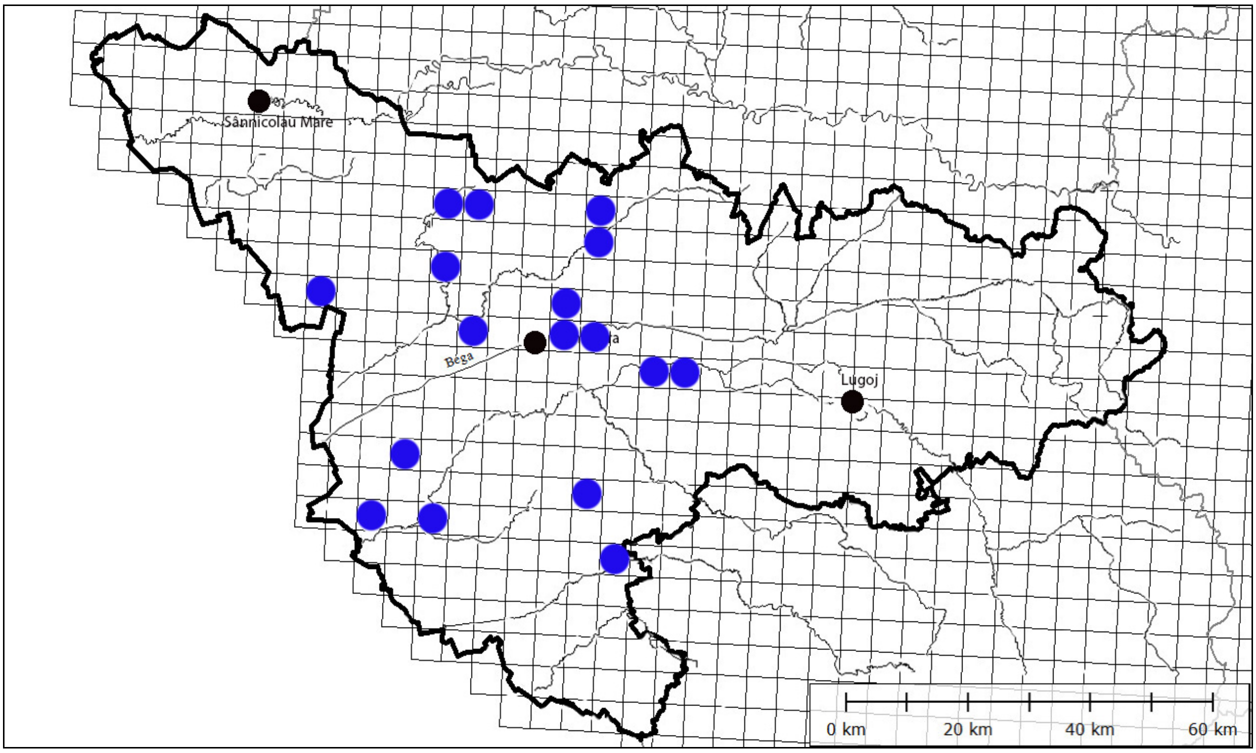

Figure 17: Distribution of *Erythromma viridulum* (Charpentier, 1825) in Timiș County.

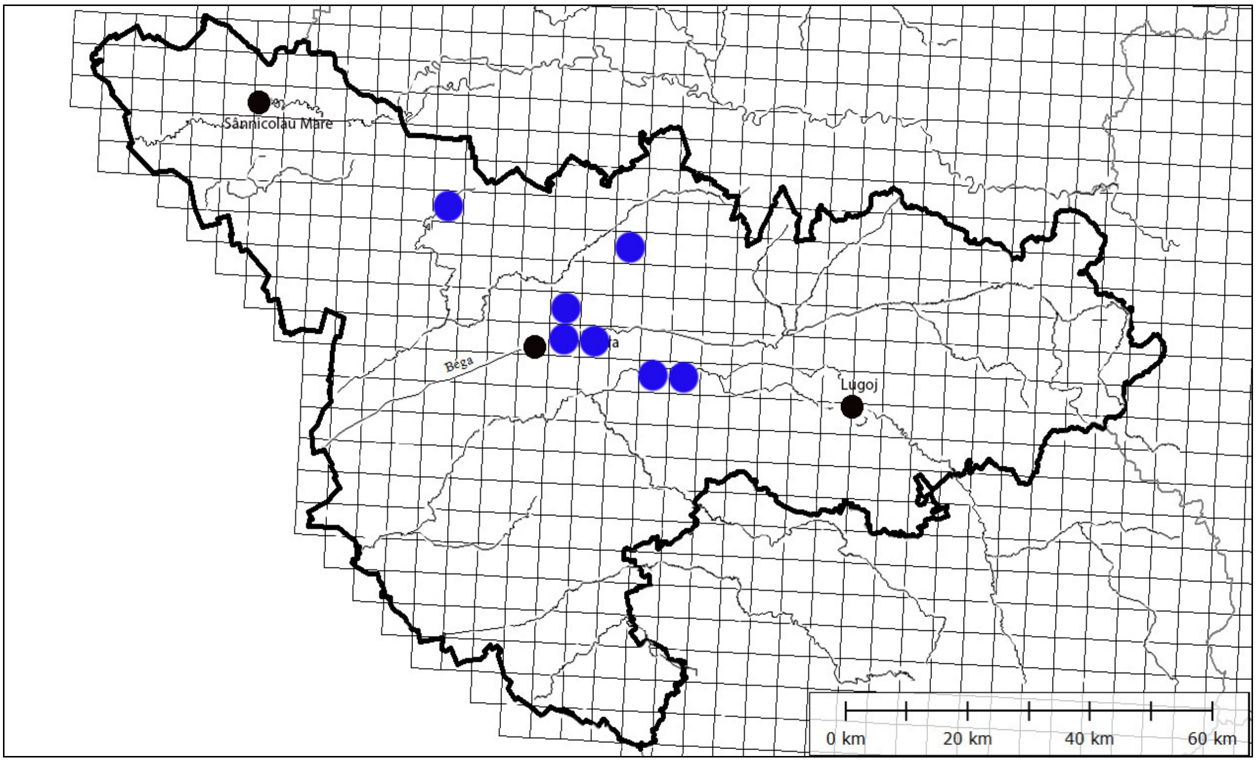

Figure 18: Distribution of *Pyrrhosoma nymphula* (Sulzer, 1776)
in Timiș County

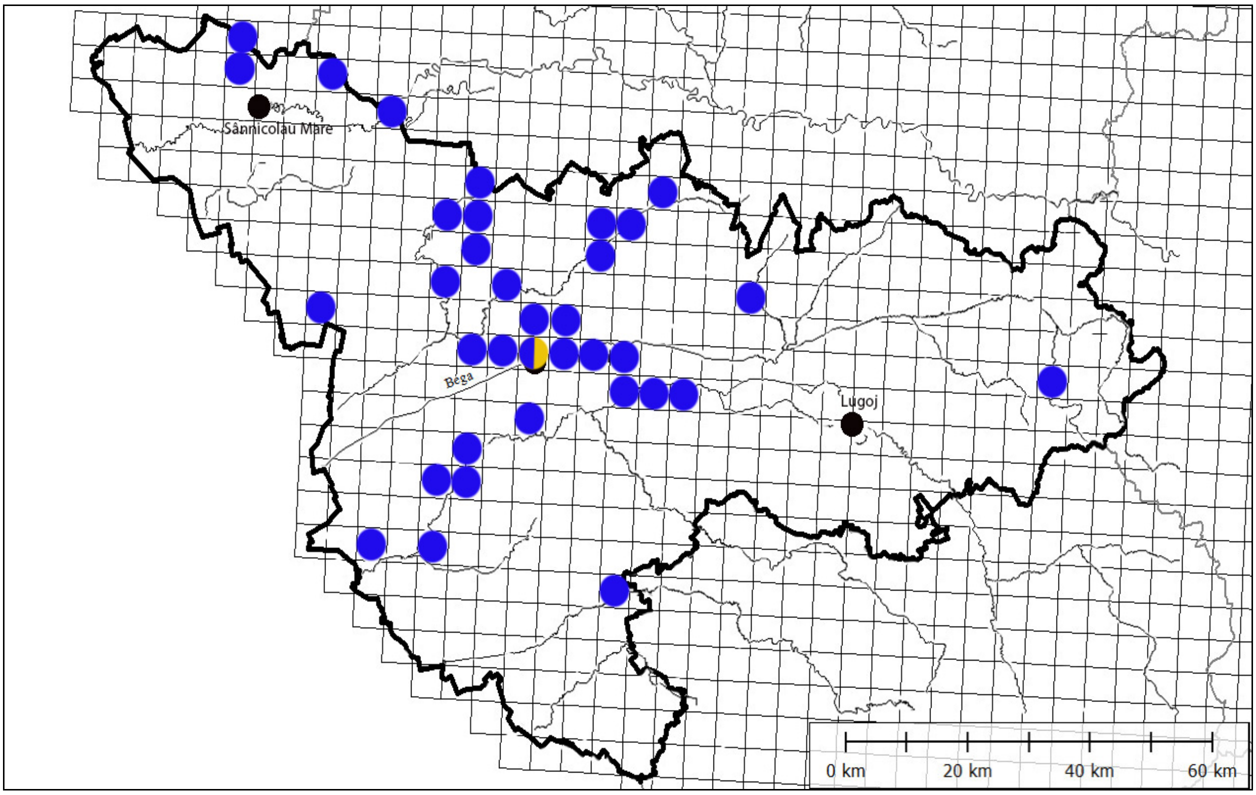

Figure 19: Distribution of *Platycnemis pennipes* (Pallas, 1771)
in Timiș County.

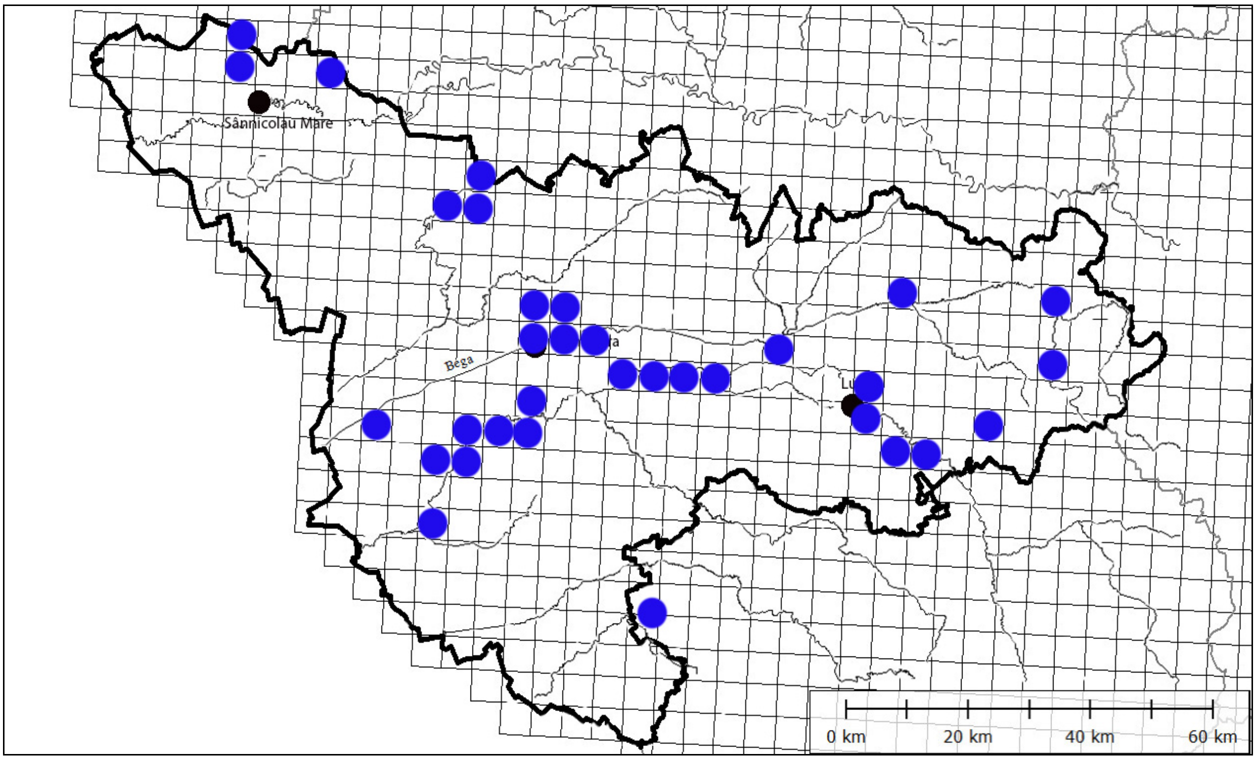

Figure 20: Distribution of *Aeshna mixta* Latreille, 1805
in Timiș County.

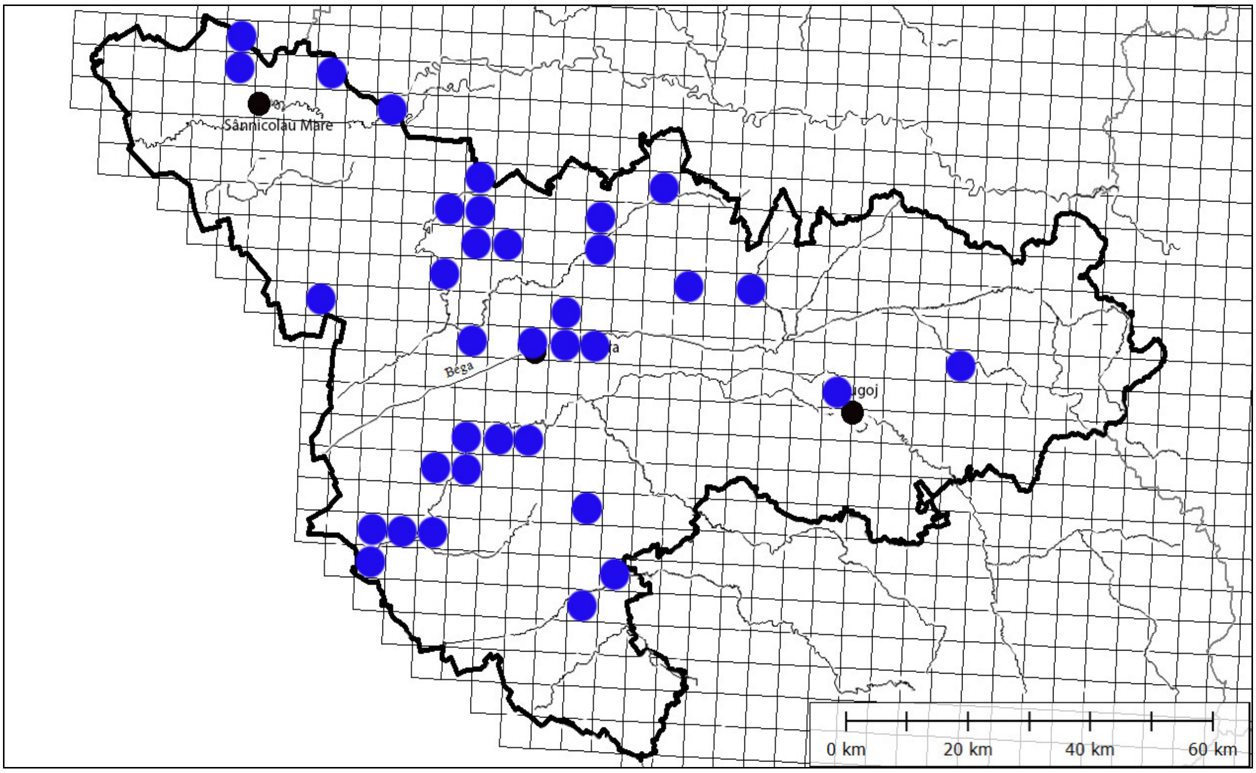

Figure 21: Distribution of *Aeshna affinis* Vander Linden, 1820
in Timiș County.

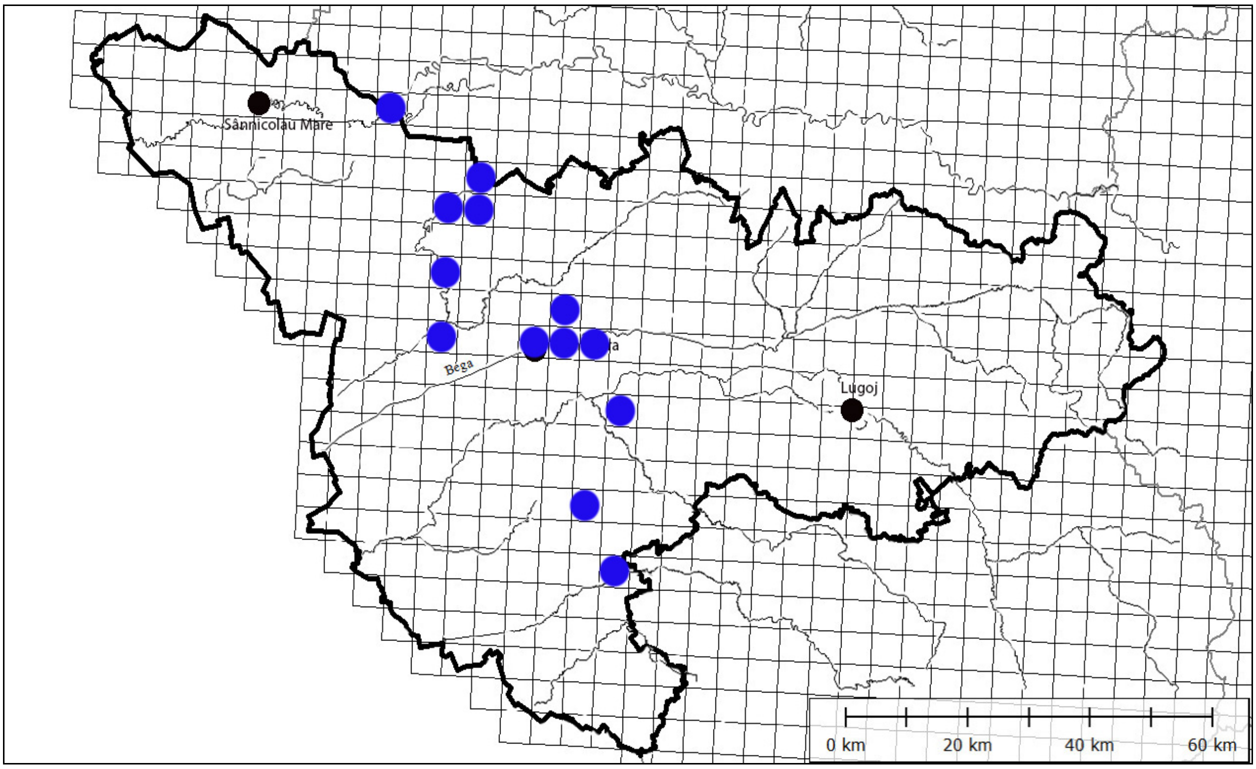

Figure 22: Distribution of *Aeshna isoceles* (Müller, 1767) in Timiş County.

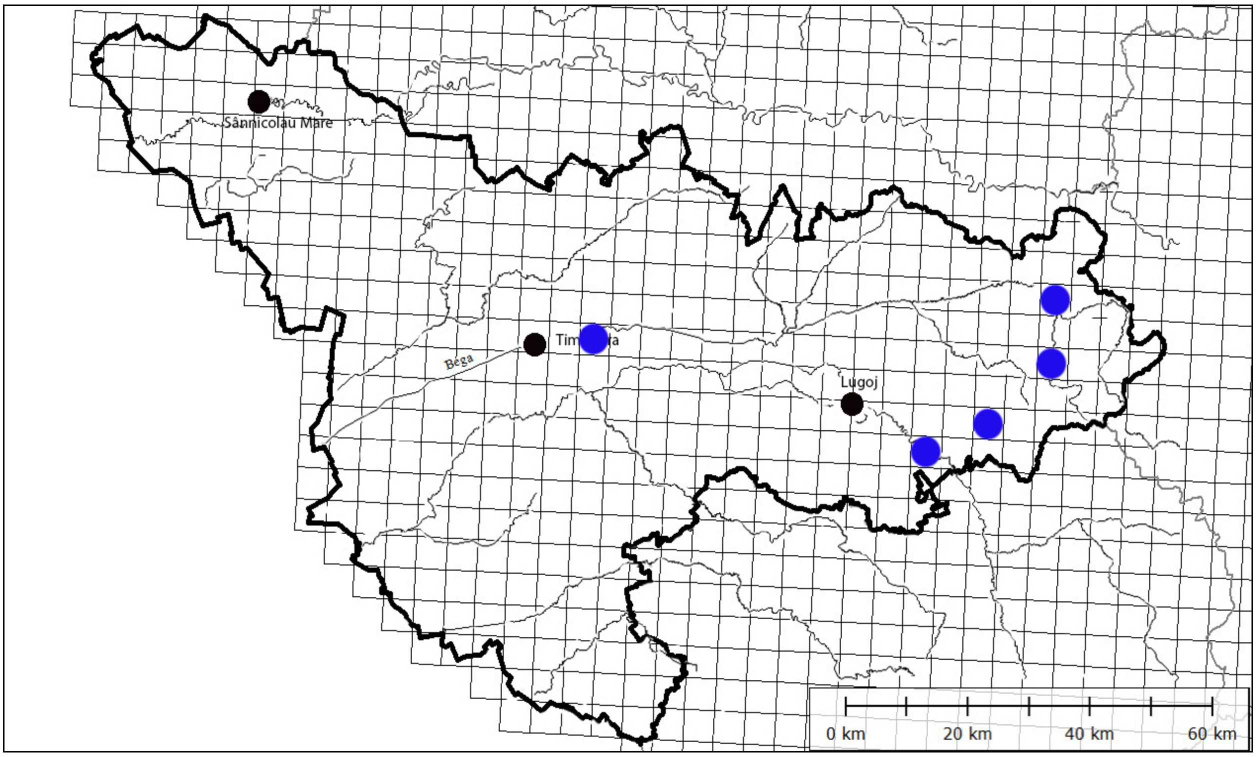

Figure 23: Distribution of *Aeshna cyanea* (Müller, 1764) in Timiş County.

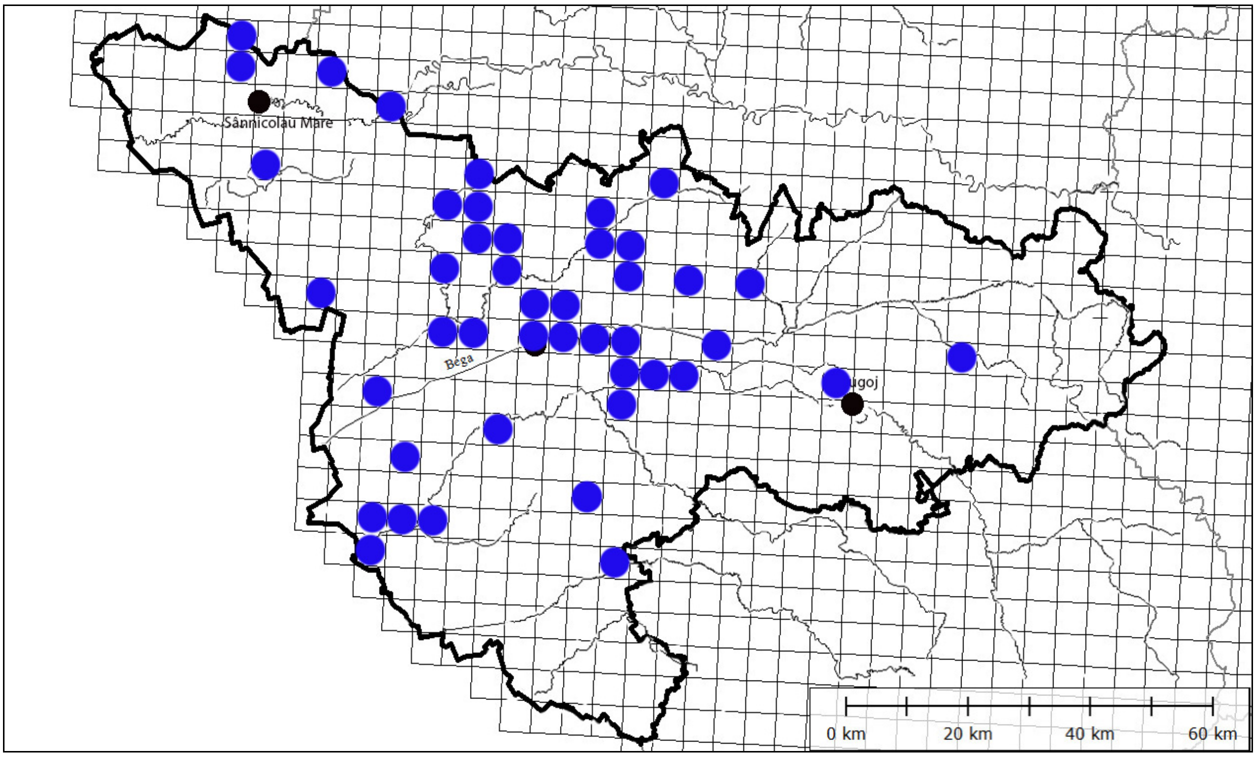

Figure 24: Distribution of *Anax imperator* Leach, 1815
in Timiș County.

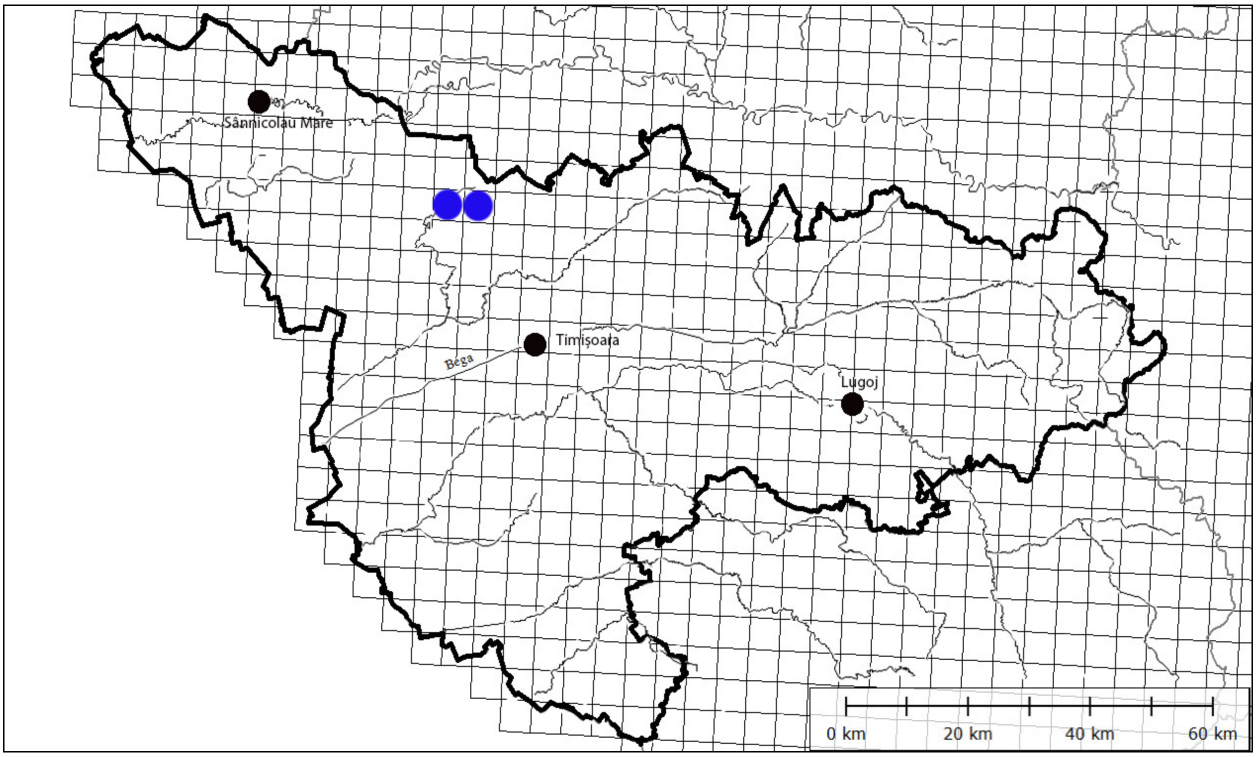

Figure 25: Distribution of *Anax parthenope* (Selys, 1839)
in Timiș County.

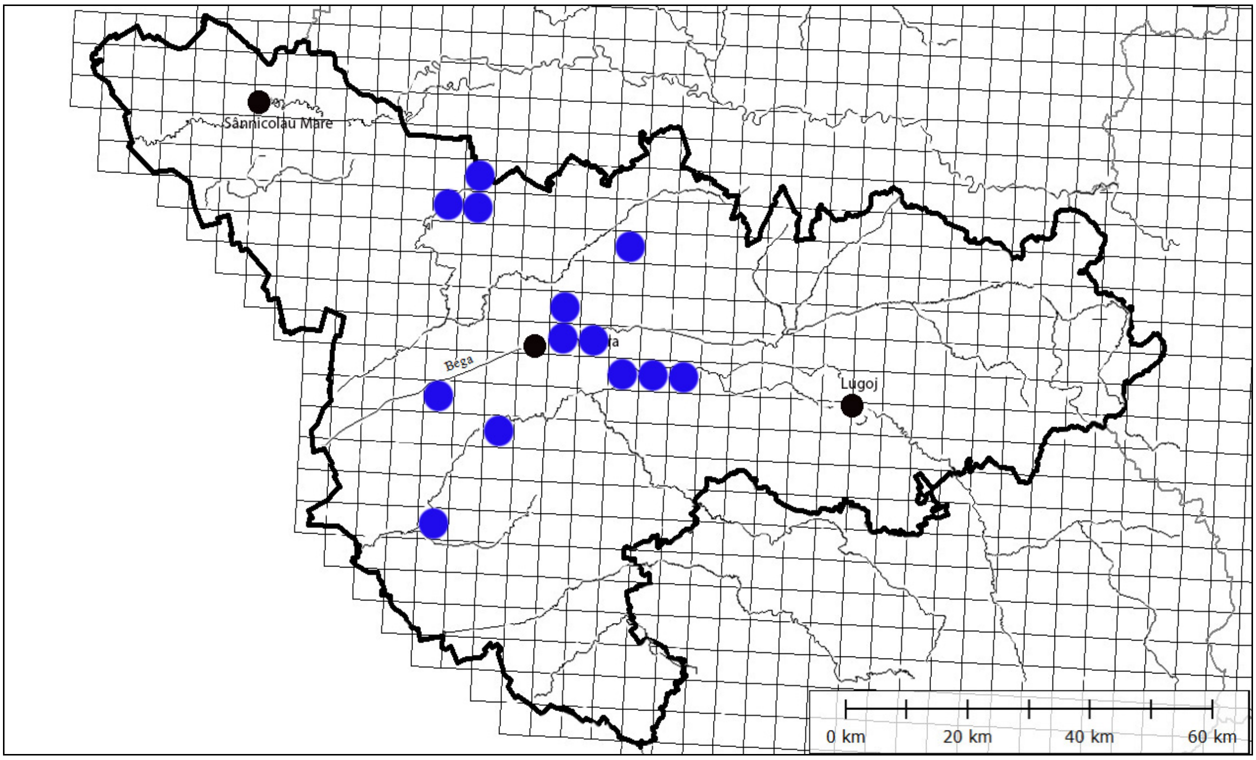

Figure 26: Distribution of *Brachytron pratense* (Müller, 1764) in Timiș County.

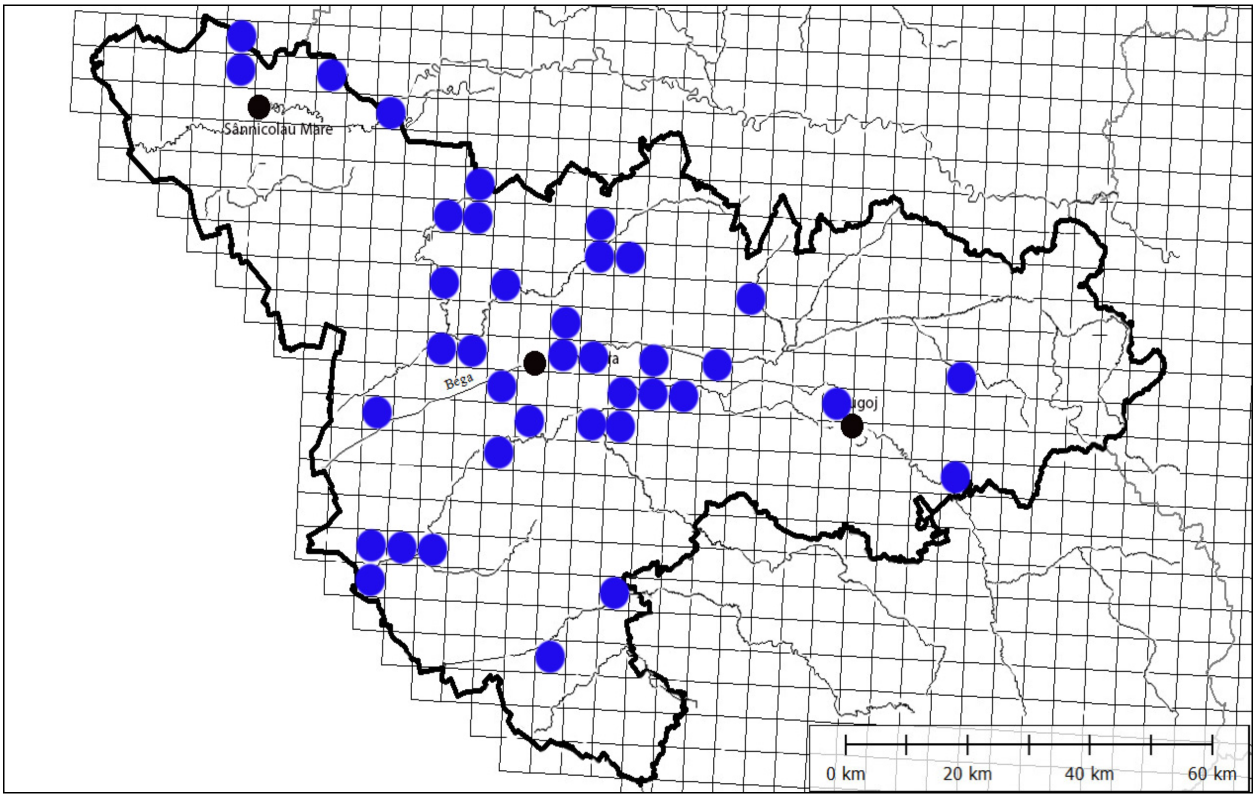

Figure 27: Distribution of *Gomphus vulgatissimus* (Linnaeus, 1758) in Timiș County.

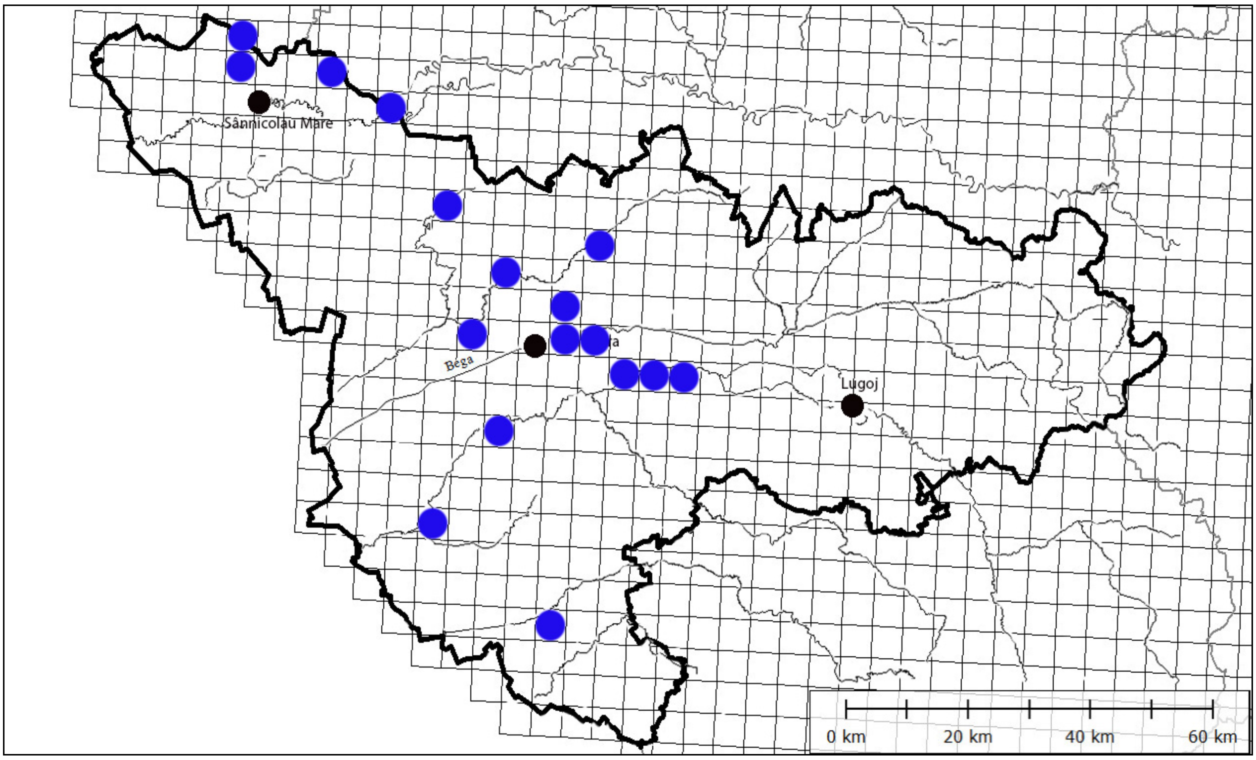

Figure 28: Distribution of *Gomphus flavipes* (Charpentier, 1825) in Timiș County.

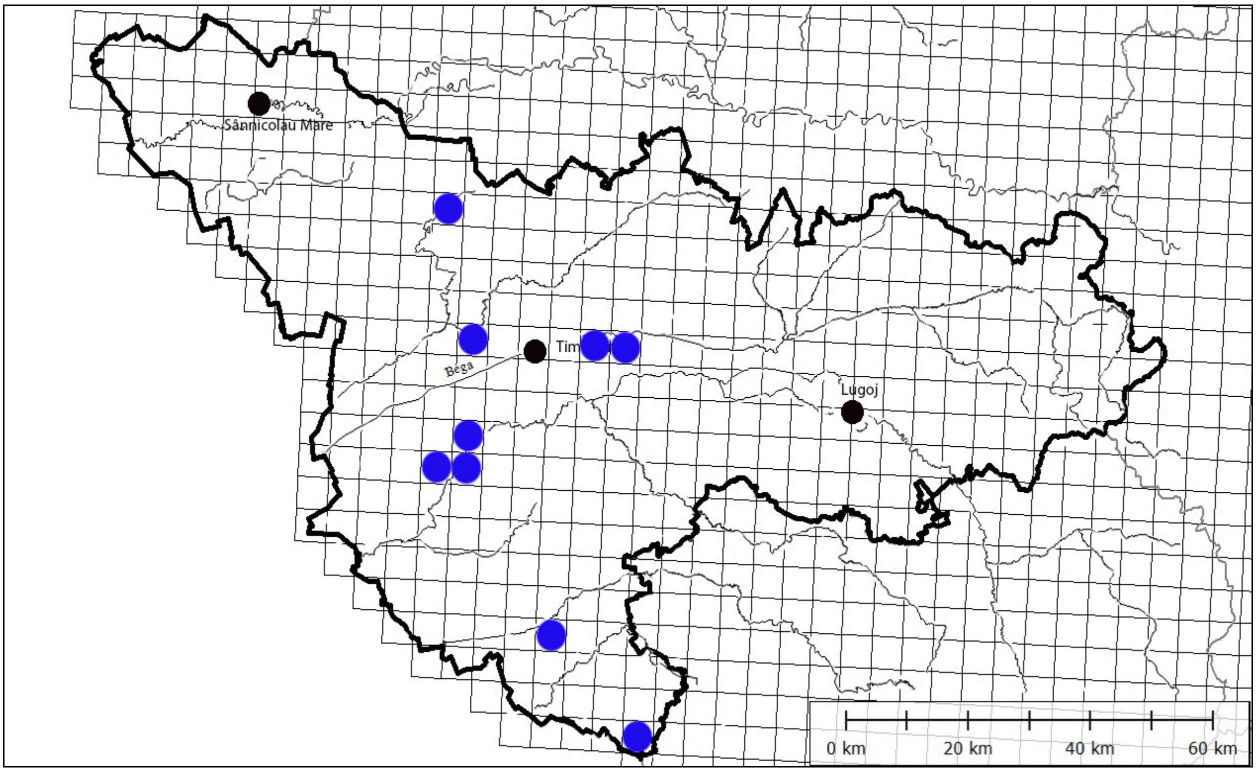

Figure 29: Distribution of *Ophiogomphus cecilia* (Linnaeus, 1758) in Timiș County.

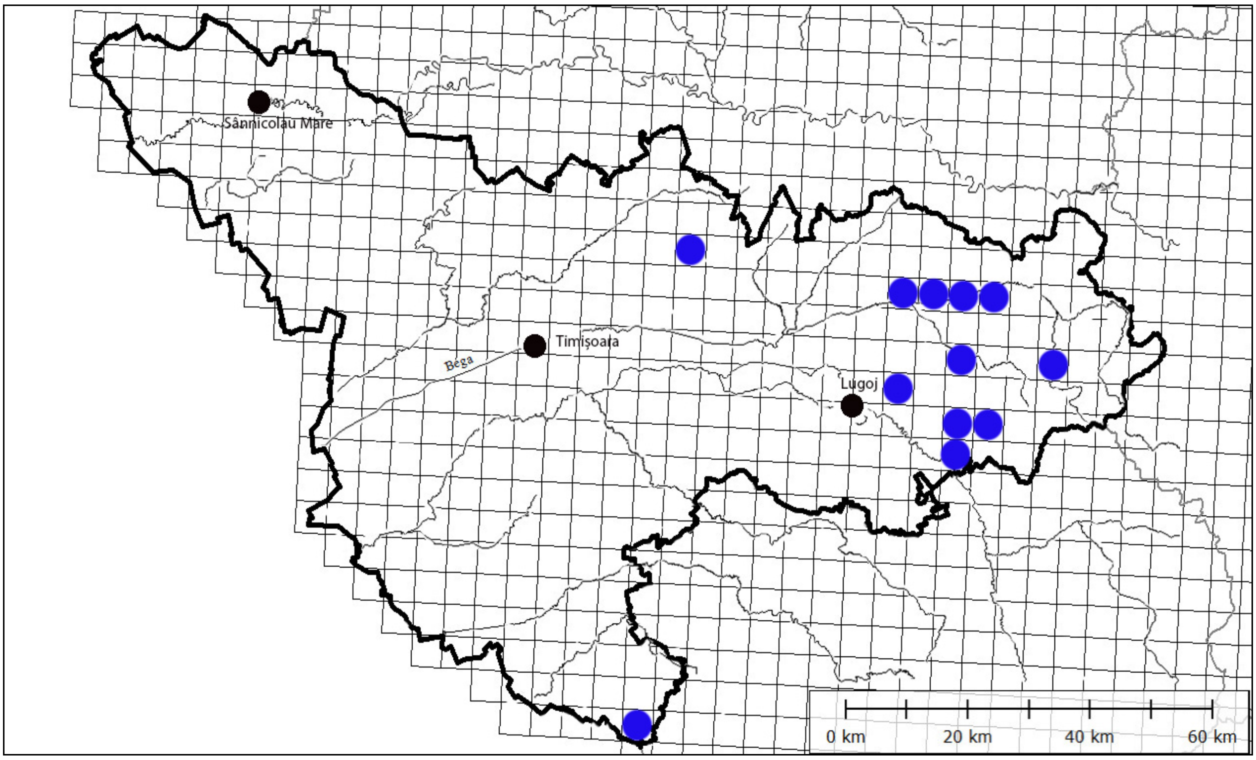

Figure 30: Distribution of *Onychogomphus forcipatus* (Linnaeus, 1758) in Timiș County.

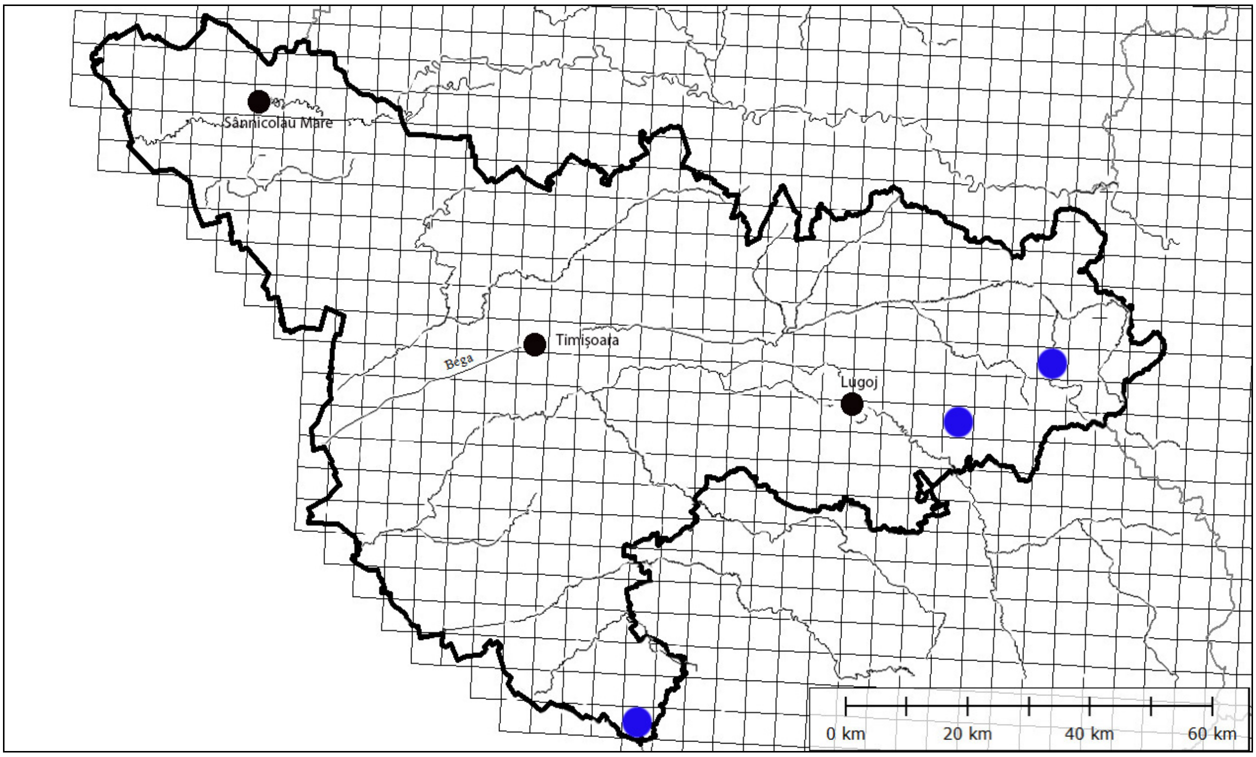

Figure 31: Distribution of *Cordulegaster bidentata* Selys, 1843 in Timiș County.

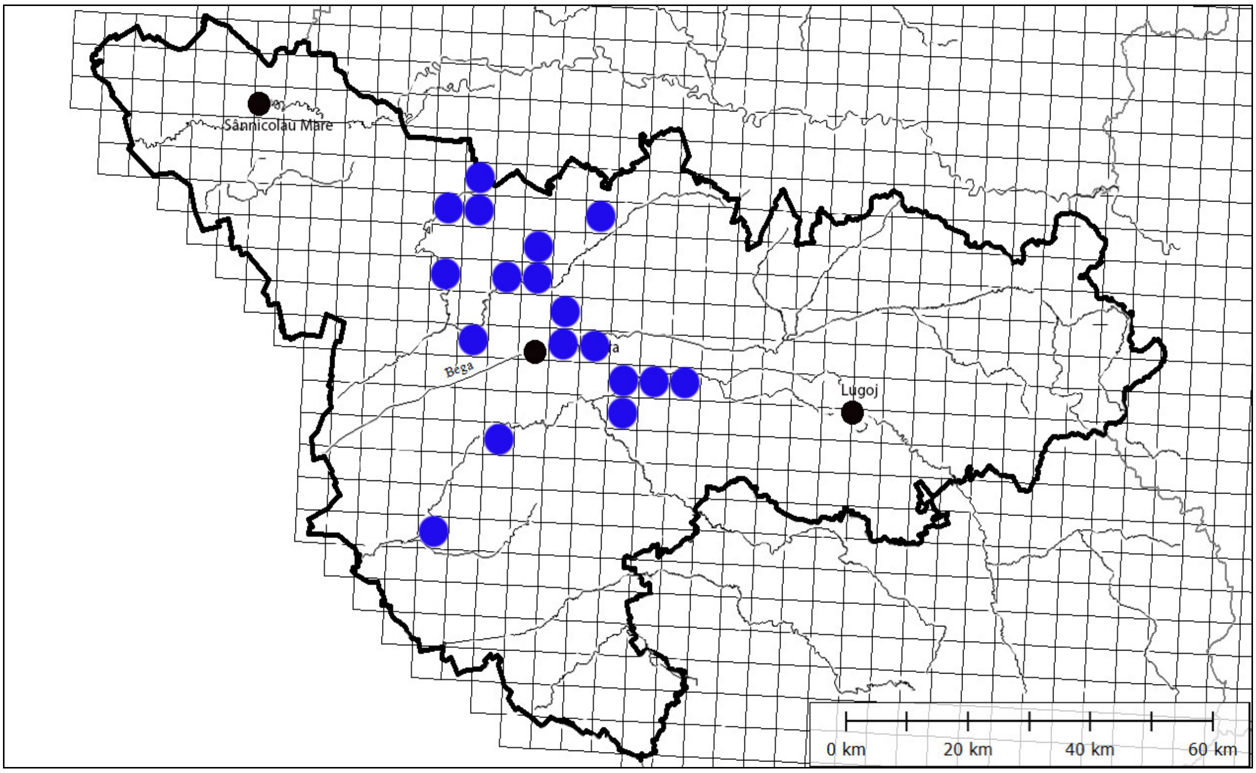

Figure 32: Distribution of *Cordulia aenea* (Linnaeus, 1758) in Timiș County.

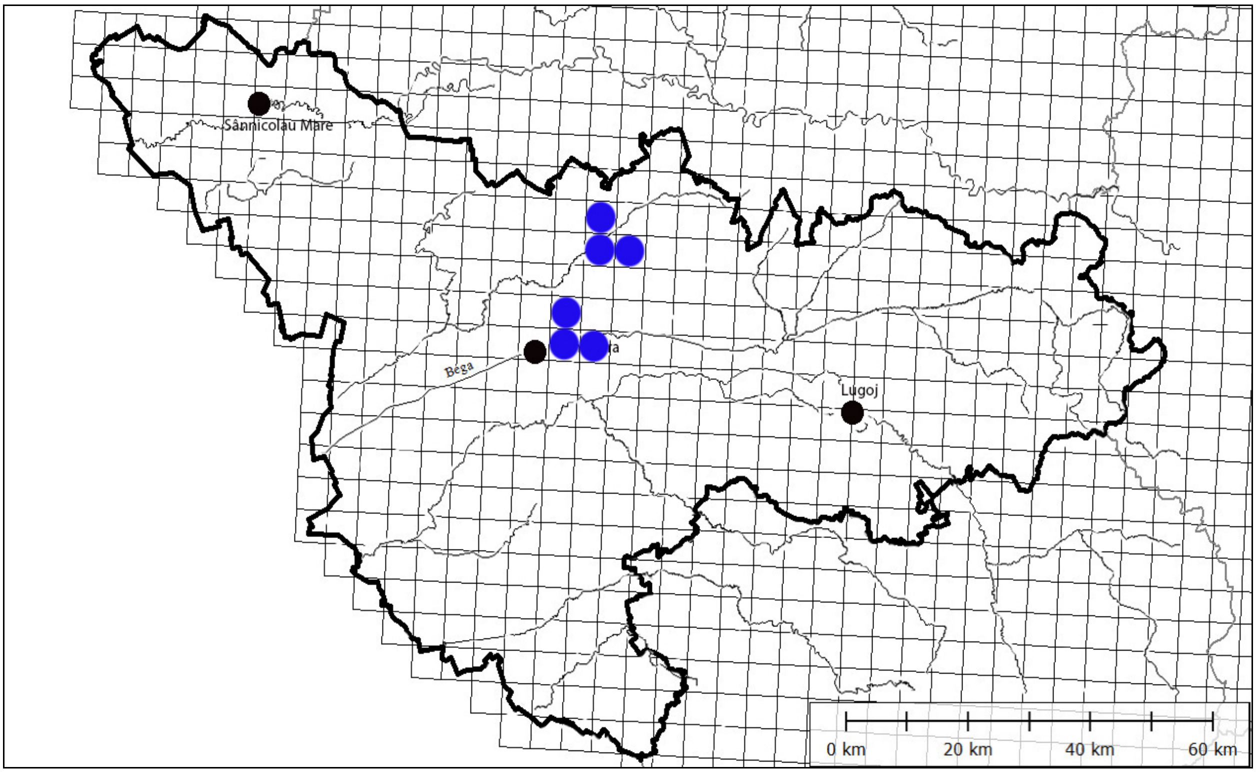

Figure 33: Distribution of *Somatochlora meridionalis* Nielsen, 1935 in Timiș County.

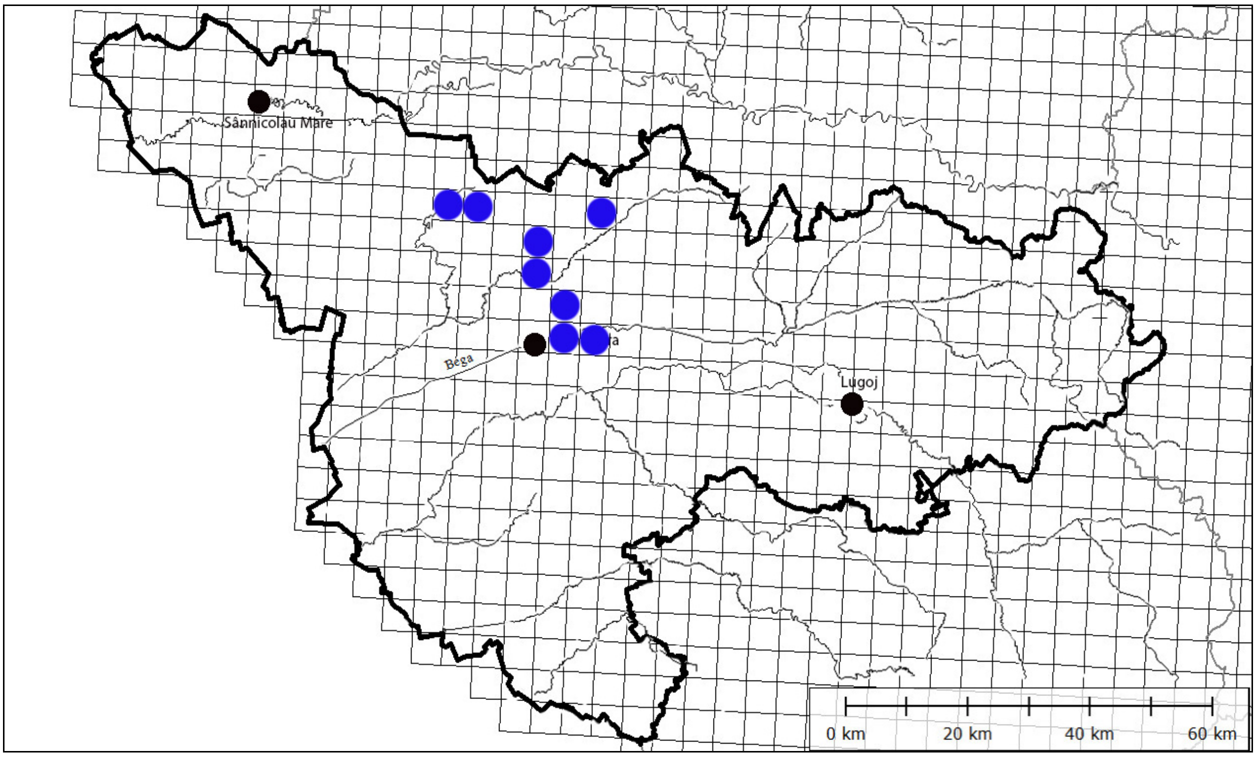

Figure 34: Distribution of *Libellula quadrimaculata* Linnaeus, 1758 in Timiș County.

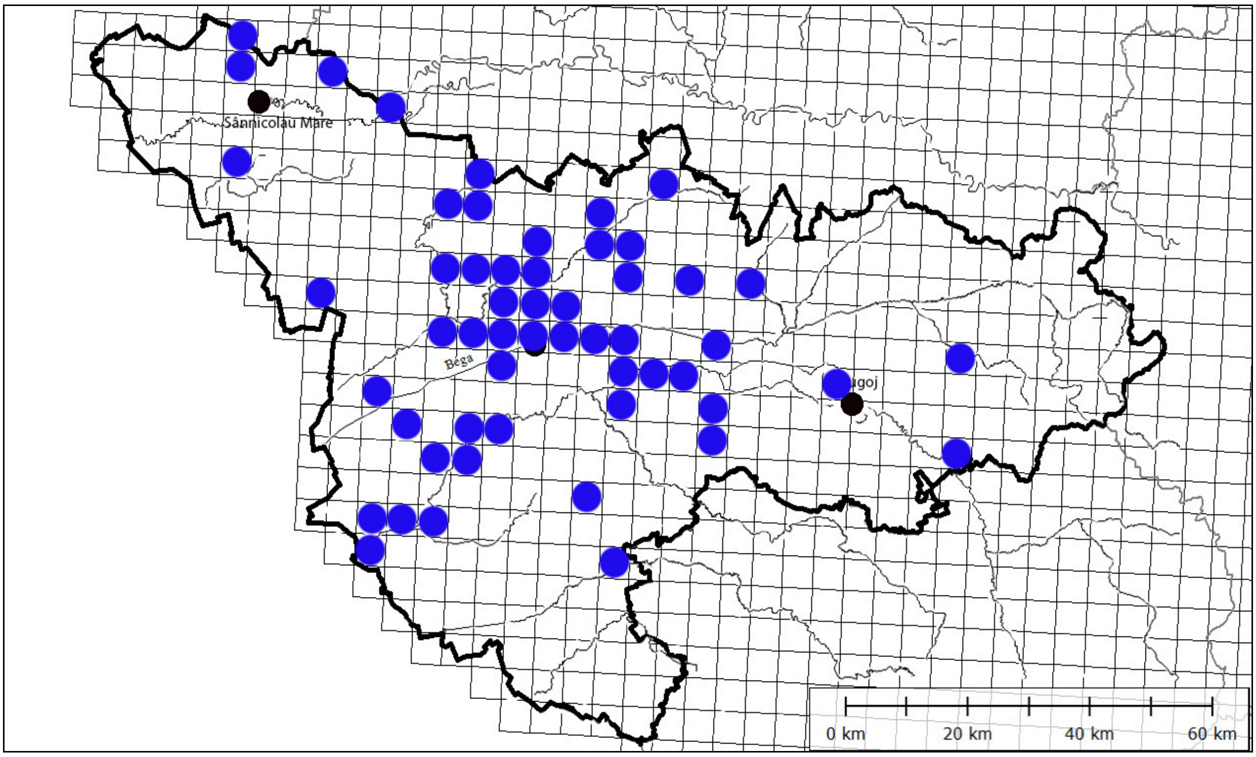

Figure 35: Distribution of *Libellula depressa* Linnaeus, 1758 in Timiș County.

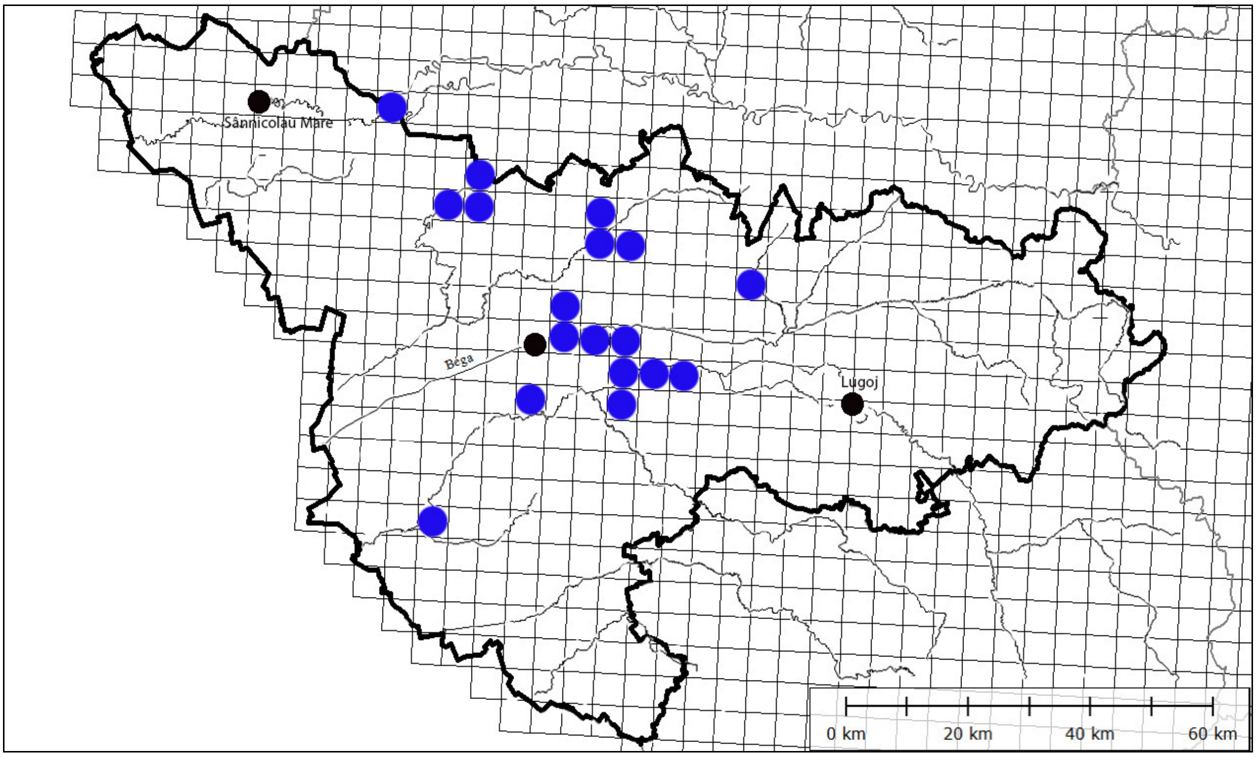

Figure 36: Distribution of *Libellula fulva* Müller, 1764
in Timiș County.

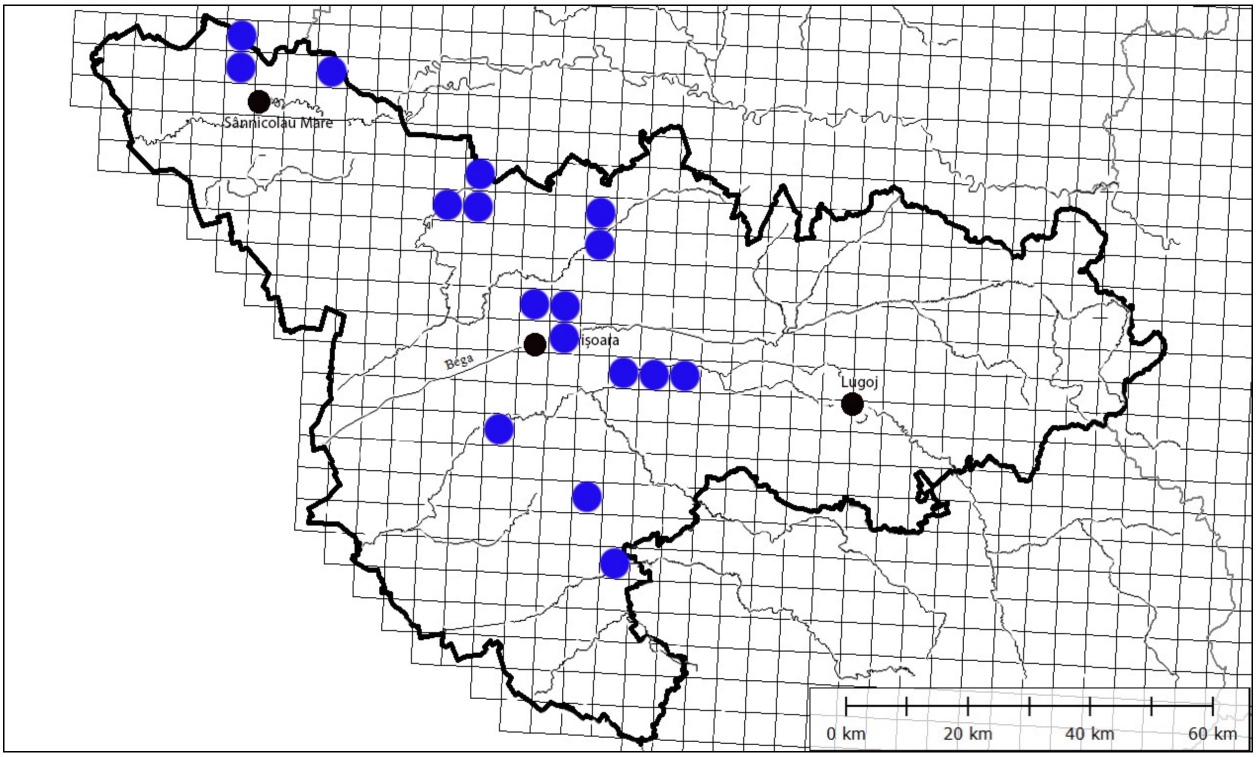

Figure 37: Distribution of *Orthetrum cancellatum* (Linnaeus, 1758)
in Timiș County.

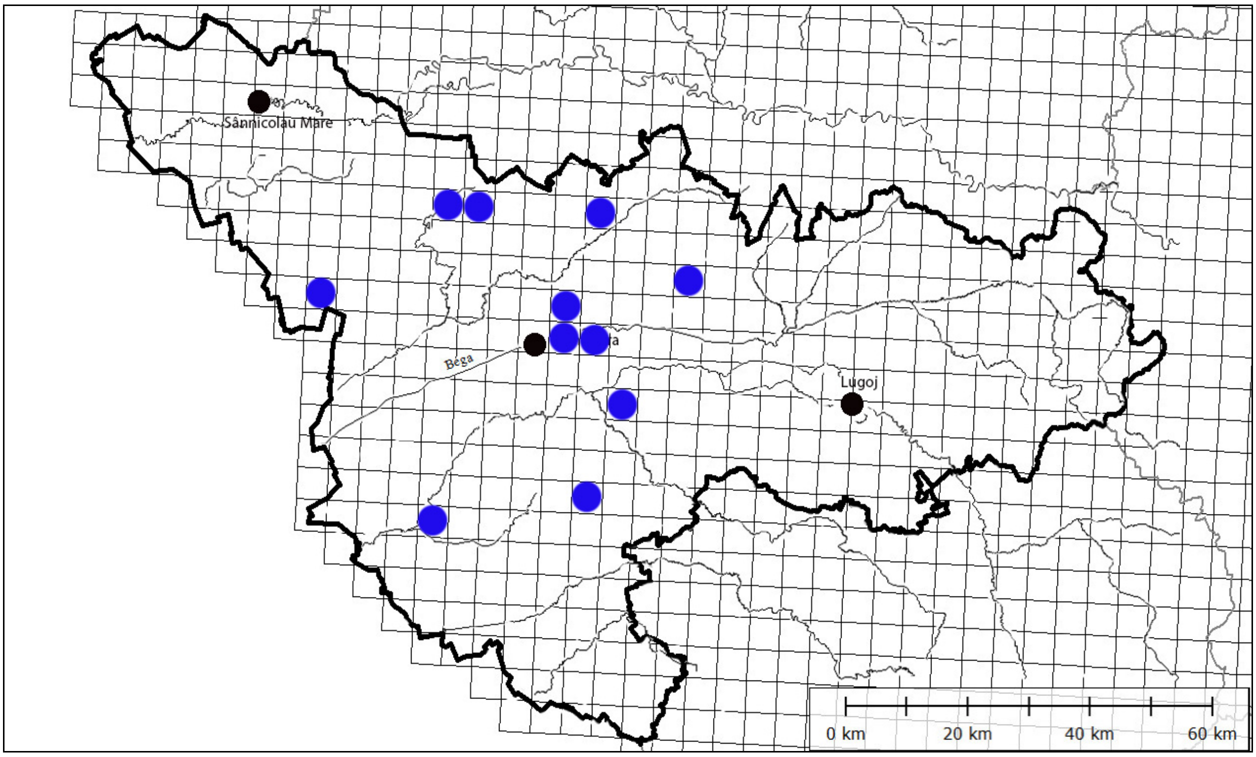

Figure 38: Distribution of *Orthetrum albistylum* (Selys, 1848) in Timiș County.

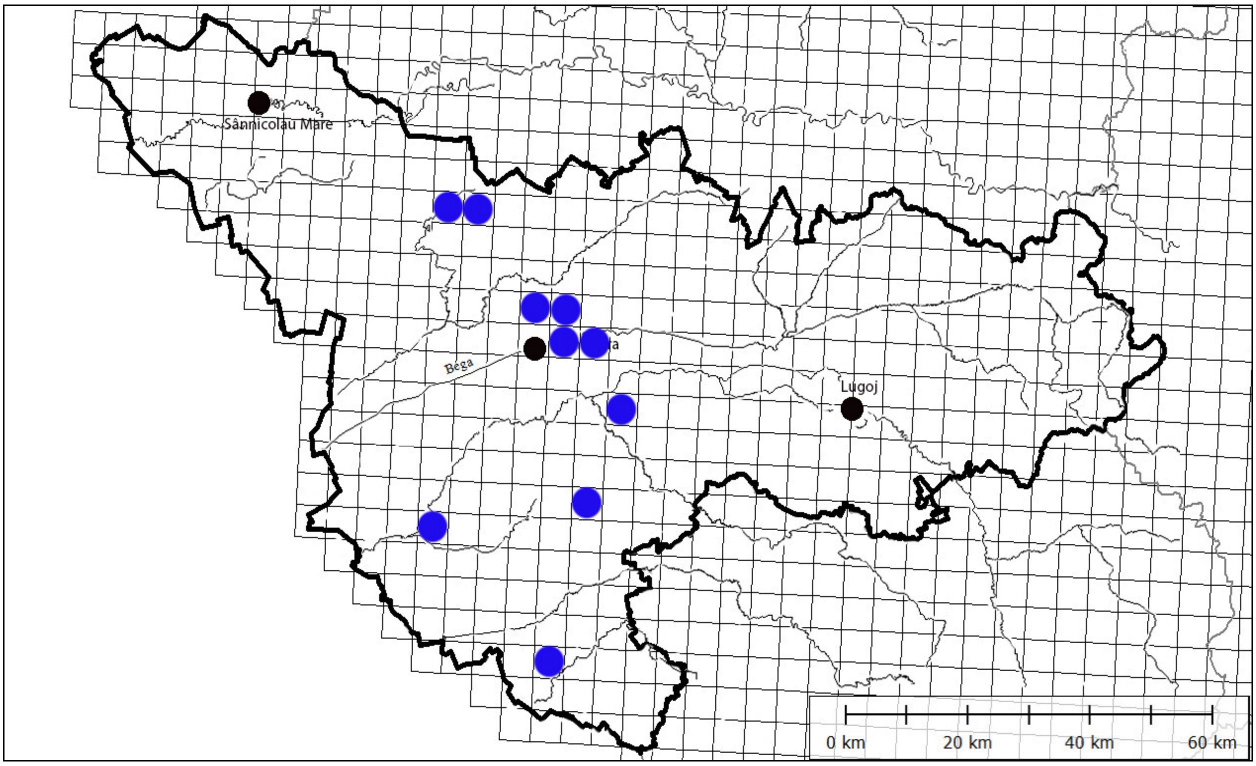

Figure 39: Distribution of *Orthetrum coerulescens* (Fabricius, 1798) in Timiș County.

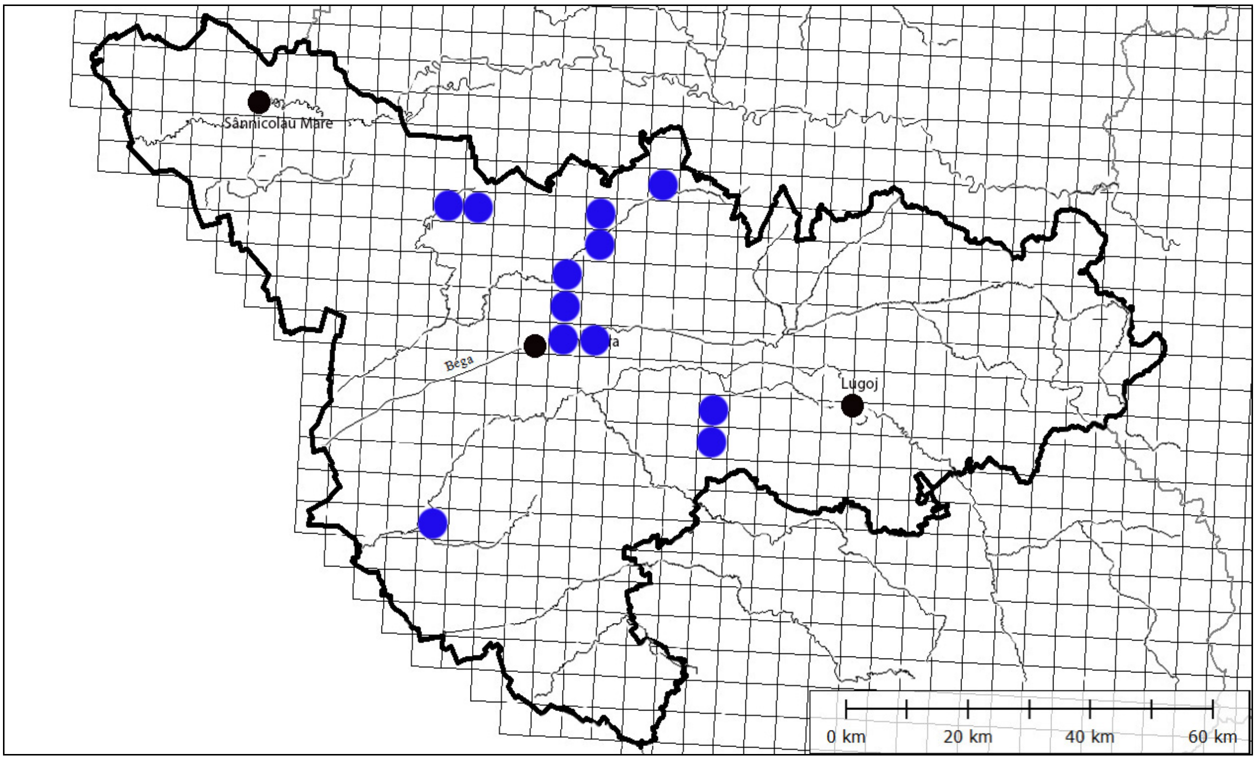

Figure 40: Distribution of *Orthetrum brunneum* (Fonscolombe, 1837) in Timiş County.

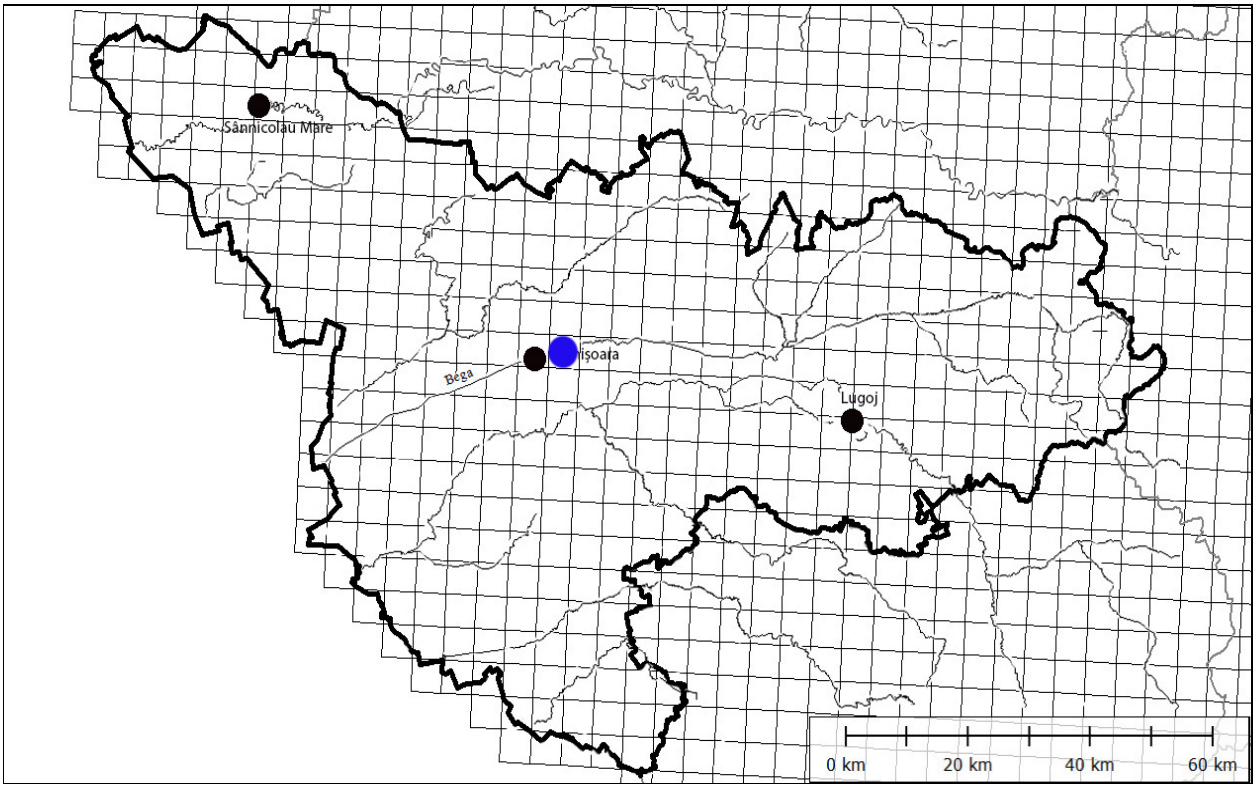

Figure 41: Distribution of *Sympetrum pedemontanum* (Müller in Allioni, 1766) in Timiş County.

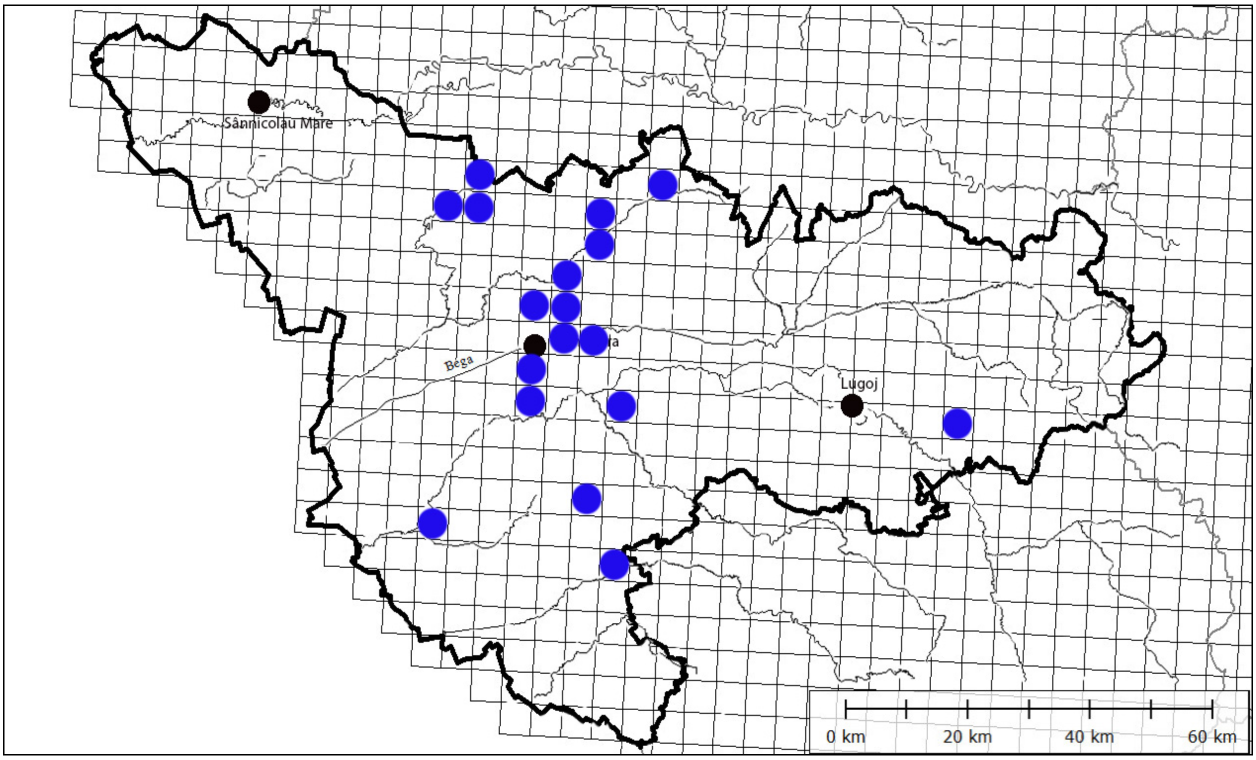

Figure 42: Distribution of *Sympetrum sanguineum* (Müller, 1764)
in Timiș County.

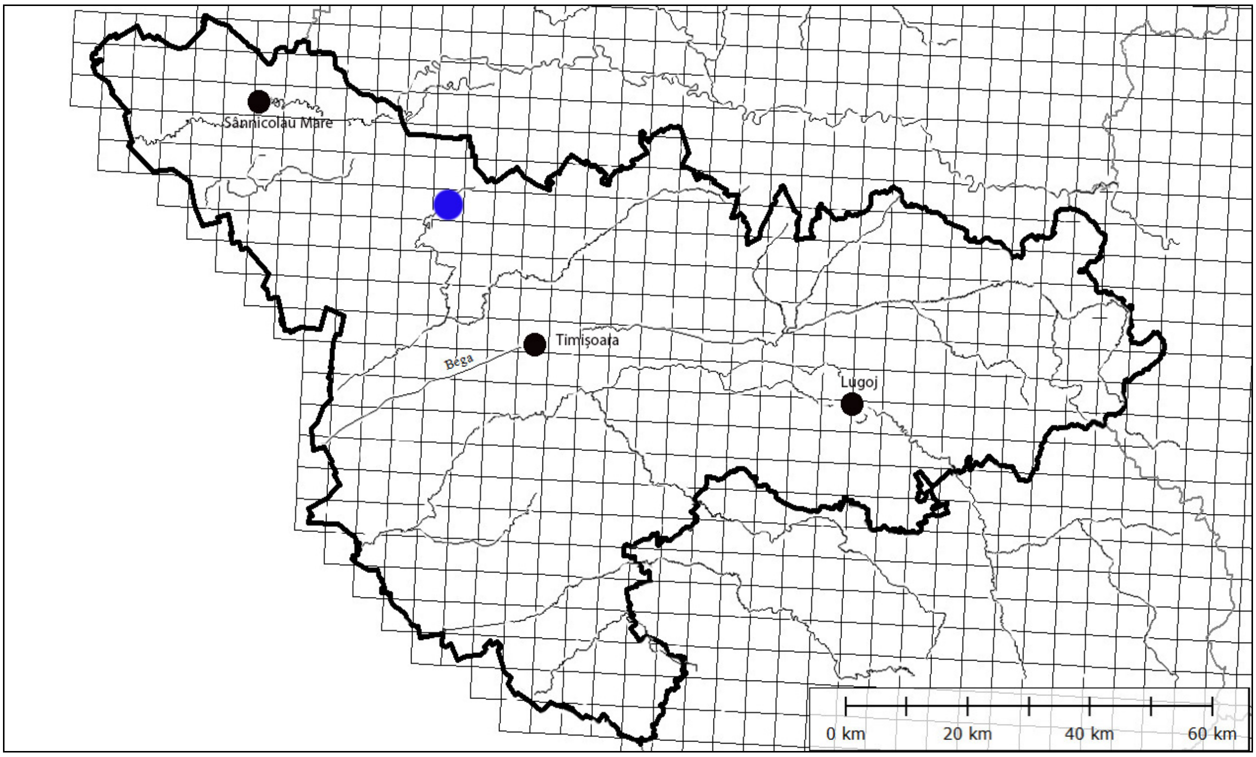

Figure 43: Distribution of *Sympetrum depressiusculum* (Selys, 1841)
in Timiș County.

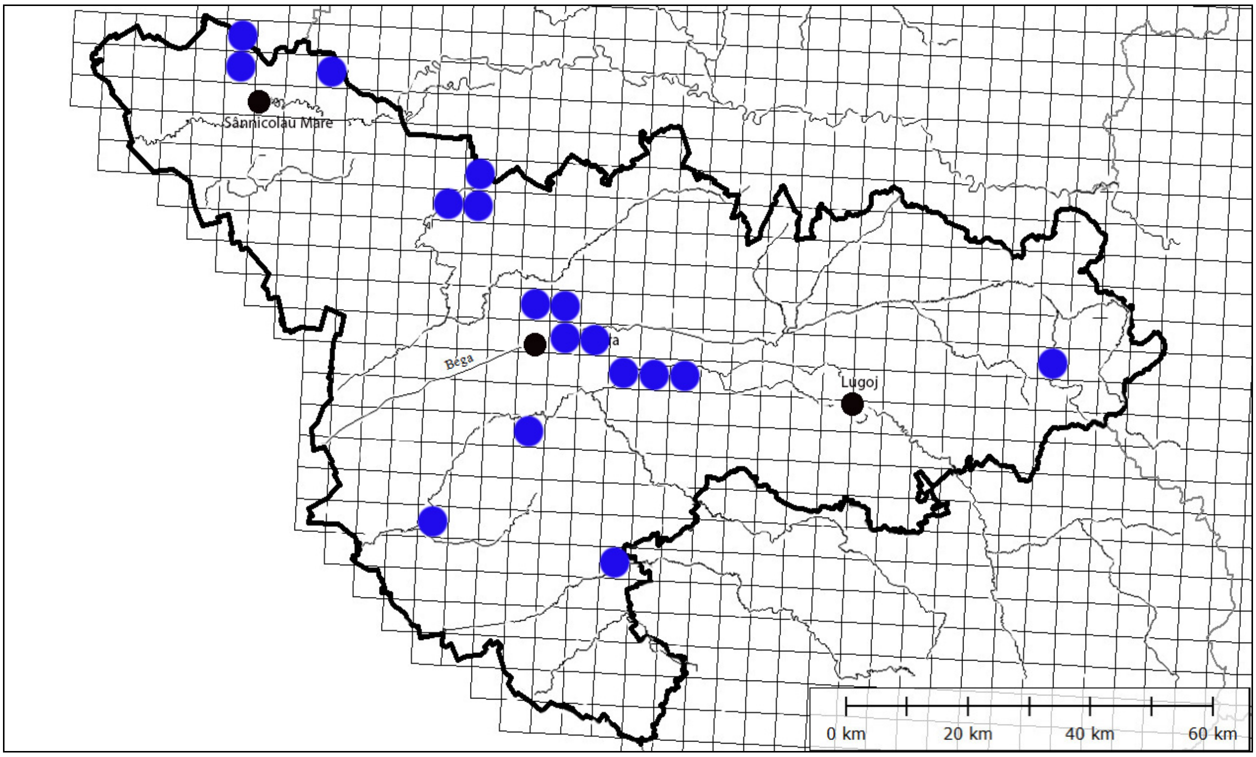

Figure 44: Distribution of *Sympetrum striolatum* (Charpentier, 1840) in Timiș County.

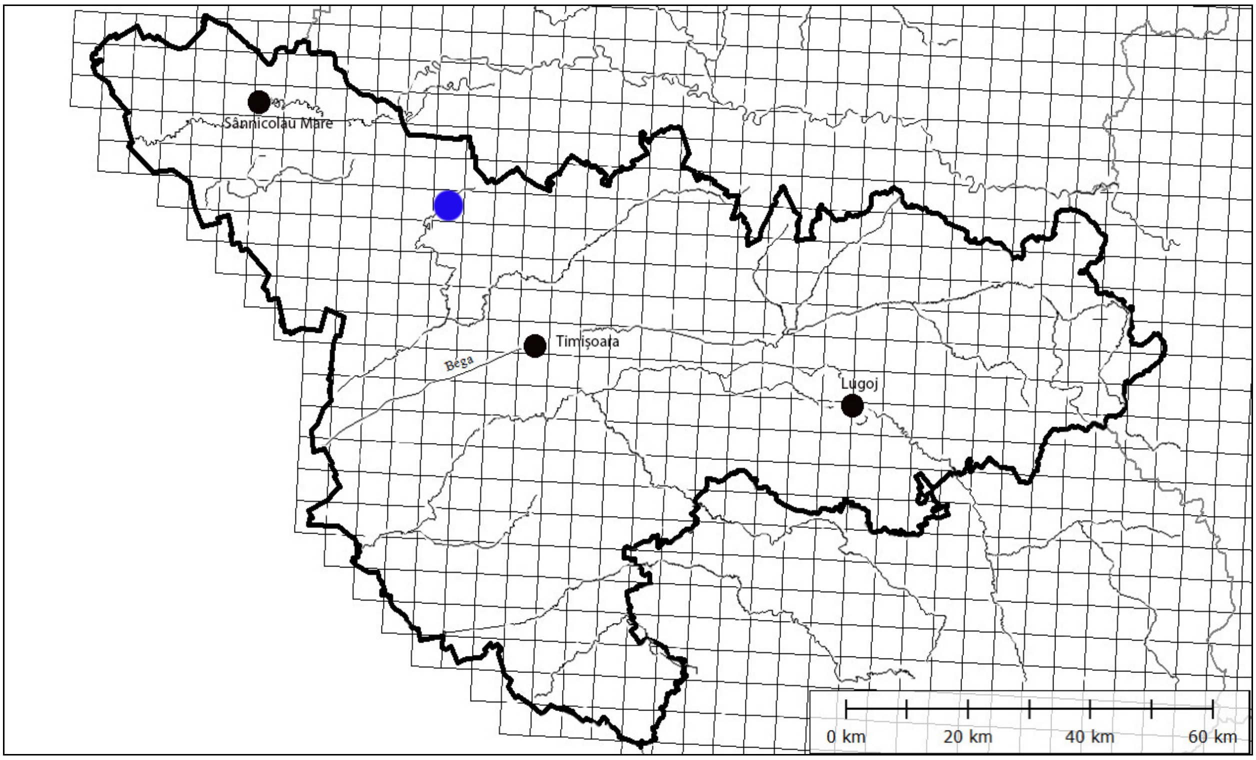

Figure 45: Distribution of *Sympetrum vulgatum* (Linnaeus, 1758) in Timiș County.

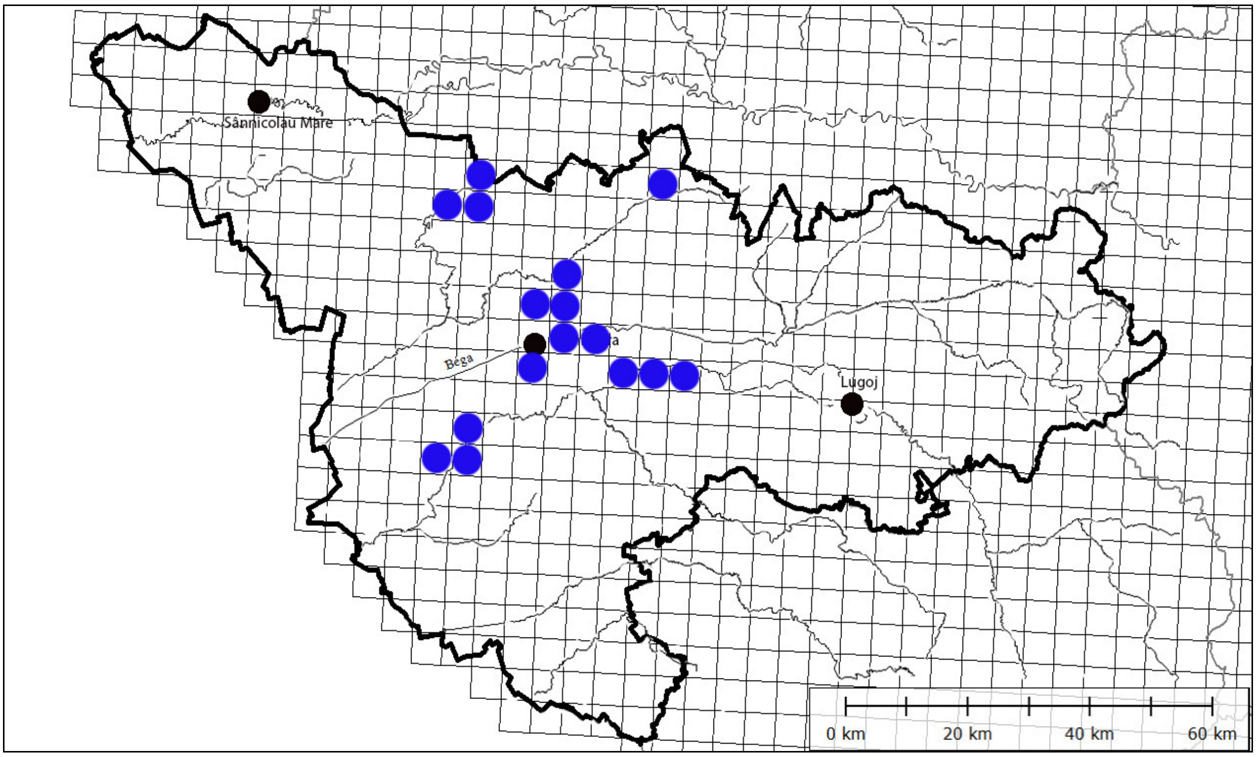

Figure 46: Distribution of *Sympetrum meridionale* (Selys, 1841) in Timiş County.

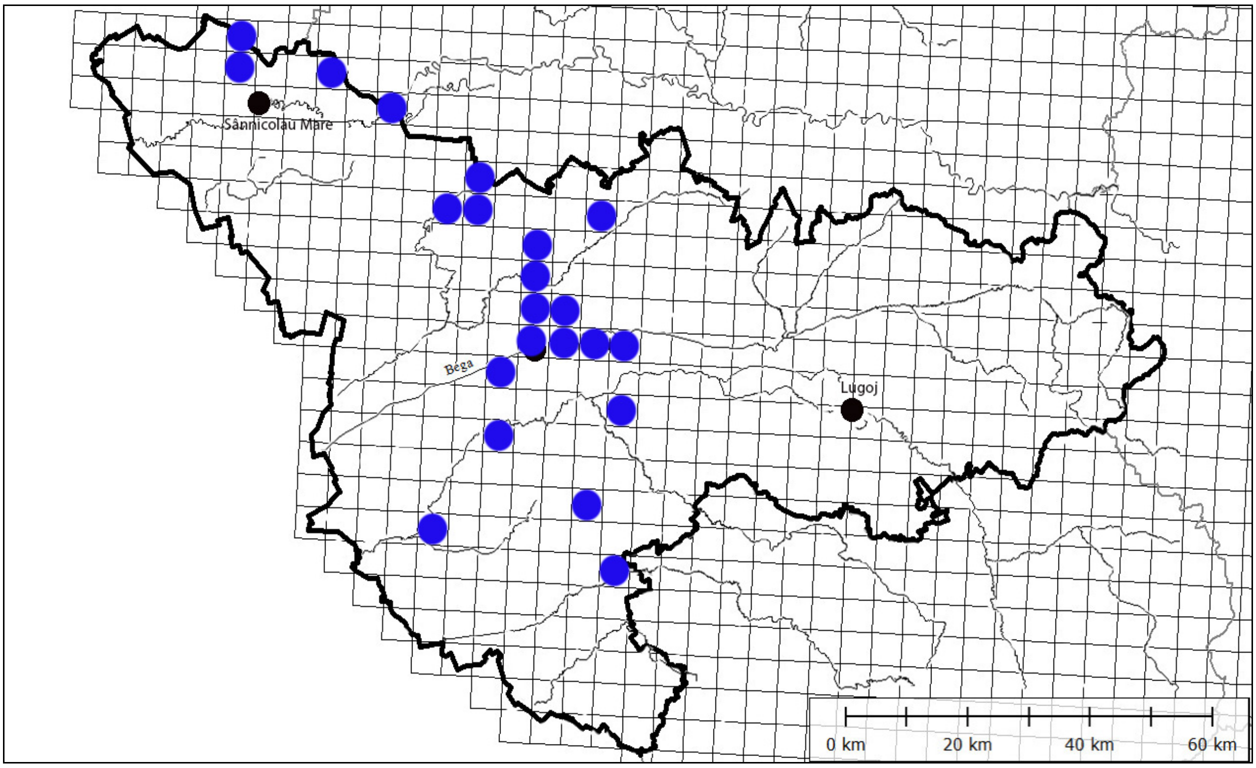

Figure 47: Distribution of *Crocothemis erythraea* (Brullé, 1841) in Timiş County.

CONCLUSIONS

A total of 45 species were found in the studied area. From these, nine are of special interest because they are rare in the area or because of conservation interest. Rare species are *Lestes parvidens*, *Coenagrion scitulum*, *Anax parthenope*, *Somatochlora meridionalis*, *Sympetrum depressiusculum* and *Sympetrum pedemontanum.* Important species for conservation are: *Coenagrion ornatum*, *Gomphus flavipes* and *Ophiogomphus cecilia*. The flagship species can be found in ROSCI0108 − Lunca Mureşului Inferior, ROSCI0109 − Lunca Timişului, ROSCI0115 − Mlaștina Satchinez and ROSCI0345 − Pajiștea Cenad.

A map with total coverage of the studied area (Fig. 48) was produced, which shows more than 50% of the territory being covered.

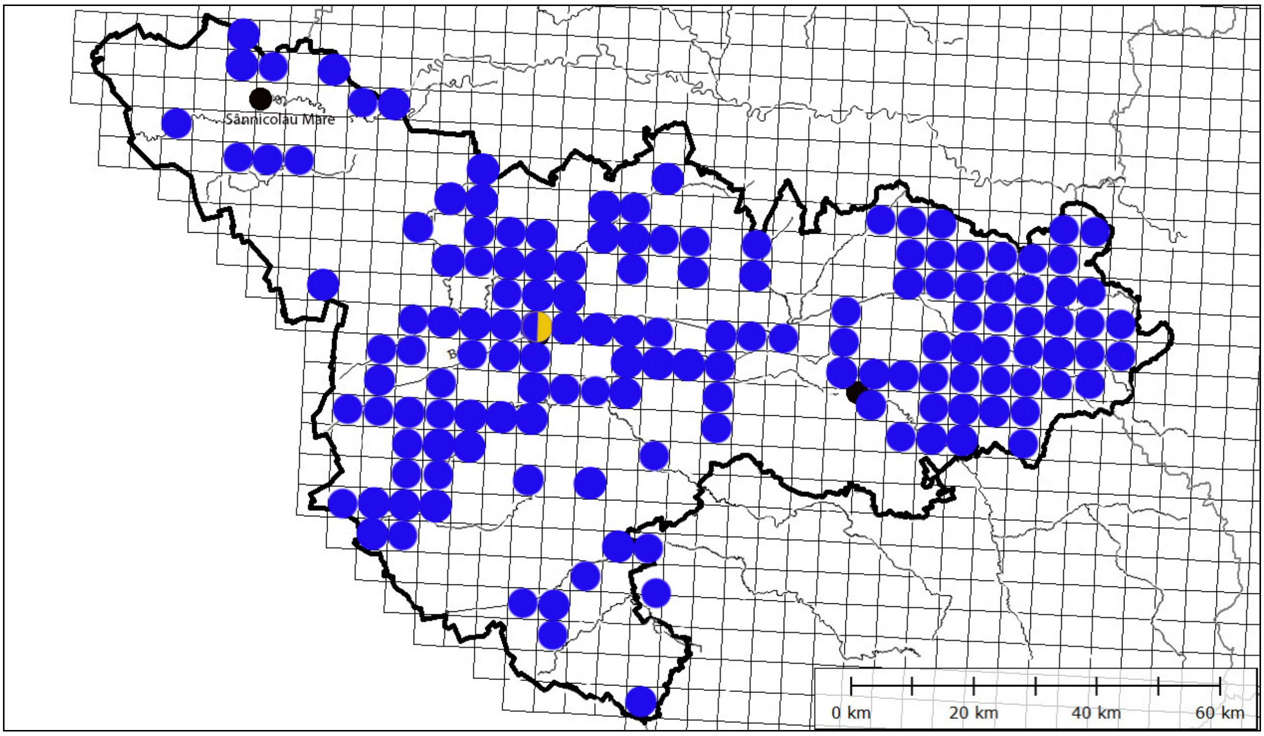

Figure 48: Map of studied area to show coverage of the data (blue circle corresponds to own data and the split circle blue/yellow with mixed authorship data).

ACKNOWLEDGEMENTS

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STUDIES REGARDING THE TRUE BUGS FAUNA (INSECTA, HETEROPTERA) IN CEFA NATURE PARK

Ioan Alexandru RĂDAC [1] and *Milca PETROVICI* [2]

KEYWORDS: checklist, *Agramma*, *Leptoglossus*, *Aradus,* rare species, invasive species, wetlands, salty meadows, protected areas, Crişana, Romania.

ABSTRACT

The heteropterological research performed until now on the Cefa Nature Park area included only the aquatic and semiaquatic species. The present paper compiles data from scientific literature and new ones from sporadic collections resulting in a preliminary checklist also including a short comparison with the neighboring Körös-Maros National Park bug fauna. Specimens collected from five different habitats by hand, pitfall traps and sweep net belong to 100 species, from which 74 are new records for the investigated area. Two rare species are interesting mentions for the Romanian Heteroptera fauna: *Aradus betulae* (Linnaeus, 1758) and *Agramma confusum* (Puton, 1879) also the invasive species *Leptoglossus occidentalis* (Heidemann, 1910), which was known only from four locations in Romania until now.

REZUMAT: Studii privind fauna de heteroptere (Insecta, Heteroptera) din Parcul Natural Cefa.

Cercetările heteropterologice desfăşurate până în prezent pe teritoriul Parcului Natural Cefa au inclus doar speciile acvatice și semiacvatice. Prezenta lucrare îmbină date din literatura de specialitate cu date noi obţinute din colectări sporadice, rezultând o listă preliminară de specii care include şi o comparaţie succintă cu fauna de ploşniţe din Parcul Național Körös-Maros. Specimenele colectate din cinci tipuri de habitate prin capturare manuală, capcane Barber și fileu entomologic aparţin la 100 specii, dintre care 74 reprezintă noi semnalări pentru zona cercetată. Două specii rare constituie menţiuni interesante pentru fauna de heteroptere din România: *Aradus betulae* (Linnaeus, 1758) și *Agramma confusum* (Puton, 1879), precum și o specie invazivă *Leptoglossus occidentalis* (Heidemann, 1910) cunoscută până în prezent în România doar din patru locaţii.

RÉSUMÉ: Etude concernant la faune des hétéroptères (Insecta, Heteroptera) du Parc Naturel Cefa.

Les recherches sur les hétéroptères effectuées jusqu'à présent sur le territoire du Parc Naturel Cefa ont inclus seulement des espèces de punaises aquatiques et semi-aquatiques. Ce travail réunit des données de la littérature spécialisée avec de nouvelles données obtenues à la suite de collections sporadiques. Une liste préliminaire des espèces qui contient aussi une courte comparaison avec la situation du Parc National Körös-Maros en résulte. Les spécimens recueillis dans cinq types d'habitats par collecte manuelle, pièges Barber et filet entomologique appartiennent à 100 espèces, dont 74 représentent des nouvelles données de présence pour la zone étudiée. Deux espèces rares constituent des découvertes intéressantes pour la faune d'hétéroptères de la Roumanie: *Aradus* betulae (Linnaeus, 1758) et *Agramma confusum* (Puton, 1879), aussi qu'une espèce invasive *Leptoglossus occidentalis* (Heidemann, 1910) connue jusqu'à présent seulement dans quatre localités en Roumanie.

INTRODUCTION

The Cefa Nature Park (CNP) was studied lately (Curtean-Bănăduc et al., 2012), but this special volume did not include Heteroptera group.

The Heteroptera is one of the most peculiar groups of insects, inhabiting very diverse biotopes and playing an important role in the biological processes of biogeocoenoses (Abdykairovna, 2011; Fauvel, 1999). The group contains around 42,300 described species worldwide, with seven infraorders and 75-89 families (Rabitsch, 2010; Schuh and Slater, 1995).

This suborder is represented in Romania by over 1,000 species (Kis, 1984) and new species are recorded due to climate change (Berchi, 2011) and introductions (Ruicănescu, 2009) or intensive research on certain taxa (Berchi et al., 2012; Berchi, 2013; Berchi and Kment, 2015). In Romania the true bugs were studied over time by various entomologists (e.g. Fuss C., Horváth G., Montandon A. L., Sienkiewicz I., Paina M. I., Kis B., and more recently by Stănescu A., Davideanu A., Ilie D. M., Olosutean H., Șerban C. and Berchi G. M.). Despite this fact, the distribution of some families as Tingidae, Lygaeidae, Aradidae or Saldidae is poorly known in Romania and data on this group is scarce due to a shortage of specialists. This fact raises major problems when it comes to explaining the species diversity in a particular area, especially in the new designated protected areas like Cefa Nature Park. Although the park has a great variety of wet and terrestrial habitats, the data on true bugs is scarce. So far, the only studies on the Heteroptera of this area were published by Ilie (2006) and Berchi et al. (2011). However, they are focused on the aquatic and semiaquatic true bugs, giving records of 26 species. Regarding Leptopodomorpha, Cimicomorpha and Pentatomomorpha no data is available, but some species are mentioned close to this area (Oradea) by Kis (1984, 2001). On the other side of the Romanian-Hungarian border, in the Körös-Maros National Park (KMNP) in Hungary, 139 species were recorded. Although the two parks have similar habitats, their species list differs.

Thus, the aim of this paper is to contribute to the knowledge of the Heteroptera of Cefa Nature Park.

We compare the lists of both protected areas (CNP and KMNP), in order to establish which taxa could be found in the future.

MATERIAL AND METHODS

The target area of our study is Cefa Nature Park. Here the landscape is dominated by a fishery complex which stretches over an area of 750 ha and has a total of 47 basins that have different sizes, water flow and depth, providing a wide range of environmental conditions (Petrovici et al., 2010). The terrestrial habitats within the park vary from wet to dry and from grassland to forest. The flora of this protected area is represented by a number of 504 cormophytes (Benedek et al., 2012).

Our specimens were collected by hand, pitfall traps and sweep net from all the major habitats of the area. The pitfall traps have been set into four biotopes: fishpond, grassland, pasture and forest. Sampling sites are presented in figure 1. In each biotope 10 pitfalls were fixed in the ground and covered with linoleum caps for rain protection. The pitfall traps were active between May 2009 and April 2010, using ethylene glycol as trapping fluid. The biological material was collected monthly and identified later in the laboratory under the stereomicroscope.

The sweep net sampling took place in May 2012 using a standard sweep net with an opening of 38 cm in diameter. All the major habitats of the area were sampled by this method. Hand sampling was done occasionally, especially to cover areas where the other methods could not be applied (e.g. under tree barks, stones or bushes).

For identification we used the work of the following authors: Heiss and Péricart (2007), Kis (1984, 2001), Péricart (1972, 1983, 1987, 1990, 1998a, 1998b, 1998c).

RESULTS AND DISCUSSION

A number of 74 species of true bugs are recorded for the first time in the Cefa Nature Park. All the new records are terrestrial species. Thereby, a total number of 100 species of true bugs are currently known from this area.

The aquatic and semiaquatic species were well studied in the past, 26 species being recorded in CNP, a third of the species occurring in Romania. However the list may be completed with eight other species present in KMNP (*Cymatia coleoptrata, Sigara nigrolineata, S. limitata, Callicorixa praeusta, Hebrus ruficeps, H. pusillus, Microvelia buenoi*, and *M. pygmaea*). On the other side of the border, only *Sigara iactans* is absent in KMNP, but present in CNP. The high species diversity in this small area may be due to the high variability of the environmental factors imprinted by the fisheries complex. Furthermore, the Cefa Nature Park is one of the last wetlands that once covered a big surface of the western Romania (Benedek et al., 2012), this could have favoured the conservation of some rare species. Regarding terrestrial species, the best represented families are Pentatomidae with 13 genera and 18 species and Lygaeidae with 17 genera and 18 species. Certain families as Lygaeidae, Tingidae and Miridae request further studies as many of the collected individuals were unidentifiable nymphs. These families are suposed to be more diverse in the protected area. It is also expected that certain species present in one park and absent in other, will be found in both parks in further studies.

Although the Körös-Maros National Park is ten times larger than Cefa Nature Park, both areas have similar habitats. Regarding Heteroptera biodiversity, the two parks compare closely but some differences are visible due to the approach of the studies on each side and some of them being focused on certain families. As a result, a total number of 183 species is present in KMNP-CNP area (Tab. 1). From this 83 species are present in KMNP, but they are absent in CNP and 44 species are present in CNP, and not mentioned in KMNP (Tab. 1).

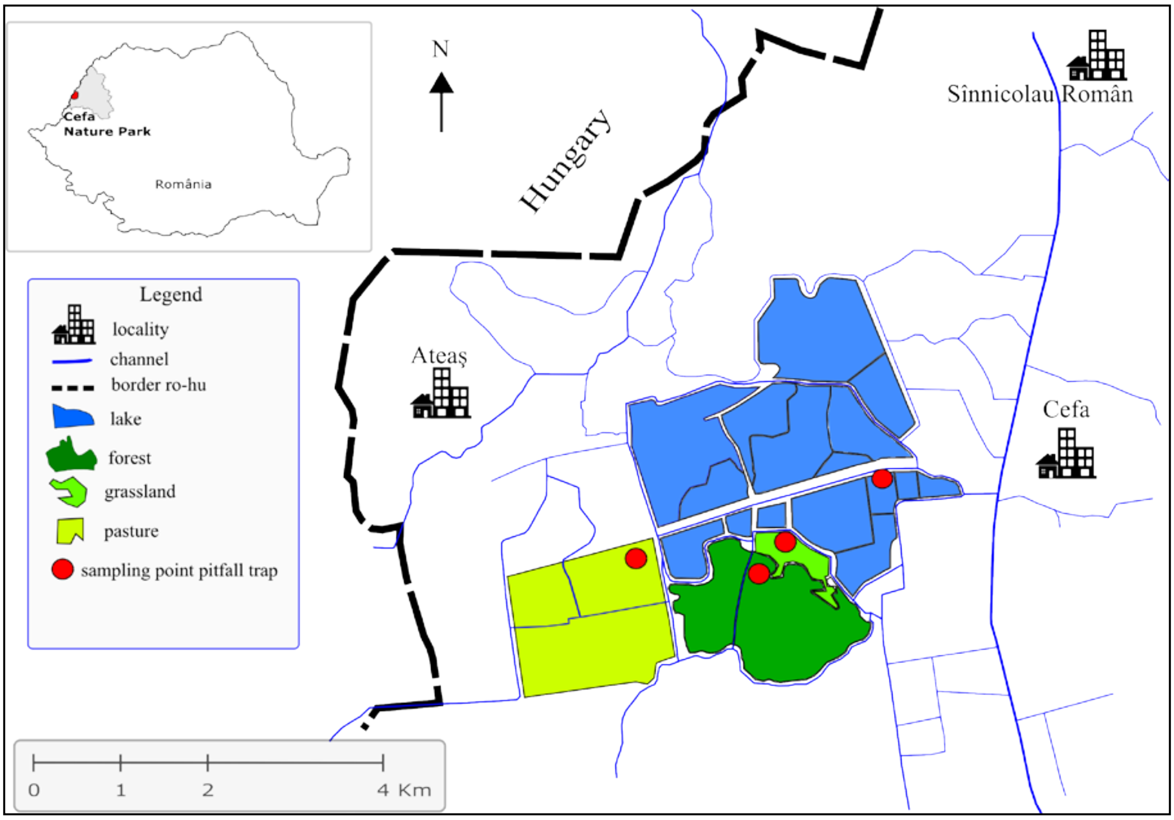

Figure 1: Location of Cefa Nature Park and pitfall trap sampling points.

Table 1: Heteroptera species list (Cefa Nature Park – Körös-Maros National Park).

Species	**Presence and location references**	
	Romanian references: **I -** this study; **II** - Berchi et al., 2011; **III** – Ilie, 2006, **IV** - Berchi and Kment, 2015. **Hungarian references:** **V** - Harmos et al., 2000; **VI** - Juhász et al., 1998; **VII** - Juhász et al., 1999; **VIII** - Juhász et al., 2000a; **IX** - Juhász et al., 2000b; **X** - Kiss et al., 1999.	
	Cefa Nature Park (CNP)	**Körös-Maros National Park (KMNP)**
Aphelocheiridae Family		
1. *Aphelocheirus aestivalis* (Fabricius, 1794)	**CNP:** II	**KMNP:** VI, VIII, IX, X
Corixidae Family		
2. *Callicorixa praeusta* (Fieber, 1848)		**KMNP:** VI, VII, X
3. *Corixa affinis* (Leach, 1817)	**CNP:** III	**KMNP:** VI, VIII, IX, X
4. *Corixa punctata* (Illiger, 1807)	**CNP:** II	**KMNP:** VI, VII, VIII, IX, X
5. *Cymatia coleoptrata* (Fabricius, 1777)		**KMNP:** VI, VII, VIII, IX, X
6. *Cymatia rogenhoferi* Fieber, 1864	**CNP:** II	**KMNP:** VI, X
7. *Hesperocorixa linnaei* (Fieber, 1848)	**CNP:** II	**KMNP:** VI, VII, VIII, IX, X
8. *Paracorixa concinna* (Fieber, 1848)	**CNP:** II	**KMNP:** VI, VIII, IX, X
9. *Sigara falleni* (Fieber, 1848)	**CNP:** II	**KMNP:** VI, VII, VIII, IX, X
10. *Sigara iactans* Jansson, 1983	**CNP:** II, III	
11. *Sigara lateralis* (Leach, 1817)	**CNP:** II, III	**KMNP:** VI, VII, VIII, IX, X
12. *Sigara limitata* (Fieber, 1848)		**KMNP:** VI, X
13. *Sigara nigrolineata* (Fieber, 1848)		**KMNP:** VIII, IX
14. *Sigara striata* (Linnaeus, 1758)	**CNP:** II, III	**KMNP:** VI, VII, VIII, IX, X
Naucoridae Family		
15. *Ilyocoris cimicoides* (Linnaeus, 1758)	**CNP:** II, III	**KMNP:** VI, VII, VIII, IX, X
Nepidae Family		
16. *Nepa cinerea* Linnaeus, 1758.	**CNP:** II	**KMNP:** VI, VII, VIII, IX, X
17. *Ranatra linearis* (Linnaeus, 1758)	**CNP:** II	**KMNP:** VI, VII, VIII, IX, X
Notonectidae Family		
18. *Notonecta glauca* Linnaeus, 1758.	**CNP:** II	**KMNP:** VI, VII, VIII, IX, X
19. *Notonecta viridis* Delcourt, 1909	**CNP:** II	**KMNP:** VI, X
Micronectidae Family		
20. *Micronecta scholtzi* (Fieber, 1860)	**CNP:** II	**KMNP:** VI, VII, VIII, IX, X
Gerridae Family		
21. *Aquarius paludum* (Fabricius, 1794)	**CNP:** II	**KMNP:** VI, VII, VIII, IX, X
22. *Gerris argentatus* Schummel, 1832	**CNP:** II, III	**KMNP:** VI, VII, VIII, IX, X
23. *Gerris lacustris* (Linnaeus, 1758)	**CNP:** II	**KMNP:** VI, VIII, IX, X
24. *Gerris odontogaster* (Zetterstedt, 1828)	**CNP:** II	**KMNP:** VI, VII, VIII, IX, X
25. *Gerris thoracicus* Schummel, 1832	**CNP:** II	**KMNP:** VI, VIII, IX, X
Mesoveliidae Family		
26. *Mesovelia furcata* Mulsant and Rey, 1852	**CNP:** III	**KMNP:** VI, VII, VIII, X
Hebridae Family		
27. *Hebrus pusillus* (Fallén, 1807)		**KMNP:** VI, VII, VIII, IX, X
28. *Hebrus ruficeps* (Thomson, 1871)		**KMNP:** VIII, IX
Hydrometridae Family		
29. *Hydrometra gracilenta* Horváth, 1899	**CNP:** II	**KMNP:** VI, VII, VIII, IX, X
30. *Hydrometra stagnorum* (Linnaeus, 1758)	**CNP:** II	**KMNP:** VI, VIII, IX, X
Pleidae Family		
31. *Plea minutissima* Leach, 1817	**CNP:** II, III	**KMNP:** VI, VII, VIII, IX, X
Veliidae Family		
32. *Microvelia buenoi* Drake, 1920		**KMNP:** VI, VII, VIII, IX, X
33. *Microvelia pygmaea* (Dufour, 1833)		**KMNP:** VII, VIII, IX
34. *Microvelia reticulata* (Burmeister, 1835)	**CNP:** IV	**KMNP:** VI, VII, VIII, IX, X

Table 1 (continued): Heteroptera species list (Cefa Nature Park – Körös-Maros Park).

Saldidae Family		
35. *Chartoscirta cincta* (Herrich-Schaeffer, 1841)	**CNP:** I	
Anthocoridae Family		
36. *Anthocoris confusus* Reuter, 1884	**CNP:** I	
37. *Anthocoris nemoralis* (Fabricius, 1794)	**CNP:** I	
Tingidae Family		
38. *Acalypta gracilis* (Fieber, 1844)		**KMNP:** V
39. *Acalypta marginata* (Wolff, 1804)		**KMNP:** V
40. *Acalypta platychila* (Fieber, 1844)		**KMNP:** V
41. *Agramma atrcapillum* (Spinola, 1837)	**CNP:** I	**KMNP:** V
42. *Agramma confusum* (Puton, 1879)	**CNP:** I	
43. *Agramma laetum* (Fallén, 1807)		**KMNP:** V
44. *Campylosteira verna* (Fallén, 1826)		**KMNP:** V
45. *Catoplatus carthusianus* (Goeze, 1778)		**KMNP:** V
46. *Catoplatus horvathi* (Puton, 1879)		**KMNP:** V
47. *Corythucha ciliata* (Say, 1832)		**KMNP:** V
48. *Derephysia foliacea* (Fallén, 1807)		**KMNP:** V
49. *Dictyla echii* (Schrank, 1781)		**KMNP:** V
50. *Dictyla humuli* (Fabricius, 1794)	**CNP:** I	**KMNP:** V
51. *Dictyla rotundata* (Herrich-Schäffer, 1830)		**KMNP:** V
52. *Elasmotropis testacea* (Herrich-Schäffer, 1830)		**KMNP:** V
53. *Kalama tricornis* (Schrank, 1801)		**KMNP:** V
54. *Lasiacantha capucina* (Germar, 1836)		**KMNP:** V
55. *Oncochila scapularis* (Fieber, 1844)		**KMNP:** V
56. *Oncochila simplex* (Herrich-Schäffer, 1830)		**KMNP:** V
57. *Physatocheila dumetorum* (Herrich-Schäffer, 1838)		**KMNP:** V
58. *Stephanitis pyri* (Fabricius, 1822)		**KMNP:** V
59. *Tingis ampliata* (Herrich-Schäffer, 1839)		**KMNP:** V
60. *Tingis auriculata* (Costa, 1843)		**KMNP:** V
61. *Tingis cardui* (Linnaeus, 1758)	**CNP:** I	**KMNP:** V
62. *Tingis crispata* (Herrich-Schäffer, 1838)		**KMNP:** V
63. *Tingis maculata* (Herrich-Schäffer, 1835)		**KMNP:** V
64. *Tingis reticulata* (Herrich-Schäffer, 1835)		**KMNP:** V
Miridae Family		
65. *Adelphocoris lineolatus* (Goeze, 1778)	**CNP:** I	
66. *Capsus ater* (Linnaeus, 1758)	**CNP:** I	
67. *Harpocera thoracica* (Fallen, 1807)	**CNP:** I	
68. *Lygus pratensis* (Linnaeus, 1758)	**CNP:** I	
69. *Lygus rugulipennis* Poppius, 1911	**CNP:** I	
70. *Mermitelocerus schmidtii* (Fieber, 1836)	**CNP:** I	
71. *Rhabdomiris striatellus* (Fabricius, 1794)	**CNP:** I	
72. *Stenodema calcarata* (Fallen, 1807)	**CNP:** I	
73. *Stenodema laevigata* (Linnaeus, 1758)	**CNP:** I	
Nabidae Family		
74. *Himacerus apterus* (Fabricius, 1798)	**CNP:** I	**KMNP:** V
75. *Himacerus mirmicoides* (O. Costa, 1834)		**KMNP:** V
76. *Nabis ferus* (Linnaeus, 1758)	**CNP:** I	
77. *Nabis pseudoferus* (Remane, 1949)	**CNP:** I	**KMNP:** V
78. *Nabis rugosus* (Linnaeus, 1758)		**KMNP:** V
79. *Prostemma aenicolle* (Stein, 1857)		**KMNP:** V
80. *Prostemma guttula* (Fabricius, 1787)	**CNP:** I	
Reduviidae Family		
81. *Coranus subapterus* (De Geer, 1773)	**CNP:** I	
82. *Peirates stridulus* (Fabricius, 1787)	**CNP:** I	
83. *Rhinocorisiracundus* (Poda, 1761)		**KMNP:** V

Table 1 (continued): Heteroptera species list (Cefa Nature Park – Körös-Maros Park).

Aradidae Family		
84. *Aradus betulae* (Linnaeus, 1758)	**CNP:** I	
Piesmidae Family		
85. *Piesma capitatum* (Wolff, 1804)		**KMNP:** V
86. *Piesma maculatum* (Laporte, 1832)		**KMNP:** V
87. *Piesma quadratum* (Fieber, 1844)		**KMNP:** V
88. *Piesma salsolae* (Becker, 1867)		**KMNP:** V
Berytidae Family		
89. *Berytinus clavipes*(Fabricius, 1775)		**KMNP:** V
90. *Berytinus montivagus* (Meyer-Dür, 1841)		**KMNP:** V
91. *Gampsocoris culicinus* Seidenstücker, 1948		**KMNP:** V
92. *Gampsocoris punctipes* (Germar, 1822)		**KMNP:** V
93. *Neides tipularius* (Linnaeus, 1758)		**KMNP:** V
Pyrrhocoridae Family		
94. *Pyrrhocoris apterus* (Linnaeus, 1758)	**CNP:** I	**KMNP:** V
Stenocephalidae Family		
95. *Dicranocephalus agilis* (Scopoli, 1763)		**KMNP:** V
96. *Dicranocephalus albipes* (Fabricius, 1781)	**CNP:** I	**KMNP:** V
97. *Dicranocephalus medius* (Mulsant and Rey, 1870)		**KMNP:** V
Coreidae Family		
98. *Ceraleptus gracilicornis* (Herrich-Schäffer, 1835)		**KMNP:** V
99. *Ceraleptus lividus* Stein, 1858	**CNP:** I	**KMNP:** V
100. *Coreus marginatus* (Linnaeus, 1758)	**CNP:** I	**KMNP:** V
101. *Coriomeris denticulatus* (Scopoli, 1763)		**KMNP:** V
102. *Leptoglossus occidentalis* Heidemann, 1910	**CNP:** I	
103. *Spathocera laticornis* (Schilling, 1829)		**KMNP:** V
104. *Spathocera lobata* (Herrich-Schäffer, 1840)		**KMNP:** V
105. *Syromastes rhombeus* (Linnaeus, 1767)		**KMNP:** V
Alydidae Family		
106. *Alydus calcaratus* (Linnaeus, 1758)		**KMNP:** V
107. *Camptopus lateralis* (Germar, 1817)	**CNP:** I	**KMNP:** V
Lygaeidae Family		
108. *Beosus maritimus* (Scopoli, 1763)	**CNP:** I	
109. *Beosus quadripunctatus* (Muller, 1766)	**CNP:** I	
110. *Dimorphopterus spinolae* (Signoret, 1857)	**CNP:** I	
111. *Geocoris ater* (Fabricius, 1787)	**CNP:** I	
112. *Graptopeltus lynceus* (Fabricius, 1775)	**CNP:** I	
113. *Ischnodemus sabuleti* (Fallen, 1826)	**CNP:** I	
114. *Liorhyssus hyalinus* (Fabricius, 1794)	**CNP:** I	
115. *Lygaeus equestris* (Linnaeus, 1758)	**CNP:** I	
116. *Metopoplax origani* (Kolenati, 1845)	**CNP:** I	
117. *Pachybrachius fracticollis* (Schilling, 1829)	**CNP:** I	
118. *Peritrechus geniculatus* (Hahn, 1832)	**CNP:** I	
119. *Pterotmetus staphyliniformis* (Schilling, 1829)	**CNP:** I	
120. *Raglius alboacuminatus* (Goeze, 1778)	**CNP:** I	
121. *Rhyparochromus vulgaris* (Schilling, 1829)	**CNP:** I	
122. *Scolopostethus affinis* (Schilling, 1829)	**CNP:** I	
123. *Spilostethus saxatilis* (Scopoli, 1763)	**CNP:** I	
124. *Stictopleurus punctatonervosus* (Goeze, 1778)	**CNP:** I	
125. *Xanthochilus quadratus* (Fabricius, 1798)	**CNP:** I	

Table 1 (continued): Heteroptera species list (Cefa Nature Park – Körös-Maros Park).

Rhopalidae Family		
126. *Chorosoma schillingi* (Schummel, 1829)		**KMNP:** V
127. *Corizus hyoscyami* (Linnaeus, 1758)	**CNP:** I	**KMNP:** V
128. *Myrmus miriformis* (Fallén, 1807)	**CNP:** I	**KMNP:** V
129. *Rhopalus parumpunctatus* (Schilling, 1817)	**CNP:** I	**KMNP:** V
130. *Rhopalus subrufus* (Gmelin, 1788)	**CNP:** I	**KMNP:** V
131. *Stictopleurus abutilon* (Rossi, 1790)		**KMNP:** V
132. *Stictopleurus punctatonervosus* (Goeze, 1778)		**KMNP:** V
Platispidae Family		
133. *Coptosoma scutellatum* (Geoffroy, 1785)		**KMNP:** V
Thyreocoridae Family		
134. *Thyreocoris scarabaeoides* (Linnaeus, 1758)	**CNP:** I	**KMNP:** V
Cydnidae Family		
135. *Cydnus aterrimus* (Förster, 1771)		**KMNP:** V
136. *Legnotus limbosus* (Geoffroy, 1785)		**KMNP:** V
137. *Microporus nigritus* (Fabricius, 1794)		**KMNP:** V
138. *Sehirus luctuosus* Mulsant and Rey, 1866		**KMNP:** V
139. *Tritomegas sexmaculatus* (Rambur, 1842)	**CNP:** I	**KMNP:** V
Scutelleridae Family		
140. *Crypsinus angustatus* (Bärensprung, 1859)		**KMNP:** V
141. *Eurygaster austriaca* (Schrank, 1776)		**KMNP:** V
142. *Eurygaster maura* (Linnaeus, 1758)	**CNP:** I	**KMNP:** V
143. *Eurygaster testudinaria* (Geoffroy, 1785)	**CNP:** I	**KMNP:** V
144. *Graphosoma lineatum* (Linnaeus, 1758)	**CNP:** I	**KMNP:** V
145. *Podops curvidens* Costa, 1847		**KMNP:** V
146. *Podops inuncta* (Fabricius, 1775)		**KMNP:** V
147. *Podops rectidens* Horváth, 1883		**KMNP:** V
148. *Psacasta exanthematica* (Scopoli, 1763)		**KMNP:** V
149. *Vilpianus galii* (Wolff, 1802)		**KMNP:** V
Pentatomidae Family		
150. *Aelia acuminata* (Linnaeus, 1758)	**CNP:** I	**KMNP:** V
151. *Aelia klugi* Hahn, 1831		**KMNP:** V
152. *Aelia rostrata* Boheman, 1852		**KMNP:** V
153. *Antheminia lunulatus* (Goeze, 1778)		**KMNP:** V
154. *Carpocoris fuscispinus* (Boheman, 1850)	**CNP:** I	
155. *Carpocoris mediterraneus* Tamanini, 1958		**KMNP:** V
156. *Carpocoris pudicus* (Poda, 1761)	**CNP:** I	
157. *Carpocoris purpureipennis* (Degeer, 1773)	**CNP:** I	**KMNP:** V
158. *Codophila varicornis* (Jakovlev, 1874)		**KMNP:** V
159. *Dyroderes umbraculatus* (Fabricius, 1775)		**KMNP:** V
160. *Eusarcoris aeneus* (Scopoli, 1763)		**KMNP:** V
161. *Eusarcoris ventralis* (Westwood, 1837)		**KMNP:** V
162. *Eysarcoris venustissimus* (Schrank, 1776)	**CNP:** I	
163. *Holcostethus sphacelatus* (Fabricius, 1794)	**CNP:** I	
164. *Holcostethus vernalis* (Wolff, 1804)		**KMNP:** V
165. *Neottiglossa leporine* (Herrich-Schäffer, 1830)	**CNP:** I	**KMNP:** V
166. *Neottiglossa pusilla* (Gmelin, 1789)	**CNP:** I	**KMNP:** V
167. *Palomena prasina* (Linnaeus, 1761)	**CNP:** I	**KMNP:** V
168. *Palomena viridissima* (Poda, 1761)		**KMNP:** V
169. *Rubiconia intermedia* (Wolff, 1811)		**KMNP:** V
170. *Sciocoris cursitans (*Fabricius, 1794)		**KMNP:** V
171. *Sciocoris deltocephalus* Fieber, 1861		**KMNP:** V
172. *Sciocoris distinctus* Fieber, 1851	**CNP:** I	**KMNP:** V
173. *Sciocoris macrocephalus* Fieber, 1851		**KMNP:** V
174. *Sciocoris microphthalmus* Flor, 1860		**KMNP:** V
175. *Sciocoris sulcatus* Fieber, 1851	**CNP:** I	**KMNP:** V
176. *Stagnomus pusillus* (Herrich-Schäffer, 1830)		**KMNP:** V

Table 1 (continued): Heteroptera species list (Cefa Nature Park – Körös-Maros Park).

Pentatomidae Family		
177. *Dolycoris baccarum* (Linnaeus, 1758)	**CNP:** I	**KMNP:** V
178. *Eurydema oleraceum* (Linnaeus, 1758)	**CNP:** I	**KMNP:** V
179. *Eurydema ornatum* (Linnaeus, 1758)	**CNP:** I	**KMNP:** V
180. *Peribalus strictus* (Fabricius, 1803)	**CNP:** I	
181. *Piezodorus lituratus* (Fabricius, 1794)	**CNP:** I	**KMNP:** V
182. *Rhaphigaster nebulosa* (Poda, 1761)	**CNP:** I	**KMNP:** V
183. *Staria lunata* (Hahn, 1835)	**CNP:** I	

Notable species

Agramma confusum

The genus *Agramma* contains so far 25 species (Lis, 2001). It is represented in the Romanian fauna only by two species (*Agramma minutum* and *Agramma atricapillum*) out of ten cited in Europe in the latest paleartic catalogue of Tingidae (Aukema and Rieger, 1996). Although *Agramma confusum* is not mentioned in the catalogue as being present in Romania, older papers mention this species in northern (Stănescu, 1997) and also in south-eastern part of this country (Sienkiewicz, 1964).

In Romania, *Agramma confusum* is a very rare lace bug with only seven records so far. Its last mention was done by Stănescu (1997) at Strâmtura (Maramureș County), but back then it was synonymized with *Agramma laetum*. For this reason, the presence of *Agramma laetum* in Körös-Maros National Park is doubtful and probably refers to *A. confusum*, but a confirmation is needed. Recent studies, based on statistical interpretation of the morphological differences showed that the two forms are indeed separate species (Golub, 1990), but there are still some suspicions on this fact and genetic analyses are required to settle down the debate. The four specimens (two males and two females) of *Agramma confusum* were collected with the sweep net in one of the few remaining Panonian salty meadows, along with one specimen of *Agramma atricapillum*. This is the first record for western Romania (Crișana region).

Aradus betulae

The flat bugs of the family Aradidae feed on wood decaying fungi and are one of the rarest terrestrial true bugs in Romania as their habitat is affected by deforestation. Six individuals of *Aradus betulae* (five males and one female) were found in Rădvani Forest in December 2011, under tree barks of *Quercus robur*. The Rădvani Forest is a fragment of the old alluvial forests that covered a much larger area in the past. The presence of *Aradus betulae* in this forest, points out a good forest management in the protected area, since that this species has a habitat tradition (Goßner et al., 2007).

Leptoglossus occidentalis

The western conifer seed bug was described in North America in 1910 (Ruicănescu, 2009). Due to human activity *L. occidentalis* spread very much and very fast (Zhu et al., 2013). It has been recorded for the first time in Europe from Italy, in 2001 (Taylor et al., 2001). After seven years, it was recorded in Romania in Alba-Iulia and one year later in Cluj-Napoca (Ruicănescu, 2009). In 2011, the species was recorded in Galați and Greci localities (Șerban, unpublished data). We collected the species by hand, mainly from Rădvani Forest in December 2011, under tree barks of *Quercus robur*. We also found two individuals inside the Tyto Laboratory House. This is the first record of *L. occidentalis* in the Crișana region (western Romania) and the fifth record for Romania.

The presence of this true bug in the park is not unusual as far as its current distribution is very wide, even reaching Asia (Hizal and İnan, 2012). The nearest food source is located 15 km away (in straight line), in the Miersig mixed forest.

CONCLUSIONS

This research paper represents a general overview of the published and newly collected data, and brings together information from both sides of the Romanian-Hungarian border, in order to provide a more comprehensive list of the Heteroptera species. The study could represent a reference point for future research in the area, revealing 183 true bug species in the KMNP-CNP area. The aquatic and semiaquatic species were well studied in the past and we expect that further research will bring less faunistic novelties on this groups compared with the terrestrial Miridae, Tingidae, and Lygaeidae, which require further research.

The presence of some rare taxa with a narrow habitat preferences indicates a good biodiversity management of the protected area. At the same time the presence of the invasive conifer seed bug *Leptoglossus occidentalis* in CNP and that of *Corythucha ciliata* in KMNP requires further monitoring.

The different species composition of CNP and KMNP advise to future studies, as there are still several taxa on the both sides to be found.

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FIRST RECORD OF A NEW ALIEN INVASIVE SPECIES IN ROMANIA: *PHYLLOCNISTIS VITEGENELLA* CLEMENS 1859 (LEPIDOPTERA, GRACILLARIIDAE)

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KEYWORDS: alien invasive species, grapevine, leafminer, *Phyllocnistis vitegenella*, Romania.

ABSTRACT

Phyllocnistis vitegenella is a leafminer moth belonging to Gracillariidae family (Lepidoptera). It is known as a monophagous species, its hostplant being the grapevine (*Vitis vinifera*). It originates from North America. In Europe it was first reported in the Province of Vicenza, Northern Italy, in 1994. In the following years, it spread to other European countries. In Romania *Phyllocnistis vitegenella* was observed for the first time on *Vitis vinifera* leaves in October, 2013 in Răcăciuni, Petreşti – Pânceşti (Bacău County, Romania).

The aim of this paper is to report the presence of this new alien invasive species in Romania. Although it is known as a monophagous species, in 2014 we found it mining the leaves of *Parthenocissus quinquefolia*. We expect that in the next few years the distribution of *Phyllocnistis vitegenella* could further increase.

REZUMAT: Prima semnalare a unei noi specii alohtone invazive în România: *Phyllocnistis vitegenella* Clemens 1859 (Lepidoptera, Gracillariidae).

Phyllocnistis vitegenella este un microlepidopter minier, aparținând familiei Gracillariidae (Lepidoptera). Este cunoscută ca fiind o specie monofagă, planta gazdă fiind vița-de-vie (*Vitis vinifera*). Originea acestei specii este nord-americană. În Europa a fost semnalată pentru prima dată în provincia Vicenza din nordul Italiei, în 1994. În România, specia *Phyllocnistis vitegenella* a fost observată pentru prima dată pe frunzele de *Vitis vinifera*, în luna octombrie a anului 2013 la Răcăciuni, Petrești – Pâncești (județul Bacău, România).

Scopul acestei lucrări este semnalarea prezenței acestei specii alohtone invazive în România. Deși este cunoscută ca fiind o specie monofagă, în anul 2014 noi am identificat-o și pe frunzele de *Parthenocissus quinquefolia.* Ne așteptăm ca răspândirea speciei *Phyllocnistis vitegenella* să crească în următorii ani.

RÉSUMÉ: Le premier signal de l'apparition d'une nouvelle espèce étrangère envahissante en Roumanie: *Phyllocnistis vitegenella* Clemens 1859 (Lepidoptera, Gracillariidae).

Phyllocnistis vitegenella est un microlépidoptère de mine, qui appartient à la famille des Gracillariidae. Il est connu comme étant une espèce monophage, la plante hôte étant la vigne vinifère (*Vitis vinifera*). Cette espèce est originaire d'Amérique du Nord. En Europe, elle a été signalée pour la première fois à Vicenza, en Italie du Nord, en 1994. En Roumanie cette espèce (*Phyllocnistis vitegenella*) a été signalée pour la première fois sur les feuilles de *Vitis vinifera*, durant le mois d'Octobre, dans les localités de Răcăciuni, Petrești – Pâncești (département de Bacău, Roumanie).

Le but de ce travail est donc de signaler la présence de cette espèce étrangère envahissante en Roumanie. Bien qu'étant considérée comme une espèce monophage, en 2014, elle a également été identifiée sur les feuilles de *Parthenocissus quinquefolia.* Une propagation de cette espèce est à prévoir dans les années prochaines.

INTRODUCTION

Phyllocnistis vitegenella Clemens, 1859 is a leafmining moth species belonging to Gracillariidae family. It is a North American species which recently invaded the European vineyards. Even if it is not yet considered a serious pest, its rapid spreading and preasence in several European countries suggests a great potential to become a real pest soon (Nieukerken et al., 2012).

In Europe it was observed and reported for the first time in Northern part of Italy in 1995 in province of Vicenza, its presence being reported in 1997 (Posenato et al., 1997a, 1997b). In the following years, it spread to other Italian regions, as well as to other European countries: Slovenia (Seljak, 2005), Switzerland (Cara and Jermini, 2011), and Hungary (Szabóky, 2014; Szabóky and Takács, 2014). The dynamics of this leafminer species invasion into European countries is shown in table 1.

In Romania, *Phyllocnistis vitegenella* was observed for the first time in 2013, in the eastern part of the country (Bacău County).

In European countries, this leafmining moth species completes three or four generations annually. On the Italy territory it develops four generations per year. The first generation is completed in less than a month period. The first attacks of the hatched larvae are noted on the leaves in early May. This species overwinter as adults in diapause (Baldessari et al., 2011).

The mine made by feeding larvae is a long, slender, wavy, upper-surface corridor with a broad, dark, cloudy frass line. Often several mines occur in a leaf. Pupation occurs within the mine in the somewhat widened terminal section of the corridor (Ellis, 2013). It is a monophagous species, its hostplants being represented by species of Vitaceae family.

We have identified this leafmining moth species mining on the leaves of *Vitis vinifera* and *Parthenocissus quinquefolia*.

For Romanian vineyards, until this observation, only *Holocacista rivillei* (Lep. Heliozelidae) has been reported (Cean, 2014).

Table 1: Dynamics of *Phyllocnistis vitegenella* leafminer in some of the European countries territories.

Year	Country	Authors
1995	Italy	Posenato et al. 1997a, b
2004	Slovenia	Seljak, 2005
2009	Switzerland	Cara and Jermini, 2011
2014	Hungary	Szabóky and Takács, 2014

MATERIAL AND METHODS

The biological material was collected during the year 2013 from Bacău County, from two particular vineyards (Răcăciuni and Petreşti – Pânceşti).

In the following two years the presence of *Phyllocnistis vitegenella* was observed also in Traian Village (Bacău county) and Râmnicu Sărat locality (Buzău County) (Fig. 1).

The infested leaves of the host plants (*Vitis vinifera* and *Parthenocissus quinquefolia*) were photographed and then collected and reared in laboratory till the end of the life cycle of the leafmining moths.

The emerged adults have been separated, and then determined, studied and photographed. The biological material was then dry preserved in labelled glass bottles.

The data obtained were compared with that of the other scientific papers.

Some observations and notes on the species biology and ecology were made.

At the same time, adults parasitoids belonging to Hymenoptera order have been obtained.

Our research on the new alien species *Phyllocnistis vitegenella* regarding its biology and possible natural enemies complex is in progress.

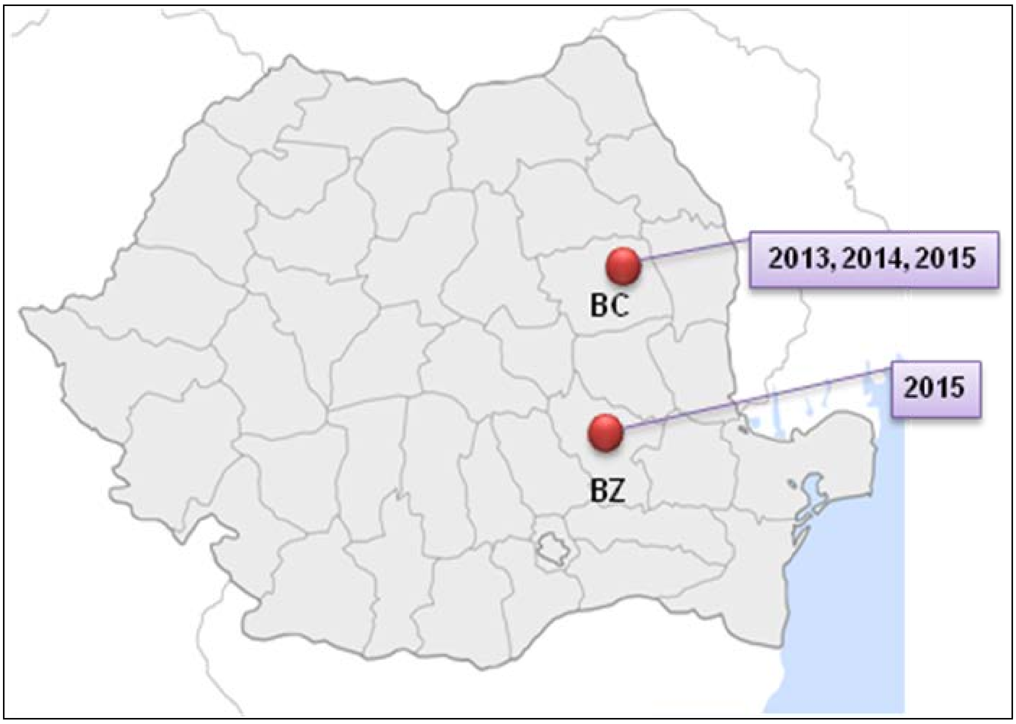

Figure 1: The presence of *Phyllocnistis vitegenella* in Romania in the period 2013-2015.

RESULTS AND DISCUSSION

The analysis of the biological material revealed the certain presence of the species *Phyllocnistis vitegenella* in Romania. This is the first record of this species in Romania.

The diagnosis of the leaves has led to identifciation of the species for the following reasons: the feeding larvae make a specific mine which begins as a long, slender, wavy, upper-surface corridor (Figs. 2 and 3).

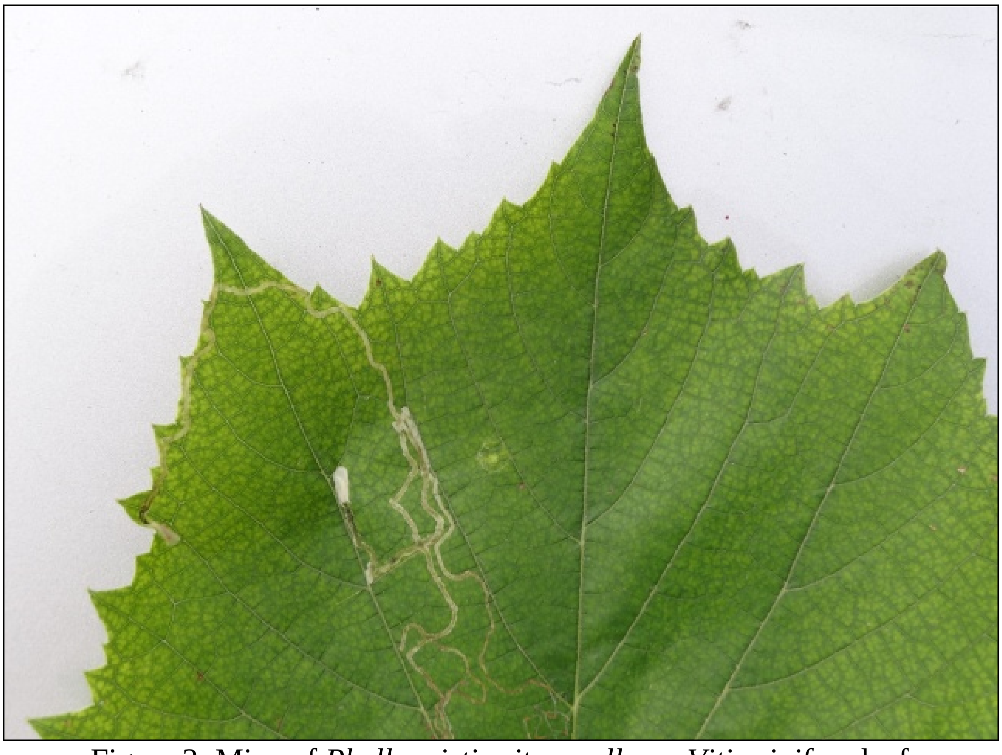

Figure 2: Mine of *Phyllocnistis vitegenella* on *Vitis vinifera* leaf.

Figure 3: Mine of *Phyllocnistis vitegenella* on *Vitis vinifera* leaf – detail.

Usually several mines occur in a each affected leaf. The slender mine leads in a terminal widened pupation chamber. The whole length of the central part of the mine has a broad, dark and cloudy frass line (Fig. 3).

The adult is a tiny whitish moth with some yellowish suffusion and a distinct black spot near the wing apex. The length of the adult is about 3 mm (Fig. 4a).

The larva is whitish, flattened, apodal, and is highly specialized. The larval stage has five instars. Usually, the first three instars possess a sapfeeding morphology and behaviour. The last instar is a highly specialized, apodal, non-feeding instar (Fig. 4b).

The pupa is brownish and it occurs in the terminal widened pupation chamber (Figs. 4c and 4d)

In Romania, *Phyllocnistis vitegenella* seems to complete three generations per year, and the overwintering adults appear in October.

Figure 4: *Phyllocnistis vitegenella* life cycle stages:
a – adult; b – larva; c – pupa, dorsal view; d – pupa, ventral view.

Owing to the previous occurrence of this new alien species in other European countries, experts have already conducted research studies regarding the level of damage and also biological control opportunities, based on the most effective native generalist parasitoid species. Thus, in Italy as well as in Switzerland, the experts found that the most important parasitoid species involved in biological control of *Phyllocnistis vitegenella* belong to Eulophidae family (Hymenoptera, Chalcidoidea): *Chrysocharis nephereus, Minotetrastichus ecus, Closterocerus trifasciatus, Cirrospilus vittatus,* and *Pediobius saulius* (Marchesini et al., 2000; Cara and Jermini, 2011; Cara et al., 2013).

CONCLUSIONS

Phyllocnistis vitegenella is an alien invasive species in European countries, which has already shown great adaptability and great invasive potential.

In Romania, although this non-native species seems to complete three generations per year, no economic damage has been reported so far.

Currently, some native natural enemies may play a major role in its biological control.

We consider that a new species needs time to adapt and acclimatise in a new habitat. Therefore, our future research will aim to clear up the main features of its life cycle as well as the structure of parasitoids communities of this species.

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AQUATIC INVERTEBRATE COMMUNITIES FROM THE TUR RIVER CATCHMENT AREA (TRANSYLVANIA, ROMANIA)

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KEYWORDS: benthic invertebrates, Coleoptera, *Graphoderus bilineatus*, microcrustaceans, Natura 2000, relative abundance, Satu-Mare County.

ABSTRACT

The present paper presents a hydrobiological study of the Tur River catchment area, based on the qualitative structure of aquatic invertebrate communities coming from nine sampling sites, located on the main river course and on its main tributaries.

There were investigated the upper and lower Tur River sectors, which includes four protected areas that lie on the lower Tur river course – ROSCI0214 (Tur River), ROSPA0068 (Lower Tur Floodplain), and within the Complex Reserve (The Tur River) the Nature Reserve (Lower Tur River) and the Nature Reserve "Pădurea Noroieni (Noroieni Forest)".

Analyses on the composition and structure of the benthic invertebrate communities emphasized the differences between the investigated areas.

REZUMAT: Comunitățile de nevertebrate acvatice din bazinul de drenaj al râului Tur (Transilvania, România).

În prezenta lucrare s-a realizat un studiu hidrobiologic în bazinul hidrografic al râului Tur. S-a identificat structura calitativă a comunităților de nevertebrate acvatice din nouă stații de prelevare a probelor, situate atât pe cursul principal al râului Tur, cât și pe afluenți.

S-a investigat zona de izvoare, dar și zona cursului inferior al Turului care cuprinde patru arii protejate: Situl de importanţă comunitară ROSCI0214 – Râul Tur, Aria de protecţie specială avifaunistică ROSPA0068 – Lunca Inferioară a Turului, Rezervația Complexă Râul Tur – Rezervația Naturală Cursul Inferior al Râului Tur, Rezervația Naturală Pădurea Noroieni.

În urma analizei compoziţiei şi structurii comunităţilor de nevertebrate bentonice au fost puse în evidenţă diferenţele dintre zonele investigate.

RÉSUMÉ: Communautés d'invertébrés aquatiques du bassin de drainage de la rivière Tur (Transylvanie, Roumanie).

Le présent document présente une étude hydrobiologique faite dans le bassin de drainage de la rivière Tur, sur la base de la structure qualitative des communautés d'invertébrés aquatiques provenant de neuf sites d'échantillonnage, situés sur le cours principal de la rivière et de ses principaux affluents.

Quatre zones protégées se trouvent sur le cour inférieur de la rivière Tur: ROSCI0214 – "Râul Tur"; ROSPA0068 – "Lunca Inferioară a Turului"; la Réserve Complexe "Râul Tur" – la réserve naturelle "Cursul Inferior al Râului Tur" et la Réserve Naturelle "Pădurea Noroieni".

Les analyses sur la composition et la structure des communautés d'invertébrés benthiques ont souligné les différences entre les zones étudiées.

INTRODUCTION

The Tur River catchment area is located in northwestern Romania, in Satu-Mare County. The river, a tributary of the Tisa River, has its source in the Oaș-Gutâi Mountains. Its' total length is 94 km; 66 km within Romanian borders and 28 km in Hungary (Ujvari, 1972). The lower Tur River region overlaps four protected areas: ROSCI0214 (Tur River), ROSPA0068 (Lower Tur Floodplain), and within the Complex Reserve (The Tur River) the Nature Reserve (Lower Tur River) and the Nature Reserve "Pădurea Noroieni (Noroieni Forest)" (*, 2014). Previous studies regarding benthic invertebrate communities from the area include only an inventory of Odonata species (Szallassy, 2008). A vulnerable coleopteran species included in the Natura 2000 Standard Data Form: *Graphoderus bilineatus*, was studied in the Tur catchment area in order to complete the Management Plan of the protected areas, but no individuals were found.

Thus, the aim of the present paper is to: (1) analyse the composition and structure of benthic invertebrate communities from the Tur catchment area from its headwaters to lower regions; (2) examine the general water quality characteristics of the Tur catchment area, as shown by the benthic invertebrates; and (3) investigate the coleopteran communities from the protected areas within the study area, as no data on the presence of *Graphoderus bilineatus* were found in the present Management Plan of the protected areas from the Tur River from 2014 to 2023 (Management Plan, 2014).

MATERIAL AND METHODS

The study area was located in the Tur River catchment area, nine sampling sites were considered. Four sites located on the main river course were sampled in August 2012: S1 – The Tur River – source, S2 – The Tur River – downstream Negrești-Oaș, S3 – The Tur River – downstream Lake Călinești-Oaș and S4 – The Tur River – downstream Turulung. The other five sites, located in different protected areas from the lower river catchment area, were sampled in May 2014 and May 2015: S5 – The Racta River – upstream Livada, S6 – The Egher River – upstream Medieș-Vii, S7 – The Racta River – downstream Livada, S8 – The Egherul Mare River – upstream Micula, S9 – The Noroieni canal (Fig. 1, Tabs. 1 and 2). The first sampling site, S1, was located upstream from the city of Negrești-Oaș, where low human impact was present. The bank vegetation was dominated by deciduous forests, mosses, and ferns. S2 and S3 were situated on the middle river course, upstream and downstream of the Călinești-Oaș dam reservoir. The dominant bank vegetation was represented by trees and hygrophilic herbs. S4 lay in the lower river course, downstream Turulung locality, therefore having submerged and emerged vegetation in the riverbed and rush on the banks (Fig. 1, Tabs. 1 and 2). The other five sampling sites were located on first and second order tributaries of the Tur River. S5 was situated on the Racta River, upstream Livada locality, where the bank vegetation was represented by hygrophilic herbs, *Salix* sp. and *Populus* sp. S6 lay on the Egher River, upstream Medieș-Vii locality, with the bank vegetation consisting of hygrophilic herbs, Rosaceae species. *Populus* sp. S7 was located at the junction of the Racta and Egher Rivers, between Livada and Adrian localities, where numerous crops and pastures were present near the river banks. S8 was situated between Micula and Agriș localities, on the Egherul Mare River, in a region dominated by semi-intensive agriculture. Finally, S9 lay on the Noroieni Canal, between Satu Mare and Micula localities, where bank vegetation consisted in deciduous forest (Fig. 1, Tabs. 1 and 2).

Qualitative samples of benthic invertebrates were collected using a 250 µm mesh net. All samples were preserved in the field in 4% formaldehyde. Identifications were made in the laboratory to the genus level for coleopterans (according to Richoux, 1982 and Tachet et al., 2000), and to order level in most cases for the other benthic invertebrate groups (according to Sansoni, 2001). Next to benthic crustaceans like amphipods and isopods, several taxa of microcrustaceans were found (cladocerans and copepods). They were identified to species or genus level (according to Negrea, 1983 and Einsle, 1993). Relative abundance was calculated for all benthic invertebrates, since it represents the index that best characterizes a community sampled qualitatively. The "Whittaker plot", or the rank-abundance plot (Whittaker, 1965), displays the relative abundance of the taxonomic groups found at one sampling site against their ranks in the community. The most abundant group is ranked 1, the second most abundant one is ranked 2, etc. The relative abundance of each group is plotted on the Y axis. Rank-abundances diagram was used to underline the differences between the sampling locations.

RESULTS AND DISCUSSION

The number of taxa decreased along the main Tur River course, from the headwaters to mouth. Nine taxa were found at S1, and only six at S4. The Călinești dam reservoir influenced the richness of benthic invertebrates, since downstream from the lake, in S3, only five taxa were identified.

Similarly, the total number of individuals belonging to the benthic communities from each sampling site also decreased from the headwaters to mouth. Thus, downstream Negrești-Oaș locality (S2) diminished by half compared to S1, probably due to the negative influences of domestic wastes or river regularization. Taxa sensitive to pollution, like Amphipoda or Plecoptera, were present only at S1, the sampling site located near the river source.

Table 1: The nine sampling sites with their codes used for the present paper.

Sampling site name	Sampling site code
The Tur River – source	S1
The Tur River – downstream Negrești-Oaș	S2
The Tur River – downstream Lake Călinești-Oaș	S3
The Tur River – downstream Turulung	S4
The Racta River – upstream Livada	S5
The Egher River – upstream Medieș-Vii	S6
The Racta River – downstream Livada	S7
The Egherul Mare River – upstream Micula	S8
The Noroieni canal	S9

The abundance percentage was calculated for the benthic invertebrate communities since it represented the index that best characterized the proportions of each taxa from the qualitative samples. The Mayflies-Ephemeroptera dominated the community at S1, reaching 48.4%. They were followed by Chironomidae (24.3%), Oligochaeta (11.7%), and Coleoptera, Trichoptera, Plecoptera, Amphipoda, etc. (up to 10%) (Fig. 2). Fewer invertebrate taxa were found at S2. However, Ephemeroptera also reached the highest abundance (66.8%), followed by Chironomidae (21.4%), while the rest of the groups (Trichoptera, Diptera, Oligochaeta, etc.) recorded lower values of up to 10% (Fig. 2). The number of taxa decreased further at S3, where Chironomidae recorded the highest abundance (65.4%), followed by Trichoptera and Oligochaeta (14.9% and 13.9%, respectively), while the rest of the groups did not exceed 5% (Fig. 2).

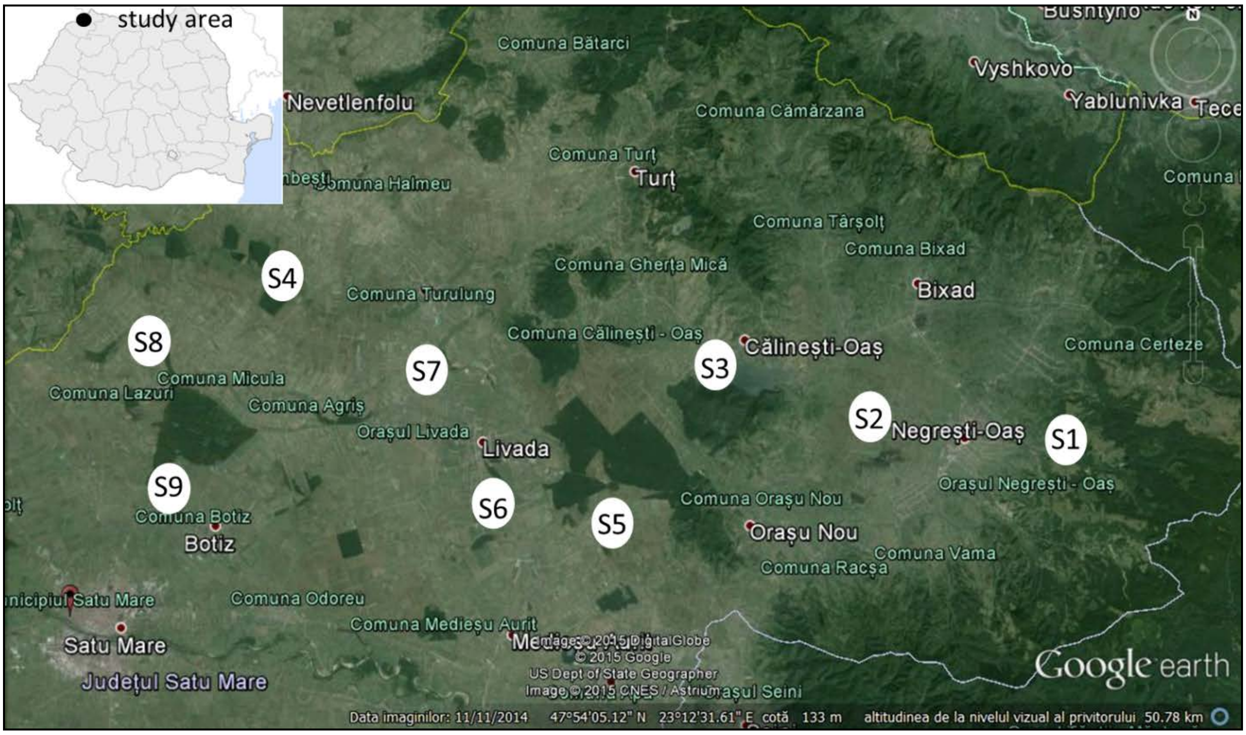

Figure 1: Location of the nine sampling sites from the Tur catchment area (S1 – The Tur River – source, S2 – The Tur River – downstream Negrești-Oaş, S3 – The Tur River – downstream Lake Călinești-Oaș, S4 – The Tur River – downstream Turulung, S5 – The Racta River – upstream Livada, S6 – The Egher River – upstream Medieș-Vii, S7 – The Racta River – downstream Livada, S8 – The Egherul Mare River – upstream Micula, S9 – The Noroieni canal).

Table 2: Location of the nine sampling sites from the Tur catchment area, with their main characteristics.

Site	Altitude (m)	GPS coordinates	Riverbed width (m)	Maxim depth (cm)
S1	340	N 47°51’03”; E 23°28’04”	4	50
S2	168	N 47°53’01”; E 23°22’10”	4	50
S3	137	N 47°54’00”; E 23°16’01”	10	80
S4	127	N 47°55’10”; E 23°05’09”	15	60
S5	133	N 47°50’16”; E 23°5’10”	4	80
S6	133	N 47°48’18”; E 23°9’20”	6	50
S7	133	N 47°53’5”; E 23°4’39”	5	70
S8	122	N 47°56’5”; E 23°4’13”	4	70
S9	122	N 47°49’4”; E 23°53’57”	6	70

The abundance of Chironomidae increased at S4, where they reached a total of 85.2%, while the rest of the benthic groups (Coleoptera, Oligochaeta, Ephemeroptera, Trichoptera, etc.) did not exceed 6% (Fig. 2).

The presence and abundance of different benthic invertebrate taxa can offer valuable information regarding the water quality from the considered sampling sites. Thus the groups sensitive to pollution, like Ephemeroptera, Plecoptera, and Trichoptera, recorded higher percentages at the first two sampling sites, S1 and S2 (53% and 72%, respectively), and lower percentages at S3 and S4. At these two sites, groups tolerant to pollution like Oligochaeta and Chironomidae, recorded high percentages, thus showing poor water quality, probably due to human caused pollution and the negative influences of the Călinești-Oaș Dam reservoir.

The taxonomical composition at the sites S5-S9, located in the protected areas from the lower Tur River catchment, shifted towards new groups like Odonata, Isopoda, Gastropoda, etc., and the disappearance of Plecoptera, Ephemeroptera and Trichoptera (except for S6). The number of individuals was higher in case of S6, S8 and S9.

Oligochaeta dominated the benthic community at S5 in 2014 and 2015, followed by Gastropoda and Isopoda in 2014 (Fig. 3); and Gastropoda, Isopoda and Turbellaria in 2015 (Fig. 4). Coleoptera had 22% in 2014.

Chironomidae and Oligochaeta clearly dominated at S6 in 2014 and 2015, recording joined percentages that exceeded 80% and 60%, respectively. Chironomidae recorded the highest abundance at S6 in 2014, followed by Gastropoda and Bivalvia (Fig. 3), while Oligochaeta dominated in 2015, followed by Gastropoda, Isopoda, and Turbellaria (Fig. 4).

Chironomidae and Oligochaeta dominated the benthic community at S7 in 2014, with a joined percentage of more than 63%, followed by Coleoptera and other dipterans (Tipulidae) (Fig. 3), while Isopoda and Gastropoda recorded the highest abundance in 2015, with a joined value exceeding 70%, followed by Chironomidae and Oligochaeta (Fig. 4).

A shift in the dominant groups was also recorded at S8, where Chironomidae dominated in 2014 reaching 40%, followed by Amphipoda (20%) (Fig. 5), while Oligochaeta dominated in 2015, reaching a very high percentage (94.33%) (Fig. 6).

Strong domination of Chironomidae and Oligochaeta was also recorded at, where a joined percentage of 93% was recorded (Fig. 5). Oligochaeta alone dominated in 2015, with 45%, followed by Coleoptera with 30% (Fig. 6).

In the two sampling years, the water quality from the lower Tur catchment area varied. Thus, at S5, S7 and S9 the average percentage of 20-65% for Oligochaeta and Chironomidae showed a moderate organic pollution. However, the joined percentage of the two tolerant groups at S6 in 2014 and at S8 in 2015, that exceeded 80% and 90%, respectively, suggested a strong organic pollution, probably caused by the vicinity of human settlements and agriculture.

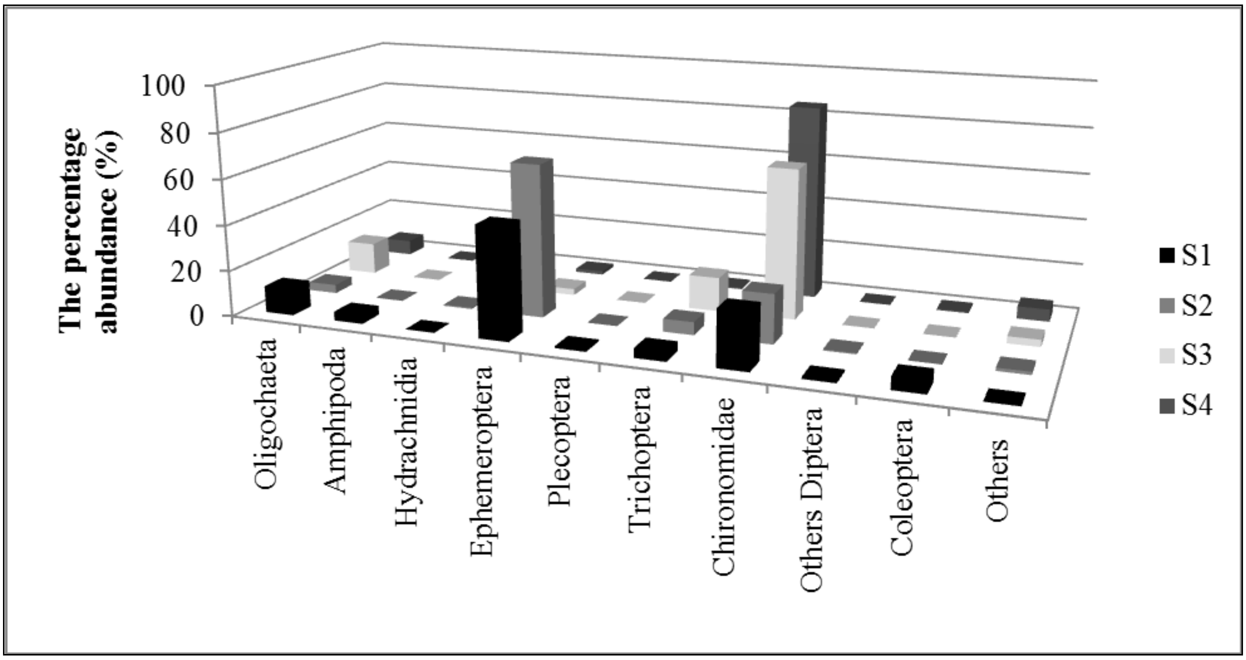

Figure 2: The abundance percentage (%) of benthic invertebrate groups from the following sampling sites: S1 – The Tur River – source, S2 – The Tur River – downstream Negrești-Oaș, S3 – The Tur River – downstream Lake Călinești-Oaș, S4 – The Tur River – downstream Turulung, in 2012.

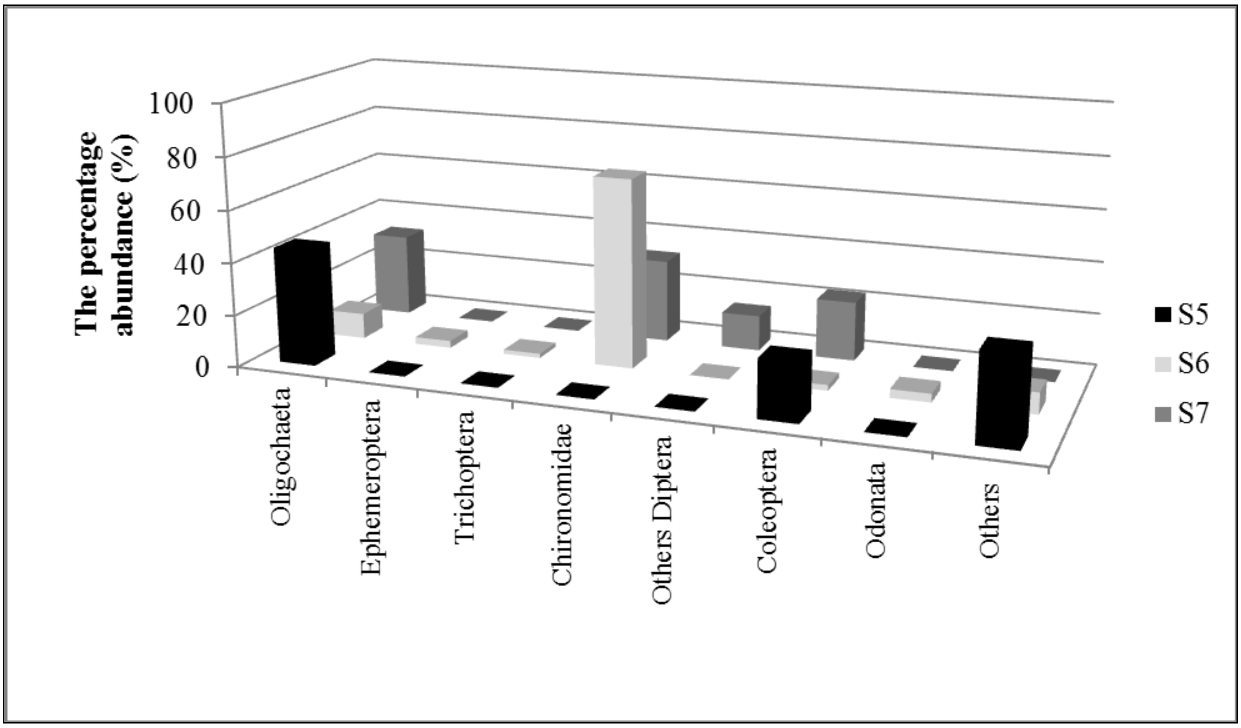

Figure 3: The abundance percentage (%) of benthic invertebrate groups from the following sampling sites: S5 – The Racta River – upstream Livada, S6 – The Egher River – upstream Medieș-Vii, S7 – The Racta River – downstream Livada, in 2014 (Others: Gastropoda, Bivalvia, Isopoda).

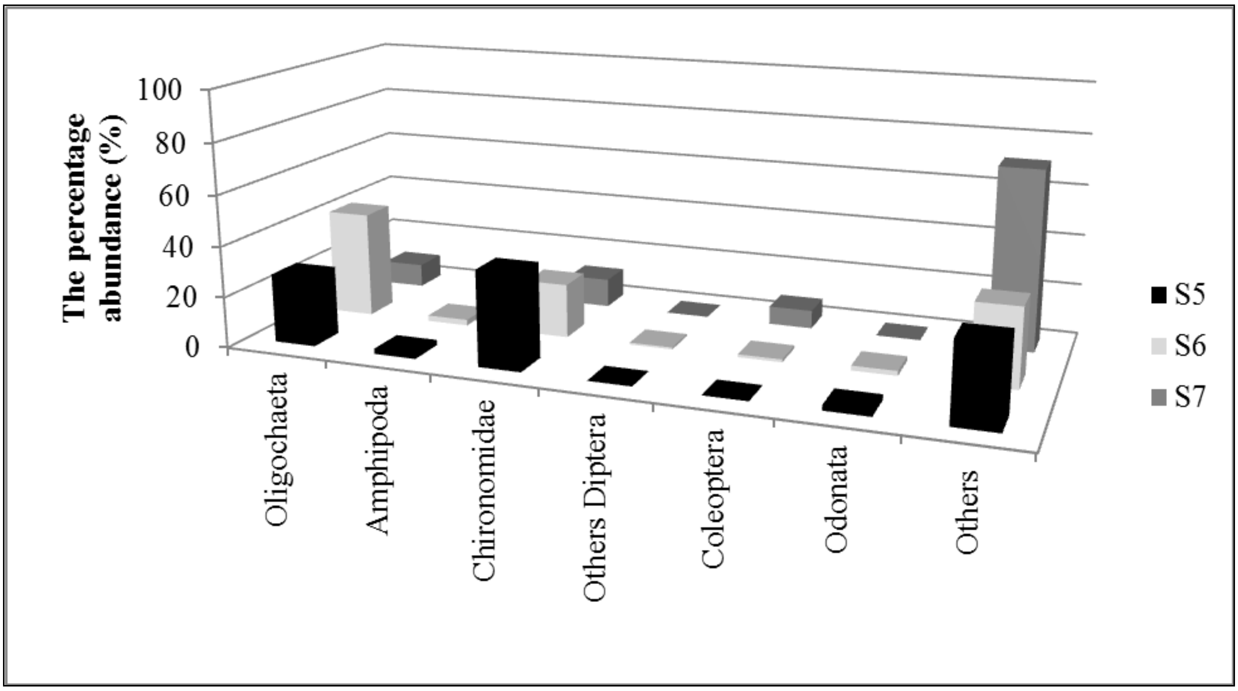

Figure 4: The abundance percentage (%) of benthic invertebrate groups from the following sampling sites: S5 – The Racta River – upstream Livada,
S6 – The Egher River – upstream Medieș-Vii,
S7 – The Racta River – downstream Livada, in 2015
(Others: Gastropoda, Turbellaria, Hirudinea, Isopoda).

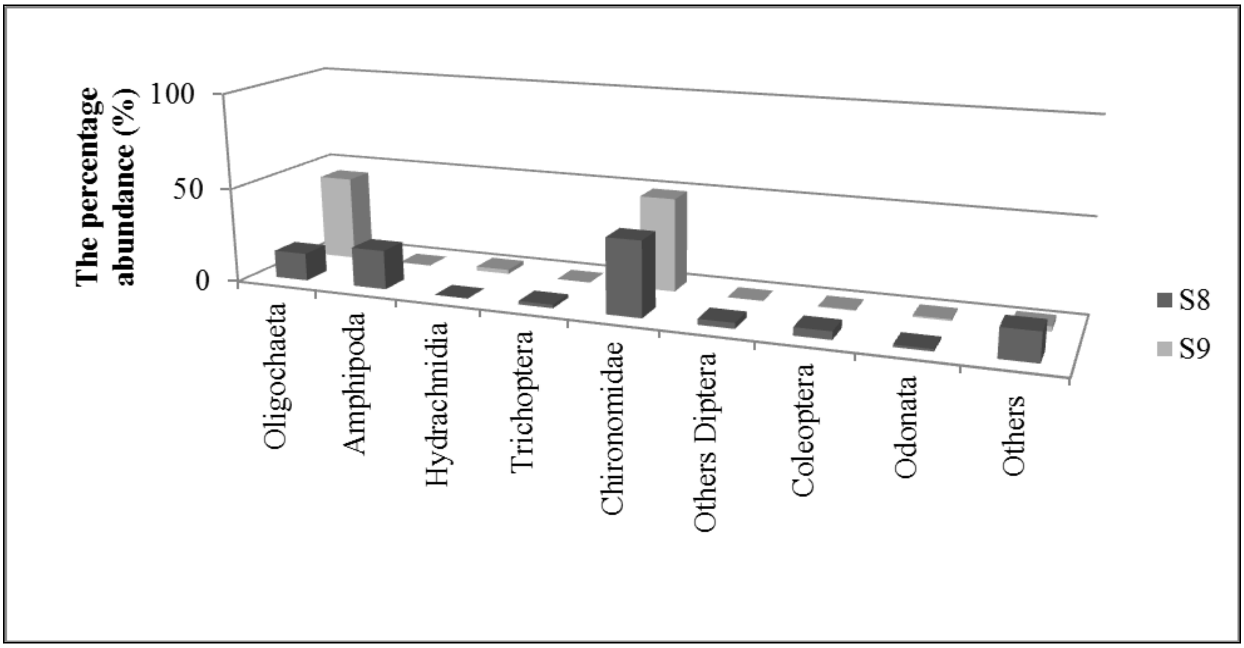

Figure 5: The abundance percentage (%) of benthic invertebrate groups from the following sampling sites: S8 – The Egherul Mare River – upstream Micula, S9 – The Noroieni canal, in 2014 (Others: Gastropoda, Bivalvia, Turbellaria, Hirudinea, Isopoda, Heteroptera).

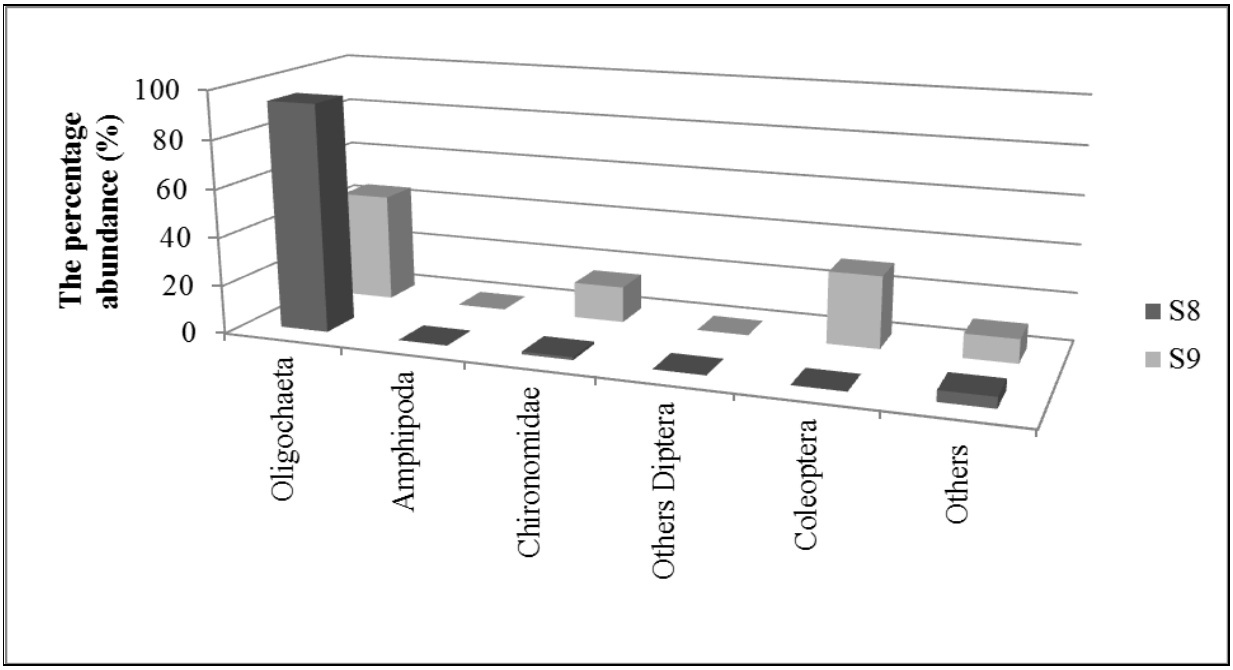

Figure 6: The abundance percentage (%) of benthic invertebrate groups from the following sampling sites: S8 – The Egherul Mare River – upstream Micula, S9 – The Noroieni canal, in 2015 (Others: Gastropoda, Bivalvia).

These tendencies described above were discernable on the Whittaker plot (Fig. 7), that displayed the relative abundances of different taxonomic groups against their ranks in two sampling sites: S1 and S8 (2015). The different shapes of the curves showed contrasting situations. The moderated slope of the curve indicated a clearly balanced benthic community for S1, where Ephemeroptera, Chironomidae and Oligochaeta recorded similar values of abundances. On the other hand, a drastically affected community was characteristic for S8 in 2015, where one group, Oligochaeta, represented almost 95% from the benthic community.

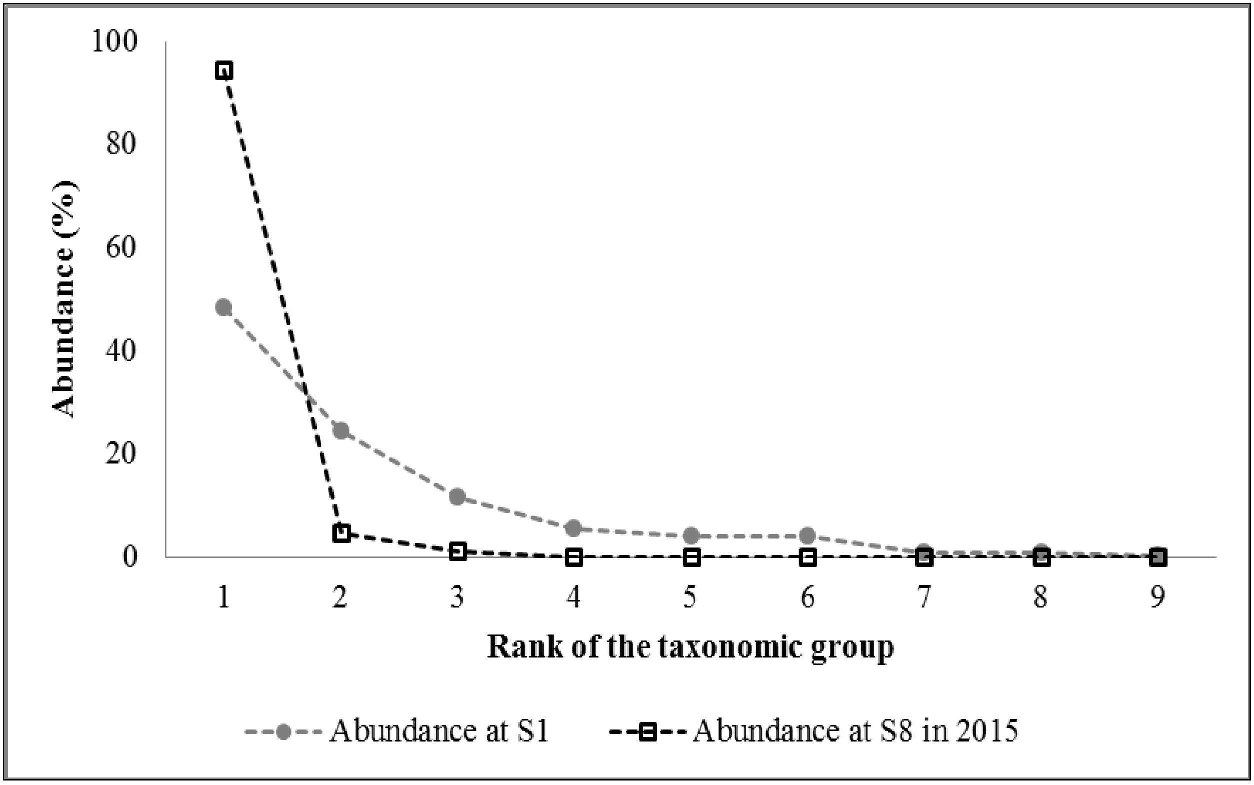

Figure 7: The rank-abundance plot for S1 (gray circles) and S8 in 2015 (hollow black squares).

Coleoptera individuals found in the sampling sites S5-S9, located in different protected areas from the lower Tur River, were identified up to the genus level to investigate the possible presence of *Graphoderus bilineatus*, a vulnerable species included in the Natura 2000 Standard Data Form used for the assignment of protected areas in EU.

The habitats preferred by *Graphoderus bilineatus* include permanent standing pools with clean waters, about 1 m deep, and with rare aquatic vegetation (**, 2014).

The European distribution of the species includes Central and Eastern Europe, from northern Italy, Austria, Hungary, and Romania to southern Scandinavia and western Siberia (Cuppen et al., 2006). *Graphoderus bilineatus* was found in north-western, central and southeastern Romania, but the citations indicated the species as "rare" (**, 2014).

Seven Coleoptera genera were identified in the five sampling sites considered for this investigation (S5-S9) (Fig. 8). *Coelostoma* sp. was found in the highest number of locations: S6-S9, compared to the other more rare genera.

Even if the samplings occurred two years in a row (2014 and 2015), *Graphoderus* sp. was not identified in the sampling sites considered in the study area. Favourable habitats for the species were present in the Natura 2000 protected areas from the lower Tur River. However, with only five sampling sites and only aquatic fauna considered, further investigations are required in order to positively identify the species.

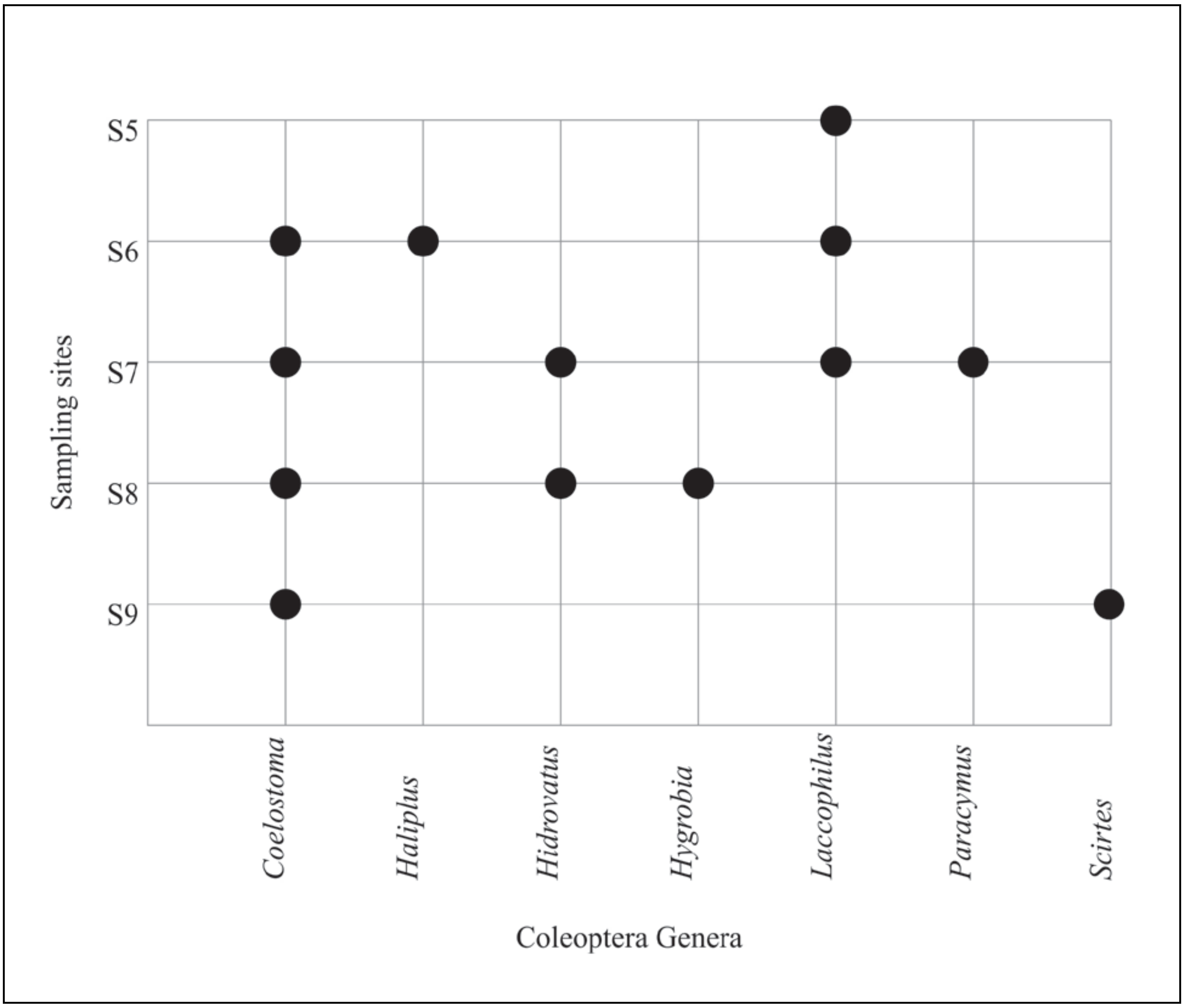

Figure 8: The presence of coleopteran genera at the following sampling sites: S5 – The Racta River – upstream Livada, S6 – The Egher River – upstream Medieș-Vii, S7 – The Racta River – downstream Livada, S8 – The Egherul Mare River – upstream Micula, S9 – The Noroieni canal.

Several microcrustacean taxa were present in three sampling sites, located in the lower catchment area on the Tur River tributaries, where abiotic factors like the presence of aquatic vegetation, higher river depth, or lower current made possible the survival of these organisms-known to dwell mostly in the pelagic habitats (Tab. 3).

Only one cladoceran individual was identified, a primiparous parthenogenetic female belonging to *Daphnia* sp., which probably drifted into the sampling net. On the other hand, several cyclopoid copepod species were found, mostly cosmopolitan and eurybiont taxa, like *Mesocyclops leuckarti*, next to immature copepodite stages (Tab. 3).

Table 3: Microcrustacean taxa (cladocerans and copepods) from the three sampling sites where they were present (♀n – nonovigerous females, ♀o – ovigerous females, ♂ – males).

Taxa	S5 The Racta River – upstream Livada	S6 The Egher River – upstream Medieș-Vii	S9 The Noroieni canal
Cl. Branchiopoda, Subcl. Phyllopoda, Ord. Diplostraca, Subord. Cladocera			
Daphnia sp.	–	–	♀n
Cl. Maxillopoda, Subcl. Copepoda, Ord. Cyclopoida			
Acanthocyclops robustus Sars 1863	–	–	♀n, ♂
Eucyclops s. proximus (Lilljeborg 1901)	♀n	♀n	–
Macrocyclops albidus (Jurine 1820)	♀n, ♂	♀n	♀n
Macrocyclops fuscus (Jurine 1820)	♀n, ♀o, ♂	–	–
Megacyclops viridis (Jurine 1820)	♀n	–	♀n, ♂
Mesocyclops leuckarti (Claus 1857)	–	–	♀n, ♂

CONCLUSIONS

The qualitative composition and structure of benthic invertebrate communities from the Tur River catchment area differed from headwaters to mouth. Thus, pollution intolerant groups like Plecoptera, Ephemeroptera, and Trichoptera, were identified only in the upper reaches of the river, while Oligochaeta and Chironomidae dominated in the lowlands next to Odonata or Mollusca.

The general characterization of the Tur River water quality followed the succession of the dominant benthic groups at the nine sampling sites. Thus, in the upper reaches of the catchment, the water quality was good, but it decreased dramatically going downstream, probably due to anthropogenic pollution, the influence of the Călinești-Oaș dam reservoir, and agriculture.

Seven Coleoptera genera were identified in the study area. However, *Graphoderus bilineatus*, a species included in the Natura 2000 Standard Data Form for the protected areas in the region was not identified at the sampling sites considered for the present study.

Several species of microcrustaceans were present at three of the nine sampling sites, but they were cosmopolitan and eurybiont, since they usually populate pelagic habitats.

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IMPACT OF HUMAN ACTIVITIES ON THE STATUS OF THE DANUBE RIVER IN SERBIA: MICROBIOLOGICAL AND ICHTHYOFAUNISTIC STUDIES

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KEYWORDS: pollution, wastewaters, large river, fish populations, genotoxicity, microbiological analyses.

ABSTRACT

The length of the Danube River through Serbia is 588 km and it is subject to huge amounts of untreated wastewater. The major pollution hot-spots along the Danube River in Serbia are the Danube-Tisza-Danube Hydrosystem canal network, the Djerdap reservoir, the industrial complex near the city of Pančevo and the Tisza River sediments. As a consequence of anthropogenic impacts, highly valuable sturgeon species are replaced in fishery catches with alien species, which are less valuable. Results of microbiological and genotoxic investigations indicate high anthropogenic impact. The detected sanitary pollution can be explained by improperly treated urban wastewaters while significant levels of DNA damage can be linked to pollution caused by agricultural activities.

REZUMAT: Impactul activităților umane asupra Dunării pe teritoriul Serbiei: studii microbiologice și ihtiologice.

Lungimea Dunării pe teritoriul Serbiei este de 588 km, aici se deversează cantități uriașe de ape uzate netratate. Punctele cu cea mai mare poluare pe cursul fluviului în Serbia sunt reprezentate de: rețeaua de canale Dunăre-Tisa-Dunăre, bazinul Djerdap, complexul industrial din proximitatea orașului Pančevo și sedimentele râului Tisa. Ca și consecință a impactului antropic, speciile de sturioni care au o valoare genetică și economică foarte mare au fost înlocuite de speciile alohtone care prezintă o valoare scăzută. De asemenea, rezultatele investigațiilor microbiologice și genotoxice indică un impact antropic accentuat. Poluarea cu ape uzate poate fi explicată prin tratarea inadecvată a apelor menajere provenite din mediul urban în timp ce un nivel ridicat de deteriorare al ADN-ului poate fi legat de poluarea cauzată de activitățile agricole.

RESUMEN: Impacto de las actividades humanas sobre el Río Danubio en Serbia: estudios microbiológicos e ictiofaunísticos.

La longitud del Danubio en territorio Serbio es de 588 km y se encuentra sujeto al influjo de grandes cantidades de agua de deshecho no tratada. Las fuentes más importantes de contaminación del Danubio en Serbia son la red hídrica de canales del Danubio-Tisza-Danubio, el reservorio Djerdap, el complejo industrial adyacente a la ciudad de Pančevo y los sedimentos del Río Tisza. Como consecuencia del alto impacto antropogénico, las especies de esturiones de alto valor comercial fueron sustituidas por especies invasoras, de menor calidad. Asímismo, el resultado de las investigaciones microbiológicas y genotóxicológicas apuntan a un alto impacto de orígen humano. La contaminación sanitaria que se identificó puede ser explicada por el vertimiento al río de aguas urbanas de deshecho que no fueron tratadas adecuadamente y el elevado grado de daño del ADN microbiano pudiera ser atribuído a las actividades de agricultura.

INTRODUCTION

The length of the Danube River through the Republic of Serbia is 588 km, with 137 and 220 km of the river flow, respectively, representing borders with Croatia and Romania.

The Serbian section of the Danube covers mainly the Middle Danube region, and only a part of the Lower Danube region.

River regulation in the Djerdap region started in the second part of the XIX century for navigational purposes (Petrović, 1998), while the construction of a hydropower system in the area of the Djerdap gorge started in the second half of the XXth century. Hydropower plant Djerdap I was constructed during the period 1964-1971 at the 943 river km and Djerdap II during 1980-1984 at the 863 river km (Fig. 1).

The construction of these two hydropower plants resulted in the formation of two reservoirs with a total area of about 25,000 ha (Janković, 1994).

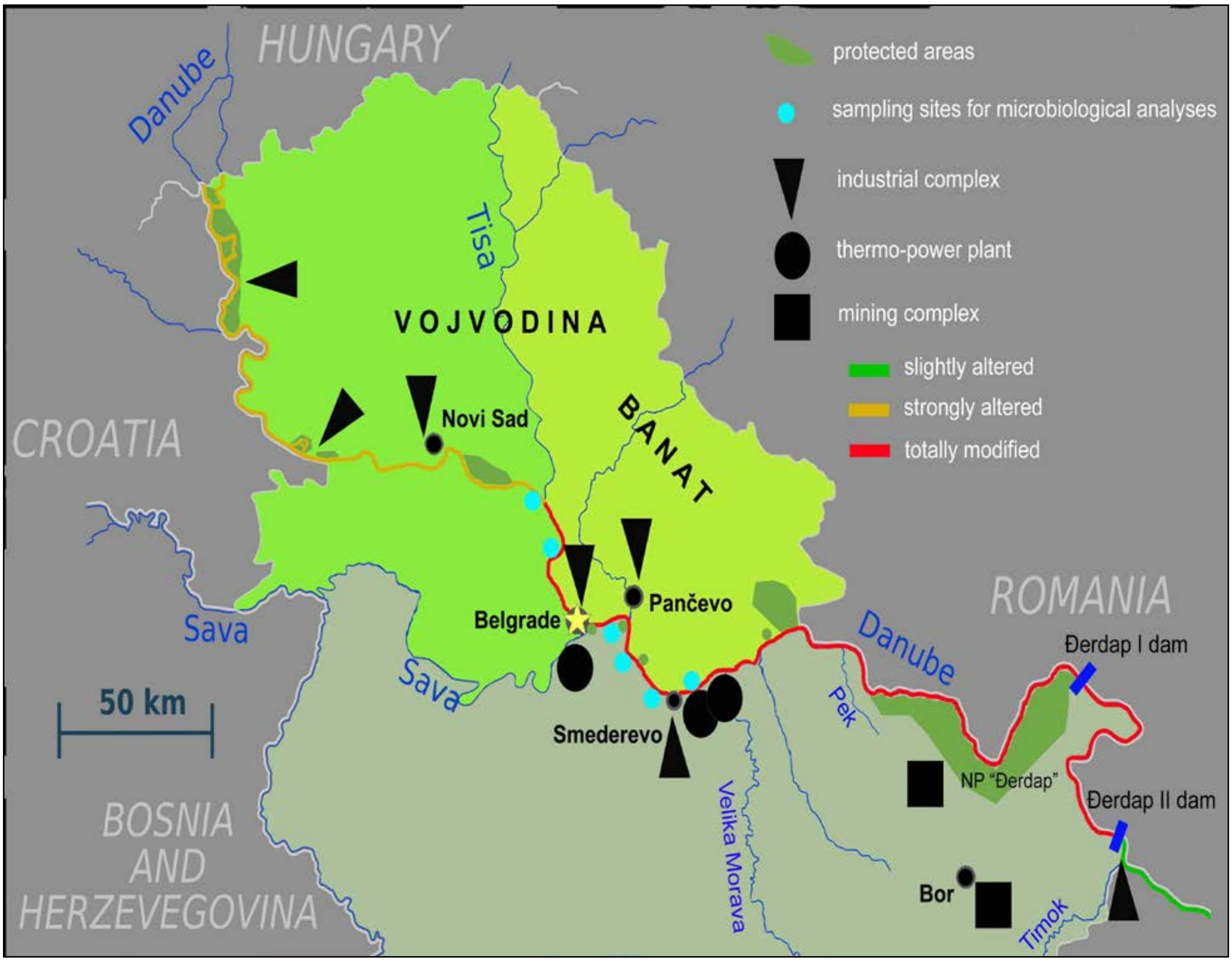

Figure 1: Serbian part of the Danube River; Map indicates protected areas, including National Park "Djerdap", the main industrial complexes that influence quality of water and sediment in the Danube, as well as thermo-power plants and a mining complex near the city of Bor that influence the status of the Danube via tributary rivers. The level of hydromorphological alterations of the Danube is presented following Habersack et al. (2010).

RESULTS AND DISCUSSION

1. Danube water and sediment pollution in Serbia

The Danube River basin is subject to huge amounts of wastewater input (Teodorović et al., 2000). The Danube in Serbia represents the major industrial development axis with a number of industrial centres (Milanović et al., 2010). Many of these facilities along the Danube release untreated wastewater into the river (Stankovic, 2006). This is especially pronounced in the vicinity of cities Novi Sad, Belgrade, Pančevo and Bor, which are surrounded by different industrial facilities that continuously discharge various pollutants into the environment (Stanic et al., 2006). It is estimated that approximately 90% of all industrial wastewaters in Serbia are being discharged into waterbodies without prior treatment (Milijašević et al., 2010). The major industry facilities along the Danube in Serbia are inorganic chemistry in Novi Sad, basic organic chemistry in Pančevo, Novi Sad and Belgrade, steel industry in Smederevo, non-metal exploitation and processing in Pančevo, and construction materials production throughout Vojvodina (Milanović et al., 2010).

Large settlements that release untreated communal wastewater in the Danube River and its tributaries represent another source of water pollution. Serbia represents one of the major emitters of untreated wastewater in the Danube Basin (Kirschner et al., 2009). The Danube River in Serbia is significantly contaminated by faecal pollution. One of the sites with the highest faecal pollution in the Danube River basin is the river stretch between Novi Sad and Belgrade (Kirschner et al., 2009).

Heavy metals are considered as the most important problem in the Danube in Serbia (Teodorović, 2009), and it is estimated that as much as 240 tons of cadmium, 4,000 tons of lead and 900 tons of chromium are released annually from the Danube into the Black Sea (SEPA, 1990). However, elevated contents of organic pollutants have also been registered, such as polychlorinated biphenyls (PCBs), organochlorine pesticides, polyaromatic hydrocarbons (PAHs) and organic micro pollutants (Teodorović, 2009). The occasional occurrence of phenols and mineral oils in the Danube water is a direct consequence of waterborne traffic (Sretenovic et al., 2004). Water pollution from ships can come from bilge water, pollution from ship paints, discharge of oil, and from accidental and illegal waste-water spills (Croitoru et al., 2008).

It is estimated that Serbia releases annually about 72,000 t/year of nitrogen and 7,000 t/year of phosphorus, which, respectively, represent 13% and 14% of the total amount of discharged nitrogen and phosphorus in the whole Danube Basin, making Serbia one of the major sources of these pollutants in the Danube water (Milanović et al., 2010). Banat is one of the major sources of nitrogen and phosphorus emission in the Danube River Basin (Schreiber et al., 2003). Main sources of the Danube pollution with nutrients are livestock farms, in particular very large pig farms, due to inadequate manure storage practices and limited and improper recycling of manure as fertilizers (Samsonová and Šarapatka, 2005). Phosphorus input from urban areas also contributes to the total phosphorus emission, and this pathway dominates especially in the Pannonian Danube, the Tisza and the Velika Morava (Schreiber et al., 2003). However, some authors claim that the Danube's self-purification ability is considerably higher than the pollution of the Danube that is created on the territory of Serbia (Milijašević et al., 2010).

The Danube water in Serbia belongs on the average to the third trophic class (Samsonová and Šarapatka, 2005; Milanović et al., 2010). The Danube enters Serbia as a river of the second trophic class, but it moves into the third class when it receives industrial and sewage water of Belgrade and Pančevo, as well as polluted Sava River (Milijašević et al., 2010).

The eco-chemical status of the Danube represents an issue of a constant interest on both the local and international level (Živadinović et al., 2010). There is however a lack of knowledge on the actual pollution by hazardous substances in the Danube River Basin (Teodorović, 2009; Vogel, 2010). According to Živadinović et al. (2010), most of the environmental studies dealing with the Danube pollution that have been conducted so far were focused on the presence of heavy metals in the water and sediments, nutrients, radioisotopes and oil.

1.1. Overview of the major pollution hot-spots along the Danube River in Serbia

Official monitoring programmes and independent studies have identified the Danube-Tisza-Danube hydrosystem canal network, Djerdap reservoir, industrial complex near the city of Pančevo and the Tisza River sediments as major hot-spots of severe freshwater pollution and soil and sediment contamination in Serbia (Teodorović, 2009).

1.1.1. Tisza River

The Tisza River has been exposed to intense pollution over the last decades (Sakan et al., 2007), and it is considered to be one of the most polluted rivers of the Pannonian plain (Milijašević et al., 2010). It receives permanent pollution from agriculture, chemical factories, municipal sewage discharge and the mining industry (Sakan et al., 2007). Its water quality is classified as the third or the fourth class (Milijašević et al., 2010). Moreover, the Tisza River was also contaminated with numerous industrial accidents from the Carpathian mountain region in Romania, which has a long tradition of mining, especially of Au, Ag, Pb, Zn, Cu, Cd and Mn (UNEP/OCHA, 2000; Triebskorn et al., 2008). The largest of these was probably the accident in 2000 in Maramureş County, when 200,000 m^3 of contaminated water and 40,000 tonnes of tailings were released into tributaries of the Tisza River, with high concentrations of cyanide and contaminant metals such as Pb, Zn, Cu and Cd, resulting in pollution and fish deaths in the Tisza and Danube rivers within Hungary, Serbia, Romania and Bulgaria (Macklin et al., 2003; Sakan et al., 2007). However, according to the study by Petrovic-Gegic et al. (2006), concentrations of heavy metals and radionuclides in fish in the Tisza River have not exceeded Maximum Acceptable Concentrations (MAC). Sakan et al. (2007) have determined that the quality of sediments in the Tisza River in Serbia was on the borderline between potentially polluted and polluted, but that the trends also indicate that this line might be easily exceeded in the future.

1.1.2. Novi Sad and Belgrade cities

The Danube River section between the cities of Novi Sad and Belgrade receives large amounts of untreated or poorly treated communal and industrial wastewaters. Sediments in the vicinity of Belgrade have elevated concentrations of As and Hg, which probably originates from the pollution brought by the Sava River and insufficiently treated municipal wastewaters (Babic-Mladenovic et al., 2003). Influence of the water and sediment pollution on aquatic biota in this section of the Danube River has been indicated by a number of studies. Stanic et al. (2006) determined that the presence of the pollution caused oxidative stress in the liver of fish in the vicinity of the oil refinery site near Novi Sad. Moreover, Lenhardt et al. (2004b) and Poleksic et al. (2010) found the presence of sublethal pathological changes in fish from this section of the Danube River. However, although Jakovčev-Todorović et al. (2005) determined that the benthic community structure in the vicinity of Belgrade indicated the presence of organic pollution, they determined that there was no difference between the estimated environmental quality of the Danube upstream and downstream from Belgrade.

The Sava River empties into Danube in this Danube section. According to Milačić and Ščančar (2007), the Sava is moderately polluted by Cr and Ni, mostly at industrially exposed sites, but they do not represent a critical environmental burden. On the other hand, elevated phosphorus concentrations in the Sava River were detected in agricultural areas and in the vicinity of big cities, such as Belgrade (Milačić and Ščančar, 2007).

1.1.3. Pančevo

The industrial complex near the city of Pančevo is considered as the largest individual hot-spot in Serbia (Teodorović, 2009). A major industrial complex is situated in the vicinity of this city, comprising a petrochemical plant, fertilizer plant and major oil refinery (Janković et al., 2011). Effluents that are discharged into the wastewater canal entering the River Danube are considered as the most important sources of pollutants in the Danube River ecosystem (Teodorović, 2009; Janković et al., 2011). Polychlorinated biphenyls (PCBs) are some of the most detrimental pollutants coming from this industrial complex. Janković et al. (2011) found significantly elevated levels of PCBs in fish tissues downstream the wastewater discharge point, and the pollution by PCBs also had a trend of increase over time.

On the other hand, the study by Sakan et al. (2010) indicated that the impact of Pančevo industrial complex on the Danube River sediment quality and its trace element contamination is only minor. Although the Pančevo refinery contributed to the Pb, Cd, Cu and Zn concentrations in sediments in this zone of the Danube River, pollution with trace metallic and metalloid elements was not significant (Sakan et al., 2010).

1.1.4. Danube-Tisza-Danube hydrosystem canal complex

Danube-Tisza-Danube (DTD) canal complex is another significantly polluted area in the Danube River basin in Serbia. Main sources of its pollution are untreated wastewaters from industry and households, as well as the pollution from agriculture (Milijašević et al., 2010). Runoffs from agricultural areas carry mineral fertilizers and pesticides, and the canal system also receives faecal and other organic pollutants from farms, effluents from chemical, petrochemical, textile and other types of industry, as well as runoff from dumps and illegal landfills (Piperski and Salvai, 2008). According to Piperski and Salvai (2008), only 71 from the total of 497 registered polluters within the DTD system have wastewater treatment facilities. Besides the problem of chemical contamination, the DTD canal complex is also impacted by problems of hypereutrophication, overgrowing and inundation (Ilić et al., 2006). Water macrophyte and marshy vegetation in canals, that filter runoff and have a role in water purification, have been degraded and reduced to small areas, partly due to pollution (Piperski and Salvai, 2008).

Some areas are considered to suffer from severe levels of pollution. Veliki Bački Canal represents one of the most polluted water flows in Europe (Milijašević et al., 2010), and the Begej Canal is highly polluted with Cr, Cu, Cd and Zn (Dalmacija et al., 2006). The study by Ilić et al. (2006) revealed a high level of accumulation of Pb in tissues of aquatic plants in DTD, as well as increased concentrations of Cu, Fe, Mn and Ni. The survey of the DTD water quality in 2006 determined increased concentrations of volatile phenols, surface active substances, sulfides, Fe, Mn, Hg and Ni (Hydrological Yearbook, 2006, in Piperski and Salvai, 2008).

1.1.5. Djerdap reservoir

Djerdap acts as a large depository, or a sink, of pollutants and nutrients in the Danube water, which is associated with the sedimentation of suspended solids carried by the Danube water due to a slowed water flow (Milenkovic et al., 2005; Milijašević et al., 2010; Živadinović et al., 2010). This is one of the reasons for a better water quality downstream the Djerdap reservoir than upstream from it (Milanović et al., 2010; Milijašević et al., 2010). The lowest faecal pollution levels in the whole Danube River basin were detected in the Djerdap area (Kirschner et al., 2009). Downstream from the Djerdap gorge there is an overall decline in the concentration of all metals, except for Cd (Milenkovic et al., 2005). On the other hand, according to Milanović et al. (2010), Djerdap reservoir has a potential for intensive eutrophication.

Sediments in the Djerdap reservoir have much higher heavy metal levels (especially of Fe and Mn) than sediments in the upstream river sections (Babic-Mladenovic et al., 2003). Besides Fe and Mn, sediments also accumulate significant amounts of Zn, Cd and Ni, and to a lesser extent Pb and Hg, while increased levels of phenols and mineral oils are also occasionally recorded (Milanović et al., 2010). A study by Milenkovic et al. (2005) has determined a trend of increasing levels of Fe, Mn, Ni, Zn, Cu, Cr and Cd in Djerdap sediments, while concentrations of Hg and Pb have decreased over time. According to the same authors, the most significant heavy metal pollution in Djerdap sediments was caused by Zn, while they could be regarded as unpolluted with respect to As and Pb.

1.1.6. Mining complex in the Bor city

The copper mining and processing complex around the city of Bor (Eastern Serbia) represents another environmental pollution hot-spot in Serbia, which causes wide environmental damages to the region (Zekovic, 2007). Wastewater from this mine, which contains increased concentrations of Cu, Fe, Pb, Zn, and Cd, affects the Kriveljska River, Timok River, and the Danube River as the final recipient (Peck and Zinke, 2006). Besides heavy metals, mining wastewaters also contain high levels of suspended material, and it is estimated that 300-350 t of As, 30-100 t of Pb, 10-35 t of Zn, and 300-500 t of sulphuric acid are annually released from this mining complex (Zekovic, 2007). In a study by Poleksic et al. (2010), the highest concentrations of Zn, Fe, and Cu were found in fish caught in the Danube River downstream from the Djerdap II dam, which could be a result of the pollution coming from this mining complex.

1.2. Impact of the Danube pollution on aquatic biota and the state of scientific research

Pollutants that have the ability to bioaccumulate, such as heavy metals, pesticides and PCBs, are considered as highly critical contaminants of aquatic ecosystems, due to their high potential to enter and accumulate in food chains (Olojo et al., 2005; Erdoğrul and Erbilir, 2007; Janković et al., 2011). Fish are commonly situated at the top of the food chain and, therefore, they can accumulate large amounts of some pollutants (Yilmaz et al., 2007; Janković et al., 2011). They are also considered as some of the most susceptible aquatic organisms to toxic substances present in water (Alibabić et al., 2007). This lower Danube sector ichtyofauna is significantly affected by human activities (Bănăduc et al., 2014, 2016).

There are ongoing research efforts in Serbia with the aim of determining the impact of the water and sediment pollution on aquatic biota. Some studies have attempted to establish a link between the Danube River pollution and pathological changes in fish (Kolarević et al., 2004; Lenhardt et al., 2004b; Poleksic et al., 2010), and to assess the use of biomarkers in fish for the assessment of Danube pollution (Stanic et al., 2006; Lenhardt et al., 2009). Elevated heavy metal levels in the Danube fish have been detected by a number of authors, with metal concentrations in some cases even exceeding prescribed MAC (Visnjic-Jeftic et al., 2010; Jarić et al., 2011). As was determined by Poleksic et al. (2010), pollution in the Danube by heavy metals and other pollutants resulted in sublethal pathological changes in the sterlet (*Acipenser ruthenus*). Teodorovic et al. (2000) have attempted to establish a Metal Pollution Index, a mathematical model and an index which would enable expressing concentrations of all metals found in fish tissues in this study as a single value.

Nevertheless, as discussed by Teodorović (2009), ecotoxicological research in Serbia is still underdeveloped and has been restricted to small or medium-scale laboratory and monitoring-like studies. Results prior to the mid-1990s either remained unpublished or published within the “grey” literature, and, even with the ongoing scientific development, this field of research in Serbia remains in the scope of fairly descriptive publications (Teodorović, 2009).

1.3. Recent management and policy initiatives and future priorities

Quality of the Danube water has been improving over time (Milijašević et al., 2010). Such trend has been strongly indicated by the analysis of a number of eco-chemical parameters (Živadinović et al., 2010). As a signatory party of ICPDR, as well as a country in the process of EU accession, Serbia has been undertaking measures to contribute to the fulfilment of the Water Framework Directive main objective – a good ecological status of all European rivers by 2015 (Teodorović, 2009).

A large-scale Danube pollution reduction project has been recently successfully completed in Serbia (Danube River Enterprise Pollution Reduction Project – DREPR; DREPR, 2010). This project, funded by GEF, has aimed to reduce nutrient loads discharged into the Danube River and its tributaries from livestock farms and slaughterhouses, as well as at the improvement of the monitoring system and the awareness raising.

Nonetheless, planned and ongoing processes of industrial development in Serbia, which will be intensive along the Danube River, could result in an increased water and sediment pollution, if it is not conducted with a strict control and proper impact assessment. As stated by Croitoru et al. (2008), planned waterborne traffic intensification in the Danube River basin over the coming years could also pose an additional pressure on the water pollution, if not regulated accordingly. Furthermore, Serbian environmental legislation regarding emissions and environmental pollution is outdated, and some standards, such as sediment quality criteria, have not yet been established (Prica et al., 2008; Teodorović, 2009). Serbia also lacks an established system of continual monitoring of sediment quality, although a systematic approach to this problem is now beginning (Prica et al., 2008).

Future main priorities for alleviating pollution in the Danube River basin in Serbia should be the establishment of proper communal wastewater treatment facilities in major settlements along the Danube in Serbia, and conducting pollution clean-up projects at major hot-spots, such as Novi Sad, Pančevo and Bor. Restoration activities in the most severely polluted areas are of special importance. As stated by Dalmacija et al. (2006), certain heavily polluted areas of the DTD canal complex require urgent and proper sanitation, dredging, and, if possible, sediment clean-up measures.

2. Influence of the Djerdap I and II dams construction on fish populations in Serbia

Besides the pollution, fish communities in the Serbian part of the Danube River were also substantially impacted by the construction of dams. Dams are one of the main reasons for the decline of sturgeon stocks, since they block free access to their major spawning grounds (Lenhardt et al., 2004a; Lenhardt et al., 2006). Furthermore, dams inevitably make profound ecosystem-wide changes in a river, altering everything from silt transportation, water clarity, and temperature to species diversity and abundance within the freshwater system itself (Schilt, 2007).

River regulation in the Djerdap region, during the period between 1890 and 1896, prevented sturgeons from reaching the upper part of the Danube River (Petrovic, 1998). Moreover, construction of the two dams presented impediments for migrations of all diadromous species in the Danube River, and to a certain extent of potamodromous species as well, such as sterlet (which makes extensive within-river migrations). Some studies (Nielsen et al., 1997) suggested that isolation by dams can cause a loss of genetic variation in fish populations that are trapped. On the other hand, research by Deiner et al. (2007) showed that specimens located upstream of the dam possessed levels of heterozygosity and allelic richness that were not significantly different from those located downstream. A higher level of genetic diversity found by Deiner et al. (2007) might be explained by the fact that the dams have been constructed only recently (25-45 years ago), so that the genetic drift may not have had enough time to erode ancestral genetic variation. Bearing in mind that the Djerdap I dam was completed in 1971 and Djerdap II dam in 1984, comparable trends of genetic similarity between sterlet populations above and below these dams might be expected. Research on the Danube sterlet populations (Reinartz et al., 2011) indicates the presence of such genetic similarity between populations. Data showed that the genetic differences were larger between individuals than between stocks/locations. Also, there is a tendency for a sub-structuring between the stocks in Slovakia, Serbia and Romania. Our unpublished data on the genetic structure of the Danube sterlet population shows similar trends as those presented by Reinartz et al. (2011), so we acknowledge their recommendation that recovery programs should preferably use specimens from the respective river sections (Upper Danube, Middle Danube, and Lower Danube). Nevertheless, our unpublished data for the Tisza sterlet population from the suggests that further research of sterlet populations from tributaries should be conducted, to improve understanding of the exchange of genetic material among populations.

Although the dam construction and formation of two reservoirs had a negative impact on economically important fish species such as sturgeon, this allowed at the same time good conditions for the non-native species to spread. A study on the fish communities of the Danube River in Djerdap resevoir during 1994, 1995 and 2000 revealed an increase in the abundance of short-snouted pipefish (*Syngnathus abaster*) in grassy littoral habitats (Simic and Simic, 2004), while many gobiids extended their distribution well beyond their native range (Black Sea and Danube Delta), due to a change in water velocity in impoundments (Lenhardt et al., in press).

3. Impact of fisheries on the ichthyofauna of the Danube River in Serbia

Fish catch in the Serbian part of the Danube River reflects complex anthropogenic effects on ichthyofauna as a result of several activities, such as over-exploitation and selective catch of particular fish species due to their higher price on market. A good example of such human activities is a decrease in the catch of anadromous sturgeon species – beluga (*Huso huso*), Russian sturgeon (*Acipenser gueldenstaedtii*) and stellate sturgeon (*Acipenser stellatus*), which was mainly induced by river modification, dam construction and over-exploitation due to their much-prized caviar. While Djerdap II dam stopped the migration of sturgeon on 863 river km and over-exploitation significantly reduced the numbers of sturgeon migrants, the introduction of alien species such as bighead carp (*Hypophthalmichthys nobilis*), silver carp (*Hypophthalmichthys molitrix*) and grass carp (*Ctenopharyngodon idella*) and regular spawning of silver carp in natural waters (Lenhardt et al., in press) showed the presence and significant increase of these species in fisherman catch (Fig. 2). Stellate sturgeon became rare in the catch after 1970, Russian sturgeon after 1996, while the catch of beluga decreased to such a level that Lower Danube countries imposed a total ban on sturgeon fishing since 2006. As populations of sturgeon species continuously declined, alien species such as Chinese carps started to become important objects for fisheries, starting from 1977. In this way, highly valuable sturgeon species were replaced in catch by alien species, which are also less valuable.

Furthermore, Cruccian carp species (*Carassius carassius*), an autochthonous species, has been recorded in the regular catch statistics only between 1954 and 1957, while Prussian carp (*Carassius gibelio*), a non-native species, started to appear regularly in catch since 1977 with the total amount varying between 2.9 t and 114.8 t.

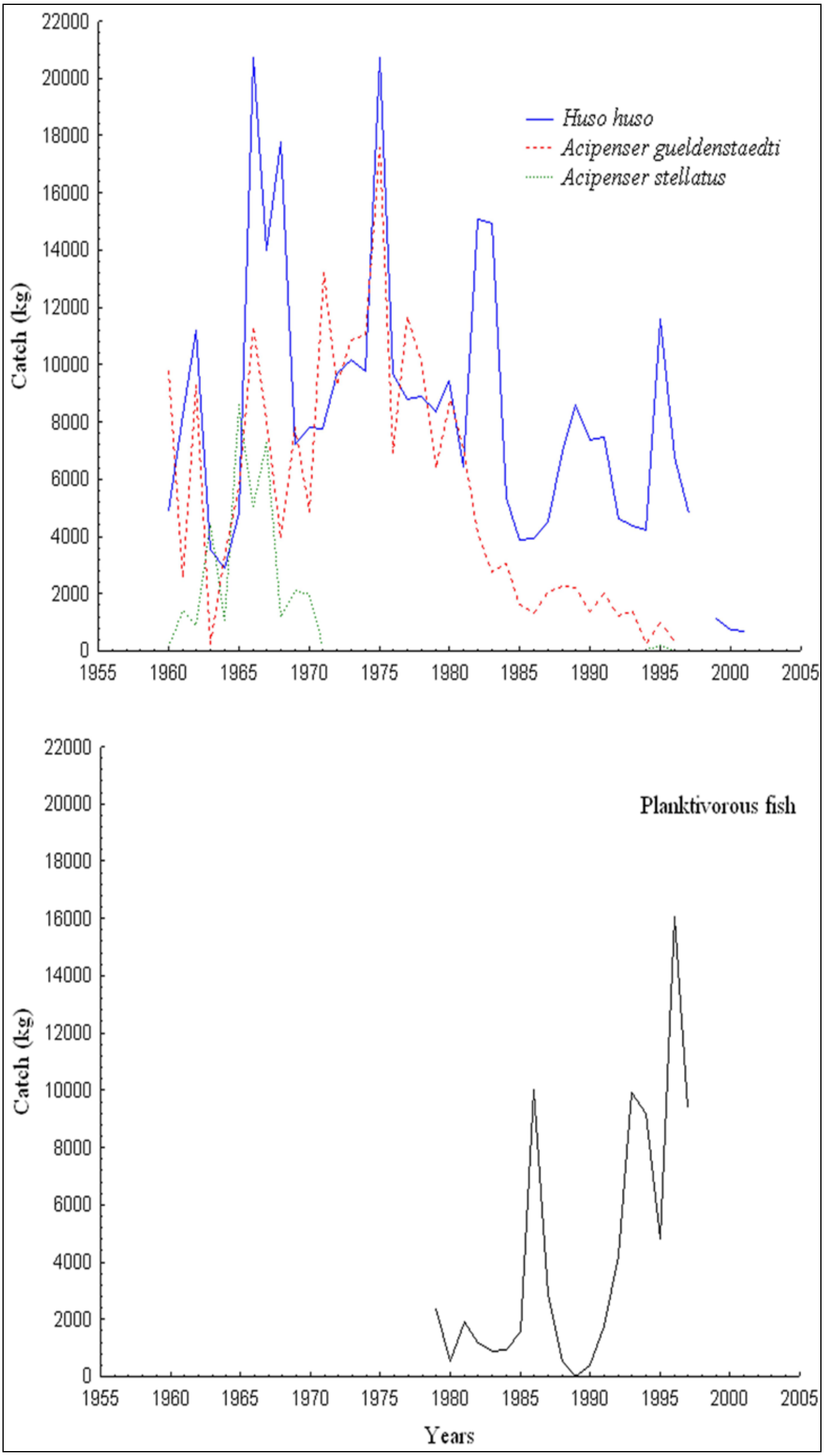

Figure 2: Decrease of the catch of sturgeons (*H. huso*, *A. gueldenstaedtii* and *A. stellatus*) and increase of the catch of allochthonous species (*C. idella*, *H. molitrix* and *H. nobilis*) in the Serbian part of the Danube River (Lower Danube Region).

4. Microbiological examination of river water

Microbiological examination of the river water is obligatory for use-related purposes such as drinking water production, irrigation and recreation. Quality of sediment, as a dynamic and integral component of aquatic ecosystems, has become of increasing interest for the river water quality evaluation. The Danube Basin is the second largest river basin in Europe. The basin extends over 17 countries. The total length of the river is 2,857 km. The Serbian reach of the Danube extends over a distance of 588 km that covers the middle and a part of the lower reaches, 220 km long waterway. The Danube flows through numerous industrial and urban centres and receives significant amount of urban and industrial wastes, leading to serious debasement of water quality. This typical low-land river flows through a region of intense agriculture (over 470.000 ha) whose effluents degrade water quality due to high concentrations of nitrogen and phosphorus. Thus, detailed knowledge on the extent and the origin of microbial faecal pollution is crucial for watershed management activities, in order to maintain water safe according to established quality targets (Farnleitner et al., 2001).

Following a long history of aquatic microbiology research (Kolarevic et al., 2010; Marinkovic et al., 2003; Stankovic et al., 1995; Stanojevic et al., 2006; Stankovic et al., 1997; Smidling et al., 2008; Zlatkovic et al., 2010), and genotoxicology (Stanojevic et al., 2008; Gacic et al., 2010; Lenhardt et al., 2010; Mimica-Dukic et al., 2010; Tomovic et al., 2010; Knezevic and Simic, 1982; Simic et al., 1985; Knezevic-Vukcevic et al., 1987; Simic et al., 1990; Simic et al., 1991; Sommer et al., 1993; Knezevic-Vukcevic and Simic, 1991; Simic, 1995; Nikolic et al., 1997; Simic et al., 2001; Nikolic et al. 2004; Nikolic et al., 2006; Vukovic-Gacic et al., 2006a; Vukovic-Gacic et al., 2006b; Mitic-Culafic et al., 2009), we have undertaken this study to evaluate the anthropogenic impact of wastewater originating from large urban settlements, such as Novi Sad, Belgrade, Pančevo, Smederevo and the present state of water quality of the Danube River in Serbia. The study includes analysis of sanitary correctness of water and sediments sampled from sites during spring and autumn 2010. Ecological aspects of microbiological analyses included monitoring of dynamics of bacterial populations during seasons, isolation of bacteria resistant to mercury and organic load assessment.

Since aquatic ecosystems are under high pressure from growing human populations accompanied by increased agricultural and industrial production, genotoxicity can be correlated with adverse reproductive effects, or may even result in an elevated extinction risk for particular species of the ecosystem. Molluscs, such as bivalves, are widely distributed sessile filter feeders that are good bioindicators of aquatic pollutants (Venier, 1997) and may be a valuable tool for the screening of pollution and potential environmental harm. These molluscs are able to accumulate pollutants and show different physiological (Bilos and Colombo, 1998; Johns and Luoma, 1990; Narbonne et al., 1999; Roberts, 1996), histological (Dowling and Mothersill, 2001) and molecular (Binelli et al., 2007; Bolognesi et al., 2004; Klobucar et al., 2008; Pavlica et al., 2001) responses. In the last decade, the comet assay has become one of the major tools for assessing pollution related to genotoxicity in aquatic organisms (Dixon et al., 2002). It is expected that benthic organisms are prone to environmental stress, which could cause genotoxic effects that are detectable with the comet assay.

Physical and chemical parameters were also assessed to give proper assessment of quality and prognosis of the situation. Only an integrated approach can provide a complete picture of the present state of the water ecosystems.

4.1. Study area

The samples for the analysis were collected during spring and autumn 2010 from six sites on the River Danube (Tab. 1). The water quality at these sites was assessed through routine monitoring by the Hydrometeorological Service of Republic of Serbia (Tab. 2). The Stari Slankamen site is located downstream the city of Novi Sad (300,000 inhabitants), and thus receives substantial amounts of urban wastewater. The Belegiš site was chosen as a proxy for the influence of the Danube tributary Tisza on water quality. Impact of the largest city in the region, Belgrade (1,600,000 inhabitants), was monitored at the downstream located at the site Višnjica.

The Vinča and the Orešac sites experience the greatest impact as they have refinery and industrial wastewater from factories upstream of the town of Pančevo (80,000 inhabitants), as well as urban wastewater from the town itself. The Kostolac site receives effluents from the domestic sewage of the town of Smederevo (80,000 inhabitants). This site is also affected by polluted water from the Danube tributary Velika Morava and the thermal power plant "Kostolac" which is also upstream of the site. The coordinates of the sampling sites were measured by GPS ("Garmin Etrex") and mapped by ArcView software (map 1:300,000, system WGS_1984)

Table 1: Sampling sites along the Danube River.

River	Locality	Latitude	Longitude	Elevation (m)
Danube	Stari Slankamen	45°9.056'	20°14.837'	91.4
	Belegiš	45°1.812'	20°21.370'	88.3
	Višnjica	44°50.381'	20°33.520'	79
	Vinča	44°46.146'	20°37.159'	77.2
	Orešac	44°39.305'	20°49.449'	72.1
	Kostolac	44°44.138'	21°9.425'	69.6

Table 2: Water quality data of the selected polluted sites (S – spring, A – autumn).

Site	Slankamen		Belegiš		Višnjica		Vinča		Orešac		Kostolac	
season	S	A	S	A	S	A	S	A	S	A	S	A
t (C°)	12.1	15.9	12.5	17	12	17.8	12.2	18	12.4	17.9	12.5	18.3
Conductivity (µS/cm)	438	-	437	-	356	-	368	-	378	-	400	-
Oxygen mg/l	11.9	7.54	12.4	7.91	9.86	6.4	10.4	7.2	9.9	6.99	10.3	6.8
Oxygen (%)	110	76.2	111	81.6	88.4	67.3	96.4	75.6	92.5	73.4	95.7	71.4
pH	8.7	8	8.8	7.8	8.19	7.8	8.1	7.8	8	8	8.17	7.8
NH_4^+ (mg/l)	0.06	0.06	0.05	0.04	0.21	0.19	0.02	0.11	0.02	0.06	0.03	0.12
NO_3^- (mg/l)	1.8	2.7	3.8	1.3	1.6	3.1	7.6	8.7	5.5	2.2	3.2	1
PO_4^- (mg/l)	1.4	1	0.7	4.5	0.8	1.8	1.1	32.2	1.3	3.2	7.6	9.5

4.2. Water quality assessment – Microbiological analyses

All samples were processed in the laboratory within 12 hours of sampling and 16 parameters were analysed in total. Microbiological indicators of sanitary correctness and indicators for organic contamination assessment were analysed using standard procedures according to the Water Law ("Official Gazzete of the Republic of Serbia" number 46/91, 53/93. 67/93. 48/94. 54/96) and EU – Bathing Water Quality Directive (2006/7/EEC). For the assessment of the recent faecal pollution and the potential presence of pathogenic bacteria, total coliforms, faecal coliforms and intestinal enterococci were monitored by the use of membrane filtration method. Faecal indicator bacteria, like total coliforms, faecal coliforms (thermotolerant coliforms), *E. coli* and intestinal enterococci (faecal streptococci) are excreted by humans and warm-blooded animals. They are able to pass through sewage treatment plants and survive for a certain time in the aquatic environment (Kavka and Poetsch, 2002).

Faecal coliforms to *Enterococci* ratio was used to indicate origin of the registered pollution. Ratio lower than 1.5 should indicate pollution by waterfowl, while ratios higher than 4 should be typical for anthropogenic pollution (Geldreich and Kenner, 1969). Identification of isolated coliform bacteria was performed using API 20e identification kit (bioMerieux). Presence of potential pathogen species was observed by the cultivation on meat peptone agar (MPA). To fulfil sanitary analyses, presence of *Proteus* sp., sulphite-reducting clostridia, *Pseudomonas aeruginosa* and *Bacillus* sp. was also determined.

To provide information about water overloading with organic compounds, the presence of the main physiological groups of bacteria (heterotrophic, oligotrophic) and phosphatase activity index (Matavulj et al., 1990) were monitored.

We also studied physical and chemical characteristics: temperature, pH, turbidity, specific conductivity, dissolved oxygen, oxygen saturation, NH_4^+ (mg/l), NO_3^- (mg/l) and PO_4^- (mg/l) (Tab. 2).

Microbiological analyses of sediment included quantification of coliform bacteria (membrane filtration), identification of isolated coliforms (API 20e), isolation of bacteria resistant to mercury, and monitoring for the presence of potential pathogens.

The sanitary analyses indicated a moderate to critical faecal contamination at the majority of the sampling sites. Faecal coliform numbers ranged from 2.5 x 10^3 to 5.4 x 10^4 CFU/100 ml. Strong faecal pollution (> 10,000 cfu/100 ml) was observed at the locality Slankamen during spring and at the locality Višnjica during autumn. Critical to strong faecal pollution was found at the majority of sites (in accordance with the 2006/7/EEC criteria). At all sampling locations, the number of faecal coliforms was more than four times higher than the number of Enterococci, indicating a big impact from communal wastewater pollution (Geldreich and Kenner, 1969) (Fig. 3).

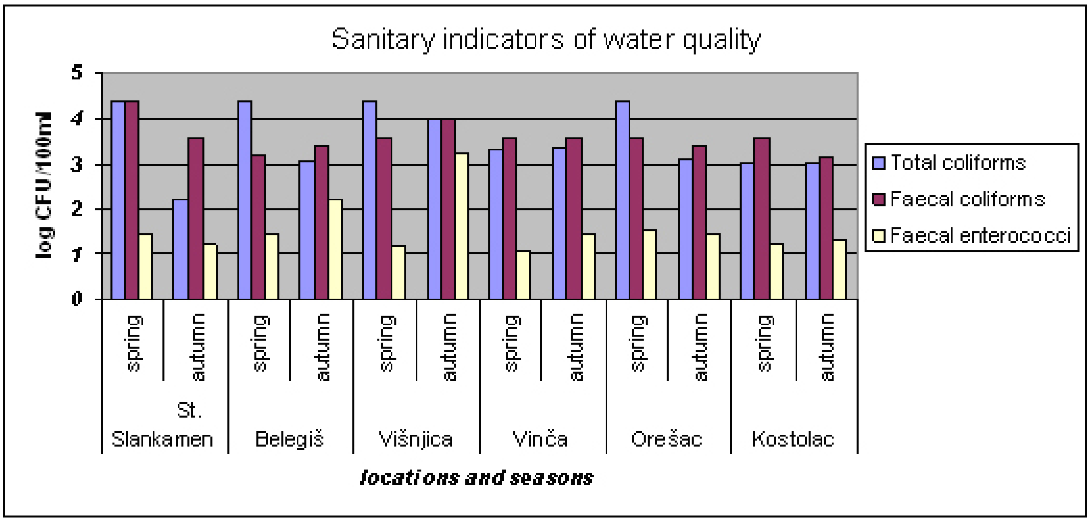

Figure 3: Sanitary indicators of water quality of samples taken from the River Danube during spring and autumn, results are shown as log CFU/100 ml.

Mercury resistant bacteria were detected in all water samples with high CFU/ml number on locations positioned downstream from Belgrade (Fig. 4). Presence of mercury resistant bacteria should indicate potential pollution of these localities with mercury. The origin of this pollution can be mainly attributed to the oil refinery of Pančevo, or to the activity of thermal power plant "Kostolac".

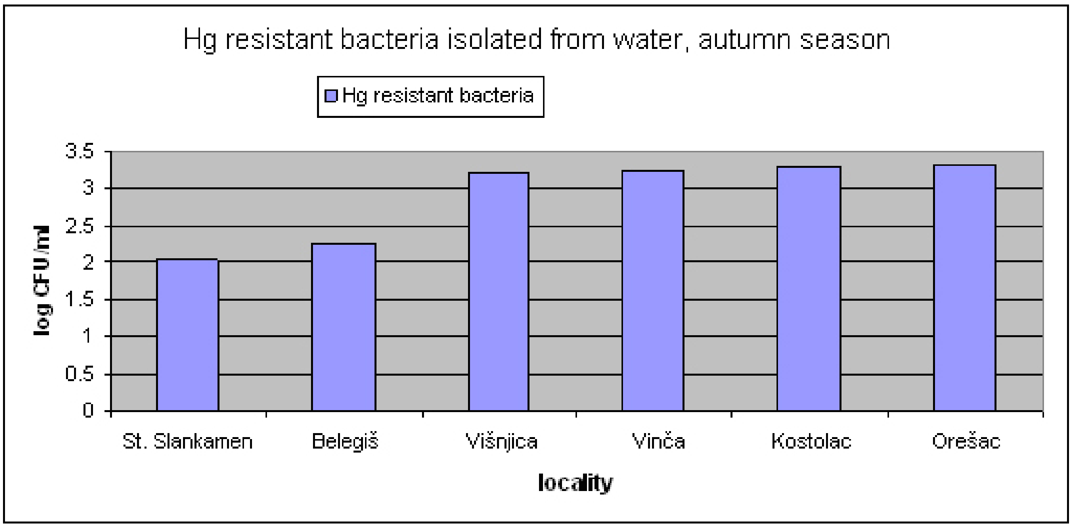

Figure 4: Number of mercury resistant bacteria isolated from water samples taken during autumn from the River Danube, results are shown as log CFU/ml.

An index of phosphatase activity was applied to evaluate organic pollution of water of the Danube River. Analyses of the results indicated a light (class IIB) and moderate (class III) pollution at the majority of the sampling sites (Fig. 5).

Organic load assessment was also performed by using the ratio of oligotrophs to heterotrophs ratio. Domination of oligotrophs in nearly all water samples indicated a satisfactory level of self-purification by the river (Fig. 6).

Microbiological parameters of sanitary correctness of sediment varied among sampling locations. Total coliform numbers ranged from 10^2 to 5 x 10^5 CFU per gram of sediment. The highest pollution levels were recorded at the location Vinča during autumn. Mercury resistant bacteria were isolated from all sediment samples with the exception of the Slankamen locality (Fig. 7).

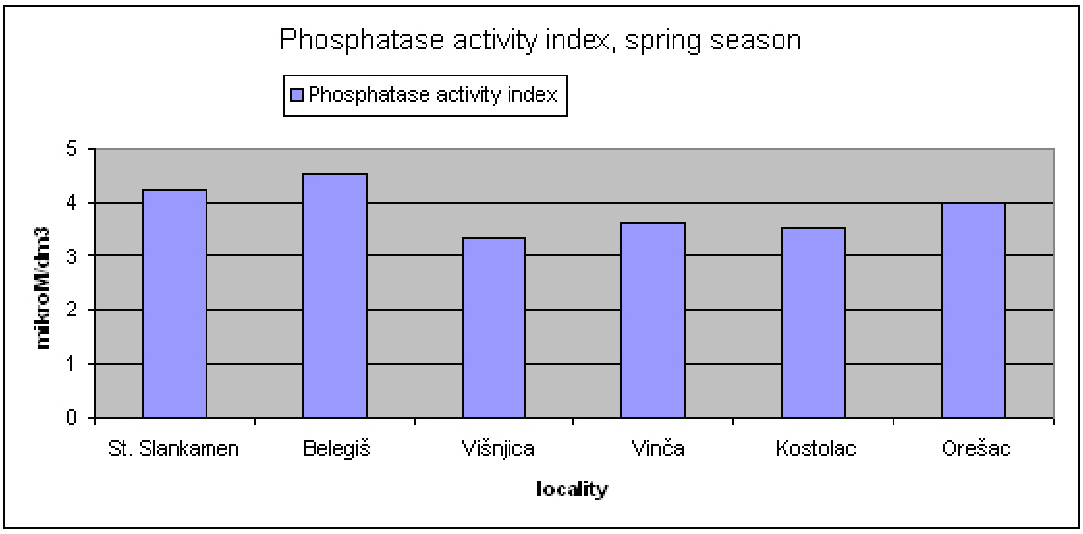

Figure 5: Results of biochemical analyses of water samples taken from the River Danube during spring, results are shown as µmol/dm^3.

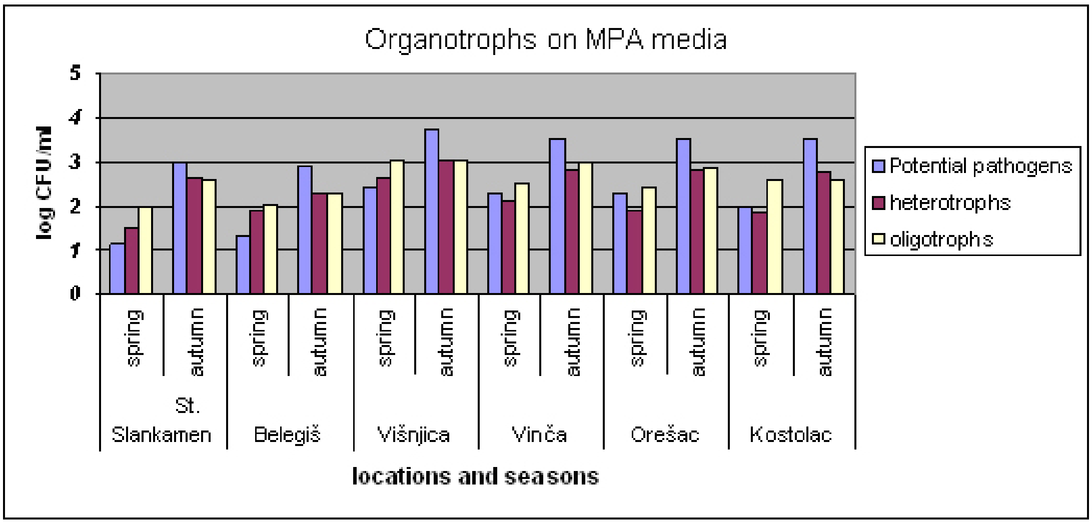

Figure 6: Number of organotrophic bacteria isolated from water samples from the River Danube during spring and autumn, results are shown as log CFU/ml.

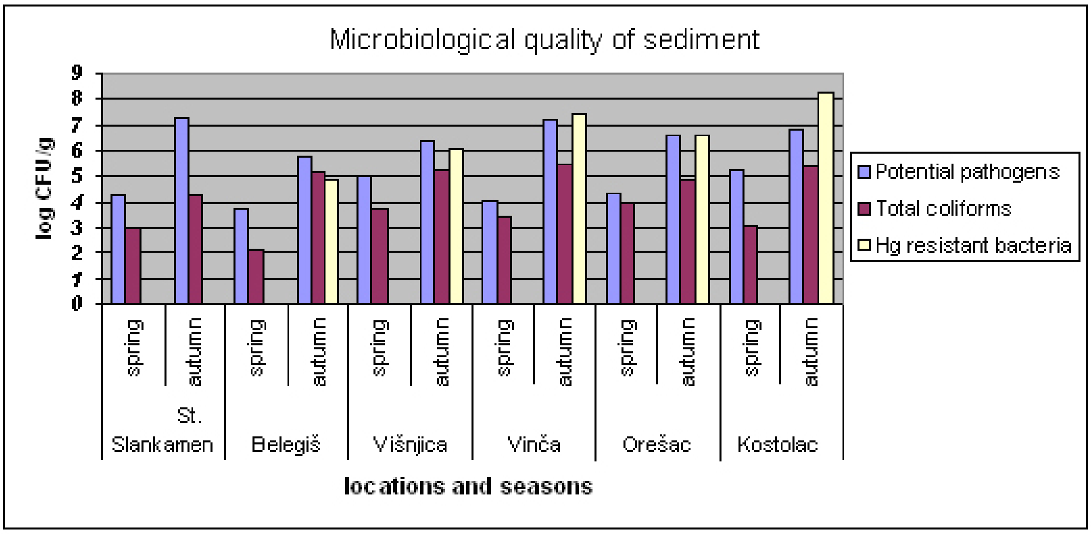

Figure 7: Microbiological parameters of sediment samples taken from the Danube River during spring and autumn; results are shown as log CFU/g.

4.3. Water quality assessment – Genotoxicity analyses

Earlier studies (Woznicki et al., 2004) revealed the potential of the mussel *Anodonta* (*Sinanodonta*) *woodiana* (Rea, 1834) to detect the genotoxicity of certain agents, such as polycyclic aromatic hydrocarbonates, a useful study species for studies on aquatic toxicology and monitoring. In this paper, genotoxic contamination was evaluated by comet assay on haemocytes of *S. woodiana* collected from selected polluted sites in the Danube River. Mussels held in proper controlled laboratory conditions were used as a reference group.

Specimens of *S. woodiana* that were used for the test had a shell length within a 7-15 cm range, and were collected by an FBA hand net (Kick and Sweep technique), benthological dredge and diving. DNA damage was assessed in haemocytes by the comet assay. The procedure involved testing the individuals immediately after sampling (within four hours), in order to measure the comet response to environmental stress.

Haemolymph for the comet test was collected in the dark from the posterior adductor muscle sinus of each freshwater mussel using a hypodermic syringe, and transferred to 1.5 mL microtubes. The samples were centrifuged for 10 min at 1,000 rpm and subjected to standard alkaline comet assay procedure. Haemocyte viability was determined by the 0.4% Trypan blue dye; cells stained blue were considered as non-viable. The applied alkaline comet assay procedure was basically the same as was described by Singh et al. (1988). Statistical analyses were performed by the Mann-Whitney U-test, using Statistica 6.0 Software (StatSoft, Inc.).

In comparison with the control group, tail moment values in mussels taken from polluted locations indicated a significant difference ($p < 0.05$) in the DNA migration.

Also, there was a difference in the response of mussels sampled from different locations to environmental stress. In the group of mussels taken from the Višnjica site, significantly higher migration of DNA was observed in comparison with the Kostolac ($p = 0.029175$) and the Slankamen site ($p = 0.04731$) (Fig. 8).

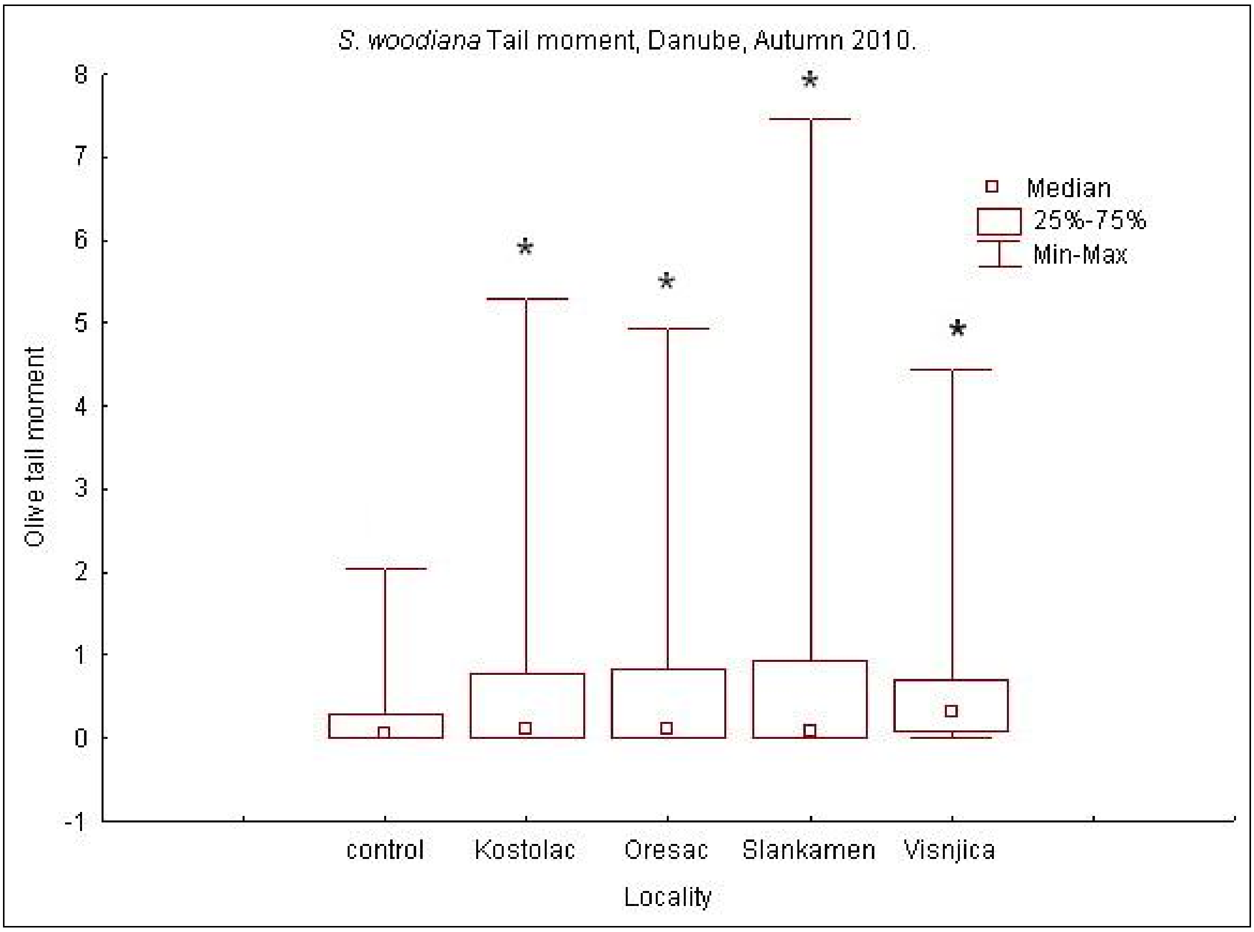

Figure 8: Nuclear DNA damage in hemocytes of *S. woodiana* (expressed as the tail moment) upon sampling from the River Danube, results of 100 comets per group are shown indicating significant difference ($p < 0.05$) between group of mussels tested directly upon sampling and control groups (*).

A significant level of DNA damage, detected in mussels collected from the Slankamen site, can be linked to the pollution caused by agricultural activities (artificial fertilization of the soil) which increased in this period/which typically increase at this time of year. DNA damage detected in mussels sampled at the Kostolac site can be attributed to the power plant “Kostolac”. The Orešac site can be linked to pollution caused by oil refinery of the town Pančevo through the Danube tributary Tamiš/Timiș. Genotoxic potential detected at the site Višnjica could originate from wastewaters and industry of the upstream located city of Belgrade. Due to high volumetric emission rates and therefore high loading values, municipal wastewater can have a noteworthy genotoxic potential, and there is a strong relationship between the surface water genotoxicity and pollution (White and Rasmussen, 1998). Well known genotoxic agents that can be found in the wastewater, such as N-nitroso compounds and PAHs (Hoffman et al., 1984; White and Rasmussen, 1998), may lead to genotoxic effects at polluted sites. DNA damage, evaluated using the tail moment values, indicated a presence of genotoxic agents on sampling locations. However, when working with living organisms, it should be taken into consideration that there is a natural inter-individual genetic variation (Mitchelmore and Chipman, 1998; Nacci et al., 1996).

CONCLUSIONS

The obtained results indicate that the detected sanitary pollution can be mainly attributed to a great amount of raw or improperly treated urban wastewaters, while the increased agricultural activity in this area has probably contributed to detected organic pollution. Faecal parameters indicated a strong pollution at some locations, which was however not supported by chemical analyses. Nevertheless, it is well-known that bacteriological parameters can be detected in critical concentrations even when biological and chemical water quality are considered acceptable (Baumann and Popp, 1991).

The results presented in this study of the microbiological, genotoxic and ichthyological research of the Danube River in Serbia indicate the presence of substantial anthropogenic impact. One of the major problems is probably a low level of wastewater treatment. Hydromorphological changes had a significant impact on the fish community composition. Together with the over-exploitation of fish stocks and the introduction of alochtonous fish species, they have led to a degradation of the Danube fish stocks. Improvement of the management of protected areas along the Danube river as it runs through Serbia, and the improvement of wastewater treatment should be considered as future priorities.

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SUPPORT ELEMENTS FOR *COBITIS TAENIA* LINNAEUS, 1758 MANAGEMENT DECISIONS SYSTEM FOR ROSCI0132 (TRANSYLVANIA, ROMANIA)

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KEYWORDS: *Cobitis taenia*, European protected area, habitat necessities of fish species, pressures, threats, management elements.

ABSTRACT

In this particular analysis, the ADONIS:CE appliance was used in the environment protection sphere to shape a specific layout management model for *Cobitis taenia* fish species based on the species' protection interest registered necessities in regard to habitats, the marks which expose the correct conservation status with the relevant measures, and the registered pressures and threats on this fish species.

If the advocated management elements will not be valued in the ROSCI0132 area, the *Cobitis taenia* fish species' preservation status can decline within the next few years.

These sorts of applications on habitats, species, and on site based management support systems for other fish species of European importance should also be realised for the ROSCI0132 protected area.

REZUMAT: Elemente suport pentru un sistem de luare a deciziilor de management pentru *Cobitis taenia* Linnaeus, 1758 în ROSCI0132 (Transilvania, România).

În această analiză specifică, instrumentul ADONIS:CE a fost folosit pentru realizarea unui model de management pentru specia de pește *Cobitis taenia*. Au fost analizate necesităţile de habitat, indicatorii care sesizează statutul de conservare favorabil și măsurile de management relevante, presiunile și ameninţările asupra acestei specii de pește.

Dacă elementele de management recomandate nu vor fi implementate în aria ROSCI0132, statutul de conservare al speciei de pește *Cobitis taenia* poate scădea în următorii ani.

Modelul de management obținut pentru specia *Cobitis taenia*, aplicat habitatului, speciei și sitului trebuie integrat cu modelele de management pentru celelalte specii de pești de importanță conservativă din aria protejată ROSCI0132.

ZUSAMMENFASSUNG: Grundlagenelemente eines Systems von Management-Entscheidungen für *Cobitis taenia* Linnaeus 1758 im Natura 2000-Gebiet ROSCI0132 (Transsilvanien, Rumänien).

In der vorliegenden spezifischen Analyse wird das Instrument ADONIS:CE im Umweltbereich zur Erstellung eines Managementmodells für die Fischart *Cobitis taenia* angewandt. Dabei wurden die Lebesraumerfordernisse, die Indikatoren, die den guten Erhaltungszustand belegen und die relevanten Managementmaßnahmen sowie die belastenden Einwirkungen und Bedrohungen auf diese Fischart analysiert.

Sollten die empfohlenen Managementelemente im Natura 2000 Gebiet ROSCI0132 nicht angenommen werden, könnte der Erhaltungszustand von *Cobitis taenia* sich in den nächsten Jahren verschlechtern.

Diese Kategorie von Unterstützungssystemen, die für das Management des Habitats, die Art und das Natura 2000 Gebiet eingesetzt werden, muss innerhalb des Schutzgebietes ROSCI0132, auch für andere Fischarten, die auf europäischer Ebene naturscshutzfachlich von Bedeutung sind, entwickelt werden.

INTRODUCTION

To guarantee that the imperilled species of Europe outlast, the EU members state harmony upon the Habitats Directive in 1992, in conformity with the fact that their countries must achieve the required situation for the conservation of the species and habitats belonging to the Habitats Directive (Annex 2,) in order to conserve and ameliorate their ecological status (*, 1992). New countries make significant efforts to join EU and benefit of Natura 2000 network advantages (Milanović et al., 2015).

In Romania, the Natura 2000 sites were proposed for conservative interests, including fish species' protection. They were proposed for their appropriateness in relation with the species' conservative value. The proposal of these European Natura 2000 net areas was realised based on a couple of main specific criteria: proper geographical positions, well preserved fish populations, low human impact, and representative habitats. There are some emblematic elements based on which the Natura 2000 initiative can heighten the European Union member states' nature preservation: the protected natural areas being spread out; institution capacity building; practical and operational management applications for precious areas from a conservative point of view; improve the peoples' knowledge. (Bănăduc, 2007; Bănăduc et al., 2012; Curtean-Bănăduc and Bănăduc, 2001; Papp and Toth, 2007).

One of the fish species of European conservative interest is *Cobitis taenia* Linnaeus, 1758. This species is terra typical to Sweden. It lives in slow-moving water and in stagnant water, with sand or clay as substrata, and is rarely found on stony substrata. Frequently it stays in the sandy substratum. It can partially use the intestinal respiration as an alternative to the low water oxygen content. During the night time it mostly ingests worms, algae and insect larvae. The breeding is from April – June. The roes are sticky (Bănărescu, 1964; Bănărescu and Bănăduc, 2007).

In the Romanian national territory, the distribution of *Cobitis taenia* includes the following river basins: Tur, Someș, Crasna, Crișul Repede, Crișul Negru, Crișul Alb, Mureș, Arieș, Târnava, Bega, Timiş, Caraş, Cerna, Jiu, Olt, Gilort, Hârtibaci, Olteţ, Vedea, Argeș, Dâmboviţa, Colentina, Neajlov, Ialomiţa, Călmăţui, Siret, Prut, Moldova, Bistriţa moldovenească, Milcov, Bârlad, Buzău, etc. It was fragmented in the last century due to the fact that the human activity induced local and regional impact; impacts which are many and various from one basin to another, and more than that from one protected area to another (Bănăduc, unpublished data).

The structure of the fish fauna, where *Cobitis taenia* species was ascertain, in ROSCI0132 (Oltul Mijlociu-Cibin-Hârtibaciu Natura 2000 Site,) calls attention to low individual numbers as a result of the human activity impact. The fragmentation on the range of this fish species population and their low abundance demostrates the effects of the Olt River basin habitat's decreasing quality (Bănăduc, 1999, 2000, Curtean-Bănăduc et al., 2007; Curtean-Bănăduc and Bănăduc 2001, 2004; Curtean et al., 1999).

In the present-day global turn in which the rivers change in more priceless natural capital, the human pressure on it will decrease the humans use of it (Curtean-Bănăduc and Bănăduc, 2012).

If this trend will continue, any standard management plan will not be sufficient in non-identical protected natural areas, in fact many and various habitat elements should be analysed first. Secondly, the applied management elements have to adjust and recommend the local habitats/species distinctive circumstances.

The modeling process elements are more adaptable to obtain an "extensive vision", of systems and actions of diverse domains. All these elements are required to distinguish the process phases for proper management. The modeling tools are composed by software products used to make models of business organizations, and to achieve data about these models. There are three pivotal functions: to validate the actual state, survey the results of possible alterations, and suggest plans to change the condition in a more desirable way. In the end, there are different suggested alternatives to generate diagrams which include elements of particular management (Hall and Harmon, 2005).

The main purposes of this study are: to reveal the present state of the populations of *Cobitis taenia* in ROSCI0132; to demonstrate the present human pressures and threats; and to counsel through management proposals for ameliorating the fish species' conservation status based on a specifically created model of management – which incorporates habitat demands of the fish species and habitat indicators as a management decisional system.

MATERIAL AND METHODS

ROSCI0132 is located in the Sibiu, Vâlcea and Braşov counties (2826.10 ha surface, 45.682778 latitude, 24.324444 longitude, 314 and 568 a.s.l. m). This Natura 2000 site is situated in the Alpine and Continental European biogeographic regions. This site was designated also for ten species of fish of community interest-species listed in the Annex 2 of the Habitats Directive (92/43/EEC), (*Cobitis taenia* Linnaeus 1758 – Natura 2000 code 1149, *Barbus meridionalis*, *Pelecus cultratus*, *Zingel zingel*, *Zingel streber*, *Romanogobio kesslerii*, *Sabanejewia aurata*, *Rhodeus amarus*, *Aspius aspius* and *Romanogobio uranoscopus*). (*, 1992)

The river zones of the studied area where *Cobitis taenia* species was sampled are presented in figure 1.

The *Cobitis taenia* individuals were sampled in the period 2010-2013, with active fishing nets, then determined and released on the sampling site/zone.

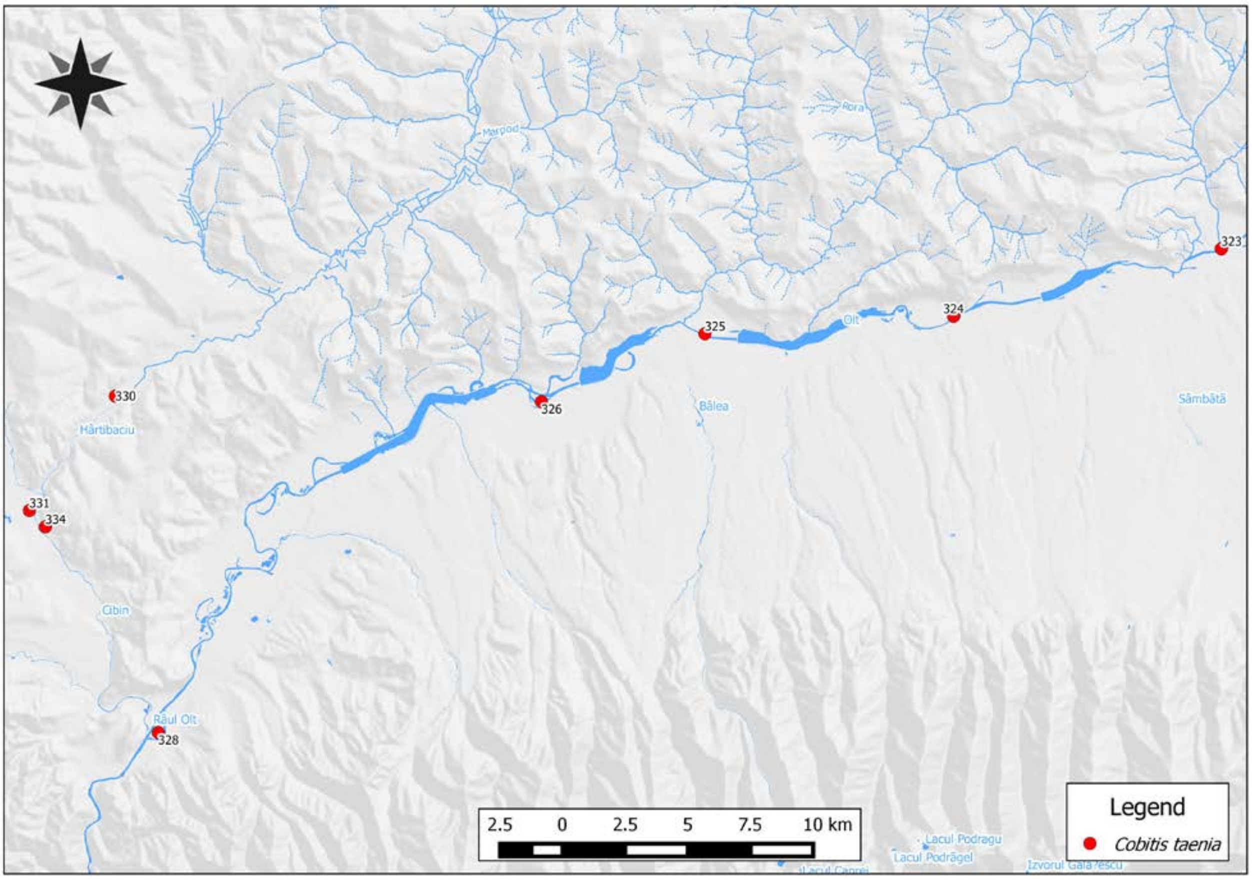

Figure 1: *Cobitis taenia* individuals sampling stations
334 in the Cibin River; 330 and 331 in the Hârtibaciu River;
323, 324, 325, 326 and 328 in the Olt River – GIS map Mr. Pătrulescu A.

The *Cobitis taenia* species was assessed in this study region and its ecological status was evaluated in the circumstances of the confirmed human impact threats and pressures, as well as on the fish population and the habitat's specificity.

The fish population and conservation status was estimated based on the following successive criteria: balanced distribution of the fish individuals on age classes, surface range, population sizes and a high or low number of fish in the fish communities.

The *Cobitis taenia* species habitat needs, pressures, and threats were analysed based on their presence and/or absence, and the reliance between them and the fish status of conservation.

To establish the right management elements expected to be used to guarantee species protection in the area of interest and to bring out the needed process, an adapted model of management was used. Therefore, ADONIS:CE was applied, produced by Business Object Consulting. ADONIS: Community Edition, a free of charge instrument supplied by the BOC Group, which can be brought into effective action as a point of entrance to Business Process Management. This is a proper way to become informed with ADONIS. ADONIS:CE which is a rich, stand-alone version of ADONIS with some certain limitations (if we have to compare it with the commercial edition). Business Process Model and Notation (BPMN) is a standardized modeling language which is useful in order to visualise the specific processes. The processes can be modeled based on uniform notation (**).

RESULTS AND DISCUSSION

Cobitis taenia populations ecological state evaluation

The conservation status of *Cobitis taenia* in the **Olt** River sampling sectors 323, 324, 325, 326 and 328 (Fig. 1) can be accepted as low in the context of: population sizes, balanced distribution of fish individuals on age classes, and a medium percentage of fish individuals of this species in the local ichthyofauna structure. The habitats of the studied fish communities are in a medium conservation state, in respect of *Cobitis taenia* ecological needs.

The preservation status of *Cobitis taenia* in the **Cibin** River sampling sectors 334 (Fig. 1) can be considered as low. The habitats are in a medium conservation state, in respect of *Cobitis taenia* ecological needs.

The conservation status of *Cobitis taenia* fish species in the **Hârtibaciu** River sampling sectors 330 and 331 (Fig. 1) can be considered as low. The habitats are in a medium conservation state, in respect of *Cobitis taenia*'s ecological necessities.

Human pressures and threats

In this study context, the next threats and pressures on *Cobitis taenia* fish species individuals were identified: pressures – water pollution; threats – water pollution, adjacent field erosion and over silting with mud of the riverbed as a result of the bad agricultural practices and the deterioration of the riverine vegetation which negatively influences this species from the perspective of the quantitative and qualitative trophic resources (benthic macroinvertebrates) and of the covering of the good substrata for reproduction; the bad influence of the numerous illegal waste dumps which eliminate different toxic substances.

As long as the sectors that shelter proper conditions are declining due to diverse human impacts, all of these such river sectors which, up to this time, provide a fairly good habitat turn out to be essential for this fish species outlive; and the specific beneficial habitats losses for the species which cause the manifestation of the overcrowding and after that the lowering of the individuals and the favour of infections, parasites, illnesses and chalanger fish species.

Specific requirements

Generally, the adults need river sectors with relatively low water speed, with a substrate formed of sand, mud, clay and rarely stone. In the reproduction period, the individuals of this species need pebbles and/or aquatic vegetation as support for their rows. The adults and juveniles are sensitive to pollution. (Bănărescu and Bănăduc, 2007)

Specific habitat indicators

Based on *Cobitis taenia*'s presence and abundance in the researched areas, the following habitat indicators were suggested: water surface percentages with relatively low speed (66%), sandy substratum surface percentages (35%), mud substratum surface percentages (35%), pebbles substratum surface (20%), aquatic vegetation and debris percentages (10%).

Management measures

The riverbeds' natural morphodynamics should be maintained where it was not already disturbed.

Preserving corridors of natural vegetation (arboreal, shrubs, and herbal) with a minimum width of 50 m (Cibin and Hârtibaciu rivers) and 100 m (Olt River) on both banks is necessary for their function as sediment traps.

The abandonment of any type of wastes of any kind in riverbeds and wetlands adjacent to watercourses should be prohibited.

A permanent seasonal monitoring system which could include the fish fauna and organic pollution elements should be implemented.

Site adjusted management model

This management model of the *Cobitis taenia* species wants to highlight its features, as well as take management measures in order to ensure a favourable conservation status.

The used modelling tool is ADONIS: CE (Hall and Harmond, 2005). With the help of this software modeling objects, we get visual interface of this species, as well as a better understanding of the process itself and management measures.

This specific on-site management model process is based on different activities, decisions, subprocesses, variables and generators.

The main objects used to realise the *Cobitis taenia* management model ROSCI0132 with ADONIS:CE are proposed below (Hall and Harmon, 2005).

As you can see in the following figure (Fig. 2), the main process is *Cobitis taenia* and has one subprocess: *Indicators for Cobitis taenia*. In turn, the subprocess *Indicators for Cobitis taenia* has two subprocesses: *Management measures for 1st to 4th indicator* and *Management measures for 5th indicator*.

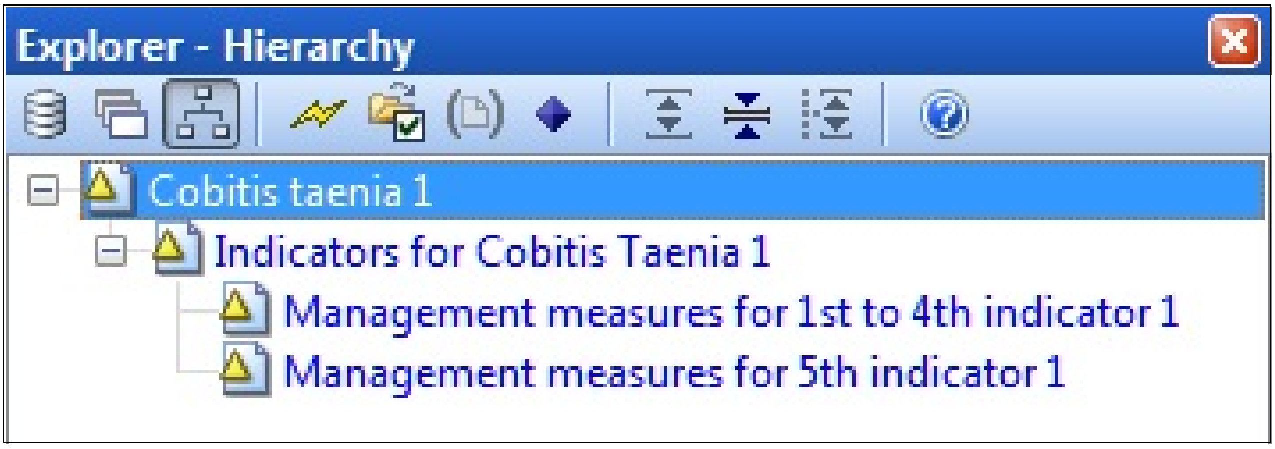

Figure 2: Table of content
for modelled processes.

The main process (= set of activities, decisions to be followed in order) is called *Cobitis taenia* (Fig. 3) and represents the ecological requirements of the species fact sheet, as well as conditions that ensure favourable conservation status. The model works as follows: the first activity (= presents the steps of a process and various fields such as description, comments, responsible persons, and can also be attached via supporting documents to certain activity) describes specific requirements of the species, then is checked using subprocess *Indicators for Cobitis taenia* (= allows sub-structuring activities that repeat for easy browsing through the basic process) If possible, indicators ensure favourable conservation status. If the state of preservation is provided (decision : **"The preservation state is favorable?", "Preservation_state = ''Yes", Probability = 99%**), follows the activity, **Field observations** and the process ends. If the state of preservation is not assured, (decision : **"The preservation state is favorable?", „Preservation_state = ''No", Probability = 1%**), then, with the help of several activities factors, this may lead to endangering the species and are described (**Other environmental requirements, Reproduction, Distribution in the protected area, Current pressures on species, Threats**) and then reach the final activity **Field observations** and the process is completed.

As mentioned above, the second process modeled is subprocess *Indicators for Cobitis taenia* (Fig. 4) – called from basic *Cobitis taenia* model process, having the same characteristics as a process – in which it is checked if possible indicators (measured on the ground) ensure favourable conservation status of the species.

The subprocess is modelled using five decisions, two subprocesses and one final activity, **Implementation of a seasonal integrated monitoring system**. In our case we have five indicators modeled as decisions (= if there are certain parameters or certain forms of verification) that checks if the percentage earned on the ground is the one who ensures the preservation of the species. For each decision, we separately assigned a variable () and a generator (). Variable names represent the name of the indicator, and using a generator we assigned our percentage for an indicator that ensures the favourable conservation status. As a result of the decision, if it goes on the 'Yes' branch (eg.: **"The current state of sandy substrate weight is 33%?, Sandy_substrate = "Yes" or "The actual state of underwater vegetation and submerged vegetation debris weight is 10%?", Underwater_debris_vegetation = "Yes"**), then proceed to the next decision/indicator. If the percentage does not fit into the standards of conservation (eg.: **"The current state of sandy substrate weight is 33%?", Sandy_substrate = "No", or "The actual state of underwater vegetation and submerged vegetation debris weight is 10%?", Underwater_debris_vegetation = "No"**), using other subprocesses are presented and the management measures are to be taken to ensure the well-being/welfare of the species. For the first four indicators, the same management measures (subprocess *Management measures for 1st to 4th indicator*, figure 5), and for the last indicator only two of the three measures of management (subprocess *Management measures for 5th indicator*, figure 6). Subprocess *Indicators for Cobitis taenia* finishes with activity **Implementing a seasonal integrated monitoring system**.

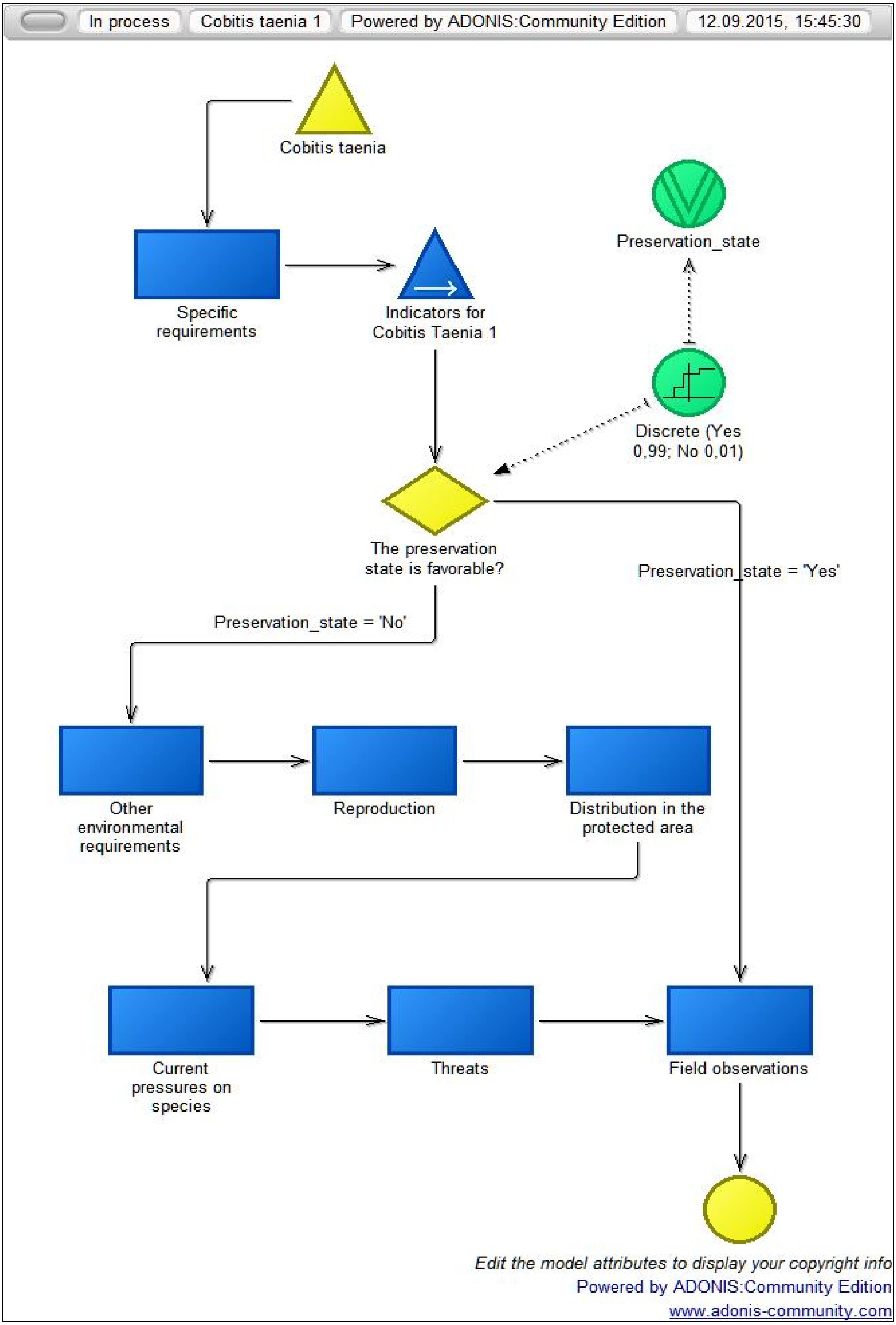

Figure 3: *Cobitis taenia* – main process.

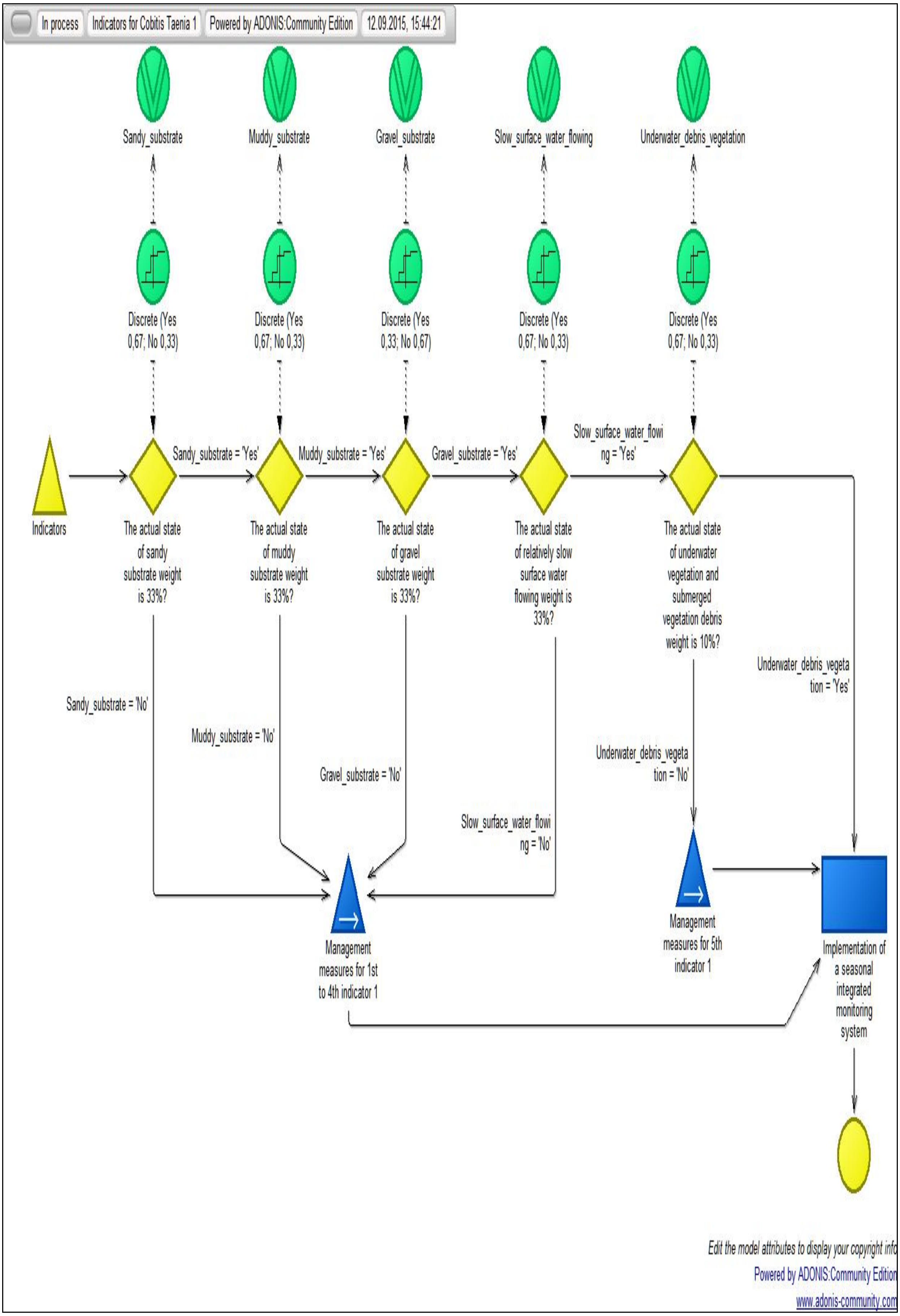

Figure 4: Indicators for
Cobitis taenia species.

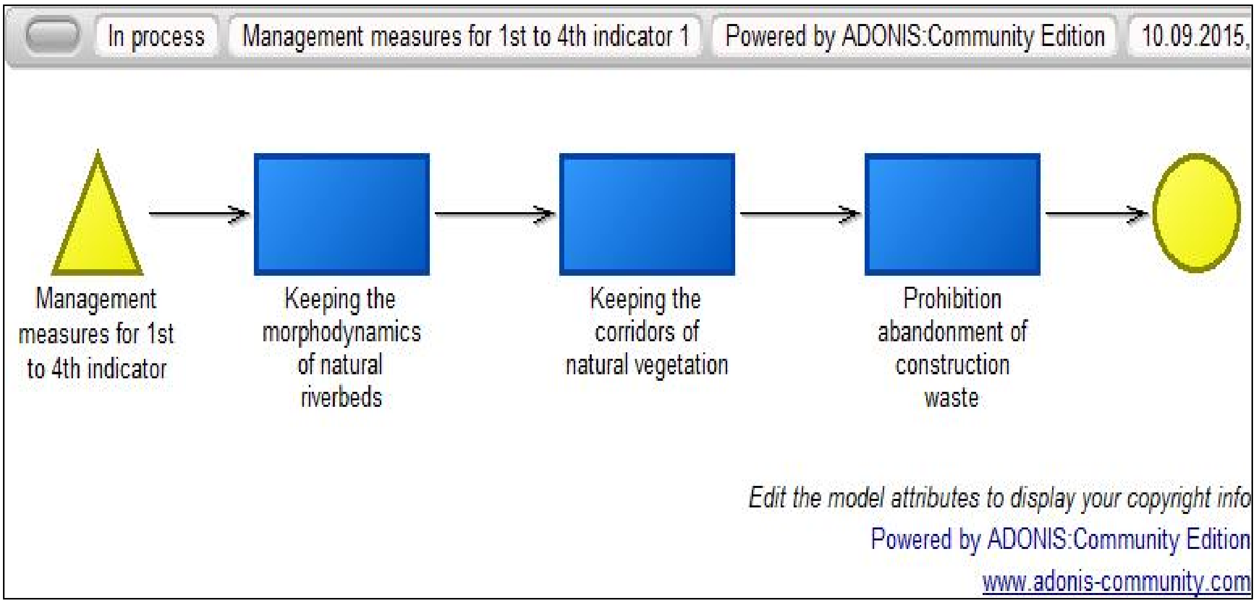

Figure 5: Management measures for 1st to 4th indicator for *Cobitis taenia*.

Management measures for the first four indicators are restrained in a subprocess named *Management measures for 1st to 4th indicator* (Fig. 5) and shows three activities: **Keeping the morphodynamics of natural riverbeds, Keeping the corridors of natural vegetation and Prohibition abandonment of construction waste**. For the fifth indicator we have subprocess *Management measures for 5th indicator* (Fig. 6) containing the following activities: **Keeping the morphodynamics of natural riverbeds and Prohibition abandonment of construction waste**.

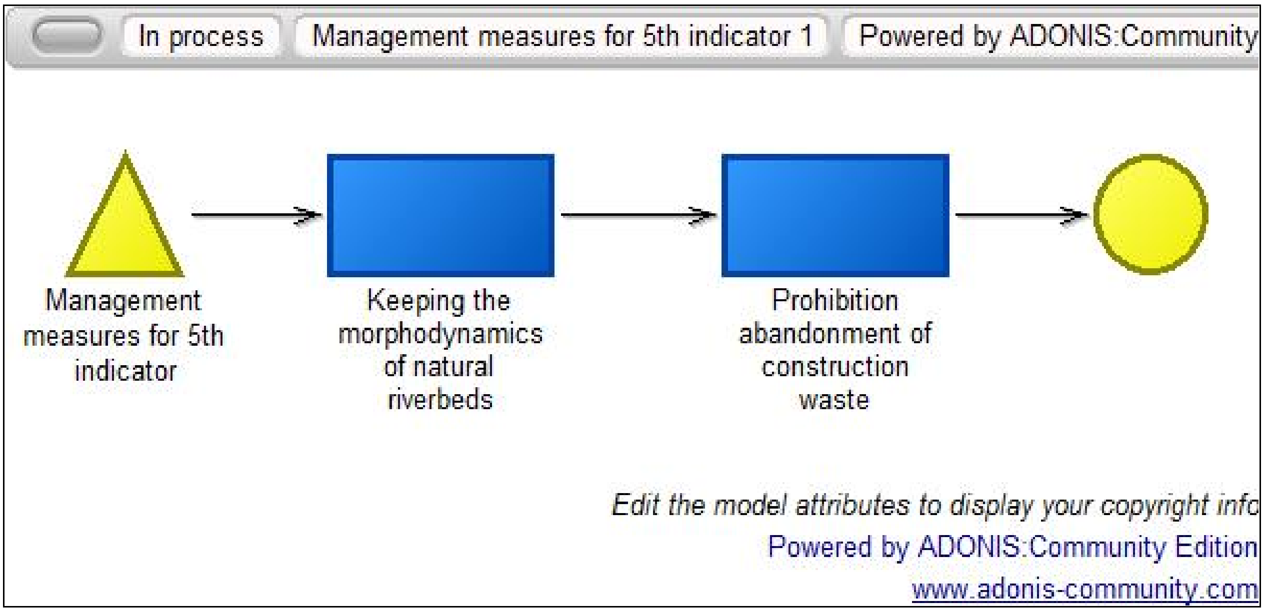

Figure 6: Management measures for 5th indicator for *Cobitis taenia*.

CONCLUSIONS

In order to manage a good conservation status in ROSCI0132 Natura 2000 site for *Cobitis taenia* the main found threats to the fish species *Cobitis taenia* good conservation status in ROSCI0132 Natura 2000 site were the following: water pollution, adjacent field erosion and over silting of mud in the riverbed. The pressure was the water pollution.

Significant for the *Cobitis taenia* species protection are: natural riverbeds morphodynamics preservation or restoration, riverine vegetation conservation, poaching control, waste management, decreasing organic and chemical pollution, and the implementation of a seasonal permanent monitoring system for the fish fauna.

In this study, a necessary model for management decisions in order to support the *Cobitis taenia* fish species was done.

The ADONIS:CE was used in this study in the nature protection concern, suggesting a management model of *Cobitis taenia* fish species that encompassse its most significant requirements in relation to the habitat, the indicators that bring to light a good ecological status – the correct management to sidestep and/or eradicate the pressures and threats which disturb this species populations.

If the suggested management elements do not prevail, *Cobitis taenia* will have a poor conservation status in the next 10-15 years in the studied area.

This on-site, on habitats and on species plan management decisions sustaining model for *Cobitis taenia*, should be assimilated in an integrating management model for the ROSCI0132 site ichthyofauna. For this objective comparable management decisions sustaining models for other fish species of European interest should be taken into account.

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HUMAN IMPACT ON TÂRNAVA MARE RIVER AND ITS EFFECTS ON AQUATIC BIODIVERSITY

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KEYWORDS: Romania, Transilvania, Târnava Mare River, human impact, biodiversity.

ABSTRACT

This paper identifies the major human pressures in Târnava Mare River to be: industry, urban and household sewage and waste, hydrotechnical works, embankment, manure, agricultural land, ballast exploitation and artificial standing water.

These pressures have a significant negative impact on the species: *Ceratoneis arcus, Achnanthes minutissima, Meridion circulare, Diatoma vulgare, Tubifex newaensis, Potamothrix vejdovski, Hydropsyche angustipennis, Hydropsyche contubernalis, Hydropsyche modesta, Ancylus fluviatilis, Perla marginata, Perla palida, Leuctra fusca, Leuctra nigra, Leuctra inermis, Capnia bifrons, Nemoura cambica, Caenis moesta, Perla palida, Melosira varians, Perlodes microcephala, Rhyacophila aurata, Rhyacophila tristis, Orthotrichia costalis, Philopotamus montanus, Neureclipsis bimaculata, Ecclisopteryx dalecarlica, Diamesa pseudodiamesa, Sericostoma schneideri, Salmo trutta* and *Cottus gobio*.

REZUMAT: Impactul antropic asupra râului Târnava Mare și efectele asupra biodiversității acvatice.

Presiunile antropice majore care au fost identificate asupra râului Târnava Mare în acest studiu sunt: poluarea din industrie, poluarea cu ape menajere, deşeuri menajere, amenajări hidrotehnice, îndiguiri și poluarea din agricultură.

Presiunile antropice identificate au avut un impact negativ semnificativ asupra speciilor: *Ceratoneis arcus, Achnanthes minutissima, Meridion circulare, Diatoma vulgare, Tubifex newaensis, Potamothrix vejdovski, Hydropsyche angustipennis, Hydropsyche contubernalis, Hydropsyche modesta, Ancylus fluviatilis, Perla marginata, Perla palida, Leuctra fusca, Leuctra nigra, Leuctra inermis, Capnia bifrons, Nemoura cambica, Caenis moesta, Perla palida, Melosira varians, Perlodes microcephala, Rhyacophila aurata, Rhyacophila tristis, Orthotrichia costalis, Philopotamus montanus, Neureclipsis bimaculata, Ecclisopteryx dalecarlica, Diamesa pseudodiamesa, Sericostoma schneideri, Salmo trutta* şi *Cottus gobio*.

ZUSAMMENFASSUNG: Die menschlichen Einflüsse auf die Große Kokel/Târnava Mare und ihre Auswirkungen auf die aquatische Biodiversität.

Als größte Beeinträchtigungs-faktoren der Großen Kokel durch den Menschen wurden Industrie, Abwässer und Abfall aus städtischen Betrieben und Haushalten, wasserbauliche Maßnahmen, Eindeichungen, Düngemittel, landwirt-schaftliche Flächen, Kies- und Sandentnahme sowie künstliche, stehende Gewässer festgestellt.

Die menschlichen Eingriffe und Beeinträchtigungen hatten einen signifikant negativen Einfluss auf die folgenden Arten von Gewässerorganismen: *Ceratoneis arcus, Achnanthes minutissima, Meridion circulare, Diatoma vulgare, Tubifex newaensis, Potamothrix vejdovski, Hydropsyche angustipennis, Hydropsyche contubernalis, Hydropsyche modesta, Ancylus fluviatilis, Perla marginata, Perla palida, Leuctra fusca, Leuctra nigra, Leuctra inermis, Capnia bifrons, Nemoura cambica, Caenis moesta, Perla palida, Melosira varians, Perlodes microcephala, Rhyacophila aurata, Rhyacophila tristis, Orthotrichia costalis, Philopotamus montanus, Neureclipsis bimaculata, Ecclisopteryx dalecarlica, Diamesa pseudodiamesa, Sericostoma schneideri, Salmo trutta* und *Cottus gobio*.

INTRODUCTION

The natural and cultural heritage are more and more endangered both by natural hazards and human activities induced effects (Hapciuc et al., 2016). The river basins are not exceptions in this respect, and Târnava Basin is a good such example (Curtean-Bănăduc et al., 2005).

The Târnava Mare River basin is located in the center of the Romanian Carpathians range. The river basin collects the water which runs off the Transylvania Depression, particularly its southern part, namely the Târnave Plateau.

With a basin area of 6,157 km^2, a length of 249 km and a descending altitude of around 1,250 m, the Târnava River is one of the major tributaries of the Mureş River, delineating 21% of its basin. It is formed at the junction of the Târnava Mare River (3,606 km^2 basin surface, 221 km length) and the Târnava Mică River (2,049 km^2, 191 km) near the city of Blaj. The first river rises on the western slopes of the volcanic Harghita Şumuleului Mountain at 1,441 m elevation and the second river on the southern slope of the volcanic Saca Mountain (1,777 m) at 1,190 m elevation. (Roşu, 1980; Badea et al., 1983; Posea et al., 1983; Curtean-Bănăduc et al., 2001)

The European Water Framework Directive (WFD) establishes a common framework for sustainable and integrated management of all water bodies (groundwater, inland surface waters, transitional waters and coastal waters) and requires signatories to consider all impact factors and economic implications of water quality improvement measures. In this sense, the directive sets out a program of measures to preserve or improve water quality. (Mihăiescu, 2009)

The Târnava Basin includes a high diversity of human impact sources.

The Târnava River basin integrated proper management depends primarily on these sources and their effects on the biodiversity indicators. This research paper studies the human impact sources, and their effects on lotic sectors of the Târnava Mare River.

MATERIAL AND METHODS

The present study was conducted in 2013 as part of a research project studying the management of Natura 2000 sites in Romania.

The current paper reports the results of an inventory on the ground of the human impact sources, combined with results from studies on biodiversity in the area, and indicates a significant dependence in relationships between the different impact sources and then quality of habitats, defined by the presence/absence or ecological status of populations or communities of plant and animal species.

Specific maps were created, on which the types of identified impact sources in each area of the studied sectors were highlighted.

RESULTS AND DISCUSSION

Human impact sources

As a result of field research, the following types of human impact sources have been identified (Fig. 1): hydrotechnical works (HW ①), households sewage (HS ②), urban sewage (US ③), ballast exploitation (BE ④), household waste (HW ⑤), manure (M ⑥), artificial standing water (ASW ⑦), industry (I ⑧), river embankment (E ⑨), and agricultural land (AL ⑩).

The first sector analysed coincides with the closest settlement springs of Târnava Mare River, **Vârşag** sector, in which three types of human impact have been found: household waste (HW ⑤), manure (M ⑥) and artificial standing water (ASW ⑦).

In **Zetea** sector four important types of human impact were identified: hydrotechnical works (HW ①) Zetea Lake, ballast exploitation (BE ④), household waste (HW ⑤) and manure (M ⑥).

The **Odorheiu-Secuiesc** sector was chosen because the Târnava Mare River crosses it. It is considered to be the area with a major impact on water quality. The sources of impact found were: households sewage (HS ②), industry (I ⑧) and predominantly household waste (HW ⑤).

In **Cristuru-Secuiesc** sector only two human impact sources have been identified because the Târnava Mare River bypasses this sector. These were manure (M ⑥) and agricultural land (AL ⑩).

In the **Vânători** sector there was only one main human impact source: agricultural land (AL ⑩).

In **Albeşti-Boiu** sector three impact sources were identified: one hydrotechnical works (HW ①) and the hydrotechnical system at Sighişoara, an area with artificial standing water (ASW ⑦) and agricultural land (AL ⑩).

A significant number of human impact sources have been identified in the **Sighişoara** sector: industry (I ⑧), ballast exploitation (BE ④), near downtown and in the entire center of the town, the river embankment (E ⑨). At the exit from Mediaş the human impact source is an area with artificial standing water (ASW ⑦).

The **Daneş-Seleuş** sector is a rural area, where the only source of human impact was agricultural land (AL ⑩).

In the next sector, **Hoghilag,** primarily household sources of impact were found: households sewage (HS ②) and the predominant type was household waste (HW ⑤).

In **Dumbrăveni** sector, as in the Hoghilag sector, the river intersects the city only at the entrance of the locality. However, two sources of human impact have been identified. The agricultural land (AL ⑩), was identified in the most sectors and the households sewage (HS ②).

The largest sector is the **Mediaş City**, five human impact sources were identified, the most extensive source is industry (I ⑧). Also before entering in the city one hydrotechnical works (HW ①) has been identified. The river banks within the city are accompanied by some industries (I ⑧), and on the other side of the river, agricultural land (AL ⑩). At the exit of the city an urban sewage (US ③) and nearby, household waste (HW ⑤) have been identified.

In the 12th sector, **Copşa Mică**, the most significant source of impact comes from the industrial area (I ⑧). For years it was considered one of the most polluted area in Europe, as it also includes the dump, which has a significant environmental impact. In the area one hydrotechnical work (HW ①) has also been identified as a threat.

In **Micăsasa** sector the following human impact sources were identified: household waste (HW ⑤), agricultural land (AL ⑩), households sewage (HS ②), industry (I ⑧), embankment (E ⑨).

In **Lunca** locality studied sector a significant number of impact sources have been identified like the followings: household waste (HW ⑤), agricultural land (AL ⑩), households sewage (HS ②), industry (I ⑧), hydrotechnical works (HW ①), ballast exploitation (BE ④) and manure (M ⑥).

In **Valea Lungă** village the human impact sources are: household waste (HW ⑤), agricultural land (AL ⑩), households sewage (HS ②), industry (I ⑧).

In **Mănărade** area, as in the Lunca case, the human impact sources are mainly the effects of rural working households: household waste (HW ⑤), agricultural land (AL ⑩), households sewage (HS ②), industry (I ⑧), hydrotechnical works (HW ①), ballast exploitation (BE ④) and manure (M ⑥).

The last studied lotic sector is represented by the **Blaj** locality zone, which is one of the largest settlements on the Târnava Mare River and that is why the predominant sources of human impact are: industry (I ⑧), household waste (HW ⑤), urban sewage (US ③) and hydrotechnical works (HW ①).

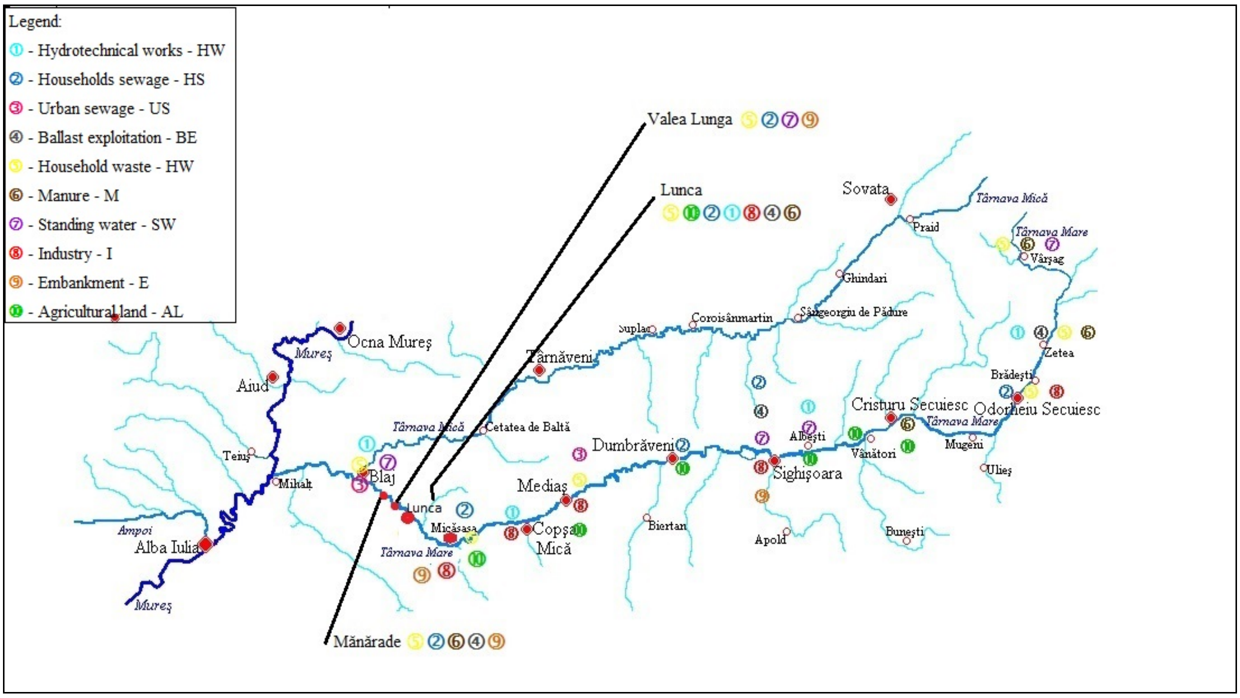

Figure 1: Human impact sources identified in the Târnava Mare River area.

Human activities effects on aquatic biodiversity

Vârşag sector

In the Vârşag sector of the Târnava Mare River the dominant diatom species are the following *Ceratoneis arcus*, *Achnanthes minutissima* and *Meridion circulare* (Momeu and Péterfi, 2005), demonstrating exceptional or good condition of aquatic and semi-aquatic habitats (Prygiel and Coste, 2000). This assessment is supported by the presence of aquatic mollusk species *Ancylus fluviatilis* (Sîrbu, 2005; Curtean-Bănăduc, 2005; Curtean-Bănăduc, unpublished data) and high numbers of terrestrial mollusk species (Gheoca, 2005) in the riverine wetland areas. The plecopterans present a relatively high specific diversity, including the species *Perla marginata*, *Perla palida*, *Leuctra fusca*, *Leuctra nigra*, *Leuctra inermis* and *Perlodes microcephala*, fact which indicates a good aquatic habitat quality (Curtean-Bănăduc, 2005; Curtean-Bănăduc, unpublished data). The trichopteran larval community structure, including the species *Rhyacophila aurata*, *Rhyacophila tristis, Orthotrichia costalis*, *Philopotamus montanus*, *Neureclipsis bimaculata*, reveals well oxygenated water with low organic matter (Robert and Curtean-Bănăduc, 2005; Curtean-Bănăduc, unpublished data). Also numerically dominant are the identified chironomid species which belong to the genera that prefer clean water like *Diamesa*, *Pseudodiamesa* and *Heptagenia* (Curtean-Bănăduc, 2005; Curtean-Bănăduc, unpublished data).

In spite of all these findings which indicate a good ecological status for the aquatic habitats of the studied lotic sector of Târnava Mare River, the benthic community structure indicates the presence of organic substances input, probably due to the local houses (Curtean-Bănăduc, 2005; Curtean-Bănăduc, unpublished data). Further, the presence of new commers fish species like *Squalius cephalus* and *Gobio gobio*, reveal some artificial organic substances input and some riverbed morphological anthropogenic changes (Bănăduc, 2005; Bănăduc unpublished data).

Zetea sector

In the Zetea sector of Târnava Mare River, upstream of the Zetea Dam, the river quality can be considered as good, based on the dominance of the diatom species *Diatoma vulgare* (Momeu and Péterfi, 2005), the presence of mollusc species *Ancylus fluviatilis* (Sîrbu, 2005; Curtean-Bănăduc, 2005; Curtean-Bănăduc, unpublished data), and also on the high specific diversity of plecopterans, including the species *Perla marginata*, *Leuctra fusca*, *Leuctra inermis* and *Perla pallida* (Curtean-Bănăduc, 2005; Curtean-Bănăduc, unpublished data). Downstream of the Zetea Dam the habitats are considered eutrophic but still in good condition, due to the dominance of the species *Melosira varians* and the double number of the diatom species in comparison with upstream dam communities. This is most likely to be due to the good hydrological conditions and favourable water chemical characteristics, demonstrated through, a relatively high diversity of plecopterans (Curtean-Bănăduc, 2005; Curtean-Bănăduc, unpublished data) and the highest specific diversity observed on this river of trichopterans (Robert and Curtean-Bănăduc, 2005; Curtean-Bănăduc, unpublished data). The trichopteran larval community structure, including the species *Rhyacophila aurata*, *Rhyacophila tristis, Neureclipsis bimaculata, Ecclisopteryx dalecarlica* and *Sericostoma schneideri* reveal well oxygenated water with low organic matter levels (Robert and Curtean-Bănăduc, 2005). The macroinvertebrate community structure (Curtean-Bănăduc, 2005; Curtean-Bănăduc, unpublished data) reveal a constant presence of oxyphilic species (*Ancylus fluviatilis, Leuctra fusca, Leuctra inermis, Capnia bifrons*, *Nemoura cambica*, *Caenis moesta*, *Rhyacophila aurata*, *Rhyacophila tristis* and *Sericostoma schneideri*).

The Zetea dam and lake proximity have the effect of fragmenting habitats, reducing the quality of the downstream lotic biocoenosis, as "nursery" for permanent new generations of mainly *Squalius cephalus* and *Gobio gobio* eurivalent fish species, reducing the biotic integrity and inducing an unnatural ichthyological zone change from the trout zone to Balkan barbell zone (Bănăduc, 2005; Bănăduc, unpublished data).

Odorhei sector

In the Odorhei sector the presence of two oligochaeta (Tubificidae) species (*Limnodrilus claparedeianus* and *Potamothrix vejdovski*) reveal the organic residue contents of the river from pollution (Cupşa, 2005; Curtean-Bănăduc, unpublished data). This conclusion is supported by the low number of mollusks species (Sîrbu, 2005) and relatively low number of terrestrial mollusc species (Gheoca, 2005) in the riverine wetland areas. The relatively small number of trichopteran species typically associated with clean water, and the dominance of Hydropsychidae eurivalent species reveal rich organic content in the water (Robert and Curtean-Bănăduc, 2005; Curtean-Bănăduc, unpublished data). The macroinvertebrate communities structure (Curtean-Bănăduc, 2005; Curtean-Bănăduc, unpublished data) reveal the dominance of species which prefer water richer in organic substances like *Hydropsyche angustipennis*, *Hydropsyche modesta* and species of the genus *Chironomus*. The domination by individuals of the organic pollution resistant *Gobio gobio* also indicates significant pollution with sewage water in this area (Bănăduc, 2005; Bănăduc, unpublished data; Bănărescu, 2005).

Sighişoara sector

In the Sighişoara sector the characteristic mollusks community for water with high organic loads is present (Sîrbu, 2005). The same indication is offered by the low number of riverine terrestrial molluscs species (Gheoca, 2005). The relatively small number of clean water trichopteran species and the dominance of Hydropsychidae eurivalent species reveal rich organic content in the water (Robert and Curtean-Bănăduc, 2005; Bănăduc unpublished data). The macroinvertebrate communities structure (Curtean-Bănăduc, 2005; Curtean-Bănăduc, unpublished data) reveal the dominance of species which prefer water richer in organic substances like *Hydropsyche angustipennis* and *Hydropsyche contubernalis*, and species which belong to the genera *Chironomus* and *Cryptochironomus*. The low fish species number indicates a relatively moderate aquatic life condition and a reduced biotic integrity (Bănăduc, 2005; Bănăduc, unpublished data). The human activities overlapping in many sectors where the amphibians are living in riverine areas reveal a moderate state of habitats (Hartel and Demeter, 2005). The negative influence on the environment of the city activities are obvious (Reti and Muntean, 2011).

Mediaş sector

The relatively low number of terrestrial mollusk species (Gheoca, 2005) reveal riverine habitat quality problems. It should also be noted that this sector has experienced significant pollution with heavy metals with bioaccumulation observed in *Helix pomatia* (Gheoca and Gheoca, 2005). The relatively small number of clean water trichopteran species and the dominance of Hydropsychidae eurivalent species reveal rich organic content in the water (Robert and Curtean-Bănăduc, 2005; Curtean-Bănăduc, unpublished data). The macroinvertebrate communities structure (Curtean-Bănăduc, 2005; Curtean-Bănăduc, unpublished data) reveal a lotic sector polluted with domestic waste water, dominated by oligochetes from the Tubificidae, chironomids belonging to the *Chironomus* genus and trichopterans *Hydropsyche angustipenis* and *Hydropsyche contubernalis*. Compared to sectors upstream of this site, the lower fish species number in this sector indicates a relatively low aquatic life condition and a significantly reduced biotic integrity (Bănăduc, 2005; Bănăduc unpublished data). The negative influence on the nature of the city activities are clear (Reti and Muntean, 2011). Urban sources of water are negative influences in this context, with five of six water sources being polluted with nitrites, nitrates, sulphites, sulphates and fluorine (Roşu et al., 2014).

Copşa Mică sector

The absence of living aquatic mollusks in this sector reveals a poor aquatic habitat quality (Sîrbu, 2005). The same indication is offered by the low number of riverine terrestrial mollusk species (Gheoca, 2005) induced by heavy metals pollution (Gheoca and Gheoca, 2005). The trichopterans reveal significant river pollution (Robert and Curtean-Bănăduc, 2005; Curtean-Bănăduc, unpublished data). The macroinvertebrate communities structure (Curtean-Bănăduc, 2005; Curtean-Bănăduc, unpublished data) reveal a lotic sector that is strongly polluted, the species *Hydropsyche contubernalis* being constantly dominant. Compared to higher sectors of the river, in this sector fish species number indicate a low water aquatic life condition and a major reduced biotic integrity (Bănăduc, 2005; Bănăduc, unpublished data). This area is affected by the air, water and soil pollution with significant risks for the environment and humans (Curseu et al., 2006; Chicea et al., 2008; Oros et al., 2009) The negative influence on the environment of the city activities are obvious (Reti and Muntean, 2011).

Blaj sector

In the Blaj sector the presence of Oligochaeta species *Tubifex newaensis* reveal water with a high organic load (Cupşa, 2005). The lack of living mollusks reveal aquatic habitat quality to be low (Sîrbu, 2005). The same indication is offered by the low number of terrestrial mollusk species in the riverine areas (Gheoca, 2005).

The macroinvertebrate communities structure (Curtean-Bănăduc, 2005; Curtean-Bănăduc, unpublished data) reveal a polluted lotic sector, present being the chironomids of *Chironomus* genus, oligochetes of Tubificidae family, trichopterans *Hydropsyche angustipennis* and *Hydropsyche contubernalis*.

Tributaries

The majority of the Târnava Mare southern tributaries have a rather low habitat and biocoenosis quality, intercalated with good quality sectors. The taxons on which this assessment was done belong to: Oligochaeta, Gastropoda, Araneida, Amphipoda, Ephemeroptera, Tichoptera, Coleoptera, Heteroptera, Chironomidae, Psychodidae, Tabanidae, Heleidae, Amphibia and Osteichthyes (Curtean-Bănăduc et al., 2007; Bănăduc, 2016; Curtean-Bănăduc, 2016).

Organic pollution and hydrotechnical works on the nearby Visa River have caused a decrease in ecosystem quality and as a consequence it is likely to have had a significantly negative influence on Târnava Mare River (Oprean et al., 2009).

CONCLUSIONS

The major human threats and pressures which were identified in the studied area of Târnava Mare River are: industry, urban sewage, households sewage, hydrotechnical works, household waste, embankment, manure, agricultural land, ballast exploitation and artificial standing water.

All these human pressures had at least a medium term significant variable impact on the aquatic and semi-aquatic habitats of Târnava Mare River, impact absence and/or presence being revealed based on a series of indicator taxons like: *Ceratoneis arcus, Achnanthes minutissima, Meridion circulare, Diatoma vulgare, Tubifex newaensis, Limnodrilus claparedeianus, Potamothrix vejdovski, Hydropsyche angustipennis, Hydropsyche contubernalis, Hydropsyche modesta, Chironomis* sp., *Cryptochironomus* sp., *Ancylus fluviatilis, Helix pomatia, Perla marginata, Perla palida, Leuctra fusca, Leuctra nigra, Leuctra inermis, Capnia bifrons, Nemoura cambica, Caenis moesta, Perla palida, Melosira varians, Perlodes microcephala, Rhyacophila aurata, Rhyacophila tristis, Orthotrichia costalis, Philopotamus montanus, Neureclipsis bimaculata, Ecclisopteryx dalecarlica, Sericostoma schneideri, Diamesa pseudodiamesa, Heptagenia* sp., *Squalius cephalus, Gobio gobio, Salmo trutta* and *Cottus gobio.*

All these taxons should be used in developing an integrated monitoring system for this river.

It should be noted that the identified threats and pressures can only be countered by collaborating with local communities.

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ELEMENT AND TRACE ELEMENT CONTENTS OF COW MILK SAMPLED IN WESTERN ROMANIAN CARPATHIANS AND ALPS AREAS

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KEYWORDS: milk, trace elements, heavy metals, authenticity.

ABSTRACT

Cow milk samples were obtained directly at various farms in Western Romanian Carpathians and Lower Austria, and analysed for main and trace elements. Levels of inorganic contaminants (Cd, Pb, As, Hg) were negligible, and most concentration ranges were overlapping. Western Romanian Carpathians milk contained more Na and Sr, and less P and Cr than milk from Lower Austria.

The presented data is compared with respective published data from Poland, Italy, Spain and the US. For grown-ups, one liter of milk satisfies the recommended daily intake (RDI) of Ca and P, and three liters of milk contains the RDI of Mg and Se.

REZUMAT: Concentrația de elemente și oligoelemente a laptelui de vacă din Carpații Occidentali și din regiuni ale Alpilor.

Probe de lapte de vacă au fost obținute direct de la diverse ferme din Carpații Occidentali și Austria Inferioară, acestea au fost analizate pentru elemente principale și pentru oligoelemente. Nivelurile de contaminanți anorganici (Cd, Pb, As, Hg) au fost neglijabile, majoritatea nivelelor de concentrație suprapunându-se. Laptele din Carpații Occidentali conținea puțin mai mult Na și Sr, și mai puțin P și Cr decât laptele din Austria Inferioară.

Setul de date prezentat este comparat cu date din Polonia, Italia, Spania și SUA. Pentru adulți, un litru de lapte satisface aportul zilnic recomandat (AZR) de Ca și P, precum și cazul a trei litri de lapte AZR pentru Mg și Se.

ZUSAMMENFASSUNG: Element- und Spurenelementgehalte von roher Kuhmilch aus den westlichen rumänischen Karpaten und Alpen Gebieten.

In verschiedenen Betrieben in den westlichen rumänischen Karpaten sowie in Niederösterreich (Kalkvoralpen, Molassezone, Waldviertel) wurden Proben roher Kuhmilch gezogen und darin sämtliche Haupt- und Spurenelemente bestimmt. Die Gehalte an anorganischen Kontaminanten (Cd, Pb, As, Hg) waren vernachlässigbar, und die in beiden Ländern gefundenen Konzentrationsbereiche überlappten sich weitgehend. Die Milch aus den westlichen Karpaten enthielt nur etwas mehr Natrium und Strontium, hingegen weniger P und Cr als die Milch aus Niederösterreich.

Der hier vorgestellte Datensatz wird mit entsprechenden bereits veröffentlichten Daten aus Polen, Italien, Spanien und den USA verglichen. Ein Liter Milch enthält die für Erwachsene pro Tag empfohlene Aufnahmemenge für Calcium und Phosphor, und drei Liter Milch für Magnesium und Selen.

INTRODUCTION

Milk and dairy products are main items of animal origin serving for human nutrition, particularly for children. In order to protect from health hazards and forgeries, they have to meet appropriate hygienic standards, to be free of contaminants, and to contain the fat and protein contents which are printed on the label. If a source is labelled, its authenticity should be traceable and verifiable. Among other parameters, elemental analysis of samples of known origin should help to establish a suitable element pattern which is characteristic for a given region. During the production of commercially available dairy products, however, mixing from various sources may not be sufficiently traceable. Therefore, sampling directly at the cow or at least directly at the studied farms, is much more preferable in order to obtain data of authentic origin.

In the past, trace element analysis could discriminate milk samples from two distinct farms or small regions (some examples will be given in the discussion section below).

Due to homeostasis, physiologically active trace element levels in cow milk are usually kept within narrow limits, to satisfy the needs of the calf. However, some effects of feeding, cow race or lactation period have been observed (Kreuzer and Kirchgessner, 1990; Kirchgessner et al., 2008). Unless these effects are kept constant, milk (like honey) is hardly suitable as an environmental indicator for these, except the pollution exceeds the buffering capacity of the mother organism. Cu has been proven to exert the strongest correlation with lactation time (Kreuzer and Kirchgessner, 1990; Hobegger, 2013), but this effect gets obviously equalized when milk of various cows are mixed within the farm. Cycling of elements of low physiological activity, however, is hardly metabolically governed, because there is no need. They might reflect local levels in feeds, and thus the levels encountered in the entire region of the studied farms.

If data of raw milk trace element composition has been assorted due to cow race, lactation period (5-100 days, 100-200 days, more than 200 days) and number of lactations. Milk from all three regions within Lower Austria could be discriminated by its contents of Ba and Cd, and two regions within Lower Austria by the contents of Co, Cs, K, Li, P, Rb, S, Sr, Ti, and Zn. Within the same lactation period, racial differences (Brown Swiss/Braunvieh – Simmental/Fleckvieh) were noted for levels of Co, P, Rb, Cr, Mo and iodine. When all samples obtained within a region were put together, however, all ranges were overlapping (Hobegger, 2013). Significant correlations between element levels contained in the feeds and in the milk were notable for Cu, I, Rb, and Zn, but not for the additional 37 elements (Se was not analyzed) (Hobegger, 2013; Sager and Hobegger, 2013).

Because the Alps and the Carpathian Mountains are of the same geological origin and relatively similar climate, certain similarities in the composition of herbage are expectable. In Western Romanian Carpathians as well as in Lower Austria, dairy cows are largely kept in rural areas of low industrialization and pollution. This helps to keep unwanted trace elements at relatively low levels.

Within this work, data from three counties situated in Western Romanian Carpathians are presented and compared with respective data from three regions of Lower Austria (Bohemian Massive, Danube Lowlands, Pre-Alpine mountains) as well as other sites published in the literature.

MATERIAL AND METHODS

In Lower Austria, milk samples were obtained directly at the cow from a sampler proportional to the entire milking volume by a bypass tube to the milking machine. The farms were situated within three geologically different regions, i.e. The Bohemian Massive (granite-gneiss), the Danube Lowlands (tertiary-quaternary sediments) and the Pre-alpine mountains (flysch and limestone) (Hobegger, 2013). The samples were filled in 120 ml screw-capped plastic vessels at the farm, deep frozen, finally freeze dried and homogenized with a plastic spatula. Their water content was at median 86.4% (range 84.8-89.9%). They were digested both with conc. HNO_3 (0.25 g sample + 3.8 ml HNO_3) and with K-chlorate-dilute nitric acid (1.0 g sample + 8 ml digestion solution) in pressure bombs by microwave assisted heating, and made up to 25 ml in plastic volumetric flasks (Sager, 2011). The digests were submitted to ICP-OES (Inductively coupled plasma optical emission spectrometry) multi-element analysis in various dilutions. Iodine was determined as the iodate by ICP-MS (inductively coupled plasma mass spectrometry) and standard addition.

Analysis of the Romanian samples started from wet weight. 0.5 g of each sample was weighed within a Teflon reaction vessel. After adding 5 ml HNO_3 (65%) and 2 ml H_2O_2 (30%), they were left to pre-digest over night, the vessels closed, finally digested by microwave assisted heating under pressure, and made up with H_2O to 25 ml. The digests were submitted to ICP-OES and ICP-MS multi-element determinations.

A certified reference material (NIST -1549 Non-fat milk powder) was analyzed for the determination of Na, K, Ca, Mg, P, Al, Cu, Fe, and Zn, in oder to check the accuracy of the method; the recovery ranged within 97-103%.

RESULTS AND DISCUSSION

According to the EU regulation (2006) about contaminants, uptake of cadmium levels should not exceed 7 µg/kg body weight over the course of one week, which approximates to intake of 500 µg for an adult person, assuming complete bioavailability. Cadmium concentrations encountered in the milk samples investigated ranged from <1-4 µg/kg of wet weight and were thus very low. Similarly, the specific threshold for Pb set in milk at 20 µg/kg fresh weight was never exceeded (Tab. 1).

With respect to the contents in milk per fresh weight, data from Western Romanian Carpathians and Lower Austria were largely overlapping (Tab. 1). Just levels of Na und Sr were higher, and to the contrary, levels of P, Zn, and Cr were lower in Western Romanian Carpathians. Referring to the cow races, in Western Romanian Carpathians, milk was collected from Bălțata Românească, Holstein and Bruna de Maramureș, and in Austria from Simmental (Fleckvieh) and Swiss Brown (Braunvieh), which are the main species both in the respective countries. This might explain some differences in the datasets obtained. In addition, feeding practices or local composition of vegetation might differ. Because all concentration ranges of investigated main and trace elements are overlapping, discrimination between milk from Transylvania and Lower Austria by trace element patterns is impossible, at least unless race and lactation period are exactly known. But some differences to the data reported from other countries could be found. The data compiled in table 2, however, refer to single farms or small regions, but not to an entire county.

Selenium levels met in Western Romanian Carpathians were similar to those encountered in the Podlasie Region (Eastern Poland) (Gabryszuk et al., 2008), lower than in Silesia (Dobrzansky et al., 2005), but higher than in Italy (Carosielli et al., 2008).

Table 1: Median and range of main and trace elements in crude milk samples from Lower Austria and Western Romanian Carpathians referring to mg/l wet weight.

	Bohemian massive (38)		Danube Lowlands (29)		Pre-Alpine (36)		Western Romanian Carpathians (42)	
	Median	Min - Max	Median	Range	Median	Range	Median	Range
Al	< 0.1	< 0.1-0.106	< 0.1	< 0.1-0.209	< 0.1	< 0.1-0.155		
As							0.00065	< 0.000085-0.00177
B	0.081	0.021-0.239	0.136	0.092-0.276	0.106	0.028-0.318		
Ba	0.087	0.048-0.135	0.054	0.030-0,086	0.070	0.029-0.118		
Be	< 0.0005		< 0.0005		< 0.0005			
Ca	1,256	950-2,053	1,539	1,255-1,904	1,363	1,188-1,684	1,296	1,092-1,450
Cd	0.0006	< 0.0001-0.0043	0.0005	0.0002-0.0021	0.0003	0.0001-0.0007	0.00099	0.00016-0.00226
Ce	< 0.003	< 0.003-0.011	< 0.003	< 0.003-0.003	< 0.003	< 0.003-0.005		
Co	0.0035	0.0022-0.0061	0.0045	0.0021-0.0063	0.0046	0.0038-0.0062	0.0022	< 0.0012-0.0350
Cr	0.013	< 0.002-0.077	0.018	0.011-0.058	0.027	0.005-0.055	0.0042	< 0.0021-0.0061
Cs	0.0037	0.0012-0.0119	0.0019	0.0008-0.0026	0.0008	0.0003-0.0014	0.0038	< 0.0032-0.0560
Cu	0.055	0.025-0.144	0.047	0.021-0.106	0.041	0.017-0.104	0.049	0.031-0.087
Hg							< 0.0001	< 0.0001-0.00113
Fe	0.170	0.061-0.314	0.254	0.149-0.313	0.209	0.118-0.279		
J	0.236	0.089-0.562	0.283	0.129-0.557	0.184	0.091-0.664		
K	1,300	1,080-1,589	1,328	1,184-1,737	1,630	1,248-2,040	1,422	1,256-1,568
La	< 0.002	< 0.002-0.004	< 0.002		< 0.002	< 0.002-0.002		
Li	0.0018	0.0009-0.0046	0.0042	0.0004-0.0121	0.0023	0.0004-0.0080		
Mg	102	73-123	111	91-132	102	87-121	83.7	53.1-112
Mn	0.027	0.010-0.054	0.029	0.020-0.043	0.026	0.010-0.049	0.029	0.011-0.045
Mo	0.046	0.025-0.103	0.052	0.040-0.104	0.046	0.033-0.109		
Na	336	232-497	367	270-483	363	264-517	623	595-689
Ni	< 0.007	< 0.007-0.024	< 0.007	< 0.007-0.018	< 0.007	< 0.007-0.024		
P	927	682-1182	1,153	914-1463	922	812-1.128	743	699-763
Pb	< 0.003	< 0.003-0.008	< 0.003	< 0.003-0.009	< 0.003	< 0.003-0.009	0.0046	0.0014-0.0142
Rb	2.14	0.76-7.03	1.01	0.70-1.41	1.35	0.56-2.00		
S	318	269-388	403	315-562	321	277-401		
Sc	< 0.004		< 0.004	< 0.004-0.0058	< 0.004	< 0.004-0.0053		
Se							0.0214	0.0176-0.0353
Si	0.96	0.46-2.09	0.97	< 0.2-2.05	1.27	0.60-3.17		
Sr	0.273	0.165-0.418	0.295	0.182-0.428	0.215	0.156-0.095	0.424	0.254-0.556
Ti	0.0152	0.0060-0.0305	0.0173	0.0107-0.0217	0.0112	0.0053-0.0196		
Tl	< 0.0002		< 0.0002	< 0.0002-0.0006	< 0.0002	< 0.0002-0.0002		
V	< 0.004		< 0.004	< 0.004-0.0057	< 0.004			
Zn	4.20	2.69-5.41	4.99	4.22-7.21	3.73	2.57-6.07	2.50	1.50-4.13

Table 2: Some main and trace element levels in milk, published in the literature, mg/l fresh weight.

	Gabryszuk et al. 2008	Dobrzanski et al. 2005	Benincasa et al. 2008	Carosielli et al. 2008		Anderson 1992	Llorent-Martinez et al. 2012
	Podlasie (Poland)	Silesia (Poland)	Calabria (Italy)	Monte Gargano (Italy)		Univ. Missouri (US)	Spanish supermarkets
	4 farms		1 farm	30 farms		1 farm	7 whole + 3 skim milks
	September pasture			October 2006/June2007			
	50 cows September	25 cows	12 cows	50 cows		48 Holstein cows cows	10 milk samples
	Mean	Mean	Mean	Median	Range	Mean	Range
Al	0.060 ± 0.034	0.28 ± 0.11				0.10 ± 0.02	0.06-0.55
As	0.013 ± 0.002	0.033 ± 0.015		0.00024	0.00015-0.004		0.002-0.004
B	0.092 ± 0.018					0.333 ± 0.033	
Ba	0.028 ± 0.013	0.217 ± 0.101	0.226 ± 0.03215			0.188 ± 0.013	0.080-0.160
Be							< 0.0015
Ca	667 ± 77		1,220 ± 183				
Cd	0.0011 ± 0.0001*			0.0026	0.0001-0.0056		< 0.0015
Ce		0.003					
Co	0.0013 ± 0.0004	0.007 ± 0.004	0.0014 ± 0.0003	0.0089	0.0042-0.0283		0.001-0.024
Cr	0.0156 ± 0.0068	0.085 ± 0.053	0.0094 ± 0.0017	0.0006	0.0002-0.,0187		0.007-0.050
Cs		0.0030 ± 0,0012	0.0025 ± 0.0005				
Cu	0.144 ± 0.111	0.080 ± 0.104		0.049	0.013-0.457	0.052 ± 0.005	0.040-0.150
Hg	0.00066 ± 0.00008**						< 0.0012-0.007
Fe	0.557 ± 0.392		0.325 ± 0.042	0.464	0.175-1.354	0.194 ± 0.013	2.400-3.800
J	0.330 ± 0.058	0.560 ± 0.061					
K	898 ± 105		1,190 ± 214				
La		0,0003					
Li	0.061 ± 0.022					0.024 ± 0.002	
Mg	65.4 ± 6.9						
Mn	0.026 ± 0.003	0.074 ± 0.034	0.032 ± 0.005	0.028	0.011-0.133	0.021	0.020-0.130
Mo	0.0822 ± 0.0116	0.0115 ± 0.0071	0.029 ± 0.007	0.054	0.010-0.128	0.0220 ± 0.0030	0.040-0.060
Na	444 ± 63						
Ni	0.044 ± 0.003	0.061 ± 0.030					0.004-0.025
P	474 ± 61		775 ± 93				
Pb	0.0056 ± 0.0013			0.0072	0.0002-		0.001-0.010
Rb		0.579 ± 0.466	2.09± 0.31				
S	14.9 ± 1.7		266± 51				
Se	0.0188 ± 0.0008	0.0605 ± 0.0434		0.0082	0.0001-		
Si	0.082 ± 0.030					0.434 ± 0.111	
Sr	0.155 ± 0.022		0.698 ± 0.119			0.417 ± 0.024	
Ti		0.079 ± 0.036				0.111 ± 0.012	
Tl		0.00085					< 0,001
V	0.017 ± 0.003	0.085 ± 0.044	0.0029±0,00615				0,001-0,010
Y							
Zn	1.70 ± 0.28	3.31 ± 1.11	3.81 ± 0.765	4.17	2.97-6.06	3.96 ± 0.15	2.90-3.60

*… but in farm II: Cd = 0,0125 ± 0.00003
** … but in farm II: Hg = < 0.0001

In Western Romanian Carpathians, as was found to occur at the same level like in Italy (Carosielli et al., 2008), and significantly less than reported from Spain (Llorent-Martinez et al., 2012). Similarly, Hg in milk from Western Romanian Carpathians was found at much lower levels than encountered in Spanish cow milk (Llorent-Martinez et al., 2012).

It is plausible that milk obtained from the Podlasie Region East of Warszawa, which is characterized by sandy soils of low levels of mobile nutrients and trace elements (Gabryszuk et al., 2008), was even lower in some trace elements (except Li) than respective samples from Lower Austria and Western Romanian Carpathians. On the other hand, pollution or maybe geologic reasons might have contributed to higher levels of As, Ba, Cr, Mn, Ni, Ti and V in milk sampled in Silesia (Dobrzansky et al., 2005).

In the Mediterranean region, milk from rather clean areas in Calabria (Benincasa et al., 2008) and Monte Gargano National Park (Carosielli et al., 2008) in Italy contained the largest trace elements at the same levels. Higher Ba than in Austria have been reported from Calabria and higher Fe has been reported in milk available in Spanish supermarkets (Llorent-Martinez et al., 2012).

Holstein cows in Missouri (Anderson, 1992) supplied milk of a composition largely similar to milk samples in Lower Austria and Western Romanian Carpathians. More Ba and Ti, but less Si in milk from North America might be due to differences in the composition of herbage due to geological reasons.

Under the aspect of human nutrition, it received the certified recommended daily intake (RDI) of 800-1000 mg Ca and 700 mg P for an adult, that can be contained in one liter of milk, and 300 mg Mg and 50 µg Se in about three liters (DACH, 2013). Requirements, of e.g. Cu, Mn, and Fe, however, have to be covered from other sources. In this case, consumers do not like the taste of milk, they might change to yogurts, which are of largely similar elemental composition to milk. A large diversification of tastes has been offered, by addition of various fruits and flavours. In yogurts commercially available in Western Romanian Carpathians (and elsewhere), no statistically significant differences between the concentrations of major and minor elements met in plain and fruit yogurts were noted. The levels of intake of essential nutrient elements from yogurts have been discussed in detail recently (Cadar et al., 2015).

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AN IMPORTANT PUBLICATION IN A SERIES OF BOTANICAL HANDBOOKS: JOHN ROBERT AKEROYD "DOCKS AND KNOTWEEDS OF BRITAIN AND IRELAND"

– REVIEW –

Erika SCHNEIDER-BINDER [1]

John Robert Akeroyd (2014): "Docks and Knotweeds of Britain and Ireland" is the Handbook no. 3 of BSBI – Botanical Society of Britain and Ireland, ISBN 978-0-90-115847-5.

The Botanical Society of Britain and Ireland published in 2014 in its series of botanical handbooks a work which attracted interest not only among experts: "Docks and Knotweeds of Britain and Ireland". This comprehensive book, a much-expanded second edition of an earlier work, presents itself after in-depth studies and evaluation as richer in content and information than the title expresses. The main objective of the book is – as its author states – the identification of the knotgrasses, knotweeds, persicarias, docks, sorrels and their relatives in Great Britain and Ireland. It is addressed to specialists in botany, but at the same time should be of interest for students of biology and ecology, biogeographers and also to all those people enthusiastic for botanical information.

The author of the book is John Robert Akeroyd, a recognised botanical researcher of Great Britain well-known as a plant taxonmist who revised Volume 1 of Flora Europaea (1993), for his popular books and articles on the wild flowers of Britain and Ireland, for Nature Conservation concepts, and research with others on the historic countryside of the Saxon villages of Southern Transylvania in Romania.

The author's interest in the Polygonaceae had its roots already in 1975 when Mr. Akeroyd began his research on the family for his PhD thesis on the genecology of Curled Dock (*Rumex crispus*). Six years later J. E. Lousley and D. H. Kent produced the first edition of "Docks and Knotweeds of the British Isles" (1981). In the more than thirty years that have passed since the first publication of "Docks and Knotweeds", research on the taxonomy of Polygonaceae has developed considerably, so that a major update of taxonomy and nomenclature became necessary. As Mr. Akeroyd underlines, a new account of the family appeared in a revised first volume of Flora Europaea (T. G. Tutin et al., 1993) and as well in the latest edition of the British Flora (C. A. Stace, 2010), with recognition of the need to divide the genus *Polygonum* sensu lato into segregate genera. That is why *Persicaria* is recognised by most modern authors as a distinct genus, embracing most of the species formerly included within *Polygonum*.

In this second edition not only the taxonomy and nomenclature have been updated, but also the introductory chapters are enlarged. Before presenting the general synopsis and determination keys to Polygonaceae, the author provides information concerning classification, taxonomic literature, ecology of docks and knotweeds, their habitats and importance as food plants for many insects. Interesting data are given about pollination for several Polygonaceae as well as seed dispersal and germination. Another chapter is devoted to economic issues, with much information about edible Polygonaceae, which can give an impetus for such type of research in different European countries, the theme of edible wild plants being of growing interest. A further two chapters are dedicated to the discussion about identification of Polygonaceae and recognising the many *Rumex* hybrids.

The general synopsis is introduced by the Key to genera of Polygonaceae, which are: *Persicaria*, *Koenigia*, *Fagopyrum*, *Oxygonum*, *Polygonum*, *Fallopia*, *Muehlenbeckia*, *Rheum*, *Rumex*, *Oxyria* and *Emex*, followed by the key for the determination of species of each genus.

All native and introduced but established species, as well as most casual species, are described and illustrated in excellent quality, helping towards an exact determination. The description of each species is followed by information about chromosome numbers, usually the earliest known count. Also data on flowering period are provided, than comes information on status, habitat, frequency, geographical distribution with clear maps and also taxonomic or ecotypic variation. Valuable as well is information about their importance as food plants for different insect species. Also are given data of use of each species and their economic importance.

For alien species is mentioned the area of origin and data on the history of the species in Britain and Ireland. These information gives also data about the existence and distribution of the species in other European countries.

Hybrids are described under the account of one of the parent species. The author mentions that knowledge about *Rumex* hybrids has expanded considerabely over the last thirty years with the discovery of several new to Great Britain and Ireland, some of them new to science, as well as numerous new distribution records, all being included in this second enlarged edition.

A glossary for explanation of the terms used, an extensive list of references, and indices to English and scientific names complete the book. In its handy size it can by taken easily on excursions and used for determination on field.

The handbook enables all interested groups to identify, with the help of clear keys and precise illustrations realised by Ann Farrer, the Docks and Knotweeds occuring in Britain and Ireland. Beyond that the book is helpful also for botanists of other European countries, not only for its determination keys and illustrations but also by giving the nomenclature of the species and systematics based on the newest level of research and actual knowledge of Polygonaceae, a plant family avoided by many European botanists as a difficult group.

The book represents as well the synthesis of the experience and awareness over decades as an expert in the field of systematic botany and ecology, the work of a scientific life, which can be followed as well in the numerous publications of J. R. Akeroyd in scientific journals and books. It demonstrate as well, that the author approached his work with high motivation and pleasure, whereby proving that which is done with heart and soul leads to great achievements.

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