TRANSYLVANIAN REVIEW OF SYSTEMATICAL AND ECOLOGICAL RESEARCH

16
– special issue –

The "Iron Gates" Nature Park

Editors

Maria Pătroescu, Angela Curtean-Bănăduc & Doru Bănăduc

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"Lucian Blaga" University of Sibiu,
Faculty of Sciences,
Department of Ecology and Environment Protection and Physics

"Iron Gates" Nature Park

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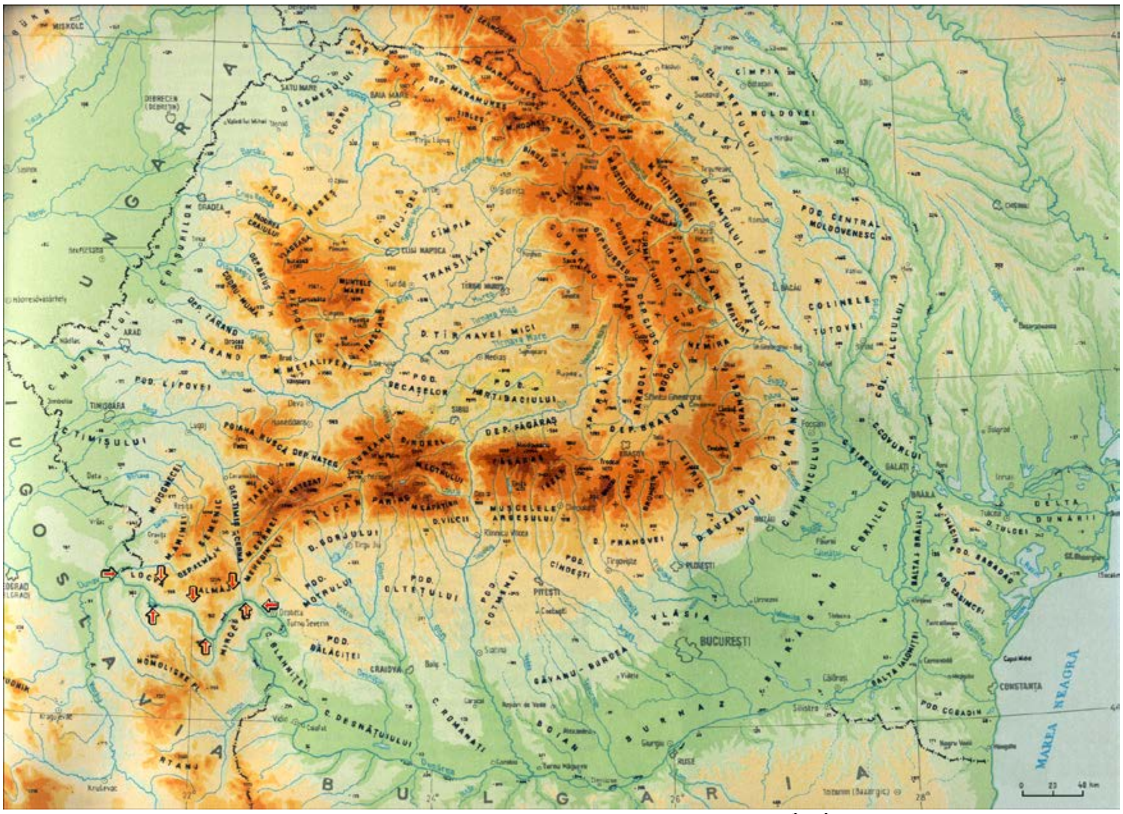
Preface

The “Iron Gates” Nature Park/Parcul Natural “Porţile de Fier” is one of the richest, most diverse and complex areas of species, habitats and ecosystems in the Danube River basin.

The many groups of humans taking advantage of the natural products and services in the area illustrates the route that local communities have taken through emergence, expansion, and progress through history, using their neighborhood natural resources, adapting and evolving in relation to each region’s particular structural and functional attributes. The “Iron Gates” transboundary (Romanian-Serbian) area, located on both sides of the Romanian-Serbian national border, here demarcated by the Danube River, significantly highlights and exemplifies this history.

This unique landscape has a high variability in terms of minerals, geological structures, relief, climate, habitats, biocoenosis and ecosystems. Conservation of these features is a key goal, and provides a reason for the development of long term studies of the area. This volume is a modest tribute to a long history of naturalists involved in local and regional knowledge acquisition and protection of this unique site.

The study area is one of the most special areas in the Danube River basin, with a remarkable variety of plant and animal organisms, showing that the interaction between humans and nature has not deteriorated the area’s natural values. This relationship of co-existence should be preserved in order to encourage the conservation of the area, as a welcome good practice example for the whole Danube Basin.



“Iron Gates” Nature Park localization (⇨⇦)
on the Romanian national territory map
(Badea et al., 1983 – modified).

The consistent long term initiatives and efforts of dedicated professionals to conserve this area's nature values culminated in the declaration of the Romanian "Porţile de Fier" Natural Park in 2000 on the northern Danube bank and of the Serbian "Djerdap" National Park on the southern bank.

The editors of the *Transylvanian Review of Systematical and Ecological Research* scientific series use this opportunity to support/present the authors who carry out research in the "Iron Gates" Nature Park area.

The interest shown, the diversity and quality of research activities and notably the data acquired, have made new contributions to the conservation of this exquisite protected area. They have also significantly improved the database used for management planning for the "Iron Gates" Nature Park.

Hence, the editors of this scientific publication believe that it should be helpful to bring together all the new available scientific research on this park into one volume that will represent an important stepping stone in the perception of this special and unique area, its nature, its iminent development and especially its proper management.

Acknowledgements

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

The Editors

IN MEMORIAM
Nicolae ROMAN
(1927 - 2014)

Nicolae Roman was a Romanian biologist.

Born on March 10, 1927 in Atârnaţi Village (now Cernetu Village) Teleorman County, *Nicolae Roman* took the primary school classes in his village and the secondary and high school classes in Alexandria, Romania. In 1952, he graduated from the Faculty of Biology, the Botany specialisation, and is assigned to the Geological Committee, Geobotanical section.

Proving, while still a student, to be a good botanist he was recruited as "external consultant" in flora inventory and vegetation mapping activities in Oltenia (Jiu-Amaradia interfluve), Muntenia (the Hills of Buzău, the Valley of Râmnicu Sărat River) alone or accompanying Şerbănescu I., Borza A. ant others. Since 1953, as graduate and permanent employee, he studies and starts mapping various regions of the country (the Romanian Plain, the sands between Jiu and Olt, Snagov and Brăneşti districts, the Subcarpathians between Dâmboviţa and Prahova and between Amaradia and Olt, the Ore Mountains in the Deva-Orăştie-Zlatna district, the catchment area of the Motru River, the Olteţ and Cerna River valleys, the Baia Mare Depression, the Region of Oaș, the Dâmboviţa-Argeş interfluve, respectively the Titu-Găești-Târgoviște district, the area of Urziceni, the Transylvanian Plain, the Ghimpaţi-Drăgăneşti Vlaşca-Gratia perimeter, the Danube River Meadow between Călăraşi and Rast Pond, etc.) and start studying the Iron Gates district, a district that will be included in the territory covered by his Doctoral thesis. Throughout the period he worked for the Geological Committee (1953-1964) he spent about 150 days each year being out in the field.

Starting with 1965 he moved to the Institute of Biology of the Bucharest Academy, in the Group of Plant Taxonomy. He worked here until retirement, continuing his taxonomical and geobotanical work. In the early years he dealt mainly with the study of flora and vegetation from the Mehedinți Plateau, developing his Doctoral thesis, that he presented in 1971 (it was published in 1974).

He researched all country regions (except Moldova), and collected a rich herbarium material. He wrote 24 scientific reports including "Geobotanic research and mapping in Snagov and Brăneşti districts" (1954), "Vegetation of the Dâmboviţa and Sușița subcarpathian region". He made 20 geobotanical maps and published 35 papers in taxonomy and phytocoenology. He found 19 new species for the Romanian flora (*Glinus lotoides*, *Fimbristylis dichotoma*, *Lathyrus inermis*, *Chenopdium multifidum*, *Thlaspi jankae*, *Minuartia hamata*, *Minuartia capillacea*, *Gladiolus illyricus*, *Scorzonera lanata*) and for science (*Stipa danubialis*). He publishes another three papers on environmental protection and nature conservation, three on chemotaxonomy and the valuable monography of "Flora and vegetation of Southern Mehedinți Plateau" in 1974, for which he received the "Emanoil Teodorescu" Romanian Academy Award.

Together with Ionescu M. A. he studied the zoocaecidia of Romania, publishing 11 papers describing, inter alia, two new genera for science, three new species for science and over 180 new species for the country.

He was member of the Natural Monuments Committee of Romanian Academy (since 1964), Member of the Geosphere-Biosphere Committee of Romanian Academy (since 1991), Member of the Society of Biology (since 1960), Member of the National Society at Soil Science (since 1963), Member of the Society at Ecology (since 1990), Member of the editorial board of the journal "Acta Biologica Montana" University of Pau-France, Member of the Scientific Coordinator Committee of the "Amicale Internationale Phytsociologie" Association Bailleul-France.

He taught between 1965 and 1968 at the Faculty of Geology and Geography in Bucharest, the class on the Soil Biology and Romanian Biogeography (Phytogeography).

Although he noted from the field, for over four decades, valuable floristical and phytocoenological data, he published only a very small part of them. After retirement, he moved to the countryside to live closer to the plants which he devoted his life to.

The Editors

DE GRUYTER OPEN

LEPIDOPHLOIOS ACEROSUS LINDLEY AND HUTTON 1831 IN THE CARBONIFEROUS CUCUIOVA FORMATION, "IRON GATES" NATURAL PARK (BANAT, ROMANIA)

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KEYWORDS: Cucuiova Formation, Carboniferous, fossil plants, Sirinia Basin, Almăj Mountains, "Iron Gates" Natural Park.

ABSTRACT

The Carboniferous Cucuiova Formation of the Sirinia Basin, Danubian Units, in Almăj Mountains, South Carpathians, yields a highly diverse yet rare compressive flora representing significant heritage values of the "Iron Gates" Natural Park. This flora includes pteridophytes (lycopsids, sphenopsids, filicopsids) and gymnosperms (pteridosperms and conifers), some of these representatives being important coal generators during the Late Carboniferous times. The facies features, distribution and paleofloral features of the Cucuiova Formation are discussed in the framework of the Sirinia Basin. The lycopsid *Lepidophloios acerosus* Lindley and Hutton 1831 is reported for the first time in Romania from the Cucuiova Formation in Dragosela Valley, in the central part of the "Iron Gates" Natural Park.

RÉSUMÉ: *Lepidophloios acerosus* Lindley et Hutton 1831 dans la Formation Carbonifère de Cucuiova, Parc Naturel des "Portes de Fer".

La Formation Carbonifère de Cucuiova, bassin de Sirinia, Unités Danubiennes, Monts des Almăj, dans les Carpathes de Sud, inclue une flore compressive rare et diverse à forte valeur patrimoniale pour le Parc Naturel des Portes de Fer. Cette flore inclue des ptéridophytes (lycopsides, sphénopsides, filicopsides) et des gymnospermes (ptéridospermes et conifères), quelques unes d'entre elles ont été des carbogénératrices importantes durant le Carbonifère tardif. Les caracteristiques de facies, la distribution et les caracteristiques paléofloristiques de la Formation de Cucuiova sont discutées dans le cadre du bassin de Sirinia. Le lycopside *Lepidophloios acerosus* Lindley et Hutton 1831 est rapporté pour la première fois en Roumanie, dans la Formation de Cucuiova, Valle de Dragosela, dans la partie moyenne du Parc Naturel des Portes de Fer.

REZUMAT: *Lepidophloios acerosus* Lindley și Hutton 1831 în Formațiunea carboniferă de Cucuiova, Parcul Natural „Porțile de Fier".

Formaţiunea de Cucuiova, de vârstă carboniferă, din cadrul Bazinului Sirinia, Unitățile Danubiene, Munții Almăj, Carpații de Sud, cuprinde o floră compresivă diversă și rară, reprezentând valori patrimoniale semnificative ale Parcului Natural „Poțile de Fier". Această floră include pteridofite (lycopside, sfenopside, filicopside) și gimnosperme (pteridosperme și conifere), unele dintre acestea fiind carbogeneratori importanți în timpul Carboniferului târziu. Caracteristicile faciale, distribuția și caracteristicile paleofloristice ale Formațiunii de Cucuiova sunt discutate în cadrul Bazinului Sirinia. Lycopsidul *Lepidophloios acerosus* Lindley şi Hutton 1831 este raportat pentru prima dată în România, din cadrul Formațiunii de Cucuiova, pe Valea Dragosela, în partea centrală a Parcului Natural „Poțile de Fier".

INTRODUCTION

The Sirinia Basin, also known as the Sviniţa-Svinecea Mare sedimentary zone, represents a part of the sedimentary cover of the Upper (Internal) Danubian Units, developed mainly within the structures of the Almăj Mountains, South Carpathians, in Romania. This basin includes Palaeozoic and Mesozoic sedimentary cycles, the Palaeozoic cycle yielding Carboniferous and Permian Formations. The central and southern parts of the Almăj Mountains, where Carboniferous deposits mainly outcrop, occur in the middle area of the "Iron Gates" Natural Park, the second largest natural park in Romania. These deposits yield rare yet diversified plant fossils, their rarity being related to the scarcity of Carboniferous outcrops in the area, as well as to the low potential of fossilisation in the area.

The Carboniferous deposits of the Sirinia Basin (Sviniţa-Svinecea Mare sedimentary zone) were known since the XIXth Century, when the first studies were published by Hauer (1870), Schafarzik (1894, 1912), Stur (1870) and Tietze (1872); while a contribution dealing with these deposits in a wider geological synthesis was provided by Codarcea (1940). Detailed research was later published by Răileanu (1953), including an inventory of Carboniferous outcropping areas in the Sirinia Basin, and a detailed geological map (Răileanu et al., 1963). Năstăseanu et al. (1973) attempted a general correlation of Carboniferous and Permian deposits, followed by the work of Stănoiu and Stan (1986) dealing with the formal definition of the Cucuiova Formation. The subject was detailed also in various textbooks, such as in Petrescu et al. (1987), Preda et al. (1994) and Răileanu et al. (1963).

Later paleobotany works dealing with the Carboniferous coal flora of the Sirinia Basin were published by Biţoianu (1972a, b, 1973, 1974, 1987), Dragastan et al. (1997), Maxim (1967, 1969), Popa and Cleal (2012), and Semaka (1962, 1970). Biţoianu (1966), Ilie and Biţoianu (1967), and Biţoianu and Ilie (1968) described fungal remains in coal petrography studies. A general revision of this flora, based on previous works and also of the early paleobotanical contributions of Hantken (1878) and Schafarzik (1894), was published by Popa (2005), who also stressed the main difficulties when undertaking paleobotanical studies in the area: the disappearance of the previous paleobotany type collections, the low quality of outcrops, and the scarcity of illustrated or described taxa in previous papers. The type collections are missing almost entirely, excepting several hand specimens partly figured in Maxim (1969), curated at the "Babeş-Bolyai" University, and an unpublished hand specimen from Cucuiova found in the Silvia Cotuţiu collection, curated at the Bucharest Geological Museum. Another difficulty is the unclear recorded geographical, local names in the region, where valleys and hills were not formally recorded, and they differ from author to author. Popa (2005) detailed the systematic lists of the Cucuiova Formation, together with updates on the lithological logs of the same formation; therefore this type of information will not be reiterated.

The Cucuiova Formation

Recent fieldwork undertaken by the author and his collaborators using GPS gear and GIS methods in the Sirinia Basin showed again the evidence of covered outcrops, as well as the emergence of new, although smaller outcrops, such as those along the Dragosela Valley.

The Carboniferous System in the Sirinia Basin is represented by the Cucuiova Formation (Stănoiu and Stan, 1986). Its stratotype was defined by Stănoiu and Stan (1986) in the Cucuiova Hill – Povalina Valley with its tributaries Coşarniţa, Zelenii (Ielenii), Zlana, Pepelaria and Drena creeks, where the sequence was considered Westphalian – Stephanian in age, based on previous paleobotanical information (Fig. 1). The local structure is represented by the Cucuiova syncline, where the Carboniferous deposits reach about 300 m in thickness, including conglomerates, sandstones, mudstones and thin coal seams. The syncline includes also the Permian terrigenous and volcanoclastic sequences, formerly defined by Stănoiu and Stan (1986) as the Povalina (terrigenous) and Trescovăţ (volcanoclastic) formations. The outcrops are scarce, as the Cucuiova Formation was recorded mainly to the east and north-east of the Cucuiova Hill. Fossil material was recently collected by the author's team in 2012-2014 through digging along the Drena Creek slopes, in an attempt to rediscover Maxim's outcrops.

The Dragosela Valley is another significant area in the Sirinia Basin, where the Cucuiova Formation outcrops (Răileanu, 1953; Biţoianu, 1972b), between the confluence of Dragosela and Tulinecea and Berzasca (Valea Mare) rivers, in the Debelilug area to the west, and towards the confluence of the Dragosela and Dragosela Mică rivers, to the east, north of the Tulinibreg Hill (Fig. 1). Here, the Cucuiova Formation has a syncline structure, as a part of the larger Sirinia Syncline, outcropping along the valley in 14 outcrops of various sizes. A former exploration gallery was found, probably the former G3 gallery of Biţoianu (1972b), as well as one supplementary sterile dump. The newly collected flora is badly preserved, including a *Lepidophloios acerosus* Lindley and Hutton 1831 fragment curated in the University of Bucharest, described here. Here, quartzite conglomerates, quartzite, micaceous, coarse grained sandstones were found overlaying the Ielova metamorphic series, together with finer sediments such as mudstones and fine, black or brownish sandstones and centimetric coals. Biţoianu (1972b) cited a floral assemblage marking the Westphalian D – lower Cantabrian interval, but the illustrations are difficult to interpret, as well as the taxonomic composition. Popa (2005) reinterpreted the age of the Cucuiova Formation in Dragosela as Bolsovian – Westphalian D – Cantabrian (Westphalian C – Stephanian).

Baia Nouă is another important area where the Cucuiova Formation was intensively mined (Fig. 1). The local structure is represented by a funnel shaped syncline, the former mine having two main horizons for the extraction of a high quality bituminous coal seam. The age of the Cucuiova Formation in Baia Nouă, based on the fossil flora, was considered by Biţoianu (1972a, 1974) as Bolsovian (Westphalian C) – lower Westphalian D. Here, the outcrops were cited by Răileanu (1953) along the Tişoviţa Valley, and by Biţoianu (1973, 1974) along the Tişoviţa Valley, Popesc Creek and the Cărbunari Creek, but today these outcrops are missing. The sterile dump permitted collecting fresh material including *Neuralethopteris rectinervis* (Kidston) Laveine 1967 and *Neuralethopteris schlehanii* (Stur) Cremer 1893, described and illustrated by Popa and Cleal (2012). This assemblage indicates the basal sequences of the Cucuiova Formation in Baia Nouă as Langsettian (Westphalian A) in age, the oldest Pennsylvanian age in the Sirinia Basin and in the South Carpathians.

According to Răileanu (1953), the Cozile Valley records the flank of the reversed Sirinia Syncline with Carboniferous and Permian sediments, caught under basement rocks (Fig. 1). Recent field work showed the occurrence of small Permian outcrops represented by red beds and lacustrine limestone lenses, but no outcrops yielding Carboniferous sediments. A former exploration gallery was found in Cozilele Valley, where under red beds sequences occur black, coaly clays which may indicate the Carboniferous age.

The Cucuiova Formation was recorded also in the eastern part of the Sirinia Basin, upstream of the Mraconia River, where the Carboniferous sediments outcrop along a north-south oriented stripe, unconformably overlying the basement (Fig. 1). Also, an outcrop with possible Carboniferous conglomerates was recorded by Răileanu (1953) upstream of the Stariştea (Staricica) Valley.

Figure 1 a: Occurrence of the studied area in the South Carpathians, Romania;
b: Outcrops of the Carboniferous Cucuiova Formation, in grey, with fossil plant occurrences (underlined); modified from Popa (2005), and Popa and Cleal (2012).

MATERIAL AND METHODS

The studied material consists of rather poorly preserved compressions, stored within the collections of the Laboratory of Palaeontology, Faculty of Geology and Geophysics, University of Bucharest. In the field, paleobotanical material was collected from small sized outcrops or from sterile dumps of the former coal mines (Popa, 2011). A Garmin GPSmap 62s unit was used in order to record accurately the occurrences. In the laboratory, the material was studied using a Carl Zeiss Stemi 2000-C dissecting microscope with a Canon Powershot A640 digital camera attached. Close-up images were taken using a Panasonic DMC-L10 digital camera with an Olympus Zuiko 35 mm macro lens and a Kaiser copy-stand with two Ikea lateral lights (Popa, 2011). Garmin Basecamp software was used for interpretation of geographical data and Corel Draw was used to prepare illustrations.

Systematics

The Carboniferous flora of the Cucuiova Formation is represented by pteridophytes and gymnosperms. This paleoflora is compressive and coal generating, as it generated the bituminous coals extracted from Baia Nouă and explored from Dragosela, Cozilele, Stânei, Cucuiova and Povalina valleys. Popa (2005) and Popa and Cleal (2012) updated the general list of taxa and described the paleoflora of the Baia Nouă mine. Regarding the Carboniferous paleobotanical heritage of the Sirinia Basin, Popa (2003) advanced the idea that the sterile dumps of former coal mines such as Baia Nouă deserve SSSI (Site of Special Scientific Interest) status. The Carboniferous list of the Sirinia Basin counts 116 taxa, but this list is under constant revision due to difficulties related to type collections and previous publications.

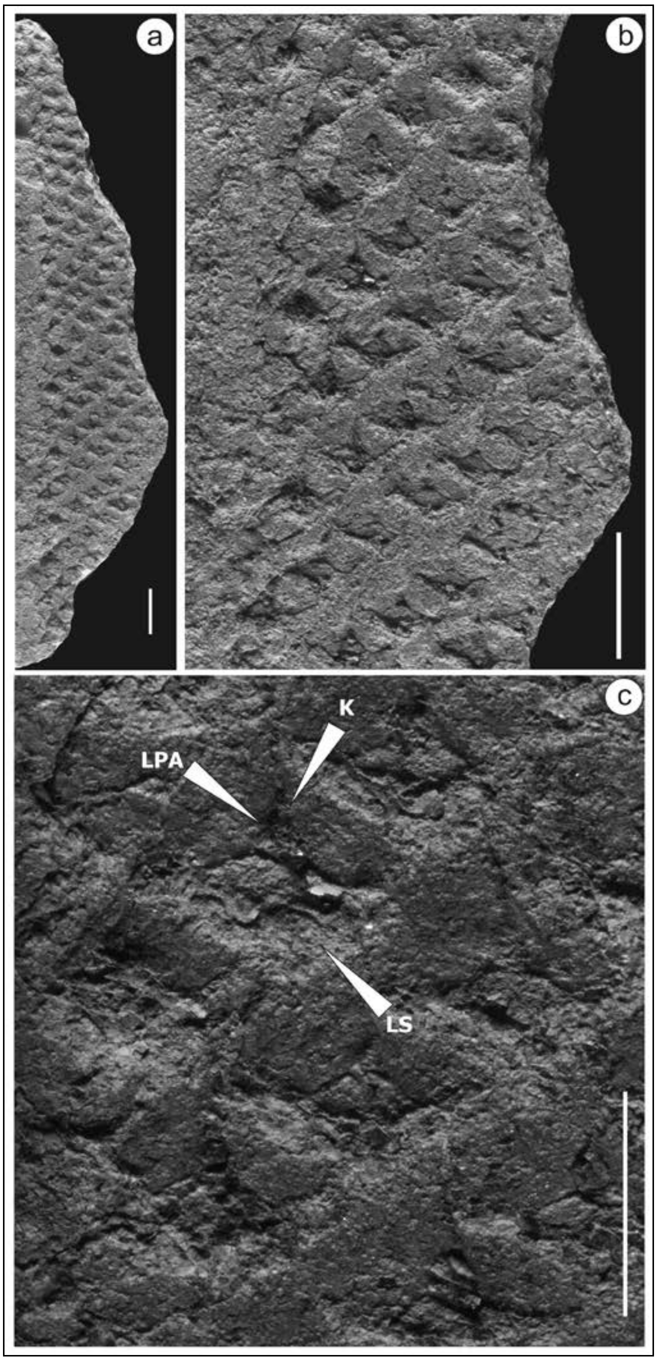
Pteridophytes include sphenopsids such as *Calamites carinatus* Sternberg, 1825, *Sphenophyllum cuneifolium* (Sternberg) Zeiller, lycopsids such as *Sigillaria tesselata* Brongniart, 1837, *Stigmaria ficoides* (Sternberg) Brongniart, 1822, and ferns such as *Pecopteris arborescens* Brongniart, and *P. cyathea* Brongniart, among many other species. Gymnosperms are represented by pteridosperms such as *Neuralethopteris rectinervis* (Kidston) Laveine, 1967 and *N. schlehanii* (Stur) Cremer, 1893 and conifers such as *Cordaites principalis* (Germar) Geinitz, 1855.

Pteridophyta
Lycopsida
Lepidodendrales
Lepidodendraceae
Genus *Lepidophloios* Sternberg, 1825

Genus *Lepidophloios* is rarer and less diverse than genus *Lepidodendron* Sternberg, and it is defined mainly by its broader than long leaf cushions (Crookal, 1929; Josten, 1991; Cleal and Thomas, 1994; Thomas et al., 2013). *Sublepidophloios* Sterzel, 1907 is also similar, with an intermediary position between *Lepidodendron* and *Lepidophloios* (Thomas et al., 2013). In Romania, the genus *Lepidophloios* was never cited, described or illustrated (Popa, 2005).

***Lepidophloios acerosus* Lindley and Hutton, 1831** (Fig. 2a-c)

1831 *Lepidophloios acerosum* Lindley and Hutton, (Fig. 1); 1910 *Lepidophloios acerosus* Renier, Pl. 8; 1929 *Lepidophloios acerosus* Crookal, p. 25-26, Pl. III, l; pl. XXII, k; 1994 *Lepidophloios acerosus* Cleal and Thomas, p. 71, text-fig. 24A, B, Pl. 4, figure 3; 2011 *Lepidophloios acerosus* Psenicka and Oplustil, p. 65, pl. II, figures 1-2; 2014 *Lepidophloios acerosus* Oplustil et al., p. 784, figure 7; figure 9A, B.



Figures 2a, b, c: *Lepidophloios acerosus* Lindley and Hutton, Dragosela Valley, Sirinia Basin, South Carpathians, stored in the Laboratory of Palaeontology, University of Bucharest as sample P377/C6/1. a. General view of the plant fragment, scale bar: 10 mm; b. Detail, showing leaf cushions, scale bar: 10 mm; Detail, showing enlarged leaf cushions.
LS: leaf scar, K: keel, LPA: ligule pit aperture, scale bar: 5 mm.

Description

An external cast of a trunk shows rhomboidal leaf cushions which are little broader than long, arranged spirally (Figs. 2a, b and c). The lower end or bulge of the leaf cushions is rather rounded, while their upper end is acute. The leaf scar occurs towards the base of the leaf cushion (Fig. 2c) and it is connected to the upper end of the leaf cushion through a prominent keel. The two other lateral keels are difficult to observe. The ligule pit aperture occurs just above the leaf scar (Fig. 2c). The leaf cushions are 6-7 mm wide and 5-6 mm long, and the leaf scars are 3-4 mm wide and 2-3 mm long (Fig. 2c).

Remarks

The shape of the leaf cushions, the lower position of the leaf scar and the prominent keel point to *Lepidophloios acerosus* Lindley and Hutton 1831. A similar species to *Lepidophloios acerosus* is *L. laricinus* Sternberg 1825, but the latter has much broader than long leaf cushions, a central position of the leaf scar and a less prominent keel.

Oplustil et al. (2014) consider *Lepidophloios acerosus* a canopy taxon, recording it within the lower part of the Radnice Member of the Kladno Formation, in Ovcin, Czech Republic. There, *Lepidophloios acerosus* is recorded as Bolsovian (Westphalian C) in age. The species was reported also from Ovcin and Svinna, by Oplustil et al. (2009), and from the Ujezd u Svateho Krize Coalfield in the Radnice Basin, where it is Bolsovian in age (Psenicka and Oplustil, 2011). In West Yorkshire, *Lepidophloios acerosus* is Langsettian (basal Westphalian or Westphalian A) in age (Cleal and Thomas, 1994). Cleal (2008) reported this species from the Etruria Formation, South Staffordshire Coalfield, where it may reach Bolsovian age, and also from northern Devon, within the upper Bideford Formation (Cleal and Thomas, 2004). In South Wales, within the Millstone Gritt sequences, *Lepidophloios acerosus* may reach even Namurian age (Cleal et al., 2009). Another occurence of *Lepidophloios acerosus* is reported from Dobrogea Coalfield (Tenchov, 1987; Cleal et al., 2009), Westphalian in age.

Lepidophloios acerosus may indicate any age in Sirinia Basin, including Langsettian, which is consistent with the ages marked by the assemblage with *Neuralethopteris schlehanii* and *N. rectinervis* in Baia Nouă, in the eastern part of the basin (Popa and Cleal, 2012). This could prove a wider development of Langsettian deposits in the Sirinia Basin, also in the western part, in Dragosela Valley. However, as *Lepidophloios acerosus* was reported elsewhere as Bolsovian in age, its occurrence in Dragosela Valley may be relevant for this age too. A Bolsovian age of *Lepidophloios acerosus* in the area is consistent with the Bolsovian – Cantabrian age of the Cucuiova Formation in Dragosela Valley, as this age was previously considered by Popa (2005). *Lepidophloios acerosus* may have no stratigraphic significance, as it could be recorded from Langsettian to Asturian (Barry T., pers. comm.).

Nevertheless, *Lepidophloios acerosus* is a coal generator, occurring in wet habitats such as the edges of coal producing mires. Libertin et al. (2009) reported *Lepidophloios acerosus* from distal floodplain paleosoils, above coal seams, from the Intra-Sudetic Basin, Czech Republic. *Lepidophloios* species marked various Late Carboniferous wet intervals, such as *L. harcourtii* (Witham) Seward and Hill for the Langsettian substage and *L. hallii* (Evers) DiMichele 1979 for the Westphalian D substage (Cleal, 1991).

Material and occurrence

Only a single fragment, rather badly preserved, recorded on hand specimen P37/C6/1 (Figs. 2a-c) was collected by Săvescu B. on the sterile dump of a former coal gallery in Dragosela Valley, in the northern-central area of the "Iron Gates" Natural Park. The fragment is curated in the collections of the Laboratory of Palaeontology, University of Bucharest.

CONCLUSIONS

The Carboniferous Cucuiova Formation of the Sirinia Basin outcrops scarcely within the Almăj Mountains, therefore its fossil plants are difficult to collect. Although they are usually poorly preserved, these fossils represent significant geological heritage values of the "Iron Gates" Natural Park, occurring especially in Baia Nouă, Cucuiova-Povalina and Dragosela localities, all of them being collected from the sterile dumps of former coal mines or rarely from small sized outcrops. In the Dragosela Valley, a former coal mine's sterile dump permitted to record a rare *Lepidophloios acerosus* fragment, the first report of this genus and species in Romania.

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REFERENCES

1. Biţoianu C., 1966 – Asupra prezenței speciei Cellulasclerotes giganteus în depozitele carbonifere de pe Valea Dragosella (Banat), *Studii şi cercetări de geologie, geofizică, geografie, Secţia geologie*, 11, 2. (in Romanian)
2. Biţoianu C., 1972a – Observaţii asupra conţinutului paleobotanic al depozitelor carbonifere din zona Baia Nouă (Banat), *Studii şi cercetări de geologie, geofizică, geografie, Secţia geologie*, 17, 125-130. (in Romanian)
3. Biţoianu C., 1972b – Conţinutul floristic al depozitelor carbonifere din zona Sviniţa, *Studii şi cercetări de geologie, geofizică, geografie, Secţia geologie*, 17, 391-399. (in Romanian)
4. Biţoianu C., 1973 – La flore du Carbonifere superieur de la Roumanie, Septieme Congres International de Stratigraphie et de geologie du Carbonifere, Krefeld, 115-127. (in French)
5. Biţoianu C., 1974 – Le Silezien des Carpathes Meridionales (Roumanie), *Bulletin de la Societe Belge de Geologie, Paleontologie et Hydrologie*, 83, 131-133. (in French)
6. Biţoianu C., 1987 – Consideraţii paleobotanice, petrografice şi genetice asupra huilelor carbonifere din Banat, *Contribuţii Botanice*, 89-97. (in Romanian)
7. Biţoianu C. and Ilie S., 1968 – Asupra prezenţei sclerotinitului în huila Carboniferă de pe Valea Dragosella (Banat), *Studii şi cercetări de geologie, geofizică, geografie, Secţia geologie*, 13, 243-247. (in Romanian)
8. Cleal C. J., 1991 – Carboniferous and Permian biostratigraphy, in Cleal C. J. (ed.), Plant fossils in geological investigation, London, Ellis Horwood, 182-215.
9 Cleal C. J., 2008 – Westphalian-Stephanian macrofloras of the southern Pennines Basin, UK, *Studia Geologica Polonica*, 129, 25-41.
10. Cleal C. J. and Thomas B. A., 1994 – Plant fossils of the British Coal Measures, The Palaeontological Association, London, 222.
11. Cleal C. J. and Thomas B. A., 2004 – Late Carboniferous palaeobotany of the upper Bideford Formation, north Devon: a coastal setting for a Coal Measures flora, *Proceedings of the Geologists Association*, 115, 267-281. (in French)
12. Cleal C. J., Oplustil S., Thomas B. A. and Tenchov Y. G., 2009 – Late Moscovian terrestrial biota and palaeoenvironments of Variscan Euramerica, *Netherlands Journal of Geosciences*, 88, 181-278.

13. Codarcea A., 1940 – Vues nouvelles sur la tectonique du Banat méridional et du Plateau de Mehedinţi, *Dări de semă ale şedinţelor Institutului Geologic Român*, 20, 1-74. (in French)
14. Crookall R., 1929 – Coal measure plants, Edward Arnold and Co., London, 80.
15. Dragastan O., Popa M. E. and Ciupercianu M., 1997 – The Late Palaeozoic phytostratigraphy and palaeoecology of the Southern Carpathians (Romania), Primul Simpozion Naţional de Paleontologie, Bucureşti, *Acta Palaeontologica Romaniae*, 1, 57-64.
16. Hantken M. P., 1878 – Die Kohlenflotze und der Kohlenbergbau in den Landern der ungarischen Krone, Legrady Testeverek, Budapest, 331. (in German)
17. Hauer F., 1870 – Kohlenvorkommen von Berzaska, Fundstelle der Ammoniten von Swinitza, 167. (in German)
18. Ilie S. and Biţoianu C., 1967 – Contribuţii la studiul huilelor de vârstă carboniferă din sinclinalul Dragosela (zona Sviniţa-Svinecea Mare), *Dări de seamă ale şedinţelor Comitetului Geologic*, 53, 60-68. (in Romanian)
19. Josten K. H., 1991 – Die Steinkohlen-Floren Nordwestdeutschlands, Tafelband, Krefeld, Geologisches Landestamt Nordrhein-Westphalen, 434. (in German)
20. Libertin M., Daskova J., Oplustil S., Bek J. and Edress N., 2009 – A palaeoecological model for a vegetated early Westphalian intramontane valley (Intra-Sudetic Basin, Czech Republic), *Review of Palaeobotany and Palynology*, 155, 175-203.
21. Maxim I. A., 1967 – Noi contribuţiuni asupra florei fosile de la Sviniţa-Banat, cu o privire comparativă între flora permo-carboniferă din zona Sviniţa, Reşiţa şi sudul Dunării, *Studia Universitaria Babeş-Bolyai*, *Geologia*, 2, 9-17. (in Romanian)
22. Maxim I. A., 1969 – Câteva plante din Stephanianul superior de la Sviniţa (Banat), *Studii și cercetări de geologie, geofizică, geografie, Secţia geologie*, 14, 405-422. (in Romanian)
23. Năstăseanu S., Stănoiu I. and Biţoianu C., 1973 – Corelarea formaţiunilor molasei hercinice (Westfalian-Permian) din partea vestică a Carpaţilor Meridionali, *Anuarul Institutului Geologic*, XL, 71-109. (in Romanian)
24. Oplustil S., Psenicka J., Libertin M. and Simunek Z., 2009 – Vegetation patterns of Westphalian and Lower Stephanian mire assemblages preserved in tuff beds of the continental basins of Czech Republic, *Review of Palaeobotany and Palynology*, 143, 107-154.
25. Oplustil S., Psenicka J., Bek J., Wang J., Feng Z., Libertin M., Simunek Z., Bures J. and Drabkova J., 2014 – T peat forming plant assemblages preserved in growth position by volcanic ash-fall: a case study from the Middle Pennsylvanian of the Czech Republic, *Bulletin of Geosciences*, 89, 773-818.
26. Petrescu I., Nicorici E., Biţoianu C., Ţicleanu N., Todros C., Ionescu M., Mărgărit G., Nicorici M., Duşa A., Pătruţoiu I., Munteanu A. and Buda A., 1987 – Geologia zăcămintelor de cărbuni, 2, Zăcăminte din România, Edit. Tehnică, Bucureşti, 386. (in Romanian)
27. Popa M. E., 2003 – Geological heritage values in the "Iron Gates" Natural Park, Romania, in Pătroescu M. (ed.), ICERA 2003, Ars Docendi Publishing House, Bucureşti, 742-751.
28. Popa M. E., 2005 – Aspects of Romanian Palaeozoic palaeobotany and palynology, II, Overview of the Upper Carboniferous formations in the South Carpathians, *Zeitschrift der Deutschen Gesellschaft fur Geowissenschaften*, 156, 415-430.
29. Popa M. E., 2011 – Field and laboratory techniques in plant compressions: an integrated approach, *Acta Palaeontologica Romaniae*, 7, 279-283.
30. Popa M. E. and Cleal C. J., 2012 – Aspects of Romanian Palaeozoic Palaeobotany and Palynology, III, The Late Carboniferous flora of Baia Nouă, Sirinia Basin, *Geologia Croatica*, 65, 329-243.
31. Preda I., Turculeţ I., Bădăluţă A., Barus T. and Androhovici A., 1994 – Geologia zăcămintelor de cărbuni, II, Răspândirea zăcămintelor de cărbuni, Edit. Universităţii din Bucureşti, Bucureşti, 392. (in Romanian)
32. Psenicka J. and Oplustil S., 2011 – Fossil flora from the Ujezd u Svateho Krize Coalfield (Bolsovian, Pennsylvanian), Radnice Basin, Czech Republic, *Folia*, 45, 61-94.

33. Răileanu G., 1953 – Cercetări geologice în regiunea Sviniţa-Faţa Mare, *Buletin Ştiinţific*, 5, 307-409. (in Romanian)
34. Răileanu G., Grigoraş N., Oncescu N. and Plisca T., 1963 – Geologia zăcămintelor de cărbuni, cu privire specială asupra teritoriului R. P. România, Bucureşti, 344. (in Romanian)
35. Schafarzik F., 1894 – Die geologischen Verhaltnisse der umgebung von Eibenthal-Ujbanya-Tiszovicza und Seinicza im Krasso-Szorenyer Komitate, *Jahrbuch de koniglisch ungarische geologische anstaldt A.*, (1892). (in German)
36. Schafarzik F., 1912 – Geologische Reambulation in der Umgebung von Berszaska, *Jahrbuch de koniglisch ungarische geologische anstaldt A.*, (1910). (in German)
37. Semaka A., 1962 – Observaţii asupra florelor paleomesozoice din Danubianul Banatului, *Dări de Seamă ale Şedinţelor Comitetului Geologic*, XLVII, 309-321. (in Romanian)
38. Semaka A., 1970 – Geologisch-Paleobotanische Untersuchungen in S. O. Banaten Danubikum, *Memorii*, XI, 1-79. (in German)
39. Stănoiu I. and Stan N., 1986 – Litostratigrafia molasei permian-carbonifere din regiunea Munteana-Sviniţa-Tîlva Frasinului (Banatul de Sud), *Dări de Seamă ale Institutului de Geologie și Geofizică*, 70-71, 39-50. (in Romanian)
40. Stur D., 1870 – Beitrage zur kenntnis der Dyas und Steinkohlen-formation im Banate, *Jahrbuch der kaiserlich-koniglichen geologische Reichsanstalt*, 20, 185-200. (in German)
41. Tenchov Y. G., 1987 – Les flores fossiles de Bulgarie, I.1, Paleozoique, Flore fossile, Megaflore, 1, Sphenopsida et Lycopsida, Sofia, Bulgarian Academy of Sciences, 165. (in French)
42. Thomas B. A., Tenchov Y. G. and Howell A., 2013 – A New Look at the Carboniferous Lepidodendroid Stem Genus Sublepidophloios Sterzel, *International Journal of Plant Sciences*, 174, 317-327.
43. Tietze E., 1872 – Geologische und Palaeontologischen Mitteilungen aus dem sudlichen Theil der Banater Gebirgstockes, *Jahrbuch der kaiserlich-koniglichen geologische*, Reichsanstalt, 22. (in German)

PHYTOGEOGRAPHICAL IMPORTANCE OF THE MOUNTAINS ALONG THE DANUBE MOUNTAIN GAP VALLEY AND SURROUNDING AREA

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ABSTRACT

The Danube mountain gap valley between Romania and Serbia is known for its high biodiversity, represented by many xero-thermophilous species, phytocoenoses and habitats of Southern origin. The occurrence of these species and phytocoenoses is strongly related to the geographical position on the continent, with related climate conditions and the geomorphological structure. The different phyto-geographical regionalisation highlights the uniqueness of the area, being the meeting point of species with their Northern, Southern, Western or Eastern limit in the Danube Gorge break. Here are presented the identifying species of characteristic phytocoenoses, threatened species and typical habitats with relevance for the European Natura 2000 network.

REZUMAT: Importanţa fitogeografică a Clisurii Dunării şi a zonelor adiacente.

Clisura Dunării situată între România şi Serbia este cunoscută pentru excepţionala sa biodiversitate, care este reprezentată prin numeroase specii, fitocenoze şi habitate xero-termofile de origine sudică. Prezenţa acestor specii şi fitocenoze este strâns legată de poziţia geografică pe continent, condiţiile climatice şi structura geomorfologică. Diferitele regionalizări fitogeografice scot în evidenţă particularitatea acestei zone, aceasta fiind punctul de întâlnire al speciilor care ating limita nordică, sudică, vestică sau estică în jurul clisurii. Sunt prezentate speciile edificatoare ale fitocenozelor caracteristice din zonă, speciile cu statut de periclitate şi habitate cu relevanţă pentru reţeaua Europeană Natura 2000.

ZUSAMMENFASSUNG: Die pflanzengeographische Bedeutung des Durchbruchtals der Donau und angrenzender Gebiete.

Das zwischen Rumänien und Serbien liegende Durchbruchtal der Donau ist bekannt für seine außergewöhnliche Biodiversität, die sich durch viele xero-thermophile Arten, Phytozönosen und Habitate submediterraner Herkunft auszeichnet. Das Vorkommen dieser Arten und Pflanzengesellschaften ist eng gebunden an die geographische Lage auf dem Kontinent, die Klimabedingungen sowie die geomorphologische Struktur. Die unterschiedlichen pflanzengeographischen Gliederungen heben die Besonderheiten des Gebietes hervor, die den Treffpunkt vieler Arten darstellt, deren nördliche, südliche, westliche oder östliche Verbreitungsgrenze im Gebiet des Donaudurchbruchs liegt. Vorgestellt werden die Bestand bildenden Arten der charakteristischen Pflanzengesellschaften, Arten mit ihren Gefährdungskategorien sowie die für das Natura 2000 Netzwerk relevanten Habitattypen.

INTRODUCTION

The mountains along the Danube mountain gap valley, also known as the Danube Gorge break valley of the South-Western Carpathians between Serbia and Romania are famous for their outstanding biodiversity. In comparison with other parts of the Carpathians this is the most thermophilous corner, sheltering many xerophilous and thermophilous species of Mediterranean, Sub-Mediterranean, Illyric, Balcanic, Pontic-Mediterranean and Pontic-Balcanic affinity. The occurrence of these species is related to the geographical position on the continent of the "Clisura" Gorge system, with related climate conditions, combined with other determining factors – especially the geomorphological structure – related to a diverse mosaic of geological substrate, with limestone, serpentine, crystalline schist and other rocks (Mutihac, 1972; Posea, 2002; Săndulescu et al., 1978).

This geology creates specific site conditions that contribute to the large variety of macro- and microhabitats in the region of the Danube Gorge. Related to the geomorphological structure and substrate that produces varied soil conditions, the inclination of the slopes and the effects of insolation contribute as well to the large variety of site conditions reflected in the occurrence of various macro- and microhabitats, biocoenoses, communities and species.

The uniqueness of the area reflects influences of the Sub-Mediterranean climate, leading to many varied considerations regarding the classification and integration of the area in a system of bio- respectively zoo- and phytogeographical or floristic-geo-botanical regions (Borza, 1931a, b; Ciocârlan, 2009; Borza and Boşcaiu, 1965; Călinescu, 1969; Horvat et al., 1974; Popova-Cucu, 1978).

According to Borza (Borza and Boșcaiu, 1965) in the geobotanical-floristic regionalization of Romania, the South-Western part of the Carpathian Mountains in the Banat area is included within the group of Southern Carpathian crystalline mountains (Carpaţii Meridionali cristalin – in Romanian), as a unit of the Banat Mountains (Oraviţa Mountains) including also the Semenic Mountains. The calcareous mountains along the Danube cross valley, the so called "Clisura" are not included here. The above-mentioned mountains are characterized by a thermophilous vegetation cover of Mediterranean, Illyrian and Balcanic-Asiatic species. Besides the beech forests characterised by European beech (*Fagus sylvatica*), at the montane level one can also mention Oriental beech (*Fagus orientalis*) and Taurian beech (*F. taurica*), Turkish hazel (*Corylus colurna*) and *Athamantha hungarica*, a species of Apiaceae, as characteristic elements. In this category too are included as well the mountains on the left side of the Cerna River.

The lower calcareous mountains in the immediate vicinity of the Danube break gorge are included, according to Borza (Borza and Boșcaiu, 1965) in the Daco-Illyrian Province characterized by oak forests dominated by Turkey oak (*Quercus cerris*), with Hungarian oak (*Quercus frainetto*), Downy oak (*Quercus pubescens*) and Silver lime (*Tilia tomentosa*). This province presents a belt-like zone of variable size in the Western foothill area of the country, running along the Danube cross valley. It includes also the middle and lower part of the Cerna Valley and the hilly area along the southern foot of the Southern Carpathians and a part of the Danube Plain as far as the arc of the Carpathians and Southern Moldova (Meusel and Niedermaier, 1985). The vegetation of this area is – as these authors conclude – of Illyrian origin, and extends westwards to the foot of the Alps and as well to the South and East as far as Anatolia. This province is almost congruent with the geomorphological subunits of the area. On the southern border of the Southern Carpathians it corresponds to the Getic Plateau and the Carpathian Mountains (Carpaţii de curbură). The Getic subunit of Oltenia of the Daco-Illyrian Province ("Circumscripţia getică a Olteniei") includes forests of *Quercus frainetto, Fraxinus ornus, Carpinus orientalis, Danaa cornubiensis* (*Physospermum cornubiense* (L.) DC.), *Helleborus odorus, Smyrnium perfoliatum, Physocaulis nodosus, Cynosurus echinatus* and many Southern clover (*Trifolium*) species. On the rocky slopes occurs the endemic Black pine of Banat, *Pinus nigra* ssp. *banatica*. At Vârciorova *Dianthus pinifolius, Prangos carinata* and other Mediterranean species can be found.

The Banat subunit of the Daco-Illyrian province extends between the Danube River, Semenic Mountains and Poiana Ruscă and is characterized by thermophilous species such as *Trifolium subterraneum, Tamus communis, Acanthus longifolius, Fagus orientalis, Symphytum ottomanum, Asperula taurina, Ruscus aculeatus, Ruscus hypoglossum, Saponaria glutinosa, Cerastium banaticum, Seseli gracile, Seseli rigidum* and *Athamantha hungarica*. To the above-mentioned species should be added Spurge laurel (*Daphne laureola*), previously mentioned from the area (Roman, 1972a; Sârbu et al., 2013) and found during our field activities in tributary valleys of the Danube: Mraconia, Ponicova, Valea Rea, and Sirinia.

The Poiana Ruscă Mountains, which make the connection between the Banat Mountains and the Western Mountains (Munţii Apuseni) North of the Mureş River with Biharia, display strong South-Western influences in the flora without being characterized by endemic and relict species. But they shelter some xerothermic species such as Wild lilac (*Syringa vulgaris*), Wild vine (*Vitis sylvestris*), Smoke bush (*Cotinus coggygria*), Oriental hornbeam (*Carpinus orientalis*) and other xero-thermophilous and thermophilous species which are characteristic for these mountains (Borza and Boşcaiu, 1965). These species have a larger distribution in the Southern Banat, the mountains along the Danube cross valley and in the Cerna and Mehedinţi Mountains as well (Meusel and Niedermaier, 1985). At the same time they are also characteristic for the mountains on the right side of the Danube cross valley of Serbia, the Miroc and Liskovac Mountains (Niculae, 2014; Horvat et al., 1974).

According to Popova-Cucu (1978) the Poiana Ruscă and the entire Banat Mountains with the mountains along the Danube cross valley are included in the Dacian Province (Banat-Getic Sub-Province) of the Macaronesian-Mediterranean Region (Sub-Mediterranean Sub-Region), a categorisation which underlines the sub-Mediterranean character of the area of the Clisura. According to the phytogeographical regionalisation of Romania by Ciocârlan (2009) the Danube Gorge is part of the District of Banat and Poiana Ruscă Mountains in the frame of the Carpathian Province. The bio-geographical classification of Călinescu (1969) presents the area of Clisura and the Banat Mountains inclusive of the lower part of the Cerna Valley mountains as a part of the Moesian Province, but the Cerna middle and upper part as part of the Dacic province.

These differing opinions concerning the phytogeographical zonation, but at the same time other converging opinions, are understandable in such an area situated on a crossing point of Central – South-West European, Daco-Illyrian and Moesian influences. Confirming Borza and Boşcaiu (1965), the limit between the Daco-Illyrian province and the Central-European-Eastern Carpathians Province is unclear, present as gradual transitions, with interlocking of the distribution area of plants, phytocoenoses and habitats, depending on relief, slope angle and aspect.

Frequently the Danube mountain crossing and the Cerna Valley are considered as separate units due to their special and high biodiversity. The occurrence of many Southern Mediterranean, Illyric and Balcanic species that reach the limits of their distribution in the area along the “Clisura” or in the mountains of Southern Banat has long attracted scientists.

Studying the different vegetation maps including the Danube Gorge break area, they represent clearly the characteristics of a transition zone from Central to Southern i.e. South-Eastern Europe and the interlocking and overlapping of different phyto-coenological units. On the map of the natural vegetation of Danubian countries (Niklfeld, 1973), the Danube Gorge break is represented as a belt with woods identified by Oriental hornbeam (*Carpinus orientalis*) and Downy oak (*Quercus pubescens*), a smaller area with *Quercus frainetto, Quercus cerris* forests and Balcanic submontane Sessile oak and Sessile oak-*Quercus cerris* forests, partly with hornbeam. Central and South European montane beech forests identified by *Fagus sylatica* are represented as well on the surrounding hills and valleys (Figs. 1 and 2).

On the vegetation map of Romania for the Clisura area are represented as characteristic vegetation units the Quercion petraeae, Quercion frainetto and Carpinion alliances, phytocoenological units of *Fagus sylvatica* var. *moesica* and secondary grasslands of Danthonio-Chrysopogonetum. In the neighbouring Nera Valley area occur also forests identified by *Quercus petraea*, with *Fraxinus ornus* and *Carpinus orientalis* of the association Orno-Quercetum praemoesicum (Doniţă and Roman, 1976). The detailed maps of the Danube Gorge break vegetation on the stretch between Tri-Kule and Ieşelniţa (Resmeriţă et al., 1972), as well between Orşova and Drobeta-Turnu Severin (Roman, 1972b) present the characteristic phytocoenological units for the area, with between them many associations of sub-Mediterranean and Mediterranean character.

According to the biogeographical regions (Doniţă et al., 2005) the Danube Gorge break is included in the continental region. But this classification is too general to allow a detailed view for the Danube Gorge break area, as all details of Mediterranean, sub-Medietarranean and Balcanic influences become lost.

The objective here is to analyse and to emphasise the characteristics of the Danube Gorge break area from the phytogeographical point of view with its characteristic species, with those reaching their limit of distribution in the Danube Gorge break area and its surroundings and also the species identifying characteristic plant communities and habitats.

Figure 1: The Danube Gorge break valley. View from the Serbian side.

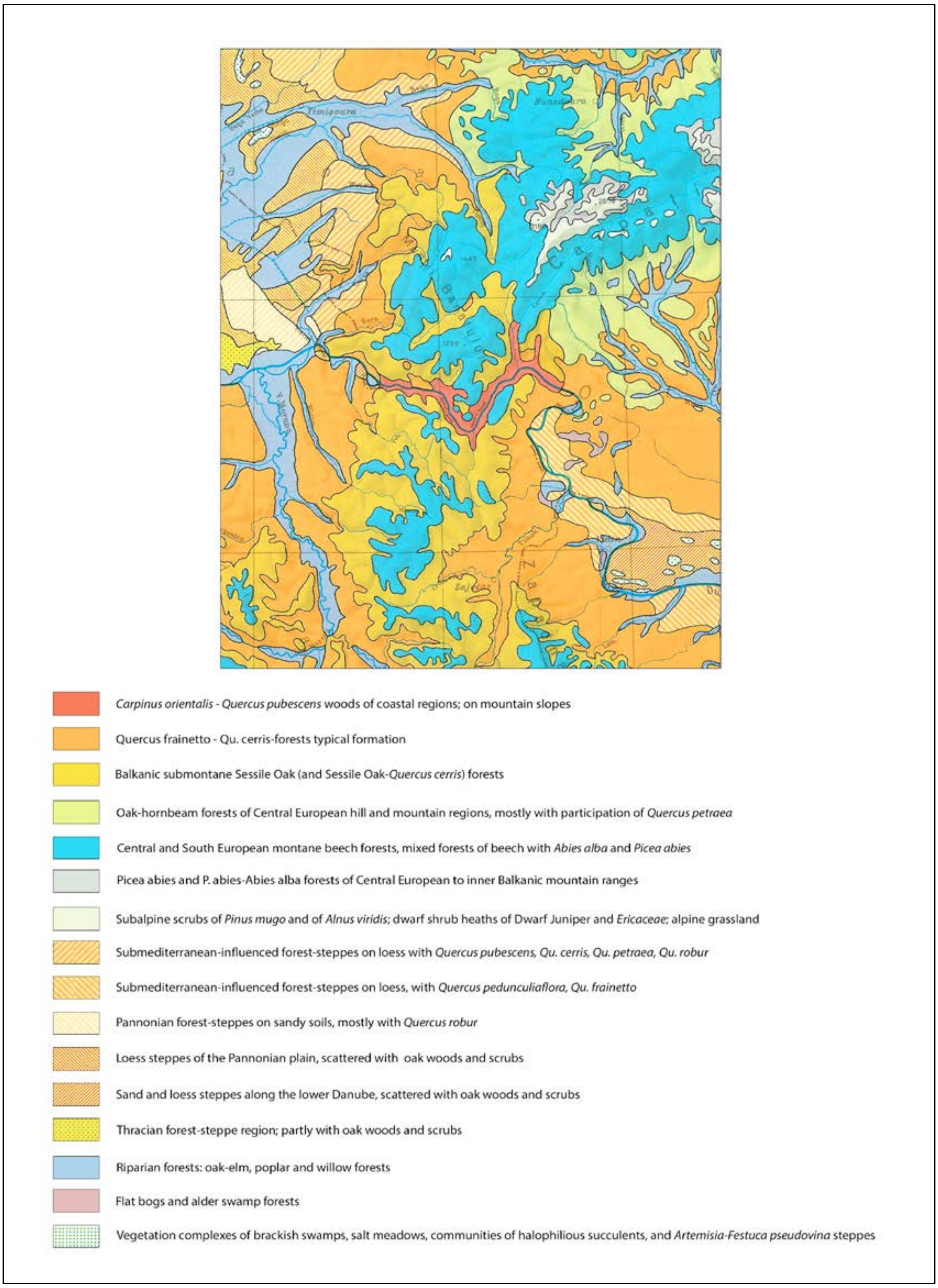

Figure 2: Natural vegetation of the Danube Gorge break and surrounding area (Natural vegetation by Niklfeld 1973 map 171 detail in the “Atlas of the Danubian countries”).

MATERIAL AND METHODS

To highlight the particularities of the Danube Gorge break valley, a list of characteristic species for the various habitats has been compiled, based on the author's earlier and recent research (2014, 2015). Attention was given on the one hand to thermophilous and xero-thermophilous species of Daco-balcanic, sub-Mediterranean and Mediterranean distribution area identifying characteristic phytocoenoses in the Clisura and surrounding area, and on the other hand to rare species which have their distribution limits in the "Clisura Dunării" or neighbouring area (Dihoru and Negrean, 2009). For these species Red List categories (IUCN criteria) are given according to the Red Book of vascular plants of Romania (Dihoru and Negrean, 2009): EX (extinct), CR (critically endangered), EN (endangered), VU (vulnerable), LR (low risk), and DD (data deficient). The other species were grouped according to their geographical distribution and analysed in the context of biogeographical zoning of the area in relation to their phyto-coenological affiliation, being characteristic for certain associations occurring in the study area. Species nomenclature follows Ciocârlan (2009), Dihoru and Negrean (2009) and Sârbu et al. (2013).

The different associations were analysed and discussed using comparative data from the surrounding area and adjacent biogeographical zones. To exemplify the Mediterranean character of some phytocoenoses of the Danube Gorge break, an analysis of phytogeographical elements was realised using published data (Boşcaiu et al., 1971), and unpublished data of the author for two associations Echinopo banatici-Quercetum pubescentis Boşcaiu 1971 and Syringo-Carpinetum orientalis Jakucs 1959.

The associations mentioned and inventoried from the area were included in the habitat types according to the Interpretation Manual of the European Union habitats (EUR 28, 2013).

RESULTS AND DISCUSSION

Analysing the characteristic elements of the flora of the Danube cross valley it becomes clear that the uniqueness is achieved by the presence of a great number of sub-Mediterranean and Mediterranean, Pontic-Mediterranean and Balcanic xero- to xero-mesophilous and thermophilous- to meso-thermophilous species. Some are identifying species for the characteristic phytocoenoses of the area and distinct elements in the natural landscape of the Danube cross valley.

In addition to the identifying species of characteristic phytocoenoses, have to be mentioned also species, which occurs frequently in many phytocoenoses, being differential for vegetation units of the Danube mountain gap valley. This fact is clearly visible if we compare them with phytocoenoses of other phytogeographical regions in the Carpathian-Danubian region. All together they are noted below grouped into categories of floristic elements according to their distribution area.

Woody species

Mediterranean flora elements: *Celtis australis* L.;
Sub-Mediterranean flora elements: *Acer monspessulanum* L., *Carpinus orientalis* Miller, *Fraxinus ornus* L., *Quercus cerris* L., *Quercus pubescens* Willd., *Prunus mahaleb* L. Miller;
Pontic-Mediterranean species: *Cotinus coggygria* Scop., *Cornus mas* L., *Vitis sylvestris* C. C. Gmelin;

Pontic-Balcanic species: *Fagus taurica* Popl., *Fagus orientalis* Lipsky;
Balcanic species: *Corylus colurna* L., *Quercus frainetto* Ten.;
Balcanic-Pannonian: *Tilia tomentosa* Moench (*T. argentea* DC);
Carpatian-Balcanic-Anatolian: *Syringa vulgaris* L.

Herbaceous species

Mediterranean: *Asperula taurina* L., *Cynosurus echinatus* L., *Lychnis coronaria* (L.) Desr.;
Physocaulis nodosus (L.) Tausch. = *Myrrhoides nodosa* (L.) Cannon, *Saponaria bellidifolia* Sm., rare, *Smyrnium perfoliatum* L., *Muscari commutatum* Guss., very rare;
Atlantic-Mediterranean: *Ceterach officinarum* Willd. ssp. *officinarum*, *Physospermum cornubiense* (L.) DC (*Dannaa cornubiensis* (L.) Burnat;
Submediterranean: *Chrysopogon gryllus* (L.) Trin., *Orlaya grandiflora* (L.) Hoffm.;
Submediterranean-Atlantic: *Dioscorea (Tamus) communis* L.;
Central-European-submediterranean: *Allium flavum* L.;
Pontic-Mediterranean: *Paronychia cephalotes* (Bieb.) Besser, *Ruscus aculeatus* L., *Verbena supina* L. (rare, Sviniţa and Tri-kule wet places); *Fritillaria orientalis* Adams, Cazane and Veliki Strbac Mountain, Serbia (Tomovici et al., 2007);
Pontic-balcanic-Pannonian. *Ruscus hypoglossum* L.;
Balcanic: *Campanula lingulata* Waldst. and Kit., *Cephalaria laevigata* (W. and K.) Schrad., *Crocus flavus* Weston (= *C. moesiacus* Ker.-Gawl), *Symphytum ottomanum* Friv.,
Helleborus odorus Waldst. and Kit., *Sesleria filifolia* Hoppe, **Daco-Balcanic**: *Seseli rigidum* Waldst. and Kit.;
Daco-Balc-Illir.: *Centaurea atropurpurea* Waldst. and Kit.;
Carp-Balc: *Cerastium banaticum* (Rochel) Heuffel, *Erysimum comatum* Pancic (E. *saxosum* Nyár.);
Alpin-Carp-Balc: *Achnatherum calamagrostis* (L.) Beauv., *Geranium macrorrhizum* L., *Peltaria alliacea* Jaq. (rare);
Endemic: *Pinus nigra* L. ssp. *banatica* (Borbás) Novák, (Southern Carpathians),
Athamantha hungarica Borbás = *A. turbith* (L.) Brot. ssp. *hungarica* (Borbás) Tutin;
South-Eastern European-Asia Minor: *Cardamine graeca* L., rare (Roman, 1972a).

In the relatively narrow and part-deeply incised valleys of the Danube tributaries occurring many European mesophilous and meso-hygrophilous species characteristic of the montane level of the Carpathians. These include for example *Telekia speciosa* and *Petasites hybridus*. Accompanying the water courses they reach in the area down to low altitudes of 80-90 m a.s.l. These species that identify tall herbaceous wet fringe communities are of great interest from the ecological and the phytogeographical point of view.

Of the 548 taxa listed in the Red Book of vascular plants of Romania (from a total of 3,795 species and subspecies in the Romanian flora) a total of 102 occur in the Danube Gorge break area. These belong to the following categories of degree of threat (Tab. 1):

Table 1: Red book species of the Danube Gorge according to their threat category.

Species and ssp. of Romanian flora	Species and ssp. Red Book	Red book species and ssp. of the Clisura area	CR	VU	EN	LR	DD	EX
3,975	548	102	39	26	21	12	3	–

Most of them belong to the same categories of phytogeographical elements as the above-mentioned species. A great number are Southern (Mediterranean, sub-Mediterranean, Balcanic) species that reach the Northern limit of their distribution in the Danube Gorge. These include for example *Euphorbia myrsinites*, *Ferula heuffelii* and *Fumaria kraliki* (see the list below). Others, as for example *Daphne laureola* and *Gagea bohemica*, attain in the Danube cross valley area the North-Eastern limit of their distribution. Some European and Central European species such as *Asplenium adulterinum*, *Minuartia capillacea* or *Stipa eriocaulis* occur in the Danube Gorge area at the Eastern limit of their distribution area. *Cardamine enneaphyllos*, an European species, reaches in the Danube Gorge the South-Eastern limit of its occurence, being rare in the area. *Thlaspi jankae* occurs in the gorge area on its Southern border. Finally there are also present Eastern taxa such as *Paeonia mascula* ssp. *tridentata* and *Silene spergulifolia*, which reach in the mountains around the Danube Gorge area the Western limit of their distribution. These facts underlines the position of the Danube Gorge break area as a meeting, crossing and interlocking point of species from different phytogeographical zones and different distribution area.

List of species of the Danube Gorge break area and surroundings included in the Red Book of vascular plants of Romania (Dihoru and Negrean, 2009) in alphabetical order with their category of threat and distribution data.

Acanthus balcanicus Heywood et I. B. K. Richardson (*A. longifolius* Host non Poiret), Balc., **VU** (Dihoru and Negrean, 2009), on the Northern limit of its distribution area.

Acinos rotundifolius Pers., Med-submed, **LR**, on the North-Western limit of its distribution area.

Aethionema saxatile R. Br., Med (montan), **CR**, on the Northern limit of its distribution area.

Alyssoides utriculata (L.) Medit., submed., **CR**, on North-Estern limit of its area.

Alyssum montanum ssp. *gmelini* (Jord.) Em. Schmid., Ec-Eu-Ct, **LR**

Alyssm pichleri Velen., rare, Balc., **CR**, on the Northern limit of its area. Recently the species has not been found in the mentioned area of the Danube cross valley between Drencova and Svinița, as well Vârciorova area (Dihoru and Negrean, 2009).

Alyssum pulvinare Velen., Balc, **CR**, on the Northern limit of its area.

Alyssum stribrnyi Velen., rare, Balc-Anat., **DD**.

Alyssum wierzbickii Heuffel, Dac-Balc, **CR**, Clisura, gorge of Nera and Beușnița.

Asplenium adulterinum Milde, Central European endemic species, “exceptionally rare” (Dihoru and Negrean, 2009), **CR**, on the Eastern limit of its distribution area.

Asplenium lepidum C. Presl., submedit, **CR**, on the North-Eastern limit of its area.

Asplenium onopteris L., Atl.-Medit., **EN**, on the N-E limit of its distribution area (Dihoru and Negrean, 2009).

Campanula crassipes Heuffel, rare, Dac., **EN**, small distribution area.

Cardamine enneaphyllos (L.) Crantz, Central-Eur., European Endemic species, very rare (Cheile Nerei and Beuşniţei), **CR**, on the South-Eastern limit of its distribution area.

Centaurea calvescens Pancic, Moesian flora element. **VU**, on the Northern limit of its distribution area.

Cephalorhynchus tuberosus (Steven) Schian, East-Submedit., **VU**, on the Northern limit of its distribution area.

Cirsium creticum (Lam.) d'Urv., ssp. *creticum*, Medit., **EN**, only in South-Western part of Romania, on the Northern limit of its distribution area.
Colchicum arenarium Wald. et Kit., Danubian endemic species – Geto-Pannonian (Dihoru and Negrean, 2009), **EN**, rare, Ostrovul Moldova Veche.
Convolvulus althaeoides L. ssp. *tenuissimus* (Sibth. and Sm.) Stace., Balc.-Anatolian, **EN,** very rare (Sviniţa).
Coronilla emerus L. ssp. *emeroides* (Boiss. and Spruner) Hayek, Medit., **VU**, rare (1972b, Dihoru and Negrean, 2009), only in South-Western Romania, on the Northern limit of its distribution area.
Daphne laureola L., Atl.-Medit., very rare, **VU**, North-Eastern limit of its area.
Dianthus giganteiformis Borbás ssp. *kladovanus* (Degen) Soó, Geto-Moesian (Balc.) element, subend., **CR**, very small distribution area.
Dianthus pinifolius Sm. in Sibth. and Sm. ssp. *serbicus* Wettat., Balc, **CR,** rare, on the Northern limit of its area.
Eleocharis mitracarpa Steud., Euro-asiatic, **VU**, rare, on the Western limit of its distribution area.
Elymus panormitanus (Parl.) Izelev, Medit., **VU**, on the Northern limit of its distribution area.
Euphorbia myrsinites L., Medit., **EN**, on the Northern limit of its area.
Ferula heuffelii Griseb. ex Heuff., Dac.-Balc., rare, **EN**, on the Northern limit of its area.
Fumaria kralikii Jord., Eu-Medit., rare, **DD**, on the Northern limit of its distribution area.
Fumaria petteri Rchb. ssp. *thuretii* (Boiss.) Pugsley, Medit., rare, **DD**, on the northen limit of its distribution area.
Gagea bohemica (Zausch.) Schultes and Schult., submedit., rare, **CR-DD**, on the North-Eastern limit of its area.
Galium lucidum All., rare, Medit.-submedit., **VU**, on the North-Eastern limit of its European area, Beuşniţa Basin.
Genista januensis Viv., Apen.-Balc-Dac, **CR-DD**, on the Northern limit of its area.
Genista radiata (L.) Scop., Alp.-Apen.-Balc.-Dac., **CR-DD**, Beuşniţa Basin, Anina Mountains, on the Northern limit of its area.
Gladiolus illyricus Koch, Medit., rare (Mraconia Valley), **CR**, on the North-Eastern limit of its distribution area.
Herniaria hirsuta L. ssp. *hirsuta*, Submedit., rare, **CR**, Northern limit of its distribution area. On flooded area of the Danube Gorge break. As a consequence of the construction of the "Iron Gates" Dam the species has almost disappeared.
Hippocrepis comosa L., Atl-Medit., **VU**, rare.
Hordeum bulbosum L., Medit., rare; **CR**, on the Northern limit of its distribution area.
Hypericum rochelii Griseb. and Schenk, Dac-Balc, **EN**, very rare (Berzeasca in the Sirinia Valley), on the limit of its distribution area.
Iris reichenbachii Heuff., **LR**, Dac-Balc (Moesian), Northern limit of its distribution area (Danube Gorge, Cheile Nerei and Beuşniţei Valley, and Cerna Valley).
Jasione heldreichii Boiss. and Orph in Boiss., Dac.-Balc., **VU**, Trescovăţ Mountains, near Sviniţa (locus clasicus), Northern limit of its distribution area.
Lathyrus cicera L., Medit., **VU**, (Vârciorova).
Lotus angustissimus L., Atl.-Submedit., **EN**, Orşova.

Ludwigia palustris (L.) Elliott, **EN**, An-Subatl-Medit (Afro-Euro-American), on Moldova Veche Islet, on fine-grained sands (not reconfirmed).
Matricaria trichophylla (Boiss.) Boiss., Dac.-Balc.-Anat., **VU**, on the Danube (Vârciorova, Orşova).
Medicago polymorpha L., Submedit., **VU**, rare, on the Northern limit of its distribution area.
Minuartia capillacea (All.) Graebner in Ascherson and Graebner, Alp.-Balc.-Dac., very rare, Eastern limit of its area.
Minuartia cataractarum Janka, Dac., very rare, **VU**.
Minuartia graminifolia (Ard.) Jáv., Dac.-Medit, rare, **LR**, Northern limit of its area.
Minuartia hamata (Hauskn. and Bornm.) Mattf., Medit.-submedit, **EN,** extremely rare on the Danube sunny and sandy hill slopes between Schela Cladovei and Oglanic, on the Northern limit of its distribution area.
Minuartia hirsuta (Bieb.) Hand.-Mazz. ssp. *falcata* (Griseb.) Mattf., Balc-Anat., **EN**, very rare (Sviniţa at Tri Kule, Gura Văii and Vârciorova), on the Northern limit of its distribution area.
Notholaena maranthae (L.) Desv., Med-submed., **EN**, very rare, on the Northern limit of its distribution area.
Onobrychis alba (Waldst. and Kit.) Desv., Balc.-Apen.-Dac., **LR**, very rare Nera-Beuşniţa), Northern limit of its distribution area.
Ophrys apifera Huds. ssp. *apifera*, Atl-Med, **CR**, very rare, (Sviniţa-Tri Kule),
Ophrys scoplopax Cav. ssp. *cornuta* (Steven) Camus, Submedit., **CR**, very rare, North-Eastern limit of its distribution area.
Orchis pallens L., submedit, rare, **CR**.
Orchis papilionacea L., Medit., **LR**, rare, on the Northern limit of its area.
Orchis simia Lam., Atl-Submed, **EN**, rare.
Ornithogalum sphaerocarpum A. Kern., Submedit, **CR**, rare, North-Eastern limit of its area.
Paeonia mascula (L.) Mill., ssp. *mascula*, Submedit, **CR** very rare (only in the Ciclova Valley below Simion Peak and Beuşniţa Basin), On the North-Eastern limit of its distribution area.
Paeonia mascula (L.) Mill., ssp. *triternata* (Pall. Ex DC) Stearn and P. H. Davis (*P. daurica* Andrews (L.) DC), Cauc-Taurian-Anatolian-Getic (Dihoru and Negrean, 2009); rare **CR**, (Ciocanu Mountains near to Vârciorova), on the Western limit of its area.
Paeonia officinalis L. ssp. *banatica* (Rochel) Soó, Pannonian, **CR**, very rare, Baziaş, Eastern limit of its area.
Parietaria lusitanica L. ssp. *serbica* (Pancic) P. W. Ball., Dac-Moesic-Dobrogean, **EN**, extremely rare.
Paronychia kapela (Hacq.) A. Kern., Submedit., **CR**, very rare (Vârciorova-Schela Cladova, Cerna Valley), North-Eastern limit of its area.
Petrorhagia illyrica (Ard.) P. W. Ball and Heywood ssp. *haynaldiana* (Janka) P. W. Ball and Heywood, Medit-submed, **CR**, very rare, Northern limit of its distribution area.
Piptatherum holciforme (M. Bieb.) Roem. and Schult., Medit-East (Balc-Taurian-Anatolian), **CR**, rare, North-North-Western limit of its distribution area.
Polycarpon tetraphyllum (L.) L. ssp. *tetraphyllum*, Atl-Medit-submedit, **CR**, very rare, on the Northern limit of its area.

Polygala supina Schreber ssp. *hospita* (Heuffel) McNeill, Dac., **CR**, very rare (Sviniţa), unique locality in Romania for the taxon.
Prangos carinata Griseb. ex Degen, Dac., **VU**, hills slopes between Vârciorova and Gura Văii, "Iron Gates" (locus classicus).
Psilurus incurvus (Gouan) Schinz and Thell., Medit., **EN**, Northern limit of its area.
Ranunculus flabellifolius Heuff. and Rchb., Dac., **VU**, very small area.
Rhinanthus alectorolophus (Scop.) Pollich, Central-European, **VU**, South and South-Eastern limit of its area.
Saccharum strictum (Host) Spreng., Eastern-Medit., rare, **CR**, Northern limit of its area.
Sagina apetala Ard., Atl-Medit., **CR**, rare.
Salvia amplexicaulis Lam., Balc-Anatolian, very rare. **EN**, on the Northern limit of its area.
Saponaria glutinosa Bieb., Medit, **LR**, small populations.
Satureja montana L. ssp. *kitaibelii* (Wierzb.) P. W. Ball., Balc (Moesian), **LR**, rare, Northern limit of its area.
Scorzonera lanata (L.) Hoffm., Eastern submedit., **CR**, extremely rare, on the North-Western limit of its area.
Scutellaria columnae All. ssp. *columnae*, submedit., **CR**, rare (Danube Gorge, Nera in Gorj), on the North-Eastern limit of its area.
Scutellaria velenovskyi Rech, **CR**, Dac-Balc-Anatolian, very small area, on the Northern limit of its distribution area.
Sedum dasyphyllum L., Medit-submedit., **EN**, rare, North-Eastern limit of its area.
Sedum ochroleucum Chaix in Vill., Medit, **EN**, North-Eastern limit of its distribution area.
Silene flavescens Waldst. and Kit., Balc-Pan., **LR**.
Silene gallinyi Rchb. Apen-Balc, **CR**, rare, Northern limit of its distribution area.
Silene spergulifolia (Willd.) M. Bieb., Medit.-Cauc., **LR**, Western limit of its area.
Sison amomum L., Atl.-Medit-Anat, **VU**, Cerna Valley.
Sorbus borbásii Jáv., Dac, **VU**, small distribution area.
Spergula pentandra L., Medit-submed., **CR**, rare, near to the Eastern limit of its area.
Sternbergia colchiciflora Wald. and Kit., submedit. (Svinița), LR.
Stipa bromoides (L.) Dörfl., submedit-medit., **CR**, rare, near the Northern limit of its area.
Stipa danubialis Dihoru and Roman, Dacian endemic species, **CR**.
Stipa eriocaulis Borbás, submedit-Medit, **LR**, Eastern limit of its area.
Thlaspi dacicum Heuff. ssp. *banaticum* (Uechtr.) Nyár., Dac., **VU**, Cerna Valley.
Thlaspi jankae A. Kerner, Pannonian, **EN**, extremely rare (North-West of Drobeta-Turnu-Severin), Southern limit of its area.
Tragopogon balcanicus Velen., Dac-Balc, **VU**, rare, North-Western limit of its area.
Trifolium subterraneum L., Medit, **CR**, Northern limit of its area.
Tulipa hungarica Borbás, Dac, local endemic species, **CR**.
Verbascum pulverulentum Vill., Atl-Medit, on the North-Eastern limit of its area, **VU**,
Verbasum vandasii (Rohlena) Rohlena, **VU**, Dac-Balc (Moesian), North-Eastern limit of its distribution area.
Veronica crassifolia Wierzb. ex Heuff., Dac-Balc (Moesian), **VU**, rare.
Veronica scardica Griseb. Submedit., **VU**, rare.
Vicia truncatula Fisch., ex M. Bieb., Moesian-Dac-Anatolic, Caucasian, **CR**, Northern limit of its distribution area.
Vulpia ciliata Dumort., Medit., **EN**, on the Northern limit of its distribution area.

With regard to the larger vegetation units existing on the rocky slopes of the Danube Gorge break valley the most characteristic for the sub-Mediterranean vegetation are the “Shibliac” scrub formations of both sides of the Danube Gorge break in Romania and Serbia (Fig. 2), identified by Wild lilac (*Syringa vulgaris*), Oriental hornbeam (*Carpinus orientalis*), Manna or Flowering ash (*Fraxinus ornus*), Wig bush (*Cotinus coggygria*), locally in the ”Cazanele Mari”, also Montpellier maple (*Acer monspessulanum*) and others. They are identifying plant communities of the alliances Orno-Cotinion, Querco-Carpinion orientalis and Syringo-Carpinion orientalis (Sanda et al., 2008; Niculae, 2014).

If we compare the species composition from the characteristic phytocoenoses of the area of interest, exemplified by the two associations Syringo-Cotinetum orientalis Jakucs 1959 and Echinopo banatici-Quercetum pubescentis Boşcaiu et al. 1971 (Figs. 3 and 4), the number of Mediterranean and sub-Mediterranean species are prevalent. If we were to take into account not only the number of species but also the abundance-dominance values of the identifying species, the representativeness of the Southern categories of phytogeographical elements in the association would be even more distinct. Such examples can be given also by other characteristic phytocoenoses of the area, by forest vegetation with the association Quercetum cerris-carpinetosum orientalis (Resmeriţă et al., 1972) including many sub-Mediterranean and Balcanic species and also with open rocky slopes, their natural grasslands and crevice vegetation. Also the semi-natural grasslands, common in the localities of the neighbouring area are characterized by Southern species. More widespread in the Clisura area and Southern Banat are phytocoenoses of the association Chrysopogonetum grylli banaticum (Resmeriţă et al., 1971), identified by the sub-Mediterranean grass species *Chrysopogon gryllus* and accompanied by many other sub-Mediterranean species.

Both, the “Iron Gates” Natural Park in Romania and the “Djerdap” National Park on the Danube in Serbia shelter a great number of plant communities of high interest from a biogeographical point of view. As the area is under the influence of a sub-Mediterranean climate, the habitats differs from those of other parts of the Carpathians, but the transition is gradually with radiation till the Mureş Valley and even North of the Mureş in the Apuseni Mountains.

The habitats occurring in the Danube cross valley and surrounding area, including each characteristic phyto- and zoo-coenoses are preponderantly of relevance for the Natura 2000 network.

The habitat type 40A0* Subcontinental peri-Pannonic scrub includes a large number of associations of the order Syringo-Carpinion orientalis Jakucs 1959, most of them relicts from the Tertiary age. Characteristic species for the alliance are: *Syringa vulgaris, Carpinus orientalis, Campanula lingulata, Celtis australis, Dianthus giganteus* ssp. *giganteus, Cardamine graeca, Echinops banaticus, Ferula heuffelii, Hypericum rochelii, Piptatherum holciforme, Scabiosa banatica, Scutellaria pichleri*, and others.

Taking into account the distribution area of *Syringa vulgaris* (Meusel and Niedermaier, 1985; Horvat et al., 1974) and the most of identifying species of the association Syringo-Carpinetum orientalis, it becomes clear that they exceed by far the Peri-Pannonian region, being of importance over a larger area, i.e. the whole Balcanic-Eastern sub-Mediterranean region (Fig. 5).

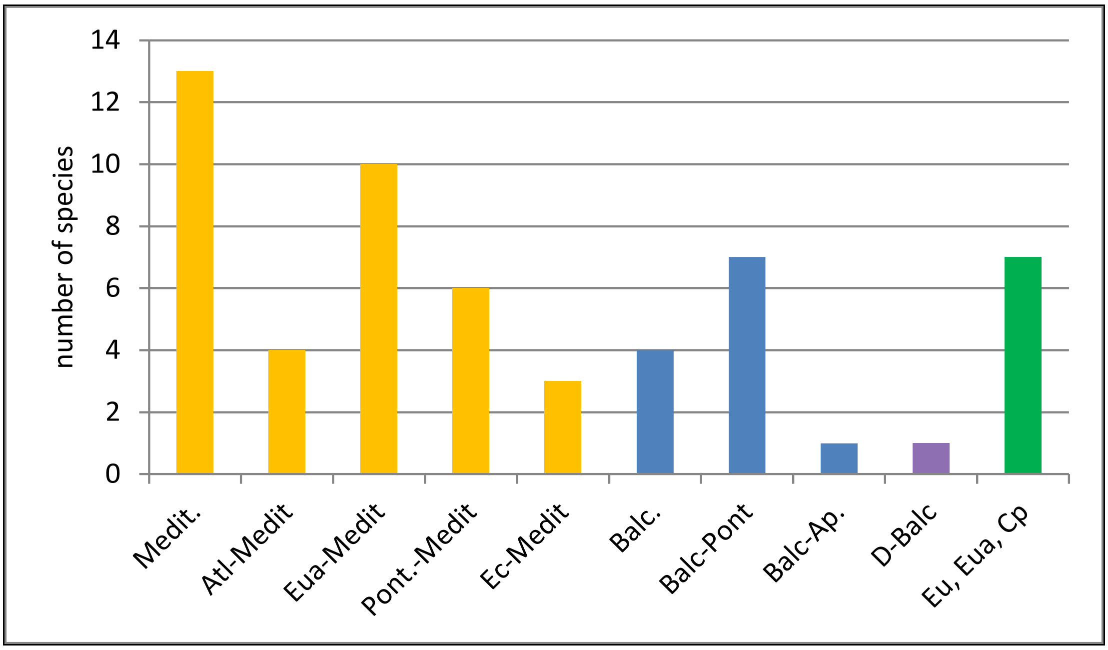

Figure 3: Syringo-Carpinetum orientalis Jakucs 1959
represented by groups of phytogeographical elements (according to data of phytocoenological tables by Boşcaiu et al. (1971), completed with recent field data 2014).

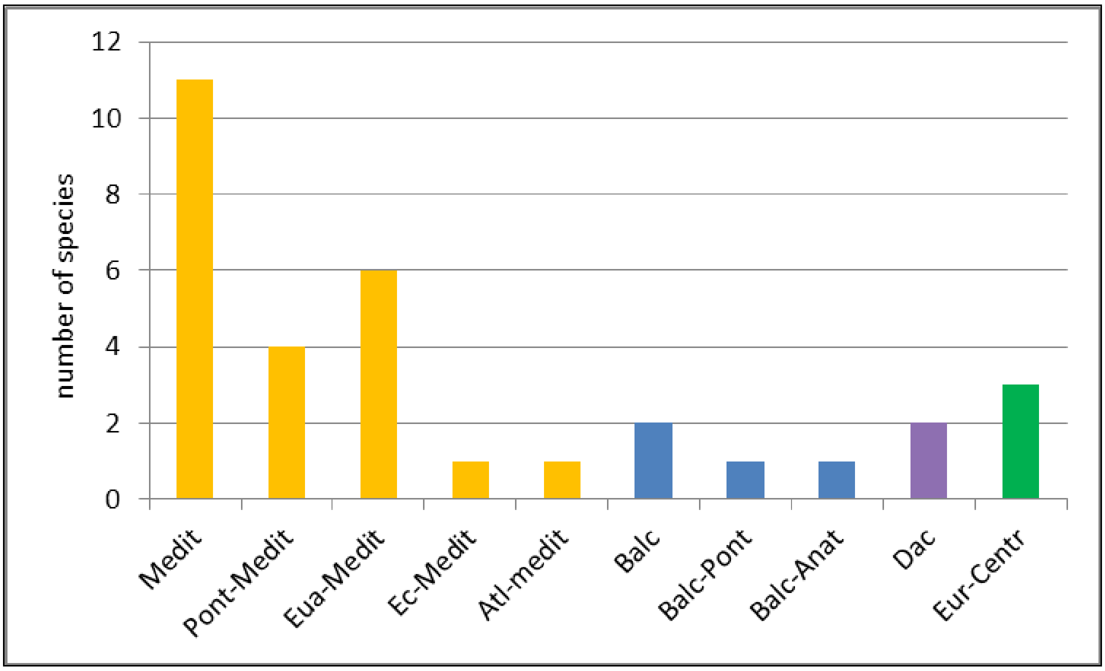

Figure 4: Echinopo banatici-Quercetum pubescentis Boşcaiu et al. (1971)
(= Acantho longifolii-Quercetum pubescentis Jakucs and Fekete 1958)
represented by groups of phytogeographical elements
(according to data in Boşcaiu 1971 completed by new data 2014).

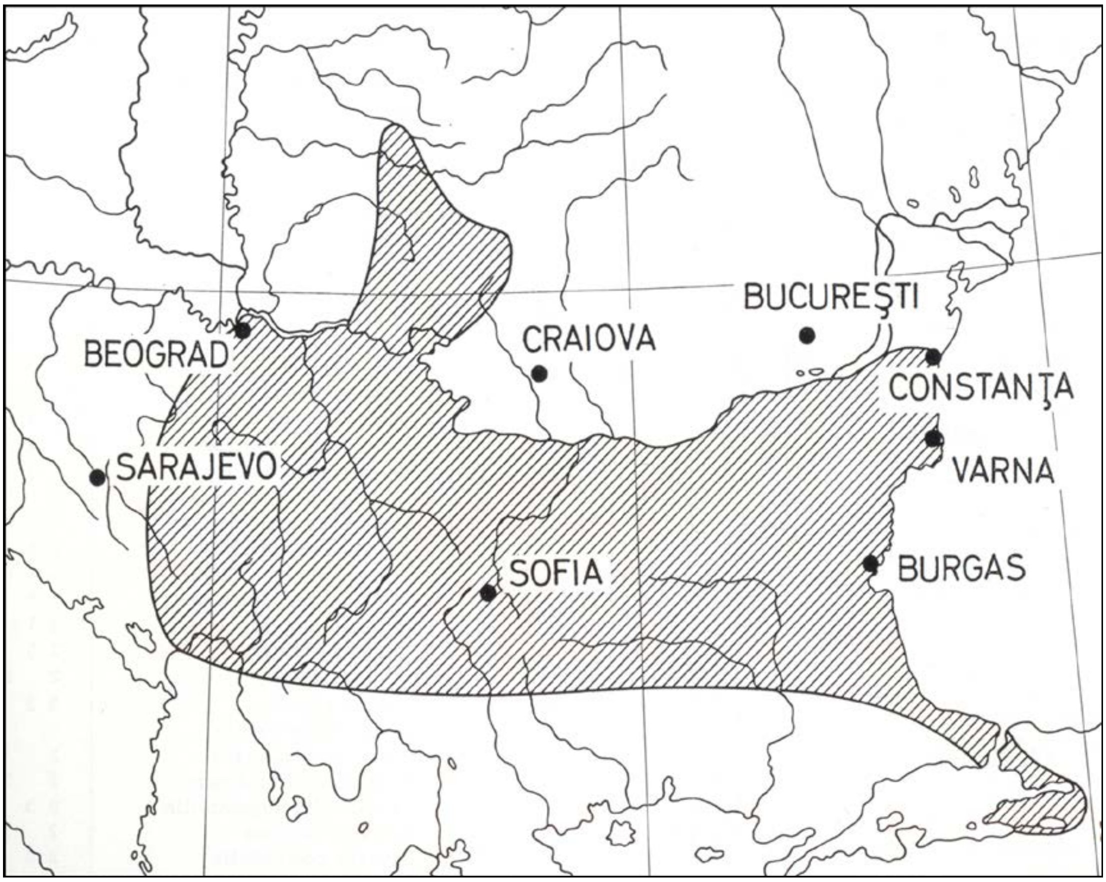

Figure 5: Distribution area of *Syringa vulgaris* (Horvat et al., 1974).

Other characteristic habitat types for the Danube Gorge break area are natural grasslands including the habitat types 6110* Rupicolous or basophile grasslands of the Alysso-Sedion albi and 6190 Rupicolous pannonic grasslands (Stipo-Festucetalia pallentis). Included are grasslands on the rocky slopes of the Clisura area between Sviniţa and Mraconia valleys (Schneider-Binder et al., 1970, 1971).

The semi-natural dry grasslands and scrubland facies are represented by the habitat types 6210 Semi-natural dry grassland and shrubland facies on calcareous substrates (Festuco-Brometalia, * important orchid sites) and 6240* Sub-Pannonic steppic grasslands. Included are grasslands of *Chrysopogon gryllus*, widespread in the Southern Banat and included in the association Danthonio-Chrysopogonetum grylli Boşcaiu (1970) 1972, Campanulo lingulatae-Brometum riparii (Roman, 1974) Sanda and Popescu 1999 (Roman, 1974; Gafta and Mountford, 2008).

The habitat type 6430 Hydrophilous tall herb fringe communities of plains and of the montane and alpine levels occurs in the small valleys of Danube tributaries where the characteristic species *Telekia speciosa* reaches the low altitude of around 80 m. These fringes with *Telekia speciosa* and *Petasites hybridus* are in strong contact with the Tilio-Acerion forests of the slopes, screes and ravines.

The rocky habitats of the Clisura area which are of interest are well represented by habitat types of siliceous and calcareous rocks substrate being strongly related to the mosaic of geological underground (Mutihac, 1972). The habitat type 8120 Calcareous and calcareous schist screes of the montane to alpine levels (Thlaspietea rotundifolii) is represented in the valleys of tributaries of the Danube Clisura area with phytocoenoses of the association Sedo fabariae-Geranietum macrorrhizi Boșcaiu and Täuber, 1977. Occurring as well in the area is the habitat type 8160* Medio-European calcareous scree of hill and montane levels in association with Stipetalia calamagrostis (EUR 28, 2013) with phytocoenoses of the association Achnatheretum calamagrostis Br.-Bl. 1918, which reaches the Northern limit of its distribution area in the South-Western Carpathians (Banat).

The rocky slopes with crevices occurring in the area are represented by the habitat type 8210 Calcareous rocky slopes with casmophytic vegetation, subtype 62.15 and 62.1 B Euro-Siberian communities and Mediterranean communities in different variants.

The shady communities of this subtype of habitats are those identified by the fern species *Cystopteris fragilis*, *Asplenium trichomanes*, *Asplenium viride* and the endemic phytocoenoses of *Campanula crassipes*. Xerophilous communities are represented by those identified mainly by *Ceterach officinarum* and *Asplenium ruta-muraria*.

Large areas of the Danube Gorge area and tributary valleys are covered by forests characteristic of temperate Europe with Central-European to South-Eastern European-Carpathian character, as well as forests with Moesian, Illyrian and Balcanic specificity with many termophilous species. The following forest habitat types occur in the area: 9110 Luzulo-Fagetum beech forest (small area), 9130 Asperulo-Fagetumbeech forest, 9150 Medio-European limestone beech forests of the Cephalanthero-Fagion, 9180* Tilio-Acerion forests of slopes, screes and ravines, characteristic for the small deep valleys of tributaries, 91E0* Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (Alno-Padion, Alnion incanae, Salicion albae), 91 H0* Pannonian woods with *Quercus pubescens*, 91K0 Illyrian *Fagus sylvatica* forests (Aremonio-Fagion), 91L0 Illyrian oak-hornbeam forests (Erythronio-Carpinion), 91 M0 Pannonian-Balkanic turkey oak-sessile oak forests, 91V0 Dacian Beech forests (Symphyto-Fagion), 91W0 Moesian beech forests, 91Y0 Dacian oak and hornbeam forests, 91Z0 Moesian Silver lime woods and 9530*(Sub-) Mediterranean pine forests with endemic black pines (*Pinus nigra* ssp. *banatica*) (EUR 28, 2008; Schneider and Drăgulescu, 2005; Doniţă et al., 2005).

The Illyrian forests of habitat type 91K0 and 91L0 occur only in a small area (Boşcaiu, 1971), interlocking gradually with the Medio-European type forest of the other parts of Carpathians. This can be stated on the one hand by following the distribution area of *Aremonia agrimonioides*, a Central European-Mediterranean species characteristic for Illyrian beech forests (Aremonio Fagion) and concentrated in the Carpathians in their South-Western part (Oprea, 2005). On the other hand the Illyrian oak-hornbeam forest (Erythronio-Carpinion) is characterised by *Erythronium dens-canis* L. and its ssp. *nivaeus* (Baumg.) Buia and Păun, the last being concentrated in the South-Western part of Carpathians.

The habitat type 91E0* Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (Alno-Padion, Alnion incanae, Salicion albae), occurs in very small area on the Danube because it suffered a loss after construction of the "Iron Gates" Dam and the barrier lake. But the habitat is present along the valleys of tributaries as gallery-type forest that is partly in a good conservation state. But on the downstream parts of tributaries suffered changes due to the backwater situation and the modification of their mouths into the backed-up Danube. Although some major changes have occurred, the Danube cross valley is of importance as an outstanding landscape area, with high biodiversity, representing the richest part of the Carpathian area. For this reason the Danube Gorge is in the attention of both countries Romania and Serbia, being under protection as a Natural Park both in Romania and Serbia with many efforts directed towards research, appropriate management and conservation (Niculae, 2014; Macura et al., 2010).

CONCLUSIONS

The Danube Gorge break valley is of high value and importance for its outstanding biodiversity and presents great interest from the biogeographical and nature conservation point of view. It shelters many Southern species that attain here their northernmost distribution limits, species that lend a sub-Mediterranean character to the vegetation of the Danube Gorge. For some of the sub-Mediterranean and Illyric-Mediterranean species the mountains around the Danube cross valley is their distribution route to the North-East as far as the Poiana Ruscă and Apuseni Mountains and even from there to the Transylvanian Basin.

At the same time the Clisura constitutes the Southern or South-eastern limit for Central European species and the Western limit of species of Pontic or Pontic-Mediterranean origin. It is a crossing and interlocking point of species characteristic for different biogeographical regions.

The Clisura functions also as a connection corridor for many species from upstream to downstream and from the right to the left side of the Danube. This function has been disturbed by the "Iron Gates" water reservoir, a barrier lake, which has changed the hydrological dynamics of the river and that of the mouth of tributaries modified by sedimentation and ponding due to the backwater situation. Overall the whole complex of the Clisura and surrounding area, with the forests, the rocky slopes and their specific vegetation is of outstanding value and needs further attention from the scientific, practical protection and conservation point of view.

REFERENCES

1. Borza A., 1931a – Die Vegetation und Flora Rumäniens. Guide de la sixième Excursion Phytogéographique Internationale, Roumanie 1931, *Jardin Botanique de l'Université de Cluj*, 1-55. (in German)
2. Borza A., 1931b – Botanischer Führer durch die Umgebung von Băile Herculane (Herkulesbad) bis an die Donau. Guide de la sixième Excursion Phytogéographique Internationale, Roumanie 1931, *Jardin Botanique de l'Université de Cluj*, 56-63. (in German)
3. Borza A. and Boşcaiu N., 1965 – Introducere în studiul covorului vegetal, Edit. Academiei R. S. România, Bucureşti, 340. (in Romanian)
4. Boşcaiu N., 1971 – Flora şi vegetaţia Munţilor Ţarcu, Godeanu şi Cernei, Edit. Academiei R. S. România, 464. (in Romanian)
5. Boşcaiu N., Lupşa V., Resmeriţă I., Coldea G. and Schneider E., 1971 – Vegetaţia lemnoasă mezo-xerotermă (Orno-Cotinetalia) din Defileul Dunării, *Ocrotirea Naturii*, 15, 1, 49-55, Edit. Academiei R. S. România, Bucureşti. (in Romanian)
6. Călinescu R., 1969 – Biogeografia României, Edit. Ştiinţifică, Bucureşti, 412. (in Romanian)
7. Ciocârlan V., 2009 – Flora ilustrată a României. Pteridophyta et Spermatophyta, Edit. Ceres, Bucureşti, 1141. (in Romanian)
8. Dihoru G. and Negrean G., 2009 – Cartea Roşie a plantelor vasculare din România/Red book of vascular plants of Romania, Edit. Academiei Române. Bucureşti, 630. (in Romanian)
9. Doniţă N. and Roman N., 1976 – Atlasul Republicii Socialiste România, foaia VI-2. Vegetaţia/Vegetation. Unităţi zonale pe altitudine, Edit. Academiei Române, Bucureşti. (in Romanian)
10. Doniţă N., Popescu A., Paucă-Comănescu M., Mihăilescu S. and Biriş I. A., 2005 – Habitatele din România, Edit. Tehnică Silvică, Bucureşti, 496. (in Romanian)
11. EUR28, 2013 – Interpretation Manual of the European Union habitats. European Commission DG Environment, 144.
12. Gafta D. and Mountford O., 2008 – Manual de interpretare a habitatelor Natura 2000 din România, Risoprint, Cluj-Napoca, 101. (in Romanian)
13. Horvat I., Glavac V. and Ellenberg H., 1974 – Vegetation Südosteuropas. Vegetation of South-Eastern Europe, 768.
14. Macura B., Bojovic D., Petric I., Cosic N., Tadic M., Jaric I., Knezevic J., Spiric J. and Jaric M., 2010 – Local Communities and Management of Protected Areas in Serbia. Ecological Society ENDEMIT, 29.
15. Meusel H. and Niedermaier K., 1985 – Dei Breitlaubwälder des Süd- und Ostkarpatenraumes in vergleichend chorologischer Sicht. Naturwissenschaftliche Forschungen über Siebenbürgen. III, Beiträge zur Pflanzengeographie des Südost-Karpatenraumes, 1-42, Siebenbürgisches Archiv Band 20, Böhlau Verlag Köln Wien. (in German)
16. Mutihac V., 1972 – Structura geologică, in Atlasul complex „Porţile de Fier", 20, 134-136, Edit. Academiei R. S. România, Bucureşti. (in Romanian)
17. Niculae M.-I., 2014 – Integrated Management of biological and landscape diversity for sustainable regional Development and ecological connectivity in the Carpathians (Bioregio Carpathians). Study on the methodology for identification, characterization and classification of landscapes from the cross-border area "Iron Gates" natural Park and Djerdap National Park, Southeast Europe Transnational Cooperation Programme, Bioregio Carpathians, Romsilva, Parcul Natural Porţile de Fier, Ramsar, European Union, 10.
18. Niklfeld H., 1973 – Natürliche Vegetation/Natural vegetation, in Atlas der Donauländer/Atlas of the Danubian countries, Map volume/Map number 171. Distributed on commission by: Franz Deuticke Verlags- und Universitätsbuchhandlung, Wien/Vienna 1970-1989, edited and redacted on behalf of the Federal Ministry of Science and Research and in the name of the Austrian Institute of East and South-East European Studies by Breu J.

19. Oprea A., 2005 – Lista critică a plantelor vasculare din România, Edit. Universităţii „Alexandru Ioan Cuza" Iaşi, 668. (in Romanian)
20. Popova-Cucu A., 1978 – Atlasul Republicii Socialiste România, foaia VI-5, 2. Regiunile fitogeografice, Edit. Academiei Române, Bucureşti. (in Romanian)
21. Popova-Cucu A. and Bunescu A., 1974 – Atlasul Republicii Socialiste România, Elemente fitogeografice şi zoogeografice, VI-3, 1-8 elemente fitogeografice, 9-14 elemente zoogeografice, Edit. Academiei Române, Bucureşti. (in Romanian)
22. Posea G., 2002 – Geomorfologia României. Relief – tipuri, geneza, evoluție, regionare. Universitatea Spiru Haret, Edit. Fundației România de mâine, București, 444. (in Romanian)
23. Resmeriţă I., Vicol E. C., Boşcaiu N., Coldea G. and Täuber F., 1972 – Vegetaţia din sectorul Ieşelniţa-Tri Kule, in Atlasul complex „Porţile de Fier", Edit. Academiei R. S. România, Bucureşti, 47. (in Romanian)
24. Roman N., 1972a – Cormophyta: Taxoni rari, in Atlasul complex „Porţile de Fier", Edit. Academiei R. S. România, Bucureşti, 43. (in Romanian)
25. Roman N., 1972b – Vegetaţia din sectorul Orşova-Drobeta-Turnu Severin, in Atlasul complex „Porţile de Fier", Edit. Academiei R. S. România, Bucureşti, 46. (in Romanian)
26. Roman N., 1974 – Flora şi vegetaţia din sudul Podişului Mehedinţi, Edit. Academiei R. S. România, Bucureşti, 222. (in Romanian)
27. Sanda V., Öllerer K. and Burescu P., 2008 – Fitocenozele din România, Sintaxonomie, structură, dinamică şi evoluţie, Edit. Ars Docendi, Universitatea din Bucureşti, 570. (in Romanian)
28. Săndulescu M., Kräutner H., Borcoş M., Năstăseanu S., Pătrulius D., Ştefãnescu M., Ghenea C., Lupu M., Haralambie S., Bercea I. and Marinescu F., 1978 – Atlasul Republicii Socialiste România, Foaia II-1 Harta geologică/Geological map, Institutul de Geografie, Edit. Academiei R. S. România, Bucureşti. (in Romanian and English)
29. Sârbu I., Ştefan N. and Oprea A., 2013 – Plante vasculare din România. Determinator ilustrat de teren, Edit. Victor B., Bucureşti, 1231. (in Romanian)
30. Schneider-Binder E., Boşcaiu N., Coldea G., Lupşa V., Plămadă E. Resmeriţă I. and Stoicovici L., 1970 – Zur Felsenvegetation der Sektoren Eşelniţa-Mraconia und Cazan-Pass-Tricule (Durchbruchtal der Donau), *Revue Roumaine de Biologie, Série de Botanique*, 15, 5, 311-322. (in German)
31. Schneider-Binder E., Boşcaiu N., Coldea G., Lupşa V. and Resmeriţă I. 1971 – Zwei neue xerotherme Felsengesellschaften aus dem Durchbruchtal der Donau, *Revue Roumaine de Biologie, Série de Botanique*, 16, 2, 97-103. (in German)
32. Schneider-B. E. and Drăgulescu C., 2005 – Habitate şi situri de interes comunitar, Edit. Universităţii „Lucian Blaga" Sibiu, 167. (in Romanian)
33. Tomovic G., Vukojicic S., Niketic M., Zlatkovic B. and Stevanovic V., 2007 – Fritillaria (Liliaceae) in Serbia: distribution, habitats and some taxonomic notes, *Phytologia Balcanica*, 13, 3, 359-370, Sofia.

MORPHOMETRIC ANALYSIS TO EXTRAPOLATE GEOECOLOGICAL POTENTIAL OF THE RIVERS IN THE "IRON GATES" NATURAL PARK (BANAT, ROMANIA)

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ABSTRACT

The present study is based on morphometric analysis of watersheds from the "Iron Gates" Natural Park. Morphometric parameters of a river basin are influenced by a series of biotic and abiotic factors. This aspect makes the morphometric analysis very useful in describing the river systems and offers an image of all the interactions and processes that define the geoecological potential of running waters ecosystems. The parameters used in morphometric analysis are a good alternative for understanding the underlying geoecological factors at watershed scale, and especially where the necessary data on soil, lithology, geomorphology, vegetation and other are scarce.

ZUSAMMENFASSUNG: Morphometrische Analyse zur Extrapolation des geoökologischen Potentials der Flüsse im Naturpark Eisernes Tor (Banat, Rumänien).

Die vorliegende Studie beruht auf einer morphometrischen Analyse der Einzugsgebiete und Wasserscheiden im Naturpark Eisernes Tor. Die morphometrischen Parameter eines Einzugsgebietes sind beeinflusst durch eine Reihe biotischer und abiotischer Faktoren. Dieser Aspekt erweist sich als sehr nützlich für die Beschreibung der Fluss-Systeme und ermöglicht einen Überblick über alle Zwischenbeziehungen und Prozesse, die das geoökologische Potential von Fließgewässerökosystemen definieren. Die für die morphometrische Analyse verwendeten Parameter stellen eine gute Alternative zum Verständnis der zugrunde gelegten geoökologischen Faktoren auf Einzugsgebietsebene dar, vor allerm dort, wo die notwendigen Daten zu Böden, Lithologie, Geomorphologie, Vegetation und andere spärlich sind.

REZUMAT: Analiza parametrilor morfometrici utilizați în evaluarea potențialului geoecologic al râurilor din Parcul Natural Porțile de Fier (Banat, România).

Studiul de față se bazează pe analiza parametrilor morfometrici ai bazinelor hidrografice și rețelei de râuri din Parcul Natural Porțile de Fier. Parametrii morfometrici ai unui bazin hidrografic sunt influențați de o serie de factori biotici și abiotici. Acest fapt face ca analiza morfometrică să fie utilă în descrierea sistemului râului oferind o imagine a interacțiunilor proceselor care definesc potențialul geoecologic al ecosistemelor apelor curgătoare. Parametrii utilizați în analiza morfometrică constituie o alternativă bună pentru înțelegerea factorilor geoecologici la nivelul bazinului, în special acolo unde lipsesc datele despre sol, litologie, geomorfologie, vegetație și altele.

INTRODUCTION

The fundamental differences between the sciences that focus on aquatic ecosystem have imposed different approaches and perceptions of these ecosystems in general, and of running waters in particular. Some researchers perceive the rivers from the point of view of benthic invertebrates or fish on a given river or physico-chemical parameters on the condition the existence of this community of organisms (Curtean et al., 1999; Manko, 2008; Trichkova, 2009). On the other side, hydrologists perceive the same river in terms of water velocity, roughness of river bed, turbidity, gravel size, etc., and simplify these physical dimensions of the river to different relations that are determinant for the evaluation of potential river changes to the river flow dynamic. None of these approaches is superior, each represents a fraction of what should be acknowledged of the river ecosystems. It is essential to be informed of the hydrological, geological, morphological and vegetational setting of a river. A geoecological approach to rivers looks at a way of integrating the information from different sciences into a "complete image" that best defines the river system in a watershed (Tetelea, 2005).

Hydrologic and geomorphic processes appear within the basin, and morphometric characterization at the basin scale offer data regarding formation and development of land surface processes and thus furnish a holistic insight into the hydrologic comportment of a basin (Farrukh et al., 2013). Morphometric analysis offers a good alternative to understand the underlying geoecological factors at basin scale where other data on soil, lithology, geomorphology, vegetation, and so forth is scarce. Moreover, some of the morphometric parameters such as bifurcation ratio and circularity ratio are input parameters in the hydrograph analysis and evaluation of surface water potential of a specific area (Farrukh et al., 2013). In this context the morphometric analysis represent a better analysis of hydrologic behaviour of study area where gauge stations are missing.

The aquatic ecosystems' research in the "Iron Gates" Natural Park has been focused to a large extent on the Danube water body and less to the tributary rivers. Moreover, the geoecological approach of aquatic ecosystems and especially of the river systems is sustained by the fact that these ecosystems have not been studied since the establishment of the "Iron Gates" Dam in beginning of '70s. These were the main arguments to study the potential of the river system from the "Iron Gates" Natural Park from a geoecological perspective.

The proposed approach offers the opportunity to obtain practical and applied results necessary for the management of both the water body, as defined in the EU Water Framework Directive, and nature conservation. The scope of the study is to promote those morphometric elements of the river system that have a direct projection in the structure of the river network and functionality of river ecosystems.

MATERIAL AND METHODS

The present study is based on morphometric analysis of river basins and drainage network that reflects the geoecological potential of rivers from the "Iron Gates" Natural Park.

Morphometry is the measurement and mathematical analysis of the configuration of earth's surface, shape, patterns, and dimension of landforms. The understanding of evolution and behaviour of drainage patterns through quantitative methods if fundamental in catchment characteristics determination. Because of the inter-relationships between factors, one (usually the one most easily measured) can often serve as a surrogate for others. The selected factors can be used in the prediction of a catchment's hydrologic response to rainfall and for distinguishing one catchment from another for comparison or classification.

The complex interactions between all living communities and their environmental factors are called biogeoecology (Troll, 1969/1971). The biogeoecology recognizes the importance of geographic relations (space, altitude, scale, and exposure, etc.) in modelling the complex interactions between biotic and abiotic factors of the landscape (Tetelea, 2005). The geosystem represents the smallest homogeneous unit that can be visible at the chosen scale. The basic unit in hydrological analyses is the watershed, an area of surface whose major runoff is conveyed to a single outlet. The watershed incorporates all the interactions and processes that shape the landscape. The forming elements of the landscape and their role in the dynamics and potential of running waters are determined by a hierarchical control of processes and interactions within a geosystem (Fig. 1).

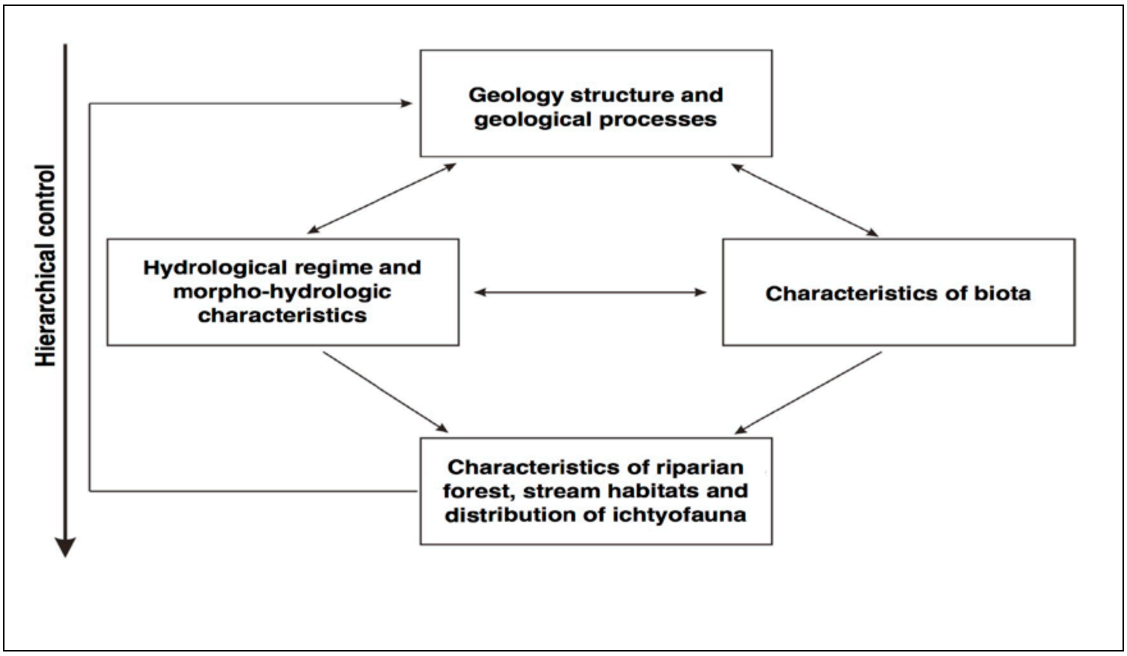

Figure 1: Hierarchical control of fundamental interactions in river systems (Naiman and Bilby, 2001).

This control can be shown through morphometric analysis of watersheds. The identification of watershed geomorphology and physical processes forms the basis for understanding the spatial extent of the riparian forest (Naiman and Bilby, 2001) as well as stream habitats, their quality, and the diversity and distribution of ichthyofauna.

River network in the "Iron Gates" Natural Park (Fig. 2) was generated in ArcGIS software from topographical maps at 1:25,000 and using a digital elevation model (DEM). Boundaries of 63 watersheds were delineated by defining the entire area contributing to flow at an outlet based on knowledge of topography. Area of watershed and perimeter were calculated based on the geometry of the derived watershed polygons. Drainage network was derived for each watershed from the "Iron Gates" Natural Park and all rivers were characterized based on stream order, flow type (perennial, intermittent), stream length, altitude at spring, and altitude at confluence.

Streams were classified using the system proposed by Sthraler in 1952 improved by Zăvoianu in 1978. The river network delineated from the topographical maps was extended with stream segments, which are usually not shown but can be derived from the contour lines. These segments have an intermittent character and were considered in the morphometric analysis. The river network of all the watersheds that are not entirely included in the limits of the "Iron Gates" Natural Park (e.g. Bahna, Mraconia, Berzasca, and Oreviţa) was fully derived in order to correctly establish all the relations of the proposed morphometric analysis.

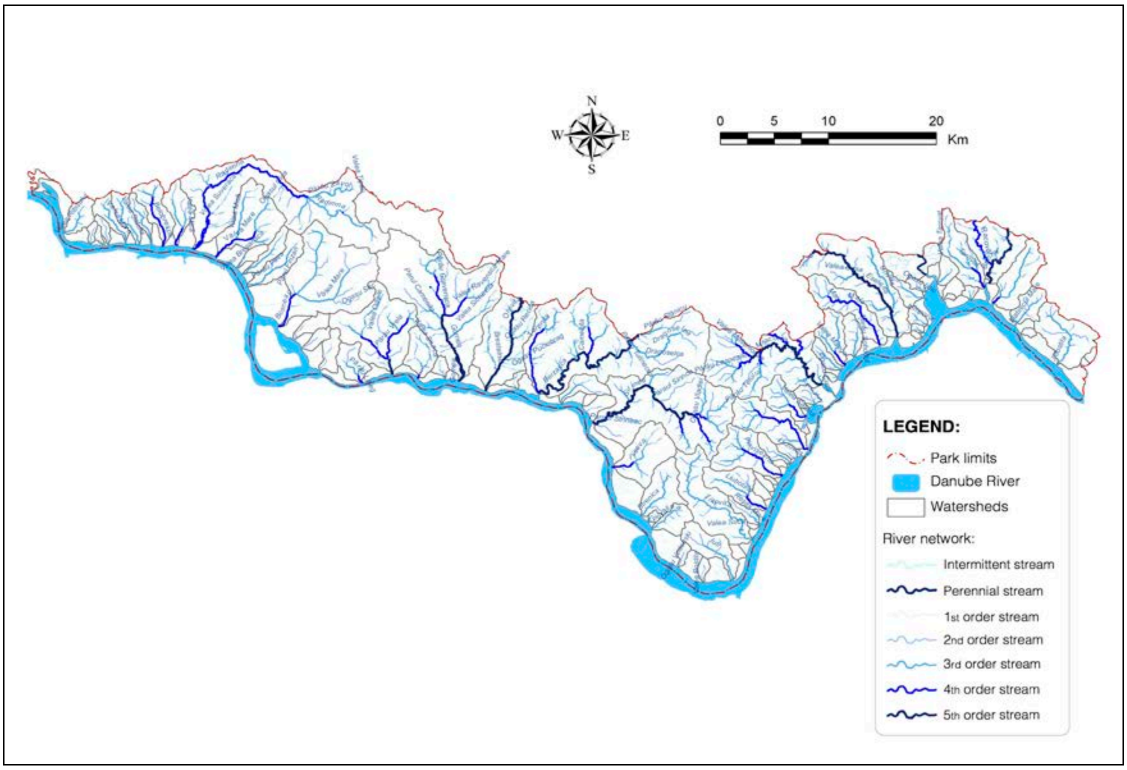

Figure 2: The hydrography of the "Iron Gates" Natural Park.

In the present study morphometric analysis of the parameters; namely, watershed surface and perimeter, length of the watershed, maximum and medium length of the watershed, relief ratio, form factor, medium slope of the watershed, mean slope width, length of the main stream in the watershed, total stream length, drainage density, total number of the length of a stream order, medium length of streams of same order, number of same stream order, stream frequency, bifurcation ratio, and drainage density for different stream orders of all 63 watersheds have been carried out using the standard mathematical formulae given in table 1. The values of all morphometric parameters are shown in table 2.

Description of the project area

The "Iron Gates" Natural Park is situated in the southwestern part of Romania and spans 115,655 ha along the Danube River in Southern Carpathians Mountains at the border with Serbia (Fig. 3). The counties of Caraș-Severin – western part, and Mehedinți – eastern part, almost equally share the park limits. The geographical location is between 21°21' and 22°36' eastern longitude and 44°51' and 44°28' northern latitude.

"Iron Gates" Natural Park is an area of outstanding diversity of landscapes, which is the result of various interactions in time of natural elements (lithology, relief, climate, hydrography, vegetation and wildlife) and human activities. These interactions have contributed to shaping one of the most spectacular areas in Romania, from the scientific, cultural, recreational, and educational perspectives. Because of the human-nature relations that shaped a landscape of aesthetic, ecological and cultural values, the "Iron Gates" Natural Park has been declared as a protected area according to the IUCN category V.

The high diversity of species and habitats of community interests present here has brought to the designation of this area as Natura 2000 site, both proposed Special Areas of Conservation (for the protection of habitats and species according to EU Habitats Directives) and Special Protection Area (for the protection of birds according to EU Habitats Directives). According to the "Iron Gates" Natural Park Management Plan approved on the 11th December 2013, there are 18 protected areas of biological, landscape, and paleontological and geological importance. Out of these 18 areas, four are Special Protection Areas for birds and wetland conservation: Divici – Pojejena 498 ha (a succession of five ponds and swamp areas along the Danube River), Calinovăţ Island of 24 ha (located on the Danube River between Baziaş and Divici), Ostrov – Moldova Veche of 1,627 ha (a large island with many wetland areas) and Nera Marsh – Danube a mixt reserve of 10 ha (situated in the western extremity of the park at the confluence of Nera River with the Danube).

After the construction of the "Iron Gates" Dam, all the confluences of the Danube's tributary streams have been flooded and transformed in gulfs of different areas. The biggest gulfs are those of Cerna, Bahna, and Mraconia rivers. Upstream the effect of the dam was the flooding of the alluvial fans formed by the tributary rivers (Berzeasca, Cameniţa). As a result the water surface increased and new wetland and riparian habitats emerged, which are characterized by specific top climate with increased humidity, low temperatures, etc. Some of the new gulfs received a high input of sediments that contributed to the formation of micro-deltas (Gornea – Sicheviţa, Cameniţa, Liuborajdea) with complex habitats necessary for the avian fauna and ichthyofauna.

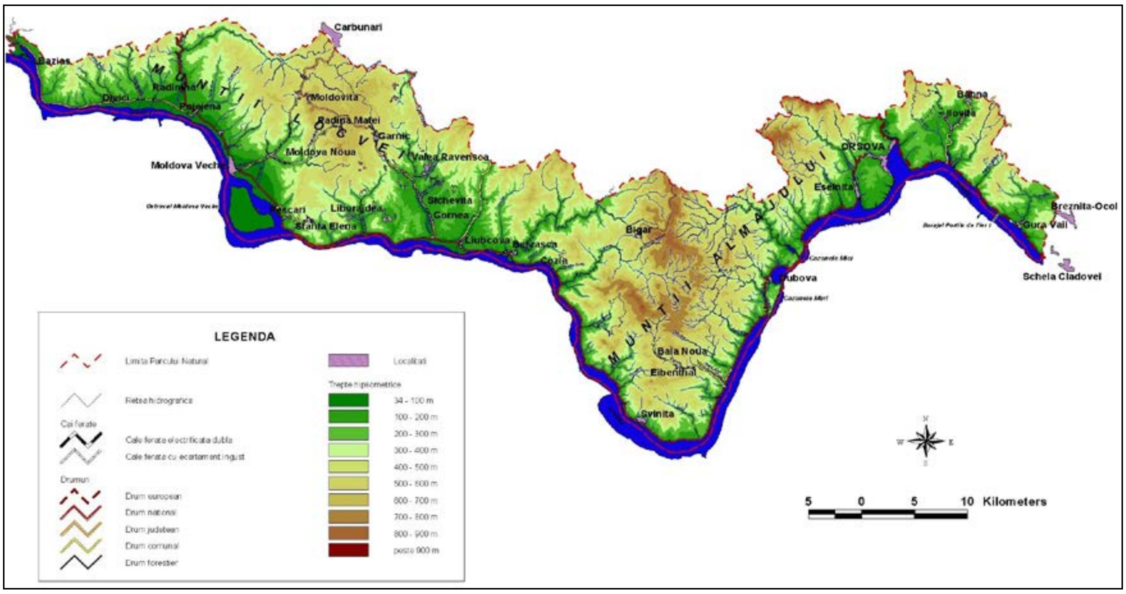

Figure 3: "Iron Gates" Natural Park – physical map.

Table 1: Methodology used for analysis of the morphometric parameters.

No.	Morphometric parameter	Formulae	Ref.
1.	Area of watershed (A)	Derived from the geometry of the delineated polygons in km^2	(18)
2.	Watershed perimeter (P)	Derived from the geometry of the delineated polygons in GIS	(18)
3.	Watershed length (L)	Distance from the pour point to a point at the watershed divide on the direction of the main stream	(18)
4.	Maximum watershed width (L_{max})	The maximum length of a perpendicular line to the line of the watershed length	(18)
5.	Mead width of watershed (B)	B = S/L; Where, B = mean width of basin; A = basin area; L = basin length	(16)
6.	Relief Ratio (R_r)	R_r = h/L; Where, h = difference of altitude between the highest point in the watershed and the pour point; L = basin length	(17)
7.	Form factor (R_f)	$R_f = D_c/L$; Where, D_c = diameter of a circle with area equal to watershed area ($D_c = \sqrt{(4xS)/p}$); L = watershed length	(1)
8.	Circularity ratio (R_c)	$R_c = 4*\pi*A/P^2$; Where, R_c = circularity ratio; π = “Pi” value that is 3.14; A = basin area; P = basin perimeter	(10)
9.	Mean slope of the watershed (S_b)	S_b = (alt. at 0.85L – alt. at 0.10L)/0.75L (S_b in % or units); L = watershed length	(23)
10.	Mean slope width (l_v)	l_v = 0.55 x S/∑L; Where, A = watershed area; L = basin length	(25)
11.	Length of main stream ($L_{râupp}$)	Derived in ArcGIS from topographical maps	(19)
12.	Total streams length (∑L)	Calculated as the sum of the length of all rivers in a basin	(19)
13.	Drainage density (D_d)	D_d = ∑L/S; Where, L = watershed length; A = basin area	(16)
14.	Number of streams of the same order (N_n)	Where n = stream order	(17)
15.	Mean length of streams of same order (L_{medNn})	Where n = stream order	(18, 19)
16.	Length of the streams of same order (∑N_n)	Where n = stream order	(17)
17.	Stream frequency (fN_n)	f = N_n/S; Where, N = number of stream segments of same order; A = watershed area	(18)
18.	Bifurcation Ratio (R_b); Mean bifurc. ratio (R_{bm})	$R_b = N_u/N_{u+1}$; Where, N_1 = total no. of stream segments of order „u”; N_{u+1} = number of segments of the next higher order	(7)
19.	Drainage density (D_n)	D_n = ∑L_n/S; Where, n = stream order; L_n = total length of stream segments of same order; S = watershed area	(18, 19)

Table 2: Morphometric characteristics of the river network in "Iron Gates" Natural Park (IGNP).

Mountain range													
			Locvei Mountains										
Watershead		Unit	Ribişului	Popin Valley	Sezova Valley	Şilianschi	Valea Mare (Divici)	Valea Staului	Valea Adâncă	Valea Mare (Şuşca)	Radimna	Valea Mare (Pojejena)	Bresansca
Danube Confluence		km	km 1068	km 1064	km 1063	km 1063	km 1061	km 1060	km 1059	km 1056	km 1055	km 1053	km 1051
Drainage basin morphometry	A	km^2	6.56	1.3	0.98	2.01	5.8	6.6	4.24	9.55	81.6	25.0	2.5
	P	km	11.8	5.6	0.49	7.5	14.9	14.1	12.4	16.2	70.8	24.7	8.3
	L	km	4.17	2.27	2.1	3.16	5.32	5.84	5.32	6.44	25.7	7.61	3.66
	Lmax	km	2.57	0.94	0.64	0.86	2.05	1.9	1.22	3.09	7.78	5.43	1.32
	B	km	1.57	0.57	0.47	0.64	1.09	1.13	0.8	1.48	3.13	3.29	0.68
	R_r	–	0.1	0.17	0.14	0.12	0.08	0.08	0.08	0.07	0.03	0.07	0.09
	R_f	–	0.39	0.32	0.3	0.29	0.29	0.28	0.25	0.31	0.22	0.42	0.28
	R_c	–	0.59	0.52	51.3	0.45	0.33	0.42	0.35	0.46	0.20	0.52	0.46
	S_b	%	5.08	15.7	13.5	9.8	7.02	6	7.22	6.83	2.13	5.5	8.96
	l_v	m	319	232	195	235	255	212	231	249	348	332	326
	Hmax	m	506	457	359	459	507	510	510	512	722	592	407
	Hmin	m	70	74	68	66	67	67	67	67	59	67	67
Drainage network morphometry	Lrâupp	km	4.52	1.78	2.01	2.9	5.81	6.37	5.28	6.94	32.5	8.22	3.31
	∑L	km	11.3	3.08	2.76	4.71	12.5	17.1	10.1	21.1	129	41.4	4.22
	D_d	km/km^2	1.73	2.37	2.82	2.34	2.16	2.6	2.38	2.21	1.54	1.66	1.69
	N1	–	16	4	2	4	15	18	11	17	112	37	2
	N2	–	5	1	1	1	3	5	3	6	32	11	1
	N3	–	1	–	–	–	1	1	1	2	6	5	–
	N4	–	–	–	–	–	–	–	–	1	2	1	–
	N5	–	–	–	–	–	–	–	–	–	–	–	–
	LmedN1	m	385	446	976	362	385	557	353	466	561	517	1,407
	LmedN2	m	459.81	1782.97	810.99	2905.74	527.59	407.06	590.22	1058.7	1008.34	706.71	1410.63
	LmedN3	m	2876.07	–	–	–	4937.46	5075.93	4441.78	2417.2	3593.41	1868	–
	LmedN4	m	–	–	–	–	–	–	–	1958.23	2368.7	5191.4	–
	LmedN5	m	–	–	–	–	–	–	–	–	–	–	–
	∑N1	km	6.15	1.78	1.95	1.80	5.8	10.0	3.87	7.92	58.3	19.1	2.81
	∑N2	km	2.29	1.72	0.82	2.9	1.6	2.03	1.77	6.35	26.3	7.73	1.41
	∑N3	km	2.87	–	–	–	4.9	5.07	4.44	4.83	21.0	9.34	–
	∑N4	km	–	–	–	–	–	–	–	1.96	23.5	5.2	–
	∑N5	km	–	–	–	–	–	–	–	–	–	–	–
	fN1	–	2.44	3.07	2.04	1.99	2.59	2.73	2.59	1.78	1.37	1.48	0.8
	fN2	–	0.76	0.76	1.02	0.5	0.52	0.76	0.71	0.63	0.39	0.44	0.4
	fN3	–	0.15	–	–	–	0.85	0.15	0.24	0.21	0.07	0.20	–
	fN4	–	–	–	–	–	–	–	–	0.1	0.02	0.04	–
	fN5	–	–	–	–	–	–	–	–	–	–	–	–
	R_{bN1}	–	3.2	4	2	4	5	3.6	3.67	2.83	3.50	3.36	2
	R_{bN2}	–	5	–	–	–	3	5	3	3	5.33	2.20	–
	R_{bN3}	–	–	–	–	–	–	–	–	2	3.00	5.00	–
	R_{bN4}	–	–	–	–	–	–	–	–	–	–	–	–
	R_{bm}	–	2.1	1.0	0.5	1.0	2.0	2.2	1.7	2.0	3.0	2.6	0.5
	DdN1	–	0.94	1.37	1.99	0.9	0.99	1.52	0.91	0.83	0.71	0.76	1.12
	DdN2	–	0.35	1.32	0.84	1.44	0.27	0.31	0.41	0.66	0.32	0.31	0.56
	DdN3	–	0.44	–	–	–	0.85	0.77	1.05	0.51	0.26	0.37	–
	DdN4	–	–	–	–	–	–	–	–	0.21	0.29	0.21	–
	DdN5	–	–	–	–	–	–	–	–	–	–	–	–

Table 2 (continued): Morphometric characteristics of the river network in the IGNP.

Mountain range			Locvei Mountains										
Watershead		Unit	Măceştilor	Pârva	Boşneag	Târnava	Văradului	Cicalovăț	Libeg	Liborajdea	Cruşovița	Caunița	Gornea +Sichevița
Danube Confluence		km	km 1050	km 1049	km 1045	km 1043	km 1042	km 1039	km 1034	km 1032	km 1030	km 1025	km 1024
Drainage basin morphometry	A	km^2	5.8	10.4	55.6	4.2	2.9	5.48	7.78	38.8	9.6	2.12	83.8
	P	km	14.5	17.8	38.0	10.6	8.3	12.4	13.1	33.1	13.8	6.75	50.2
	L	km	6.19	7.02	10.8	4.19	3.36	4.46	4.4	9.13	5.07	2.4	16
	Lmax	km	1.46	2.1	8.71	1.52	1.36	1.8	2.59	8.27	3.05	1.69	28.4
	B	km	0.94	1.48	5.13	1	0.86	1.23	1.77	4.25	1.89	0.88	5.24
	R_r	–	0.09	0.08	0.06	0.11	0.14	0.1	0.09	0.07	0.08	0.11	0.04
	R_f	–	0.25	0.29	0.44	0.31	0.32	0.33	0.4	0.43	0.39	0.39	0.36
	R_c	–	0.34	0.41	0.48	0.47	0.53	0.45	0.57	0.45	0.63	0.58	0.42
	S_b	%	8.4	6.7	5.8	10.0	17.3	9.18	8.24	7.08	4.1	7.11	3.6
	l_v	m	299	376	416	416	469	441	323	375	244	186	371
	Hmax	m	599	631	737	542	527	491	445	734	481	332	765
	Hmin	m	67	67	67	66	67	66	61	50	66	65	58
Drainage network morphometry	Lrâupp	km	6.06	8.09	11.7	4.53	2.5	3.12	4.67	6.38	4	2.51	9.75
	∑L	km	10.7	15.2	73.5	5.55	3.4	6.83	13.3	56.9	21.7	6.26	124
	D_d	km/km^2	1.84	1.46	1.32	1.32	1.17	1.25	1.7	1.47	2.26	2.95	1.48
	N1	–	12	7	58	2	2	7	21	54	25	11	127
	N2	–	3	2	21	1	1	1	5	17	14	2	40
	N3	–	1	1	2	–	–	–	2	7	2	1	8
	N4	–	–	–	1	–	–	–	1	2	1	–	2
	N5	–	–	–	–	–	–	–	–	1	–	–	1
	LmedN1	m	334.88	937.18	645.793	1800.8	768.84	529.52	309.71	437.37	435.92	358.46	455.439
	LmedN2	m	854.09	1181.7	1113.27	1949.81	1867.7	3124.44	677.2	833.57	707.45	770.04	806.04
	LmedN3	m	4100.69	6291.1	7432.7	–	–	–	1201.3	1227.9	2311.8	784.19	2128.07
	LmedN4	m	–	–	4056.6	–	–	–	967.09	2229.5	1191.98	–	3691.58
	LmedN5	m	–	–	–	–	–	–	–	4458.9	–	–	9759
	∑N1	km	4.01	6.560	36.81	3.60	1.53	3.70	6.50	23.16	10.89	3.94	57.84
	∑N2	km	2.56	2.36	17.81	1.94	1.86	3.12	3.39	14.17	4.95	1.54	32.24
	∑N3	km	4.1	6.29	14.86	–	–	–	2.40	8.59	4.62	0.78	17.02
	∑N4	km	–	–	4.06	–	–	–	0.97	8.917	1.19	–	7.38
	∑N5	km	–	–	–	–	–	–	–	1.65	–	–	9.75
	fN1	–	2.05	0.67	1.04	0.48	0.69	1.28	2.7	1.39	2.6	5.19	1.51
	fN2	–	0.52	0.19	0.38	0.24	0.34	0.18	0.64	0.44	1.46	0.94	0.48
	fN3	–	0.17	0.1	0.04	–	–	–	0.26	0.18	0.21	0.47	0.1
	fN4	–	–	–	0.02	–	–	–	0.13	0.05	0.1	–	0.02
	fN5	–	–	–	–	–	–	–	–	0.03	–	–	0.01
	R_{bN1}	–	4	3.5	2.76	2	2	7	4.2	3.18	1.79	5.5	3.18
	R_{bN2}	–	3	2	10.5	–	–	–	2.5	2.43	7	2	5
	R_{bN3}	–	–	–	2	–	–	–	2	3.5	2	–	4
	R_{bN4}	–	–	–	–	–	–	–	–	2	–	–	2
	R_{bm}	–	1.8	1.4	3.8	0.5	0.5	1.8	2.2	2.8	2.7	1.9	3.5
	DdN1	–	0.68	0.63	0.66	0.86	0.53	0.68	0.84	0.6	1.13	1.87	0.69
	DdN2	–	0.44	0.23	0.32	0.46	0.54	0.57	0.44	0.36	0.52	0.73	0.38
	DdN3	–	0.71	0.6	0.27	–	–	–	0.31	0.22	0.48	0.37	0.2
	DdN4	–	–	–	0.07	–	–	–	0.12	0.23	0.12	–	0.09
	DdN5	–	–	–	–	–	–	–	–	0.04	–	–	0.12

Table 2 (continued): Morphometric characteristics of the river network in the IGNP.

Mountain range			Almăj Mountains											
Watershead		Unit	Orevița	Zăstoc creek	Berzasca	Recita	Cozla	Sirinea	Elișeva	Strenica	Dâlbochi	Povalina	Vodeniski creek	Boșțița
Danube Confluence		km	km 1023	km 1020	km 1018	km 1015	km 1013	km 1012	km 1007	km 1001	km 998.6	km 998	km 993	km 990
Drainage basin morphometry	A	km^2	102	1.51	229	6.6	3.04	74.2	20.22	14.23	1.1	6.6	1.71	1.7
	P	km	28.1	6.6	245	13.76	7.59	46.8	20.19	18.71	4.4	11.7	6.29	6.1
	L	km	20.3	2.42	26.28	5.62	3.08	13.4	6.081	6.46	1.39	4.03	2.43	2.5
	Lmax	km	9.07	1.31	14.51	2.01	1.45	8.61	4.11	4.07	1.04	2.5	1.01	1.1
	B	km	5.03	0.62	8.71	1.17	0.99	5.54	3.33	2.2	0.79	1.64	0.7	0.7
	R_r	–	0.04	0.13	0.04	0.11	0.2	0.06	0.14	0.11	0.23	0.17	0.24	0.2
	R_f	–	0.32	0.32	0.37	0.29	0.36	0.41	0.47	0.37	0.48	0.41	0.34	0.3
	R_c	–	1.62	0.44	0.05	0.44	0.66	0.43	0.62	0.51	0.71	0.61	0.54	0.6
	S_b	%	4.2	11.57	2.6	9.8	19.26	5.73	11.25	9.7	18.23	13.46	18.66	23
	l_v	m	326	281	295	283	398	277	358	310	189	300	399	288
	Hmax	m	852	373	1068	687	659	874.5	908	776	392	752	651	600
	Hmin	m	66	66	54	65	51	48	61	61	68	63	67	70
Drainage network morphometry	Lrâupp	km	25	2.24	48.56	6.17	3.34	21.27	6.94	6.56	1.38	4.42	1.97	1.8
	∑L	km	172.3	2.96	427.2	12.83	4.2	147.5	31.09	25.28	3.2	12.08	2.36	3.3
	D_d	km/km^2	1.69	1.96	1.87	1.94	1.38	1.99	1.54	1.78	2.91	1.83	1.38	1.9
	N1	–	159	3	503	11	2	167	34	30	6	14	2	6
	N2	–	51	1	129	3	1	46	9	7	2	6	1	1
	N3	–	13	–	26	1	–	9	2	1	1	1	–	–
	N4	–	3	–	5	–	–	3	1	–	–	–	–	–
	N5	–	1	–	1	–	–	1	–	–	–	–	–	–
	LmedN1	m	536.5	440.5	516.2	447.6	1230	468.1	508.6	526.6	385.7	452.5	353.2	261
	LmedN2	m	829.8	1646	683.7	1676	1740	679	869.2	584.7	123.5	454.7	1657	1782
	LmedN3	m	1474	–	2346	2877	–	1643	1797	5397	642.4	3024	–	–
	LmedN4	m	2705	–	5882	–	–	2082	2379	–	–	–	–	–
	LmedN5	m	17421	–	33893	–	–	17.265	–	–	–	–	–	–
	∑N1	km	85.30	1.32	259.7	4.920	2.46	78.17	17.29	15.79	2.31	6.33	0.71	1.6
	∑N2	km	42.31	1.64	88.20	5.03	1.74	31.23	7.82	4.092	0.246	2.72	1.65	1.8
	∑N3	km	19.16	–	61.00	2.87	–	14.78	3.59	5.39	0.64	3.02	–	–
	∑N4	km	8.115	–	29.41	–	–	62.46	2.37	–	–	–	–	–
	∑N5	km	17.42	–	33.89	–	–	17.26	–	–	–	–	–	–
	fN1	–	1.56	1.98	2.20	1.67	0.66	2.25	1.68	2.11	5.45	2.12	1.17	3.4
	fN2	–	0.5	0.66	0.56	0.45	0.33	0.62	0.45	0.49	1.82	2.72	0.58	0.6
	fN3	–	0.13	–	0.11	0.15	–	0.12	0.1	0.07	0.91	3.02	–	–
	fN4	–	0.03	–	0.02	–	–	0.04	0.05	–	–	–	–	–
	fN5	–	0.05	–	0.004	–	–	0.01	–	–	–	–	–	–
	R_{bN1}	–	3.12	3	3.90	3.67	2	3.63	3.78	4.29	3	2.33	2	6
	R_{bN2}	–	3.92	–	4.96	3	–	5.11	4.5	7	2	6	–	–
	R_{bN3}	–	4.33	–	5.20	–	–	3	2	–	–	–	–	–
	R_{bN4}	–	3	–	5.00	–	–	3	–	–	–	–	–	–
	R_{bm}	–	3.6	0.8	4.8	1.7	0.5	3.7	2.6	2.8	1.3	2.1	0.5	1.5
	DdN1	–	1.2	0.87	1.13	0.75	0.81	1.05	0.86	1.11	2.1	0.96	0.41	0.89
	DdN2	–	2.41	1.09	0.39	0.76	0.57	0.42	0.39	0.29	0.22	0.41	0.96	1.0
	DdN3	–	5.32	–	0.27	0.43	–	0.2	0.18	0.38	0.58	0.46	–	–
	DdN4	–	12.57	–	0.13	–	–	0.84	0.12	–	–	–	–	–
	DdN5	–	5.86	–	0.15	–	–	0.23	–	–	–	–	–	–

Table 2 (continued): Morphometric characteristics of the river network in the IGNP.

Mountain range												
						Almăj Mountains						
Watershead		Unit	Iuţi	Bayinul Mare	Tişoviţa	Reşiţa Mare	Liubotina	Plavişeviţa	Cârnina Valley	Luzovoţa	Pârâul Morilor	Mare creek	Satului Valley
Danube Confluence		km	km 988	km 985	km 983	km 981.6	km 980	km 976	km 948.8	km 974	km 972.7	km 970.2	km 970
Drainage basin morphometry	A	km^2	12.22	1.49	30.47	3.08	14.1	18.33	3.8	1.95	19.48	1.1	8.97
	P	km	18.93	5.4	31.93	9.4	18.63	21.31	10	5.8	22.45	5.1	14.6
	L	km	7.16	2.13	11.22	4.09	7.06	7.02	4.28	2.39	8.49	1.3	4.85
	Lmax	km	2.83	1.59	4.03	0.15	3.31	5.36	1.23	1.18	3.52	1.2	2.77
	B	km	1.71	0.7	2.71	0.75	2	2.61	0.89	0.82	2.29	0.85	1.85
	R_r	–	0.09	0.22	0.07	0.12	0.1	0.11	0.14	0.18	0.09	0.24	0.15
	R_f	–	0.31	0.37	0.31	0.27	0.34	0.39	0.29	0.37	0.33	0.51	0.39
	R_c	–	0.43	0.64	0.38	0.44	0.51	0.51	0.48	0.73	0.49	0.53	0.53
	S_b	%	8.88	24.6	3.56	11.14	8.28	9.2	13.27	18.8	5.3	2.67	7.59
	l_v	m	313	264	310	239	280	205	269	228	220	240	213
	Hmax	m	747	531	890	553	803	803	663	500	800	369	793
	Hmin	m	77	59	62	62	62	60	60	61	76	60	59
Drainage network morphometry	Lrâupp	km	7.32	1.13	16	4.05	4.45	8.21	2.43	2.24	9.5	1.17	5.17
	∑L	km	21.5	3.1	54.11	7.1	27.7	49.2	7.77	4.7	48.67	2.52	23.2
	D_d	km/km^2	1.76	2.08	1.78	2.31	1.96	2.68	2.05	2.41	2.5	2.29	2.59
	N1	–	23	3	63	10	29	71	6	3	58	4	29
	N2	–	13	1	15	4	7	20	2	1	30	1	6
	N3	–	1	–	2	1	1	4	1	–	12	–	2
	N4	–	–	–	–	–	1	1	–	–	1	–	1
	N5	–	–	–	–	–	–	–	–	–	–	–	–
	LmedN1	m	468.48	725.48	474.2	264.44	540.56	395.04	437.13	1219.2	423.36	338.5	451.52
	LmedN2	m	399.29	926.91	791.48	757.41	634.44	554.22	1064.3	1042.5	824.5	1174.1	924.6
	LmedN3	m	5538.4	–	15059	1435.2	4883.3	1184.1	1709.2	–	1386.9	–	1082.1
	LmedN4	m	–	–	–	–	2702.7	5337	–	–	7851.9	–	930.96
	LmedN5	m	–	–	–	–	15.67	–	–	–	–	–	–
	∑N1	km	10.77	2.17	27.98	2.64	4.44	28.05	3.93	3	24.55	1.35	1.31
	∑N2	km	5.19	0.92	11.08	3.029	4.88	11.084	2.12	1	10.71	1.17	5.54
	∑N3	km	5.538	–	15.058	1.4	2.702	4.73	1.7	–	5.54	–	2.16
	∑N4	km	–	–	–	–	–	5.337	–	–	7.85	–	0.93
	∑N5	km	–	–	–	–	–	–	–	–	–	–	–
	fN1	–	1.88	2.01	2.07	3.25	2.06	3.87	1.58	1.54	2.98	3.64	3.23
	fN2	–	1.06	0.67	0.49	1.3	0.5	1.09	0.53	1.04	1.54	0.91	0.67
	fN3	–	0.08	–	0.07	0.32	0.07	0.22	0.26	–	0.62	–	0.22
	fN4	–	–	–	–	–	0.07	0.05	–	–	0.05	–	0.11
	fN5	–	–	–	–	–	–	–	–	–	–	–	–
	R_{bN1}	–	1.77	3	4.2	2.5	4.14	3.55	3	3	1.93	4	4.83
	R_{bN2}	–	13	–	7.5	4	7	5	2	–	2.5	–	3
	R_{bN3}	–	–	–	–	–	1	4	–	–	12	–	2
	R_{bN4}	–	–	–	–	–	–	–	–	–	–	–	–
	R_{bm}	–	3.7	0.8	2.9	1.6	3.0	3.1	1.3	0.8	4.1	1.0	2.5
	DdN1	–	0.88	1.46	0.92	0.86	1.11	1.53	1.03	1.87	1.26	1.23	0.15
	DdN2	–	0.42	0.62	0.36	0.98	0.31	0.6	0.56	0.53	0.55	1.06	0.62
	DdN3	–	0.45	–	0.49	0.45	0.35	0.26	0.45	–	0.28	–	0.24
	DdN4	–	–	–	–	–	0.19	0.29	–	–	0.4	–	0.1
	DdN5	–	–	–	–	–	–	–	–	–	–	–	–

Table 2 (continued): Morphometric characteristics of the river network in the IGNP.

Mountain range			Almăj Mountains									
	Watershed	Unit	Strineacului creek	Mraconia	Costeneț Valley	Satului Valley (Ogradena)	Sohodol	Mala	Eșelnița	Mozna Valley	Greasca Valley	Târlui Brook
	Danube Confluence	km	km 969.5	km 967	km 964.4	km 963.6	km 962.7	km 961	km 960	km 956.4	km 965.5	km 955
Drainage basin morphometry	A	km^2	2.8	113	3.8	9.69	5.7	17.74	48.61	0.8	2.3	4.6
	P	km	7.6	42.6	10.1	15.76	11.26	24.46	39.35	3.8	6.6	11.67
	L	km	2.4	13.42	4.19	5.71	4.4	9.13	20.66	1.34	2.3	4.25
	Lmax	km	1.6	12.24	1.29	2.94	1.7	2.84	5.74	0.8	1.54	2.06
	B	km	1.17	8.42	0.91	1.7	0.13	1.94	2.35	0.6	1	1.08
	R_r	–	0.16	0.06	0.1	0.1	0.11	0.09	0.04	0.12	0.1	0.1
	R_f	–	0.44	0.5	0.3	0.35	0.35	0.29	0.21	0.43	0.42	0.32
	R_c	–	0.61	0.78	0.47	0.49	0.56	0.37	0.39	0.70	0.66	0.42
	S_b	%	18.67	5.58	9.67	9.9	10.85	7.16	5.12	10.2	7.4	7.97
	l_v	m	157	208	162	220	189	179	166	171	225	218
	Hmax	m	455	820	483	643	563	905	969	230	291	489
	Hmin	m	62	69	59	60	60	59	59	68	65	62
Drainage network morphometry	Lrâupp	km	1.16	19	4.47	6.38	4.41	8.8	24.47	1.007	2.1	4.33
	∑L	km	9.84	299.18	12.94	24.24	16.56	54.45	160.78	2.58	5.62	11.61
	D_d	km/km^2	3.51	2.65	3.41	2.5	2.91	3.07	3.31	3.23	2.44	2.52
	N1	–	15	399	15	31	20	82	178	4	7	16
	N2	–	5	108	7	7	4	20	53	2	3	3
	N3	–	1	25	1	2	1	4	17	1	1	1
	N4	–	–	6	–	1	–	1	2	–	–	–
	N5	–	–	1	–	–	–	–	1	–	–	–
	LmedN1	m	375.22	407.7	482.83	443.59	530.03	353.38	480.54	189.88	471.48	364.35
	LmedN2	m	662.08	605.44	458.38	429.35	842.45	732.56	663.06	469.39	268.95	1094.2
	LmedN3	m	468.72	1275.4	2492.9	2893.8	2595.7	491.62	1032.6	359.88	1515.4	1501.8
	LmedN4	m	–	4317.3	–	1696.3	–	6671.7	1233.4	–	–	–
	LmedN5	m	–	13333	–	–	–	–	10.043	–	–	–
	∑N1	km	5.62	162.67	7.24	13.75	10.60	28.97	85.54	0.75	3.30	5.82
	∑N2	km	3.31	65.39	3.2	30.05	3.36	14.65	35.14	0.93	0.806	3.28
	∑N3	km	0.46	31.88	2.29	5.78	2.59	1.97	17.55	0.36	1.51	1.501
	∑N4	km	–	25.90	–	1.696	–	6.67	2.47	–	–	–
	∑N5	km	–	13.33	–	–	–	–	20.09	–	–	–
	fN1	–	5	3.53	3.95	3.2	3.51	4.62	3.36	5	3.04	3.48
	fN2	–	1.07	0.96	1.84	0.72	0.7	1.13	1.09	2.5	1.3	0.65
	fN3	–	1.36	0.22	0.26	0.21	0.18	0.23	0.35	1.25	0.43	0.22
	fN4	–	–	0.05	–	0.1	–	0.06	0.04	–	–	–
	fN5	–	–	0.01	–	–	–	–	0.02	–	–	–
	R_{bN1}	–	4.67	3.69	2.14	4.43	5	4.1	3.36	2	2.33	5.33
	R_{bN2}	–	3	4.32	7	3.5	4	5	3.12	2	3	3
	R_{bN3}	–	–	4.17	–	2	–	4	8.50	–	–	–
	R_{bN4}	–	–	6.00	–	–	–	–	2.00	–	–	–
	R_{bm}	–	1.9	4.5	2.3	2.5	2.3	3.3	4.2	1.0	1.3	2.1
	DdN1	–	2.01	1.44	1.91	1.42	1.86	1.63	1.76	0.94	1.43	1.27
	DdN2	–	1.18	0.58	0.84	3.1	0.59	0.83	0.72	1.16	0.35	0.71
	DdN3	–	0.16	0.28	0.6	0.6	0.45	0.11	0.36	0.45	0.66	0.33
	DdN4	–	–	0.23	–	0.17	–	0.38	0.05	–	–	–
	DdN5	–	–	0.11	–	–	–	–	0.41	–	–	–

Table 2 (continued): Morphometric characteristics of the river network in the IGNP.

Mountain range			Almăj Mountains	Mehedinți Mountains						
Watershed		Unit	Ijnic creek	Slătinic	Târziului Creek	Țarovăț	Bahna	Vodița	Slătinicul Mare	Jidoștița
Danube Confluence		km	km 955	km 953	km 951.2	km 950	km 950	km 954	km 947	km 941.7
Drainage basin morphometry	A	km^2	1.5	3.7	1.4	15.18	137	16.26	7.38	20.87
	P	km	6	8.3	0.52	21.2	73.92	20.14	12.8	22.21
	L	km	2.18	2.48	1.48	8.44	23.97	7.22	4.06	7.1
	Lmax	km	1.09	2.41	1.5	2.81	8.86	2.96	2.4	3.99
	B	km	0.68	1.49	0.95	1.8	5.73	2.25	1.82	2.94
	R_r	–	0.13	0.17	0.15	0.08	0.04	0.08	0.12	0.06
	R_f	–	0.36	0.49	0.51	0.29	0.31	0.36	0.43	0.41
	R_c	–	0.52	0.67	65.03	0.42	0.31	0.50	0.57	0.53
	S_b	%	9.6	6.18	9.64	7.41	2.45	6.9	10.92	6.57
	l_v	m	202	234	186	195	289	272	230	323
	Hmax	m	346	480	288	719	1047	633	548	484
	Hmin	m	64	64	67	80	62	62	71	34
Drainage network morphometry	Lrâupp	km	2.1	2.75	1.42	10.11	35	7.29	4.4	7.53
	∑L	km	4.09	8.69	4.13	42.78	261.09	32.89	17.68	35.56
	D_d	km/km^2	2.73	2.35	2.95	2.82	1.91	2.02	2.4	1.7
	N1	–	7	10	7	53	285	32	25	35
	N2	–	2	2	2	13	89	7	8	10
	N3	–	1	1	1	5	21	2	1	1
	N4	–	–	–	–	1	4	1	–	–
	N5	–	–	–	–	–	1	–	–	–
	LmedN1	m	341.77	636.18	338.56	398.85	474.73	602.5	388.93	547.06
	LmedN2	m	282.25	294.3	647.25	695.57	593.14	667.84	620.71	937.19
	LmedN3	m	1137.81	1454.64	475.49	2001	1471.50	3513.5	3001	7084.71
	LmedN4	m	–	–	–	2598.2	5074.90	917.62	–	–
	LmedN5	m	–	–	–	–	21.893	–	–	–
	∑N1	km	2.39	6.36	2.36	21.14	135.21	19.27	9.72	19.11
	∑N2	km	0.564	0.883	1.29	9.042	52.79	4.67	4.96	9.37
	∑N3	km	1.137	1.45	0.47	10.005	30.90	7.02	3	7.084
	∑N4	km	–	–	–	2.598	20.30	0.917	–	–
	∑N5	km	–	–	–	–	21.89	–	–	–
	fN1	–	4.67	2.7	5	3.49	1.29	1.97	3.39	1.68
	fN2	–	1.33	0.54	1.43	0.86	0.40	0.43	1.08	0.48
	fN3	–	0.67	0.27	0.71	0.33	0.10	0.12	0.14	0.05
	fN4	–	–	–	–	0.07	0.02	0.06	–	–
	fN5	–	–	–	–	–	–	–	–	–
	R_{bN1}	–	3.5	5	3.5	4.08	3.20	4.57	3.12	3.5
	R_{bN2}	–	2	2	2	2.6	4.24	3.5	8	10
	R_{bN3}	–	–	–	–	5	5.25	2	–	–
	R_{bN4}	–	–	–	–	–	4.00	–	–	–
	DdN1	–	1.59	1.72	1.69	1.39	0.61	1.19	1.32	0.92
	DdN2	–	0.38	0.24	0.92	0.6	0.24	0.29	0.67	0.45
	DdN3	–	0.76	0.39	0.34	0.66	0.14	0.43	0.41	0.34
	DdN4	–	–	–	–	0.17	0.09	0.06	–	–
	DdN5	–	–	–	–	–	0.10	–	–	–

RESULTS AND DISCUSSION

The "Iron Gates" Natural Park hydrography is defined by the Danube River, which contributed significantly to the individualization of this unique region in Europe known as Danube Gorge, or the transversal valley of the Danube.

As a definitive element of the landscape the Danube River has an influence on the particularities of other landscape components. On the Romanian sector of the Danube Gorge, the river is supplied by a series of tributary rivers with springs in the Semenic Mountains, Almăj Mountains, Cernei Mountains and Mehedinți Mountains. These rivers are presented from West to East in figure 2 and listed in table 2.

Most of the watersheds are aligned on N-S or NW-SW directions. Radimna and Sirinea watersheds are exceptions to this general feature and their orientation is quite longitudinal in the park area on a direction E-W (Tetelea, 2005). The length of the perennial rivers increases from West to East. The river network type in the "Iron Gates" Natural Park is dendritic, and the tributary streams of the main rivers make a sharp angle at the confluence depending on the watershed lithology.

Watershed area is one of the most important morphometric parameters of a river basin, having a great influence on the water availability in the river bodies and in shaping their size as well as the number of stream within the river basin. The watersheds in Locvei Mountains have areas below 10 km^2 with few exceptions of those watersheds extending outside the park limits in Locvei Mountains: Radimna (A = 81.5 km^2), Valea Mare (A = 25 km^2), Boşneag (A = 55.6 km^2) and Gornea-Sicheviţa (A = 83.8 km^2).

Watersheds in Almăj Mountains have areas larger than 10 km^2 and it is reflected in the river hydrological conditions. The largest watershed areas are over 100 km^2 and extend beyond the park limits: Oreviţa (A = 102 km^2), Berzasca (A = 229 km^2), Mraconia (A = 113 km^2). In Mehedinţi Mountains the seven watersheds that are inside the park have A between 1.4 km^2 and 22.1 km^2 with Bahna River basin extending outside the park limits with A = 137 km^2.

The length of the main rivers ($L_{râupp}$) from Locvei Mountains varies between 1.78 km (Popin Valley) and 32.5 km (Radimna) with a mean length of the main rivers of six km (Tab. 2). Most of the rivers run dry during the summer and have an intermittent character of torrentiality. The length of the main rivers in Almăj Mountains is between 1.13 km (Valea Mare) and 48.56 km (Berzasca) with a majority of the main rivers being longer than six km. The majority of rivers from the eastern part of the "Iron Gates" Natural Park have length below 10 km with one exception of Bahna River $L_{râupp}$ = 35 km which extends outside the park limit.

In the "Iron Gates" Natural Park are a series of small intermittent streams with small watersheds and a pronounced torrentiality hydrological pattern. These streams were not included in the morphometric analysis from table 2, and they are from West to East, Trăilă, Gârbovăţ, Codicea Mică Stream, Călina Mică, Jorbăjului, Grigore, Dâlboca, Ivanului, Stamati Valley, Virului Valley, and Oglănic.

Stream size is an important component to water management and very important to geographers, geologists, hydrologists and other scientists because it gives them an idea of the size and strength of specific waterways within river networks. In addition, classifying stream order allows scientists to easily study the amount of sediment in an area and effectively use waterways as natural resources.

Stream order also helps in determining what types of life might be present in the waterway. This is the idea behind the River Continuum Concept (Vannote et al., 1980), a model used to determine the number and types of organisms present in a stream of a given size. Different types of plants for example can live in sediment filed, slower flowing rivers like the Danube than can live in a fast flowing tributary of the same river.

The highest stream order among the 63 watersheds is five and is shown by eight watersheds: Liuborajdea (L_{medN5} = 4.45 km), Gornea – Sicheviţa (L_{medN5} = 9.7 km), Oreviţa (L_{medN5} = 17.4 km), Berzeasca (L_{medN5} = 33.9 km), Sirinia (L_{medN5} = 17.2 km), Mraconia (L_{medN5} = 13.3 km), Eşelniţa (L_{medN5} = 10 km) and Bahna (L_{medN5} = 21.8 km). Total number of stream or order five is $N_n = 1$ for all these watersheds.

Form factor (R_f) has values under one underlying the elongated shape of all watersheds within the "Iron Gates" Natural Park. The river basins with $R_f < 0.4$ are considered very elongated (according to the classification of Diaconu and Lăzărescu, 1965), which is obvious in the park in the case of small streams and the rivers developed more longitudinally compared to their width. The river basins with R_f between 0.4 and 0.5 are considered elongated ant those with $R_f > 0.5$ are quasicircular (Mare Creek, Mraconia, Târziului, etc.). The large river basins with a well-developed drainage network and high values of the drainage density (D_d) are not necessary elongated, make obvious the importance of lithology and relief in shaping the watersheds and explain the different values of R_f.

Relief ratio (R_r) expresses the sediment load of the rivers (Hadley and Schum, 1961, cited by Gordon et al., 2004) and grows exponentially with relief ratio. The values of R_r for the "Iron Gates" Natural Park watersheds are sub-unitary $R_r > 1$ with the highest values of R_r in the case of small stream watersheds with steep slopes: Vodenski and Mare creek (R_r = 0.24), Big Basin (R_r = 0.22), Dalbochi (R_r = 0.23), Bostiţa (R_r = 0.21). The values $R_r < 1$ suggest a relatively high capacity of sediment load of these rivers, but without a continuous input of sediments in the Danube due to their intermittent character.

Mean slope of the watershed (S_b) is correlated with drainage density and the relief of the watershed and has a strong influence on the runoff and sediment transport. The highest values of S_b are found in Almăj Mountains S_b = 24.6.

Bifurcation ratio (R_b) does not remain constant from one order to the next because the variation in lithology and geometry but it tends to be constant throughout the series. High R_{bm} indicates early hydrograph peak with a potential of flash flooding during spring. Higher R_{bm} values are the characteristics of structurally more disturbed watersheds with prominent distortion in drainage pattern and vice versa (Nag, 1998). Maximum R_{bm} is seen in several watersheds, Berzeasca (R_{bm} = 4.8), Mraconia (R_{bm} = 4.5), Eşelniţa (R_{bm} = 4.2), Morilor Stream (R_{bm} = 4.1). Here earlier hydrograph peaks are expected indicating strong structural control on the drainage development for these watersheds.

Based on the River Continuum Concept perspective (Vannote et al., 1980), it is assumed that high values of R_b suggests a larger contribution of a higher number of streams of inferior order with organic matter to high order streams. The total and mean length of low stream orders tributaries, together with the drainage density, have a contribution to the uptake and transport potential of organic matter and dissolved matter of rivers. We assume that watersheds with developed upstream river network and with high number of inferior stream orders and considerable lengths contribute with a higher amount of organic matters to the trophic circuit of the river systems. However, such assumptions are needed to verify the importance of morphometric elements in the development of the river systems with primary productivity ratios calculations or quantitative distribution or different groups of organisms in the river systems (Tetelea, 2005).

Stream frequency (fN_n) indicator shows the contribution of different stream orders with the amount of organic matter. The low values of fN_n indicate a slow discharge time and longer peak times of each of these stream orders because of low runoff rates due to fewer streams draining the watersheds. Further, it is noted that fN_n decreases as the stream number increases.

Drainage density (D_d) controls the travel time of the water within a river basin (Patton, 1998). Generally, a low value of D_d suggests areas with highly resistant permeable material and vegetative cover and low relief. High drainage density is noted in areas of week and permeable subsurface material and sparse vegetation and mountainous relief. Examination of D_d values from table 2 indicates that most of the watersheds have low D_d values (below two km/km^2). Watersheds with moderate D_d values (2.0-2.5 km/km^2) are found in all mountains from the "Iron Gates" Natural Park, like Popin Valley, Silianschi, Big Valley – Divici, Valea Adâncă, Susca, Crușovița, Reșița Mare, etc. Dalbochi, Plavișevița, Mraconia, Sohodol, Tarovat, Ijnic, Târziului watersheds have high D_d values (between 2.5 and 3.0 km/km^2). Values of D_d higher than three km/km^2 are found in Eșelnița, Mala, Costeneț and Strineacului. On the basis of low D_d value it is assumed that these watersheds will have the greatest basin lag time while the watersheds with high D_d value will demonstrate the shortest lag time. From the geological point of view low and moderate D_d values reveal a composition of watersheds with permeable subsurface material, good vegetation cover and low relief, which results in more infiltration capacity and water recharge.

Circularity ratio (R_c) is the ratio of the area of the basin to the area of circle having the same circumference as the basin perimeter (Miller, 1953). This parameter is influenced by the length and frequency of the streams, geological structures, land use and land cove, climate, relief and slope of the basin. Low values of R_c indicate low relief and impermeable subsurface resulting in lower basin lag time and these watersheds will show shorter time to peak flow. On the opposite high R_c values characterize high relief, elongated and permeable surface resulting in greater basin lag time and these watersheds will show delayed time to peak.

The mountainous character of the Danube's tributary rivers is also shown by their longitudinal profiles in figure 3. This character is obvious from spring to pouring mouth and has an influence on the hydrological regime throughout the feeding and flow variation, flow velocity, turbidity, etc. The rivers from the "Iron Gates" Natural Park are typical to the Western Carpathian types and are characterized by high waters during spring and winter. Winter flow is high due to the sub-Mediterranean climatic influences that contribute to melting of the snow. The feeding of the rivers is done more than 50% through surface waters coming from rain and snow. Some of the small rivers that run through karst substrate are fed by underground springs. The lithology has a big influence on river hydrology, especially on big rivers like Cerna and Nera where due to diversity of lithology and area of the watershed, the hydrologic regime is fluctuating according to the geological area.

The water discharge of the rivers in the "Iron Gates" Natural Park is influenced by the quantity of precipitation available at the watershed. Maximum discharge is recorded usually at the end of winter and the beginning of spring (February-April), when the early snow melt due to warm Mediterranean air overlap with the spring rains. This is the beginning of the high waters of spring. From April on a period of continuous decrease of water runoff dictates the considerable low discharge of rivers and even water depletion of small streams, which run downstream into own sediments. July-September is the driest period of the year and some of the rivers run dry due to the sub-Mediterranean climate and low frequency of rain.

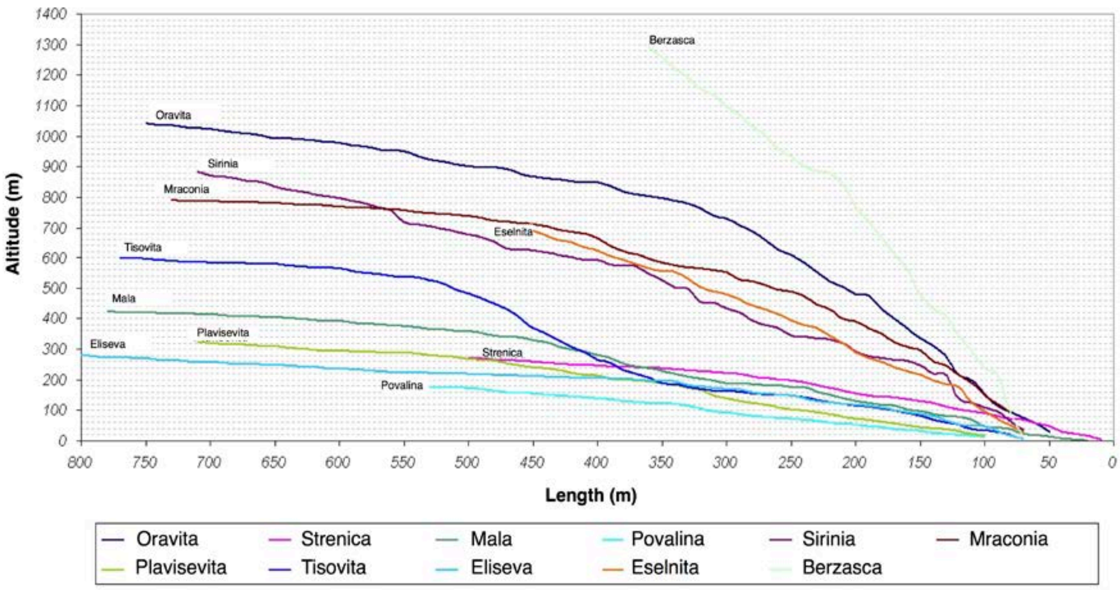

Figure 4: Longitudinal profiles of the main trybutaries to the Danube from Almăj Mountains.

From this point of view there are three river categories in the “Iron Gates” Natural Park: perennial streams and rivers that never run dry even in the most torrid summer, like Cerna, Nera, Berzasca, Bahna; semi-perennial streams and rivers, which run dry only in the most arid years, like Vodiţa, Dubova, Cozla, Mala, etc.; intermittent streams and rivers, which run dry every year during the summer, like Ribiş, Reciţa, Cameniţa, Glaucina and creeks.

After their mean multiannual discharge, the Danube’s tributary rivers from the “Iron Gates” Natural Park can be classified as: large mountainous rivers, with watershed area between 200 and 1,500 km^2, length of the river between 30 and 100 km and mean discharge between 0.5 and 15 m^3/s. Berzasca and Cerna falls into this category; small mountainous rivers, with watershed area between 100 and 200 km^2, length of the river between 20 and 50 km and mean discharge between 0.2 and 5 m^3/s. Eşelniţa, Mraconia, Sirinia, Bahna and other rivers are in this category; mountainous streams, with much smaller watershed areas, river lengths and discharge that of the small mountainous rivers. This category is including most of the tributary streams to the Danube in the “Iron Gates” Natural Park: Dubova, Liubotina, Plavişeviţa, Reciţa Mare, Povalina, Iuţi, Elişeva, Oreviţa, Liuborajdea, etc.

Solid discharge is conditioned by four factors: morphometry of the relief, structure of lithology, watershed cover (grass, vegetation, etc.) and discharge frequency. In the “Iron Gates” Natural Park the complex lithological structure of volcanic, sedimentary and metamorphic rocks defines the sediment components, which are mostly gravel and boulders. Dragged sediments predominate against suspended sediments. The narrow river valleys confined by abrupt versants and steep slopes, the riverbed has large boulders with a diameter of 1 m to 1.5 m that are covered with a rich vegetative layer.

The quantity of eroded and transported material by the rivers into the Danube has been changed since the water level has risen due to the damming of the river. Because of this the relief energy decreases with almost 50 m and the decreased transport capacity of the rivers, and the aggradation of sediments shifted to upstream. This contributed greatly to the filling with sediments of the lower segments of the tributary rivers to the Danube. The gulfs along the confluence of the rivers with the Danube started to form submersible deltas which will grow in the future with the input of more sediment from the Danube and upstream (Figs. 5a, b).

Figure 5a, b: Alluvial processes with the formation of submerse deltas in Bahna gulf (left) and Vodiţa (right).

CONCLUSIONS

The forming elements of the landscape and their role in the dynamics and geoecological potential of running waters are determined by a hierarchical control of processes and interactions within a geosystem. This control can be shown through morphometric analysis of watersheds. The identification of watershed geomorphology and physical processes forms the basis for understanding the spatial extent of the riparian forest as well as stream habitats, their quality.

The morphometric parameters of the river network with relevance to the determination of geoecological potential of river ecosystems in the "Iron Gates" Natural Park are the total number of stream segments of the same order, total and mean length of stream segments of an order, bifurcation ratio, and circularity ratio. A positive aspect for the good status of the rivers in the "Iron Gates" Natural Park is the distribution and frequency of the human settlements and the existing quarries in the watersheds of the Danube's tributary rivers. These are concentrated especially along the high order streams in the lower part of the watersheds especially on the confluence with the Danube River.

Using the morphometric analysis of the river network and watersheds can be of great support in the determination of river ecosystem health. However, the evaluation of river habitats in the "Iron Gates" Natural Park and the changes imposed by the potential loses of their specific structure and functions should be a continuous research theme for the future. The results of this study can be useful for the conservation of aquatic and riparian habitats; as well as, for the ecological restoration of certain river segments and water bodies.

The evaluation of the aquatic habitats loss and their components remains an open question since the expansion of build areas, arable land use, and spill of untreated sewage waters in the park area was not addressed enough by the existing researches.

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REFERENCES

1. Farrukh A., Gowhar M. and Shakil A. R., 2013 – Morphometric Analysis to Infer Hydrological Behaviour of Lidder Watershed, Western Himalaya, India, *Geography Journal*, http://dx.doi.org/10.1155/2013/178021 (accessed in 27 May 2015).
2. Curtean A., Morariu A., Făcălău S., Bianca L. and Chişu S., 1999 – Data concerning the benthic communities of the Cibin River (Olt River Basin), *Transylvanian Review of Systematical and Ecological Research*, The Upper and Middle Olt River Basin, 1, 99-110.
3. Gordon D. N., McMahon A. T., Finlayson L. B., Gippel J. C. and Nathan J. R., 2004 – Stream Hydrology – An introduction for Ecologists, Second Edition, Wiley, 429.
4. Manko P., 2008 – Aquatic macroinvertebrate communities in River Torysa across the Javrina military training area in Levočske Vrchy Mountains (Slovakia), *Transylvanian Review of Systematical and Ecological Research, The Wetlands Diversity*, 6, 41-50.
5. Miller V. C., 1953 – A Quantitative geomorphic study of drainage basin characteristics in the Clinch Mountain area, Virginia and Tennessee, *Technical Report*, 3, 389-402, Columbia University, Department of Geology, ONR, New York, NY, USA, 1953.
6. Nag S. K., 1998 – Morphometric analysis using remote sensing techniques in the Chaka sub-basin, West Bengal, *Journal of Indian Society of Remote Sensing*, 26, 1-2, 69-76.
7. Naiman J. R. and Bilby E. R., 2001 – River Ecology and Management, Springer, 705.
8. Patton P. C., 1998 – Drainage basin morphometry and floods, *Flood Geomorphology*, 51-64, John Wiley and Sons, New York, USA, 1988, 51-64.
9. Tetelea C., 2005 – Potențialul geoecologic al ecosistemelor acvatice din Parcul Natural Porțile de Fier, Teză de doctorat, Universitatea din București, 232. (in Romanian)
10. Trichkova T., Stefanov T., Vassilev M. and Zivkov M., 2009 – Fish species diversity in the rivers of the north-west Bulgaria, *Transylvanian Review of Systematical and Ecologica Research, The Wetlands* Diversity, 8, 161-168.
11. Troll C., 1969/1971 – Landscape ecology and biogeoecology, Geoforum, 8, 43-46.
12. Vannote L. R., Minshall G. W., Cummins K. W., Sedell J. R. and Cushing C. E., 1980 – The river continuum project, *Canadian Jorunal of Fisheries and Aquatic Sciences*, 37, 130-137.
13. Zăvoianu I., 1978 – Morfometria bazinelor, Edit. Academiei R. S. R., București. (in Romanian)
14. * I. N. M. H., 1994 – Instrucţiuni metodologice pentru calculul scurgerii maxime în bazine mici. (in Romanian)

DE GRUYTER OPEN

MICROCLIMATE OBSERVATION AT HERMANN'S TORTOISE (*TESTUDO HERMANNI BOETTGERI*) HABITAT IN THE "IRON GATES" NATURAL PARK. CASE STUDY: LOWER EȘELNIȚA WATERSHED (BANAT, ROMANIA)

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KEYWORDS: microclimate, Eșelnița, "Iron Gates" Natural Park, Romania.

ABSTRACT

"Iron Gates" Natural Park is located in the South-Western part of Romania and is recognized for its great diversity of ecosystems, wide variety of species and emblematic landscapes. Due to its Mediterranean climatic influences and vegetation structure, the area is a suitable habitat for the existence and development of *Testudo hermanni boettgeri*.

Monitoring both, the evolution of the microclimatic features in the lower Eșelnița watershed and the species behaviour, represents a useful step in order to determine if the global climate change endangers the conservation management of the tortoise.

RESUMEN: Observaciones microclimáticas del habitat de la tortuga de Hermann (*Testudo hermanni boettgeri*) en el Parque Natural "Puertas de Hierro". Estudio de caso: la cuenca baja del Río Eșelnița (Rumania).

El Parque Natural "Puertas de Hierro", situado en el suroeste de Rumanía, es reconocido por albergar una gran diversidad de ecosistemas, especies y paisajes emblemáticos. Gracias a la influencia climática mediterránea, el área representa un hábitat adecuado para la especie *Testudo hermanni boettgeri*.

El monitoreo de los cambios microclimáticos en la cuenca baja del Río Eşelniţa y las observaciones del comportamiento de la especie, son indispensables para establecer si la conservación de la especie va a estar afectada por el cambio climático global.

REZUMAT: Observații microclimatice în habitatul țestoasei lui Hermann (*Testudo hermanni boettgeri*) din Parcul Natural „Porţile de Fier". Studiu de caz: Bazinul inferior al râului Eșelnița (România).

Parcul Natural „Porţile de Fier", localizat în partea de sud-vest a României, este recunoscut pentru diversitatea ecosistemelor, varietatea mare de specii şi peisajele emblematice. Datorită influenţelor climatice mediteraneene și a vegetaţiei specifice, arealul reprezintă un habitat propice existenţei şi dezvoltării speciei *Testudo hermanni boettgeri*.

Monitorizarea evoluției caracteristicilor alături de observații privind comportamentul speciei, reprezintă un demers necesar pentru a stabili dacă, în contextul schimbărilor climatice, conservarea speciei poate fi periclitată în arealul bazinului inferior al râului Eșelnița.

INTRODUCTION

Human society's adaptation to global climate change represents a major challenge of the 21st century (EEA, 2012). Biodiversity is one of the most vulnerable components facing the global climate change due to the habitat loss (Zisenis, 2010; Lavergne et al., 2010). Climate changes occurring at a global level are causing changes at a microclimatic level, affecting restricted habitats with high biodiversity (Fernández-Chacón et al., 2011). Thus, the areas exposed to the global climate changes are under a constant threat generated by the irreversible phenomenon that cannot be man handled. If the habitat fragmentation level, the overpopulation, the extent of the built-up or agricultural areas can be managed by sustainable management and policies, climate changes cannot be stopped on a long term because they are part of the cyclic process of Earth (IPCC, 2001). Therefore, the scientific community along with stakeholders and local actors have to acknowledge which are the required actions in order to slow down the rhythm of climate change. The reduction or loss of habitats due to climate change represents a direct threat to species with a narrow range of activity and a low velocity that can't cover long distances and are highly sensitive towards changes that occur in the environment (Popescu et al., 2013). The sensitiveness is generated by the fact that these species depend on other support species affected by climate changes.

Hermann's tortoise (*Testudo hermanni boettgeri*) represents a flagship species for the "Iron Gates" Natural Park (IGNP) and it is strictly protected due to the decreased number of individuals caused by illegal trade and habitat reduction (Rozylowicz and Dobre, 2010; Cucu et al., 2013). *Testudo hermanni*'s biogeographic area is located along the northern shore of the Mediterranean Sea. There are three subspecies in this area: *Testudo hermanni hermanni*, in the north-east of Spain, Italian shore, Sicily and Sardinia islands, southern shore of France and Corsica Island; *Testudo hermanni hercegovinensis* on the eastern shore of the Adriatic Sea and *Testudo hermanni boettgeri* spreaded in the Balcanic Peninsula and south-western Romania (Fritz et al., 2006). The present study is addressed to the *Testudo hermanni boettgeri* from the IGNP.

This tortoise is a species that prefers habitats with a mosaic pattern, with different types of land use. It prefers areas with relatively restricted wide opened vegetation, surrounded by shrubs and forest selvage dominated by thermophile edge elements (Meek, 1985; Rozylowicz, 2008; Fernández-Chacón et al., 2011). These types of vegetal associations are the proper habitat for the tortoise which ensures the required elements for all its developmental stages. Changes occurring at a microclimatic level have a great impact over the habitat structures and we can add to that the usually anthropic threats. *Testudo hermanni boettgeri* has a high rate of survival among adult individuals, with longevity that exceeds 50 years and low range of movement (1-2 ha) (Bertolero et al., 2007; Couturier et al., 2014). The presence of *Testudo hermanni boettgeri* in the IGNP represents the northernmost area where the species was spotted the main explanation being the Mediterranean climate influence in this part of the country. Therefore it is of national importance to preserve the habitats and to reduce the threats towards Hermann's tortoise.

As all reptiles, Hermann's tortoise behaviour is strongly influenced by the environmental conditions, mostly by the air temperature and humidity (Meek, 1988a; Popescu et al., 2013; Berardo et al., 2015). The optimum thermic range for Hermann's tortoise is situated between 25°C and 30°C (Huot-Daubremont et al., 1996). The minimum critical range is situated between +1.5°C and –2°C, and the maximum critical range is situated between 40ºC and 44ºC (Cherchi, 1956; Huot-Daumbremont, 2002; Royzlowicz, 2008). Temperature has a decisive influence over the tortoise's metabolism, its diurnal and nocturnal activities, reproduction or hibernation period (Huot-Daubremont et al., 1996; Mazzoti et al., 2002; Hulin et al., 2009). Hermann's tortoise is a species with a small distribution area, restricted by climatic variables (Rozylowicz, 2008; Fernández-Chacón et al., 2011), which imposes natural barriers that are amplified by anthropogenic threats.

Being a poikilothermic species it does not have any internal metabolic mechanism for maintaining an optimum physiological body temperature (Meek, 1988a). Variation in air temperature determines the variation of the tortoise body temperature, thus during extreme climatic events their activity is ceased (Meek, 1988b; Huot-Daubremont et al., 1996). Hermann's tortoise has several behavioural features that help them survive during an episode of extreme cold or extreme heat such as soil or foliage burial and hiding under shrubs. Besides the behavioural features, *Testudo hermanni boettgeri* has some physiological features that help it pass through an episode of extreme temperatures such as becoming immovable while its biological functions are at a minimum stage, activities such as grazing being inhibited (Chelazzi and Calzolai, 1986; Meek, 1988b). This thermoregulatory behaviour makes it vulnerable in face of attacks from various predators during its inactivity period. Thus, the habitat expansion possibilities towards areas with an optimum climate are limited. In case of repeated extreme temperatures the number of the Hermann's tortoise individuals will constantly decrease, the most vulnerable individuals being the juveniles.

Air temperature shapes also the sexual cycle of the tortoise. The physiological processes linked to the reproductive cycle (spermiogenesis, gonadal cycle) are differently influenced by temperature, thus there is no perfect synchronization of these processes (Cheylan, 2001). Hermann's tortoise spermiogenesis start at a diurnal average temperature above 26ºC and it stops at 21°C diurnal average temperature. The tortoise gender is determined by the incubation temperature (Eendebak, 2001). It has been ascertained that the tortoise sex ratio can be strongly imbalanced by uncharacteristic temperatures. Thus, at an incubation temperature around 26°C the hatched individuals would be males and at an incubation temperature around 32ºC, the hatched individuals would be females. The ideal temperature that determines a well-balanced sex ration and a low mortality of unhatched individuals is 28.5°C (Rozylowicz, 2008).

The study area is represented by the lower Eșelnița Watershed, located in south-western part of Romania (Mehedinți County) on the left bank of the Danube, as a part of IGNP (Fig. 1). The study area is characterized by a temperate climate with strong Mediterranean influences which determines specific vegetation structures with Mediterranean thermophile plant species. Thus, the study area represents a proper habitat for the *Testudo hermanni boettgeri* subspecies.

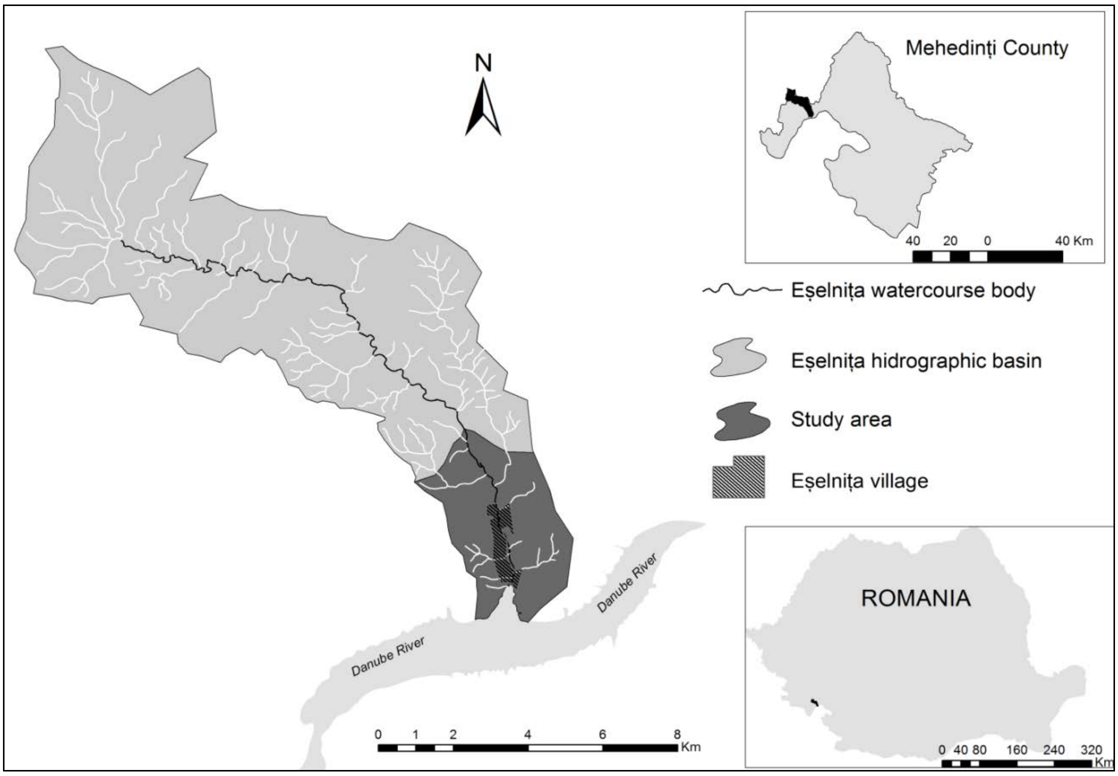

Figure 1: Study area and its position within Romania and Mehedinți County.

Due to circulation of the Mediterranean warm air masses, the temperature recorded in the mountains of the IGNP are higher than the average mountain temperatures. Near the Danube the local climate is similar with the Mediterranean climate; the multi-annual mean temperature recorded is 11^{o}C. The morphological features of the Danube River in the IGNP sector, determines an increase of temperature from west to east (Bazac and Moldoveanu, 1996; Pătroescu et al., 2005).

Monitoring the evolution of the microclimatic features in lower Eșelnița Watershed is a necessary step for many aspects. Being part of a protected natural area the current study may have an important role in improving the efficiency of the conservation measures, generating clear objectives to be included in the management plans or in future conservation policies. On the other hand, Hermann’s tortoise behaviour correlated with the evolution of microclimatic features from our study area shows if in this particular case global climate changes generates positive or negative effects over its habitat.

The research question of this study is whether the evolution of the microclimatic features from our study area could endanger the conservation level for Testudo hermanni boettgeri. In order to answer the research question it was necessary to 1) evaluate the evolution of the microclimatic features in the past 10 years in comparison with the data recorded at three other meteorological stations within the IGNP and 2) to asses if these local microclimatic feature threatens to Hermann’s tortoise presence in the area. The study is focused mainly on the temperature features because it induces important changes in the tortoise’s habitat along with the soil temperature and air relative humidity.

METHODS

We monitored and recorded the temperature and humidity parameters for the study area in the past eight years (2007-2014), at the location of the Centre for Habitats and Species Monitoring (University of Bucharest) located in Eșelnița (Mehedinți County). We used climatic data for comparisons between the lower Eșelnița Watershed and other areas from the "Iron Gates" Natural Park or its proximity from the meteorological stations Moldova Nouă, Berzasca and Drobeta Turnu Severin. We also compared the data from the analysed period with recordings extracted from the WorldClim database for the 1950-2000 timeframe.

We extracted information about tortoise behaviour from observations made between 2007-2013 in the reproduction and captivity-breeding habitat, which exists in the premises of the Centre for Habitats and Species Monitoring. The habitat was created using European funding in the LIFE Nature project RO/02/71/72 "Iron Gates" Natural Park – habitats conservation and management, implemented by the Centre for Environmental Research and Impact Studies (University of Bucharest).

We analysed data for the main climatic parameters (air and soil temperature, air relative humidity) using Microsoft Excel 2010, and derived a series of descriptive statistics from the data (multiannual, seasonal and hourly averages of air temperature, soil temperature and air relative humidity). We used the obtained data in establishing representative values for the habitat and behaviour of Hermann's tortoise in the "Iron Gates" Natural Park.

We used soil temperature in our analysis as a correlation parameter that would explain the direct relation between tortoises' presence and air parameters. The measurements were realised in the same habitat described above at depths of 0, 5 and 10 centimetres, using the average temperature for the purpose of this present study.

RESULTS

Data analysis and processing revealed higher multiannual mean temperatures in our study area than in other areas within the IGNP (Fig. 2). The temperature in lower Eșelnița Watershed recorded +2^{o}C above the average temperature from the IGNP during the *Testudo hermanni boettgeri* (Fig. 3) activity seasons (Tab. 1).

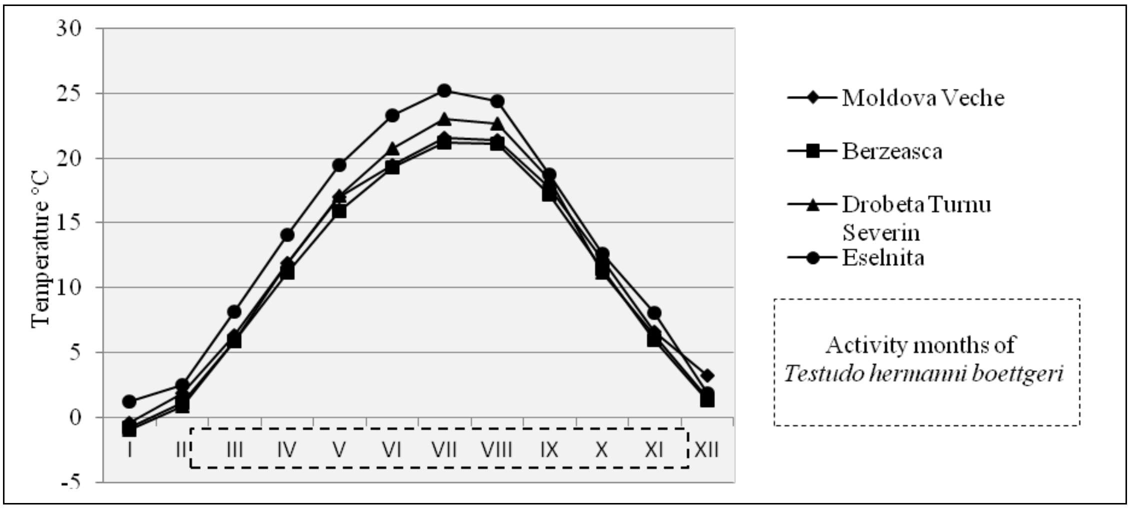

Figure 2: Multi-annual temperature recorded at
Eșelnița, Moldova Veche, Berzasca and Drobeta Turnu Severin.

Table 1: Comparison between multiannual temperature values recorded at Eşelniţa and the other three meteorological stations from the “Iron Gates” Natural Park.

Month	Moldova Veche	Berzasca	Drobeta Turnu Severin	Eşelniţa
	ºC	ºC	ºC	ºC
I	–0.4	–0.8	–1	1.25
II	1.9	1.1	0.9	2.52
III	6.3	5.9	5.9	8.18
IV	11.9	11.2	11.9	14.11
V	17	15.9	17.1	19.42
VI	19.5	19.3	20.7	23.31
VII	21.6	21.2	23	25.2
VIII	21.4	21.1	22.7	24.38
IX	17.7	17.2	18.4	18.72
X	12.2	11.4	11.2	12.59
XI	6.6	6	6.3	8.03
XII	3.2	1.3	1.5	1.86

Figure 3: *Testudo hermanni boettgeri* in its natural habitat in Lower Eşelniţa Watershed.

In order to determine if there has been important variation of the temperatures and relative humidity during the analysed period, a multiannual mean temperature and relative humidity values were calculated for three particular hours – 07:00, 13:00 and 19:00. Results revealed that the multiannual evolution had an oscillating pattern with an increasing trend for air and soil temperatures (Figs. 3 and 5) and a decreasing trend for the relative air humidity (Fig. 4). The current results can’t lead to a major conclusion but they can emphasize the need for further analysis and monitoring. In order to conclude that the microclimatic parameters are changing in the lower Eşelniţa Watershed an analysis of more than 50 years is required.

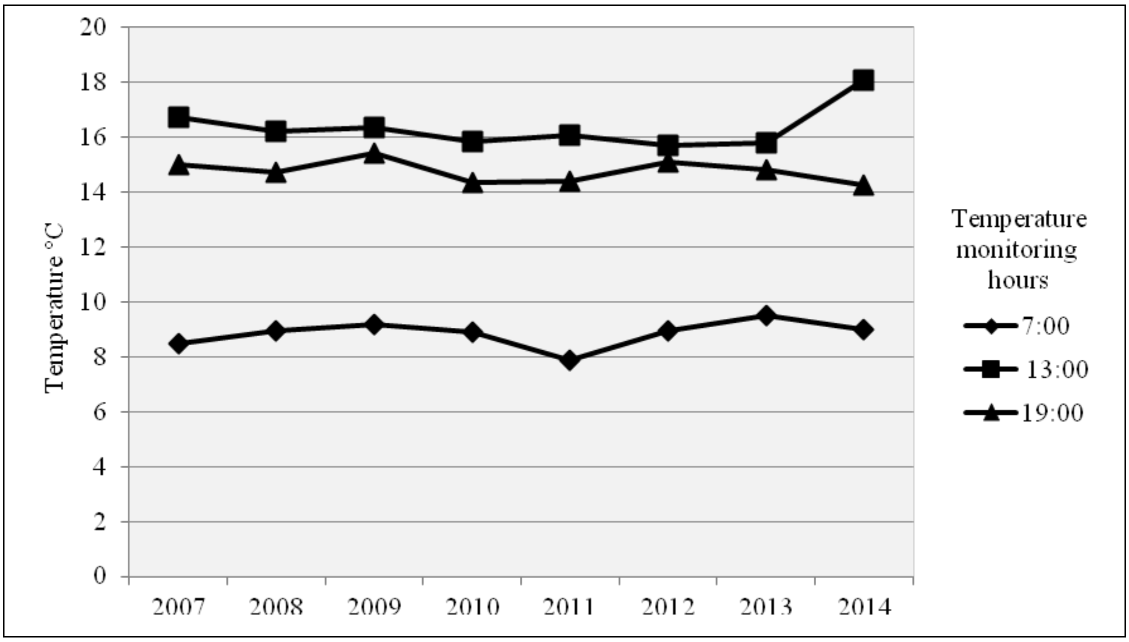

Figure 3: Air temperature evolution
in lower Eșelnița Watershed (2007-2014).

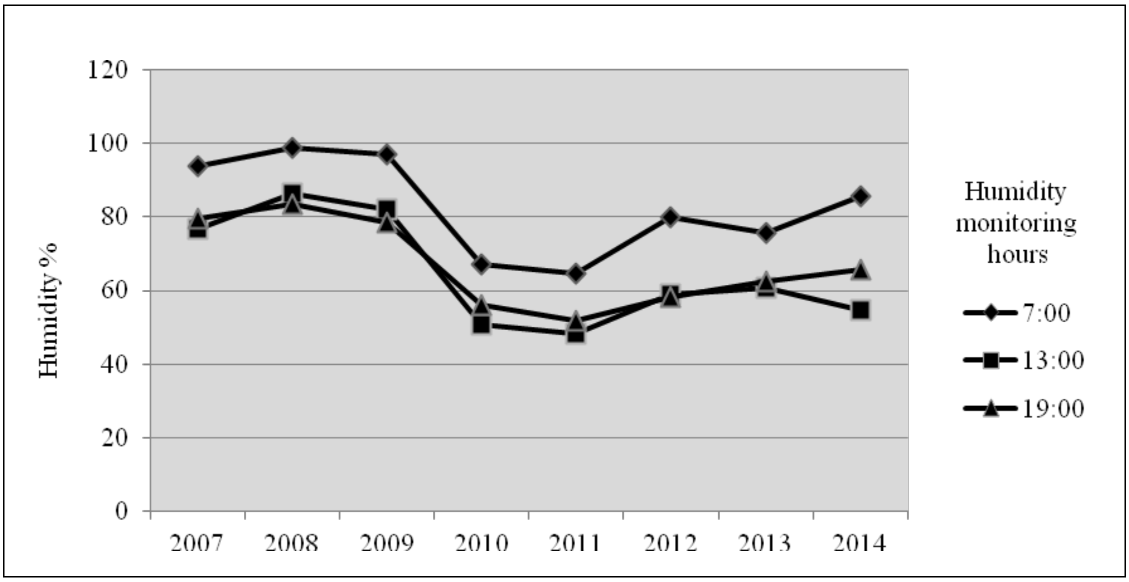

Figure 4: Air relative humidity evolution
in lower Eșelnița Watershed (2007-2014).

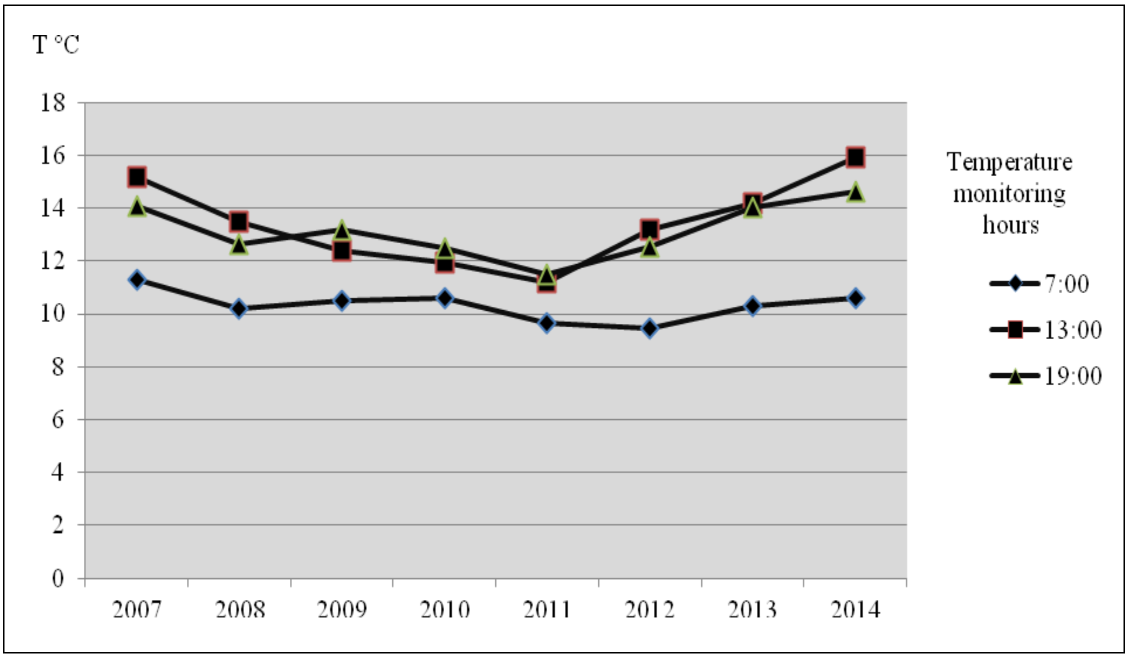

Figure 5: Soil temperature evolution
in lower Eșelnița Watershed (2007-2014).

Assessing the individual behaviour of *Testudo hermanni boettgeri* held in captivity at the Species and Habitat Monitoring Centre from Eșelnița, it was noted that during the monitoring period, the earliest date for the end of the hibernation season was recorded for the year 2008 on the 4th of March and the latest date for the activity season was recorded for 2007 and 2010 on the 11th of November (Fig. 6). It was also recorded that the year with the longest activity season for the individuals of *Testudo hermanni boettgeri* was in 2007 (Fig. 7), starting on the 10th of March and ending on the 11th of November.

In figure 8, the oscillation of temperatures for each month of the year is emphasized using the multiannual mean values processed using the available data. According to the Hermann's tortoise activity month mentioned earlier, the longest period of activity for a tortoise starts from the 3rd month (March) and ends in the 11th month (November). As it is emphasized in the graph chart the month with the widest interquartile range is November fact that can explain why for two years the hibernation season started so late, due to high temperature values. Also the other two autumn months (September and October) have a wide interquartile range which suggests that the temperature values oscillate a lot in autumn influencing the behaviour pattern of the tortoise. Spring and summer seasons, which represent the period when *Testudo hermanni boettgeri* reaches its peak activity season, recorded more stable temperatures values representing a positive fact for the tortoise habitat.

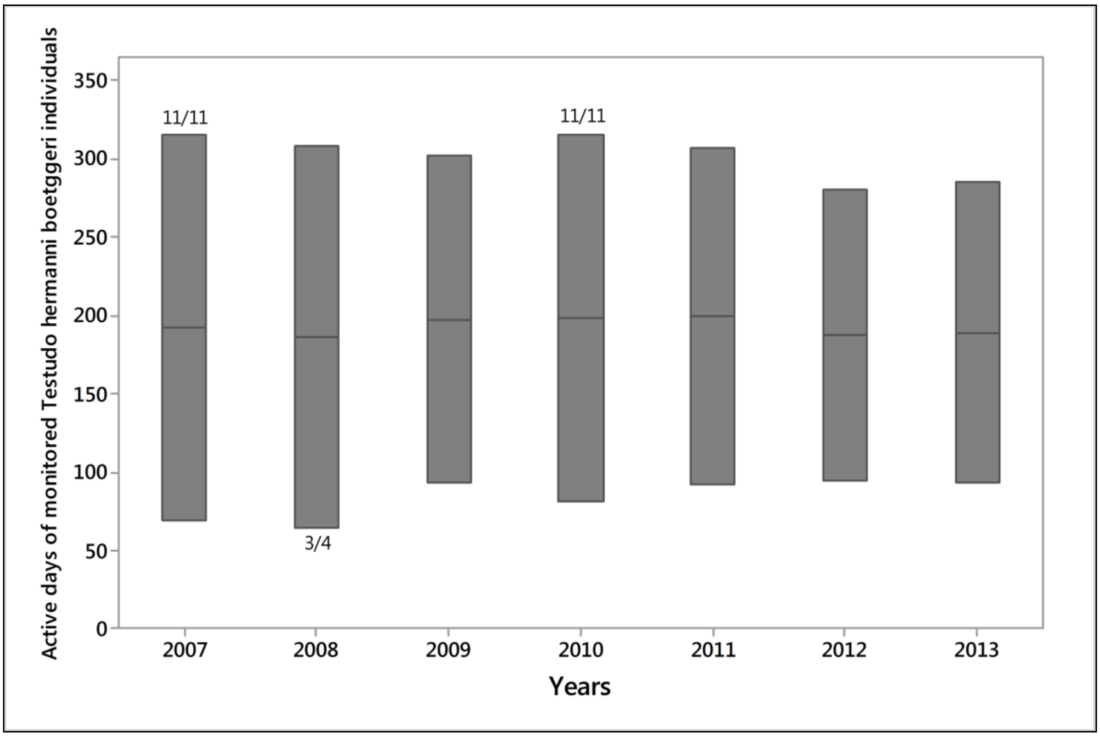

Figure 6: The time period within a year that *Testudo hermanni boettgeri* individuals were active in the Species and Habitat Monitoring Centre – Eşelniţa.

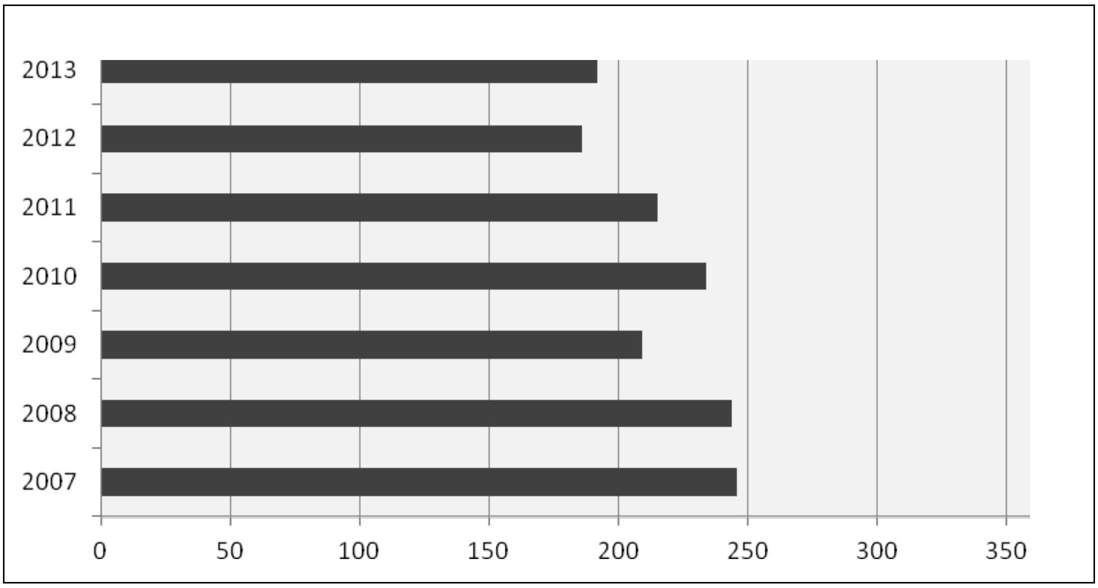

Figure 7: Number of effective days that *Testudo hermanni boettgeri* individuals were active in the Species and Habitat Monitoring Centre – Eşelniţa.

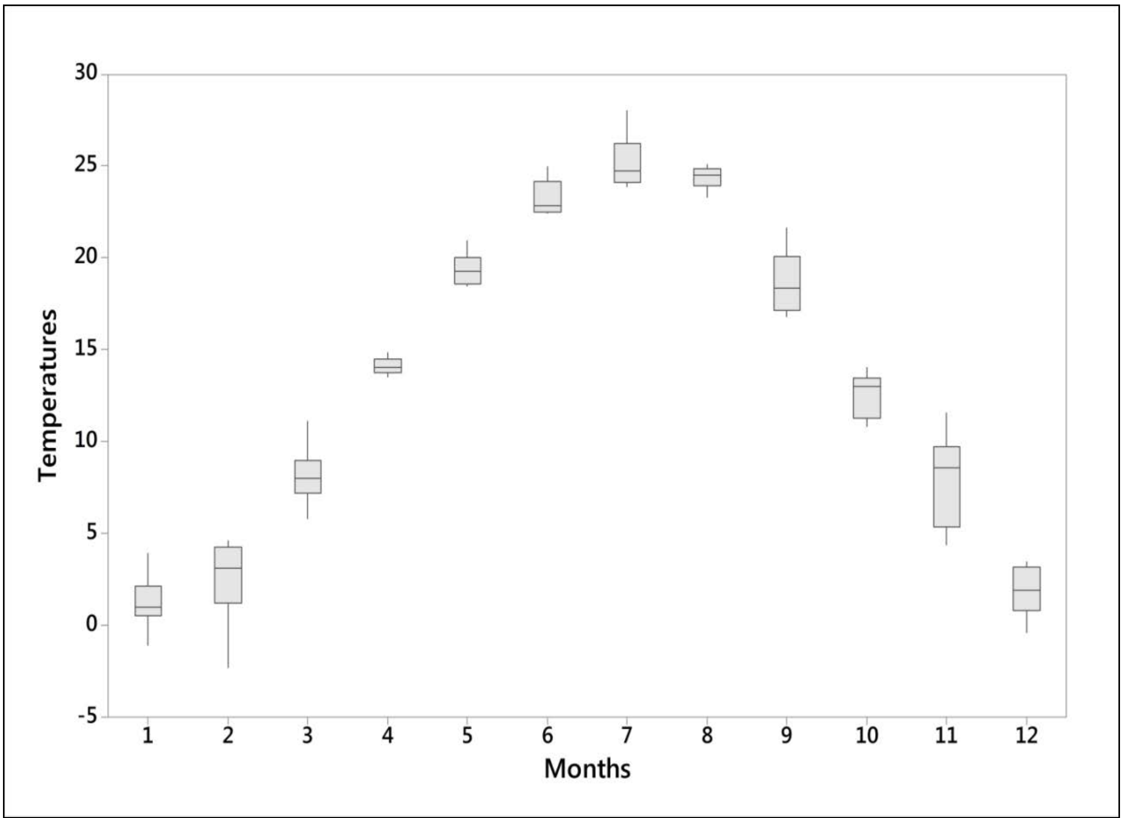

Figure 8: Multiannual mean temperature values for each month, the absolute oscillating range values and the interquartile range values recorded in the lower Eșelnița Watershed.

DISCUSSION

The annual life cycle for Hermann’s tortoise can be divided into the sleep – hibernation period (November – March/April) and the active period (March/April – November), as confirmed by the data recorded at the Centre for Habitats and Species Monitoring, Eşelniţa. The sleep – hibernation period can be interrupted when periods of extremely high temperature are registered (Huot-Daumbremont, 2002).

The annual and diurnal life cycle of the tortoise is determined almost entirely by temperature. Being a poikilothermic species, the tortoise lacks internal metabolic mechanisms that would help it maintain an optimal body temperature when air temperature is higher or lower than the optimum. Fluctuations in air temperature determine variations of the behaviour and their adjustments to the environment (Fry, 1967). For Hermann’s tortoise, numerous studies exist on the topic of thermoregulation mechanisms, in France, Greece, Italy and former Yugoslavia (Meek, 1988b; Huot-Daumbremont, 1997; Huot-Daumbremont, 2002; Mazzoti et al., 2002). Meek, 1987 observed that during summers with sunny days, body temperature for tortoises tends to be higher than air and soil temperature. At the maximum temperature of air and soil, body temperature is always lower. We therefore observed that *Testudo hermanni boettgeri* has a higher thermoregulation capacity in relation with air and soil temperatures.

Results of the present study do not confirm the hypothesis that temperature oscillations are high enough in the lower Eșelnița Watershed so that they would endanger the adaptability of Hermann's tortoise. Rozylowicz and Dobre (2010) presented the average multiannual temperature in the area of *Testudo hermanni boettgeri* from south-western Romania to be +10.28°C, but climatic data from the Centre for Habitats and Species Monitoring, Eșelnița, revealed that the multiannual temperature is +13.30°C. Therefore, the lower Eșelnița Watershed represents an area with temperatures higher than the average of habitats occupied by *Testudo hermanni boettgeri*, as temperatures have increased between 2010 and 2013.

Centre for captivity breeding of Hermann's tortoise (the present Centre for Habitats and Species Monitoring) organised between 2005 and 2006 a radio-telemetry survey of tortoises in the Eşelniţa-Mala interfluve (Pătroescu et al., 2005). The conclusion of the study was that the relation between the home-range of Hermann's tortoise, behaviour, movements and environmental factors is highly influenced by temperatures (Rozylowicz, 2008).

A potential element of risk generated by higher temperatures in the lower Eșelnița Watershed is related to the appearance of vegetation fires. The vulnerability of the tortoise to fires is increased by the fact that many of the habitats used by *Testudo hermanni boettgeri* are pastures maintained and exploited by local population.

CONCLUSIONS

The study area of the lower Eșelnița Basin represents a stable region regarding climatic parameters, therefore an excellent habitat for populations of *Testudo hermanni boettgeri*. Higher temperature values in the study area compared to those recorded at the meteorological stations of Moldova Veche, Berzasca and Drobeta Turnu Severin is an indicator of a warmer climate. The reduced amplitude of oscillations in the annual values for the period of observations (a maximum of 2°C for air temperature, 26.87% for relative humidity and 3.48°C for soil temperature) is an element favourable for the different evolution phases of *Testudo hermanni boettgeri* individuals. In order to elaborate in-depth conclusions on the oscillations of climatic parameters in the lower Eșelnița Basin the monitoring period should be of 50 years.

REFERENCES

1. Bazac G. and Moldoveanu M., 1996 – Unele caracteristici ale influenţei mediteraneene asupra climei din sud-vestul României, *Terra*, XXVIII, 50-54. (in Romanian)
2. Berardo F., Carranza M. L., Frate F., Stanisci A. and Loy A., 2015 – Seasonal habitat preference by the flagship species Testudo hermanni, *Comptes rendus biologies*, 338, 5, 343-350.
3. Bertolero A., Oro D. and Besnard A., 2007 – Assessing the efficacy of reintroduction programmes by modelling adult survival, *Animal Conservation*, 10, 3, 360-368.
4. Chelazzi G. and Calzolai R., 1986 – Thermal benefits from familiarity with the environment in a reptile, *Oecologia*, 68, 4, 557-558.
5. Cherchi M. A., 1956 – Termoreglazione in Testudo hermanni Gmelin, *Bolletino dei Musei e Degli Istituti Biologici dell'Universita di Genova*, 26, 5-46. (in Italian)
6. Cheylan M., 2001 – Testudo hermanni Gmelin, 1789 – Griechische Landschildkrote, in Fritz U., (ed.), Handbuch der Reptilien und Amphibien Europas, Aula Verlag, 179-289. (in German)
7. Couturier T., Besnard A., Bertolero A., Bosc V., Astruc G. and Cheylan M., 2014 – The abundance of Hermann's tortoise in France and Spain, *Biological Conservation*, 170, 177-187.
8. Cucu L. A., Niculae M. I. and Pătroescu M., 2013 – Hierarchical analysis of the threats for Species of Community Interest in the "Iron Gates" Natural Park, Romania, Forum geografic, *Studii și cercetări de geografie și protecția mediului*, 12, 1, 52-58.

9. EEA, 2012 – Climate change, impacts and vulnerability in Europe 2012, Copenhagen European Environment Agency, 213-237.
10. Eendebak B. T., 2001 – Incubation period and sex ratio of Testudo hermanni boettgeri, International Congress on Testudo Genus, Hyères, 227-331.
11. Fernández-Chacón A., Bertolero A., Amengual A., Tavecchia G., Homar V. and Oro D., 2011 – Spatial heterogeneity in the effects of climate change on the population dynamics of a Mediterranean tortoise, *Global Change Biology*, 17, 10, 3075-3088.
12. Fritz U., Auer M., Bertolero A., Cheylan M., Fattizzo T., Hundsdorfer A. K., Sampayo M. M., Pretus J. L., Široky P. and Wink M., 2006 – A rangewide phylogeography of Hermann’s tortoise, Testudo hermanni: implications for taxonomy, *Zoologica Scripta*, 35, 5, 531-543.
13. Fry F. E. J., 1967 – Responses of vertebrate poikilotherms, Academic Press, London, 375-409.
14. Hulin V., Delmas V., Girondot M., Godfrey M. H. and Guillon J. M. 2009 – Temperature-dependent sex determination and global change, *Oecologia*, 160, 3, 493-506.
15. Huot-Daumbremont C., 1996 – Contribution a l’etude ecophysiologique de different aspects du cycle de la tortue d’Hermann (Testudo hermanni hermanni) dans le massif des Maures (Variable), Thèse de Doctorat, Université de Tours-François Rabelais, 35-152. (in French)
16. Huot-Daubremont C., Grenot C. and Bradshaw D., 1996 – Temperature regulation in the tortoise Testudo hermanni, studied with indwelling probes, *Amphibia-Reptilia*, 17, 2, 91-102.
17. Huot-Daumbremont C., 1997 – Rythme d’activite de la tortue d’Hermann, *Bolletino dei Musei e Degli Istituti Biologici dell'Universita di Genova*, 26, 5-46. (in French)
18. Huot-Daumbremont C., 2002 – Etude de la thermoregulation de la tortue d’Hermann (Testudo hermanni hermanni) en semi-liberte dans le massif des Maures (Variable), *Revue d’Ecologie (Terre Vie)*, 52, 331-334. (in French), 52, 331-334. (in French)
19. IPCC, 2001 – The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Houghton J. T., Ding Y., Griggs D. J., Noguer M., van der Linden P. J., Dai X., Maskell K. and Johnson C. A. (eds), Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 881.
20. Lavergne S., Mouquet N., Thuiller W. and Ronce O., 2010 – Biodiversity and climate change: integrating evolutionary and ecological responses of species and communities, *Annual review of ecology, evolution and systematics*, 41, 321-350.
21. Mazzoti S., Pisapia A. and Fasola M., 2002 – Activity and home range of Testudo hermanni in Northern Italy, *Amphibia-Reptilia*, 23, 305-312.
22. Meek R., 1985 – Thermoregulatory behaviour in a population of Hermann tortoise (Testudo hermanni) in southern Yugoslavia, *British Journal of Herpetology*, 6, 387-39.
23. Meek R., 1988a – The comparative population ecology of Hermann tortoise, Testudo hermanni, in Croatia and Montenegro, Yugoslavia, *Herpethological Journal*, 404-414.
24. Meek R., 1988b – The thermal ecology of Hermann’s tortoise (Testudo hermanni) in summer and autumn in Yugoslavia, *Journal of Zoology*, London, 215, 99-111.
25. Pătroescu M., Rozylowicz L. and Dobre M., 2005 – Activitatea şi teritoriul ţestoasei lui Hermann din Parcul Natural Porţile de Fier, raport de cercetare, 4-19. (in Romanian)
26. Popescu V. D., Rozylowicz L., Cogălniceanu D., Niculae M. I. and Cucu L. A, 2013 – Moving into protected areas? *PLoS ONE*, 9, 1, 1-14.
27. Primack R. B., Pătroescu M., Rozylowicz L. and Iojă I. C., 2008 – Fundamentele conservării diversităţii biologice, Edit. AGIR, Bucureşti, 196-237. (in Romanian)
28. Rozylowicz L., 2008 – Metode de analiză a distribuţiei areal-geografice a ţestoasei lui Hermann (Testudo hermanni Gmelin, 1789) în România, 16-115. (in Romanian)
29. Rozylowicz L. and Dobre M., 2010 – Assessing the threatened status of Testudo hermanni boettgeri Mojsisovics, 1889, *North-Western Journal of Zoology*, 6, 2, 190-202.

THE CURRENT STATE OF PHYTO-COENOLOGICAL RESEARCH IN THE "IRON GATES" DANUBE GORGE (BANAT, ROMANIA)

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KEYWORDS: Romania, Danube Gorge, phyto-coenology, natural park, vegetation, research history.

ABSTRACT

The author of the study writes a concise history of the phyto-coenological research conducted previously in the Danube Gorge; he notes the papers and the respective publishing years for the botanists who contributed with research to the knowledge of the cormophyte vegetation along the aforementioned sector of the Danube River.

55 important papers are highlighted, authored by fifty-four specialists in the years 1931-2006.

ZUSAMMENFASSUNG: Gegenwärtiger Stand der phytozönologischen Forschungen im Durchbruchtal der Donau (Banat, Rumanien).

Der Verfasser liefert einen geschichtlichen Überblick über die im Donau-Durchbruchtal (Cazan-Pass und Eisernes Tor) durchgeführten phytozönologischen Untersuchungen und erwähnt in chronologischer Reihenfolge, nach dem Erscheinungsjahr der Arbeiten, die Botaniker, die durch ihre Forschungen zur Kenntnis der Vegetation aus diesem Abschnitt der Donau beigetragen haben.

Es werden 55 wichtige wissenschaftliche Arbeiten erwähnt, die von 54 Fachleuten im Zeitraum 1931-2006 veröffentlicht wurden.

REZUMAT: Stadiul actual al cercetărilor fitocenologice în Defileul Dunării (Banat, România).

Autorul realizează un scurt istoric al cercetărilor fitocenologice din Defileul Dunării, amintind, cronologic, după anul apariţiei lucrărilor, botaniştii care au contribuit prin cercetările lor la cunoaşterea vegetaţiei cormofitelor din acest sector al Dunării.

Sunt evidenţiate 55 lucrări ştiinţifice importante scrise de 54 specialişti în intervalul 1931-2006.

INTRODUCTION

The expected construction of the "Iron Gates" hydro-electric and navigation system motivated a number of research teams (made up of geologists, geographers, hydrologists, botanists, zoologists, ecologists, etc.) to undertake studies aiming at evincing the habitat diversity and the specificity of the territories to be flooded, along with other areas in their near vicinity. That is how, beginning with 1968, dozens of papers were published on the local flora and vegetation, with nearly 200 coeno-taxons being described, a tenth of them being endemic.

The area whose vegetation constitutes the subject matter of the present paper is the Danube River segment known as the Danube Gorge, especially in its most well-known part, the "Iron Gates". Most of that area is included in the "Iron Gates" National Park.

MATERIALS AND METHODS

The paper is based on the bibliography mentioned below.

RESULTS AND DISCUSSIONS

The Danube Gorge is an area where elements of Carpathian vegetation intermingle with Pannonian, Balkan and Sub-Mediterranean ones. Most of the local phyto-coenoses, both ligneous and gramineous species share an obvious thermophilous character and rarity – which was noted as early as a century ago. That is why among the earliest proposals of natural reserves in Romania (made in 1920) were "The Gorge Pass in Banat", or "Danube's Gorge with forest and rock vegetation" and "The Iron Gates – the slopes at Gura Văii". To those reservations of botanical interest (Cazanele Mari and Cazanele Mici, Gura Văii – Vârciorova) others were added in time: Oglănicului Valley, Valea Mare/Mare Valley, Cracul Găioara, Cracul Crucii, Faţa Virului, Vărănic Hill, Duhovnei Hill – all parts of the "Iron Gates" Natural Park (covering 115,655.85 hectares), a protected natural area since 1998.

The phyto-sociological study of the Danube Gorge area was initiated in 1931, with the phyto-geographic excursion (of an international team) organised by Borza A. on the following itinerary: Sviniţa – Tricule – Drencova – Cazane – Orşova – Ada-Kaleh Isle – Vârciorova – Gura Văii.

The first paper following the excursion was published by Domin (1932); it included phyto-sociological input on the area Cazane – Ada Kaleh Isle – Gura Văii. Călinescu (1935, 1957) provided information on the biodiversity of the former Ada Kaleh Isle and on "şibliac", a type of shrubbery specific for that segment of the Danube. Popescu and Samoilă (1962) wrote a description of the Danube Gorge, both in floristic and in phyto-coenological terms.

Costache (1967) reveal some phyto-geographic elements between Orşova and Baziaş. Raţiu (1968) ofer information regarding the Ada-Kaleh Island vegetation. Sanda et al. (1968) introduced palustral coenoses in the gorge, while Csűrös et al. (1968, 1969) and Pop et al. (1969) described their investigations on vegetal aggregation in the Orşova – Eşelniţa area. Boşcaiu and Resmeriţă (1969) focused their research on the xerophilous gramineous alluvial vegetation, while Anghel et al. (1970) wrote about the division into zones of the ligneous and gramineous vegetation in the "Iron Gates" area. Păun et al. (1970) the vegetation in the Berzasca – Pescari area. Ştefureac (1970) complete the flora and vegetation located at Porţile de Fier with new species and vegetal associations. Morariu et al. (1970, 1973) wrote about the vegetation of the "Iron Gates" and Moldova Veche Isle areas, while Dihoru et al. (1970, 1973) about that extant between Valea (i.e. valley) Mraconiei and Depresiunea (i.e. depression)

Dubova; Coldea et al. (1970) described the beech forests in the area between Eşelniţa Valley and Mraconiei Valley; Ştefureac and Popescu (1970) described the coenoses of *Stipa bromoides*. Şerbănescu and Sanda (1970) introduced the river-meadow and hill-side vegetations in between Cazanele Mari and Plavişeviţa, while Schneider-Binder et al. (1970, 1971) highlighted the features of the saxicolous vegetation in the Eşelniţa – Tricule area. Mišič (1971) light shed on the relict vegetation in the gorge, while Boşcaiu et al. (1971) did the same on the characteristic features of the meso-xerothermal ligneous vegetation of the order Orno-Cotinetalia. Todor et al. (1971) contributed to increase the knowledge of the flora and vegetation of the Danube Gorge area in between the town of Moldova Veche and the village Pojejena. Purcelean et al. (1971) researched Porţile de Fier forest vegetatin. Resmeriţă et al. (1971, 1972) realised a mapping of the vegetation in the sectors Eşelniţa – Mraconia and Cazane – Tricule, as well as a study of the nitrophilous vegetation. The anthropogenous, ruderal vegetations, along with the pratal and palustral ones, were also studied by Raclaru and Alexan (1973).

Roman (1974) worked out a rather comprehensive study of the vegetation in the respective sector of the Danube, with many descriptions of coenotaxons that were new for both science and Romanian botany. Also in 1974 Stere and Coste reveal botanical aspects from Valea Mare-Moldova Nouă natural reservation. Popescu and Ştefureac (1976) published their findings on the vegetation in the Sviniţa – Tricule sector, while Grigore and Coste (1978) reveal the vegetation between Moldova Veche and Pescari. Sanda and Popescu (1980) describe the water and palustral vegetation in the area of the "Iron Gates" reservoir. Oprea et al. (1982), and Nedelcu and Sanda (1983) added new studies to the descriptions about the extant forest vegetation. Arsene et al. (2006) focused their study on thermophilous shrubs. The most valuable contribution to the knowledge of the vegetation in the "Iron Gates" area was made by Matacă, who described in several papers (published between 2000-2005), including her doctoral thesis, the whole of the respective vegetation, from aquatic, palustral, or saxicolous coenoses to forests.

CONCLUSIONS

This study reveals the fact that the vegetation and flora of the "Iron Gates" Gorges is well studied, both before the "Iron Gates" Dam construction (more than half of a century ago) and after the formation of the new anthropogenic lake, especially after the establishment of the "Iron Gates" Natural Park.

Based on these old and new data in the area of interest, different comparisons regarding the vegetation can be made and the evolution of phytocoenosis can be revealed.

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REFERENCES

1. Anghel G., Turcu G., Ciocârlan V. and Doniţă N., 1970 – Zonarea vegetaţiei lemnoase şi ierboase de la Porţile de Fier (sectorul Cozla – Berzasca), *Lucrările ştiinţifice ale Institutului Agronomic Bucureşti, seria Agronomie*, 13, 413-418. (in Romanian)
2. Arsene G. G., Coste I., Neacşu A. G., Avrămuţ O. I. and Fărcăşescu A., 2006 – A syntaxonomic review of thermophilous shrub communities (Syringo-Carpinetum orientalis) in SW Romania in Gafta D. and Akeroyd J. R., Nature conservation: Concepts and practice, Springer Verlag Berlin Heidelberg, 142-168.
3. Borza A., 1931 – Die Vegetation und Flora Rumäniens, I Partie, Guide de la sexiéme Excursion Phytocenologique International en Roumanie, Cluj-Napoca, 1-55. (in German)
4. Boşcaiu N. and Resmeriţă I., 1969 – Vegetaţia ierboasă xerofilă de aluviuni din sectorul Valea Eşelniţa – Valea Mraconiei la Defileului Dunării, *Studii şi cercetări de biologie, Seria botanică*, Bucureşti, 21, 3, 209-216. (in Romanian)
5. Boşcaiu N., Lupşa V., Resmeriţă I., Coldea G. and Schneider-Binder E., 1971 – Vegetaţia lemnoasă mezo-xerotermă (Orno-Cotinetalia) din Defileul Dunării, *Ocrotirea Naturii*, Bucureşti, 15, 1, 49-55. (in Romanian)
6. Călinescu I. R., 1935 – Contribuţii la studiul insulei Ada-Kaleh, *Arhiva Olteniei*, XIV, 7-78. (in Romanian)
7. Călinescu R., 1957 – Contribuţii la studiul şibliacului în R. P. Română, *Revista Pădurilor*, LXX, 2, Bucureşti, 76-84. (in Romanian)
8. Călinescu R. and Iana S., 1964 – Consideraţiuni biogeografice asupra Defileului Dunării, *Analele Universităţii Bucureşti, Seria Geologie-Geografie*, Bucureşti, XIII, l, 151-168. (in Romanian)
9. Coldea G., Boşcaiu N., Lupşa V., Plămadă E. and Resmeriţă I., 1970 – Vegetaţia făgetelor din sectorul Valea Eşelniţa – Valea Mraconiei al Defileului Dunării, *Studii şi cercetări de biologie, Seria Botanică*, Bucureşti, XXII, 6, 467-474. (in Romanian)
10. Costache N., 1967 – Consideraţii fitogeografice asupra Defileului Dunării între Orşova şi Baziaş, *Analele Universităţii Bucureşti, Seria ştiinţele naturii, Geologie-Geografie*, Bucureşti, XVI, 2, 157-162. (in Romanian)
11. Csűrös S., Pop I., Hodişan I. and Csűrös-Kaptalan M., 1968 – Cercetări floristice şi de vegetaţie între Orşova şi Eşelniţa, *Contribuţii botanice*, Cluj, 277-312. (in Romanian)
12. Csűrös S., 1969 – Aspecte de vegetaţie de pe Valea Eşelniţa (Munţii Almăjului, Banat), *Contribuţii botanice*, Cluj, 235-243. (in Romanian)
13. Dihoru G., Andrei M. and Cristurean I., 1970 – Date preliminare despre flora şi vegetaţia ierboasă din Valea Mraconiei şi Cazanele Mari ale Dunării, *Acta botanica Horti Bucurestiensis*, Bucureşti, 1968, 207-214. (in Romanian)
14. Dihoru G., Andrei M. and Cristurean I., 1973 –Vegetaţia dintre Valea Mraconiei – Depresiunea Dubova, *Acta botanica Horti Bucureştiensis*, Bucureşti, 1972-1973, 353-423. (in Romanian)
15. Domin K., 1932 – Domugled, Kazanski sontesky, Ada Kaleh a Varciorova, *Publications de la Faculte de Sciences de Universite Charles*, Praha, 122-144. (in Czech)
16. Grigore S. and Coste I., 1978 – Cercetări asupra vegetaţiei dintre Moldova Veche şi Pescari (judeţul Caraş-Severin), *Banatica, Caiete de Ştiinţe naturale*, Reşiţa, 7, 173-189. (in Romanian)
17. Matacă S. Ş., 2000 – Istoricul cercetărilor botanice din teritoriul Parcului Natural Porţile de Fier, *Studii şi Comunicări, Ştiinţele Naturii*, Craiova, XVI, 85-89. (in Romanian)
18. Matacă S. Ş., 2002a – Arondarea fitogeografică a teritoriului Parcului Natural Porţile de Fier, *Marisia, Studia Scientiarum Naturale*, Târgu-Mureş, XXVI, 151-160. (in Romanian)

19. Matacă S. Ş., 2002b – Vegetaţia forestieră şi arbustivă din Parcul Natural Porţile de Fier, *Drobeta*, XI, 296-306, Drobeta Turnu Severin. (in Romanian)
20. Matacă S. Ş., 2002c – Vegetaţia saxicolă din Parcul Natural Porţile de Fier, *Marisia, Studia Scientiarum Naturale*, XXVI, Târgu-Mureş. (in Romanian)
21. Matacă S. Ş., 2003a – Contribuţii privind clasa Thlaspietea rotundifoli Br-Bl, 1948 în arealul Parcului Natural Porţile de Fier, *Studii şi Comunicări, Ştiințele Naturii, Muzeul Olteniei*, XIX, Craiova. (in Romanian)
22. Matacă S. Ş., 2003b – Contribuţii privind vegetaţia acvatică şi palustră din arealul Parcului Natural Porţile de Fier, *Drobeta*, XII, 218-238, Drobeta Turnu-Severin. (in Romanian)
23. Matacă S. Ş., 2003c – Études géosymphytosociologiques dans le Parc Naturel „Porţile de Fier" (Roumanie), *Contribuţii botanice*, XXXVIII, 2, 57-66, Cluj-Napoca. (in French)
24. Matacă S. Ş., 2004a – Asociaţii endemice din Parcul Natural Porţile de Fier, *Drobeta, Seria Ştiințe Naturale*, XIV, 15-34, Craiova. (in Romanian)
25. Matacă S. Ş., 2004b – Noi asociaţii în arealul Parcului Natural Porţile de Fier, *Argesis, Studii şi Comunicări, Ştiinţe Naturale*, 12, 65-78, Piteşti. (in Romanian)
26. Matacă S. Ş., 2005 – Flora şi vegetaţia ocrotită din Parcul Natural Porţile de Fier, *Ecos*, Piteşti, 82-95. (in Romanian)
27. Matacă S. Ş., 2005a – Parcul Natural Porţile de Fier. Floră, vegetaţie şi protecţia naturii, Edit. Universitaria, Craiova, 550. (in Romanian)
28. Matacă S. Ş., 2005b – Contributions concervant l'ordre Fagetalia sylvaticae, Pawlowski in Pawlowski et al. 1928 dans le territoire du Parc Naturel "Porţile de Fier", *Contribuții Botanice*, XL, 77-87, Cluj-Napoca. (in French)
29. Mišić V., 1971 – Reliktna vegetacija Resavske klisure, *Arhiv bioloških nauka*, 23, 1-2, 17-18, Beograd. (in Serbian)
30. Morariu I. and Danciu M., 1970 – In der Gegend des Eisernen Tores (Porţile de Fier) gemeldete Pflanzenasoziationen, *Revue Roumaine de Biologie, Botanique*, XV, 6, 419-429, Bucureşti. (in German)
31. Morariu I., Danciu M. and Ularu P., 1973 – Die Vegetation der Flussinsel Moldova Veche, *Acta botanica Horti Bucurestiensis*, 1972-1973, 465-499, Bucureşti. (in Romanian)
32. Nedelcu G. A. and Sanda V., 1983 – Vegetaţia lemnoasă din zona lacului de acumulare "Porţile de Fier" (Baziaş – Drobeta-Turnu Severin), *Acta botanica Horti Bucurestiensis*, 1981-1982, 147-158, Bucureşti. (in Romanian)
33. Oprea I. V., Oprea V. and Purdelea L., 1982a – Contribuţii la sintaxonomia făgetelor din proiectatele parcuri naţionale din Munţii Banatului, in Preda V. and Boşcaiu N. – Făgetele carpatine, Cluj-Napoca, 206-216. (in Romanian)
34. Oprea I. V., Oprea V. and Purdelea L., 1982b – Rezervaţii forestiere din sud-vestul României şi vegetaţia acestora, *Ocrotirea Naturii şi a Mediului Înconjurător*, Bucureşti, 26, l, 2, 97-99. (in Romanian)
35. Păun M., Popescu G., Cârţu M. and Cârţu D., 1970 – Aspecte din vegetaţia dintre Berzeasca şi Pescari (jud. Caraş-Severin), *Analele Universităţii Craiova Seria Bioogie – Ştiinţe Agricole*, Craiova, 61-70. (in Romanian)
36. Pop I., Hodişan I. and Csűrös S., 1969 – Aspecte de vegetaţie de pe Valea Eşelniţa (Munţii Almăjului, Banat), *Contribuţii Botanice*, 233-243, Cluj. (in Romanian)
37. Popescu P. C. and Samoilă Z., 1962 – Ghid geobotanic pentru Banat, Societatea de Ştiinţele Naturii şi Geografie, Secţia Botanică, Bucureşti, 82. (in Romanian)
38. Popescu A. and Ştefureac T. I., 1976 – Vegetations Forschungen aus dem Sektor Sviniţa-Tri Kule-Eisernes Tor Rumäniens, *Acta botanica Horti Bucurestiensis*, 1975-1976, 341-368, Bucureşti. (in German)

39. Purcelean S., Lupe I. Z., Leandru V. and Cambir F., 1971 – Cercetări asupra vegetaţiei forestiere din zona de la Porţile de Fier care va fi inundată prin crearea lacului de acumulare, *Studii şi cercetări Institutul de Cercetări Silvice*, Bucureşti, Sect. 1, 28 (Silvic), 9-32. (in Romanian)
40. Raclaru P. and Alexan M., 1973a – Vegetaţia pajiştilor şi cea ruderală din Defileul Dunării, Baziaş-Pojejena, *Studii şi cercetări de biologie, Seria Botanică*, 25, 3, 205-214, Bucureşti. (in Romanian)
41. Raclaru P. and Alexan M., 1973b – Asociaţii vegetale palustre din Defileul Dunării între Baziaş şi Pojejena, *Studii şi Cercetări de biologie, Seria Botanică*, 25, 2, 131-139, Bucureşti. (in Romanian)
42. Raţiu O., 1968 – Cercetări fitocenologice asupra vegetaţiei ierboase pe insula Ada-Kaleh, *Contribuţii Botanice*, 189-208, Cluj. (in Romanian)
43. Resmeriţă I., Vicol E. C., Coldea G. and Schneider-Binder E., 1971 – Vegetaţia nitrofilă din sectoarele Eşelniţa-Mraconia şi Cazane-Tricule (Defileul Dunării), *Comunicări de botanică*, Bucureşti, XII, 331-348. (in Romanian)
44. Resmeriţă I., Vicol E. C., Boşcaiu N., Coldea G. and Täuber F., 1972 – Cartarea vegetaţiei din sectorul Valea Eşelniţa-Trei Cule (Defileul Dunării), *Studii şi Cercetări de biologie, Seria Botanică*, 24, 3, 213-220, Bucureşti. (in Romanian)
45. Roman N., 1974 – Flora şi vegetaţia din sudul Podişului Mehedinţi, Edit. Academiei Române, Bucureşti, 222. (in Romanian)
46. Sanda V., Şerbănescu G. and Zăvoianu I., 1968 – Aspecte ale florei şi vegetaţiei palustre din Clisura Cazanelor, *Studii şi Cercetări de biologie, Seria Botanică*, 20, 3, 217-224, Bucureşti. (in Romanian)
47. Sanda V. and Popescu A., 1980 – Vegetaţia acvatică şi palustră din zona lacului de acumulare „Porţile de Fier" (Baziaş – Drobeta-Turnu Severin), *Contribuţii Botanice*, 161-175, Cluj-Napoca. (in Romanian)
48. Schneider-Binder E., Boşcaiu N., Coldea G., Lupşa V., Plămadă E., Resmeriţă I. and Stoicovici L., 1970 – Zur Felsenvegetation der Sektoren Eşelniţa-Mraconia und Kazanpass-Tricule (Durchbruchtal der Donau), *Revue Roumain de Biologie, Botanique*, 15, 5, 311-322, Bucureşti. (in German)
49. Schneider-Binder E., Boşcaiu N., Coldea G., Lupşa V., Plămadă E. and Resmeriţă I., 1971 – Zwei neue xerotherme Felsengesellschaften aus dem Durchbruchtal der Donau, *Revue Roumain de Biologie, Botanique*, 16, 2, 97-103, Bucureşti. (in German)
50. Stere G. and Coste I., 1974 – Aspecte botanice din rezervaţia naturală Valea Mare-Moldova Nouă, *Ocrotirea Naturii*, 18, 2, Bucureşti, 159-166. (in Romanian)
51. Şerbănescu G. and Sanda V., 1970 – Cercetări asupra vegetaţiei de luncă şi dealuri între Cazanele Mari şi Plavişeviţa, *Studii şi Cercetări de Biologie, Seria Botanică*, 22, 3, Bucureşti, 171-178. (in Romanian)
52. Ştefureac T., 1970 – Cercetări asupra florei şi vegetaţiei de la Porţile de Fier, *Analele Universităţii Bucureşti, Biologie vegetală*, 19, 193-204, Bucureşti. (in Romanian)
53. Ştefureac T. and Popescu A., 1970 – Recherches sur les phytocenoses a Stipa aristela L. du sud-est de la Roumanie, *Revue Roumain de Biologie, Botanique*, 15, 5, 323-350, Bucureşti. (in French)
54. Todor I., Gergely I. and Bârcă C., 1971 – Contribuţii la cunoaşterea florei şi vegetaţiei din zona Defileului Dunării între oraşul Moldova Veche şi comuna Pojejena (jud. Caraş-Severin), *Contribuţii Botanice*, 203-256, Cluj-Napoca. (in Romanian)
55. ***, 1972 – Atlasul complex „Porţile de Fier", Edit. Academiei R. S. România, Bucureşti, Vulcănescu R. (coordinator), 260. (in Romanian)
56. ***, 2013 – Planul de management al Parcului Natural Porţile de Fier. (in Romanian)

ORCHIDACEAE L. FAMILY IN THE "IRON GATES" PARK (ROMANIA)

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KEYWORDS: orchidaceae, biodiversity, inventory, population, conservation, protection, threats, Locvei Mountains, Almăj Mountains, Mehedinți Plateau, distribution.

ABSTRACT

Currently, little information is available about the orchid flora in the "Iron Gates" Nature Park, especially due to the lack of the data regarding the detailed geographical distribution and the actual conservation status of species and populations. According to the data provided by the specialist literature for the south-west of Romania, 39 species of orchids are found in this area, of which 29 are in the Danube Gorge (known as Clisura Dunării – "Iron Gates" Nature Park). The field researches regarding the Orchidaceae L. family in the "Iron Gates" Nature Park area have been conducted over a period covering 15 years, from 1996 to 2011. During research conducted in the field I acknowledged the presence of 23 orchid species in the Danube Gorge area and ascertained the presence of new orchid species in the research area: two new species in the Danube Gorge area ("Iron Gates" Nature Park): *Epipactis purpurata* Sm. and *Listera ovata* (L.) R. Br.

RÉSUMÉ: La Famille des Orchidacees L. dans le Parc des "Portes de Fer" (Roumanie).

La flore des orchidées dans le Parc Naturel des "Portes de Fer", est peu connue à l'heure actuelle, en particulier à cause du manque de données détaillées sur la répartition géographique et l'état actuel de conservation des genres et des populations. Les données littéraires à propos du sud du Banat (plus exactement, sur le secteur des deux régions protégées étudiées) dénombrent 39 espèces, dont 29 poussant dans la région de la Clisura Dunării (vallée étroite hébergeant des espèces clés, dans la gorge du Danube – Parc Naturel des "Portes de Fer"). La période pendant laquelle les recherches sur le terrain ont été menées sur la famille des Orchidaceae L. dans le Parc Naturel "Portes de Fer", a été de 15 ans entre 1996 et 2011. Après des recherches personnelles sur le terrain, 23 espèces d'orchidées terrestres ont été confirmées pour le Parc Naturel des "Portes de Fer". La présence de nouvelles espèces d'orchidées ont été remarquées pour la région étudiée, à savoir, deux nouvelles espèces pour la région de Clisura Dunarii (Parc Naturel des "Portes de Fer"): *Epipactis purpurata* Sm. Et *Listera ovata* (L.) R. Br.

REZUMAT: Familia Orchidaceae L. în Parcul Natural Porţile de Fier (Banat, România).

Flora orhideelor din zona Parcului Natural „Porţile de Fier" (Clisura Dunării), în prezent, este puţin cunoscută, lipsind mai ales datele despre răspândirea geografică detaliată, precum şi starea reală de conservare a speciilor şi a populaţiilor de orhidee terestre. Conform datelor din literatura de specialitate pentru zona sudică a Banatului, aici cresc un număr de 39 de specii, din care 29 în zona Clisurii Dunării (Parcul Natural „Porţile de Fier"). Perioada în care s-au desfăşurat cercetările în teren a fost de 15 ani, între 1996 şi 2011. Din cercetările personale în teren s-a confirmat prezenţa a 23 de specii de orhidee pentru Clisura Dunării (Parcul Natural „Porţile de Fier"). S-a constatat prezenţa a noi specii de orhidee pentru zona cercetată, şi anume: două specii noi pentru Clisura Dunării (Parcul Natural „Porţile de Fier"): *Epipactis purpurata* Sm. şi *Listera ovata* (L.) R. Br.

INTRODUCTION

Currently, little information is available about the orchid flora of the "Iron Gates" area (South-West Romania), especially due to the lack of the data regarding the detailed geographical distribution and the actual conservation status of species and populations.

Orchids are present in a large number of plant associations in Romania, including here the large majority of the natural and semi-natural habitats (except for the steep rocks) from the area studied in the South-West of Romania, but the importance regarding their occurrence, distribution and ecology is usually disregarded. The orchids from the study areas have not been sufficiently researched from a vegetation perspective and the specialist literature emphasizes only few data about several species. The scanty information about these orchids may be linked to several factors, such as their scarcity, the small and scattered populations as well as to the degradation and even extinction of the natural habitats (Savić, 2001).

58 orchid species are growing in Romania according to the data provided by the botanical literature (Flora României/Romanian Flora). For the South-West of Romania (i.e. the surface of the "Iron Gates" Nature Park, as the subject to this study), 39 species of orchids are encountered in this area, of which 29 are in the Danube Gorge (Csürös et al., 1968; Boşcaiu et al., 1971; Roman, 1974; Coste, 1974; Grigore and Coste, 1974, 1975, 1978; Milanovici, 2004, 2006, 2009, 2012; Matacă, 2005).

MATERIAL AND METHODS

Researches regarding the Orchidaceae L. family in the "Iron Gates" Nature Park, the species inventory, the inventory, distribution, size and dynamics of populations as well as the acknowledgment of the threats with (direct and indirect) impact upon the orchid species and populations have been conducted over a period covering 15 years, from 1996 to 2011.

The main bibliographical source related to the western region of Romania, starting with the basic studies: Rochel – "Plantae Banatus rariores ..." (1828); Heuffel "Enumeratio plantarum in Banatu Temesiensi ..." (1858); Panţiu – „Orchidaceele din România", studiu monografic/Orchids of Romania. A monographical study (1915); "Flora Republicii Socialiste România", XII, (Paucă et al., 1972). To understand the biology, ecology and history of native orchid species the following were used as basic works: "The orchids: natural history and classification" (Dressler, 1981); "Terrestrial orchids from seed to mycotrophic plant", (Rasmussen, 1995), and others.

The first research stage consisted of taking samples for archiving purposes (i.e. for herbarium) only from the areas which numerically allowed the sample collection without yet affecting the orchid population. Since, I consider, based on my field researches, that most orchid species are rare or even extremely rare in nature (i.e. in the areas covered by this study), I started to determine the species directly in the field, and during the subsequent research phases, I avoided as far as possible collecting vegetal material for the herbarium in order to avoid potential damage to individuals. Every emergence of species (individuals) and populations has been recorded (genus, place, phonological stage, vegetal association, threats to this genus, and during the last three years, data has been collected by means of GPS devices), and the location where these have been found was pointed out on the relevant work maps. Herbarium material has been lodged in the Banat National Museum, Timişoara.

The determination of species has been made based on the data provided by "Flora of The Socialist Republic of Romania" XII (Paucă et al., 1972) up to the species level and the nomenclature of taxa that was used has been harmonized with „Flora Europea" (Moore, 1980). Other specialist bibliographical sources have also been used (Soó, 1973; picture-based identification guides; specialist websites).

The synecological characteristics of the orchid species recognized in the research area have been defined based on the principles and methods prescribed by the Central-European Phytocenological School (Braun-Blanquet, 1965).

The determination of the vegetal associations has been made directly in situ, based on the dominance and codominance principles. For denominating the vegetal associations presented within this study, I have used the "Phytocenoses from Romania. Syntaxonomy, structure, dynamics and evolution" monograph (Sanda et al., 2008).

RESULTS AND DISCUSSION

The first personal research notes, in situ, regarding the presence of the orchid species have been laid down in 1996, in the western part of the Locvei Mountains (the surroundings of Belobreşca Village), being then gradually extended over the entire area of the southern versants of Locvei Mountains, between Şuşca Village and Baziaş Village.

After 2004, the research has been extended across the entire area of the "Iron Gates" Nature Park. Until 2009, I have managed to acknowledge in situ a number of 23 orchid species (Milanovici, 2009) from which two new orchid species in the Danube Gorge, out of the 29 orchid species described by different scientific sources. However, I have not recognized the presence of several orchid species described by certain scientific data in this area.

Henceforth, the study emphasizes the orchid species existing in the research area, according to the data provided by the scientific literature and based on my personal researches (Tab. 1). Brief data have been provided for each individual species, regarding its biology and ecology thereof (i.e. the species sheet), followed by the chronological data concerning the account of the presence of the species, based on personal findings and information provided by the specialist literature, the table showing the vegetal associations where the orchid species have been found (personal observations), the graphic describing the threats to the species and implicitly, to the habitats where the species have been found (personal observations), the multi-annual chart related to the monitoring of the populations' dynamics (for the species with significant representation in the field), the distribution map emphasizing the presence and presentation of the approximate size of the populations within the same species (based on multi-annual observations).

Over the entire period of researches, in parallel with the species inventory process, the populations inventory process (populations size and dynamics as well as the threats to the populations and habitats where these have been found) has also been carried out in order to initiate the control of fluctuations of the orchid species populations with significant numerical presence in the study area.

Table 1: The orchid flora from the "Iron Gates" Nature Park area, subject to this study (data from scientific literature and personal observations); C – comments, NFP – new for park.

Species		Present in park		C.
		Reference data	Own data	
1.	*Anacamptis coriophora* (L.) R. M. Bateman, Pridgeon and M. W. Chase	x	x	–
2.	*Anacamptis morio* (L.) R. M. Bateman, Pridgeon and M. W. Chase	x	x	–
3.	*Anacamptis palustris* ssp. *elegans* (Heuff.) R. M. Bat., Pridg. and M. W. Chase	x	x	–
4.	*Anacamptis papilionácea* (L.) R. M. Bateman, Pridgeon and M. W. Chase	x	x	–
5.	*Anacamptis pyramidalis* (L.) Rich.	x	x	–
6.	*Cephalanthera damasonium* (Mill.) Druce	x	x	–
7.	*Cephalanthera longifolia* (Huds.) Fritsch	x	x	–
8.	*Cephalanthera rubra* (L.) L. C. Rich.	x	x	–
9.	*Epipactis atrorubens* (Hoffm.) Schult.	x	–	–
10.	*Epipactis helleborine* (L.) Crantz.	x	x	–
11.	*Epipactis microphylla* (Ehrh.) Sw.	x	–	–
12.	*Epipactis palustris* (L.) Cranz	x	–	–
13.	*Epipactis purpurata* Sm.	–	x	NFP
14.	*Epipogium aphyllum* (Schmidt) Sw.	x	–	–
15.	*Gymnadenia conopsea* (L.) R. Br.	x	x	–
16.	*Himantoglossum jankae* Somlyay, Kreutz and Óvári.	x	–	–
17.	*Limodorum abortivum* (L.) Sw.	x	x	–
18.	*Listera ovata* (L.) R. Br.	–	x	NFP
19.	*Neotinea tridentáta* (L.) R. M. Bateman	x	x	–
20.	*Neotinea ustulata* (L.) R. M. Bateman	x	–	–
21.	*Neottia nidus-avis* (L.) L. C. Rich.	x	x	–
22.	*Ophrys apifera* Hudson	x	–	–
23.	*Ophrys scolopax* Cav. ssp. cornuta (Steven) Soó	x	x	–
24.	*Orchis mascula* L.	x	x	–
25.	*Orchis militaris* L.	x	x	–
26.	*Orchis pallens* L.	x	x	–
27.	*Orchis purpurea* Huds.	x	–	–
28.	*Orchis simia* Lam.	x	x	–
29.	*Platanthera bifolia* (L.) L. C. Rich.	x	x	–
30.	*Platanthera chlorantha* (Cust.) Rchb.	x	x	–
31.	*Spiranthes spiralis* (L.) Chevall.	x	x	–

In respect of the analysis and synthetic presentation of the research data, for every species found in the field there have been presented relevant synthetic data (Fig. 2, "*the species sheet*"), as follows:

– brief data regarding the biology and ecology of the species according to "Romanian Flora" (Flora României); Soó, 1973; Ciocârlan, 2009;

– the chronological data regarding the presence of the species, based on the information provided by the botanical scientific literature and my personal researches, for all species;

– the phenological table regarding the blossom period of the orchid species found in the field (based on my personal notes and considerations, there has been used the simple presentation method synthesized in an explanatory table; Tab. 2);

– the table emphasizing the vegetal associations where the field researches found different orchid species (based on personal observations; there has been used the simple presentation method synthesized in an explanatory table, according to some of my personal considerations; Tab. 3);

– a chart including the potential threats for the species and implicitly for the habitats where the species has been found; I used an imaginary scale from one to 10 where I represented the influence degree of the threats in direct correlation with the habitats where the orchid species have been found (Fig. 4);

– the multi-annual chart regarding the monitoring of the dynamics of populations (for certain orchid species with significant representation, from the numeric perspective; I used my own research method, as follows: firstly, I chose a population of a particular species and I delimited the monitoring area, as follows: in the (imaginary) center of the population I sank deep down into the earth a permanent pole to be used as a bench-mark for the future years (Fig. 1); using a string attached to the pole by one tag, I measured the population length, i.e. 25 m (monitoring for grasslands), stretching the string to the south; the same principle was applied for the other three directions; at the other tag end of the string (at exact 25 m length) I fastened in a provisory stick and thus I created a measurable monitoring area, namely a 50 x 50 m square; as for the forest habitats, I set up a 100 x 100 m monitoring measurable area (as a central land mark, I used a marked tree placed exactly in the centre of the orchid population) since the orchid species that characterize the forest phytocenoses are more sporadic and scattered; for each monitoring area I indicated the park area where the population was found, as well as the name of the monitored place the surface, the type of habitat, and the type of the vegetal association (Sanda et al., 2008), as well as the area exposure and slope angle) (Figs 3a, b);

– the distribution map, underlining the presence and description of the approximate size of the populations belonging to the same species (there have been used ArcWiev shapes, processed and specially customized for the two protected areas subject to this study; the presence of the species as well as the size of its population has been indicated by means of a full black or white circle of different sizes which also shows the size of the population, from the numerical perspective; the literary data has been represented by means of a white triangle; Fig. 5);

– synthetic map have been attached to this specific study, as appendixes, describing all species that have been found using both the literary data and my personal observations (Fig. 10).

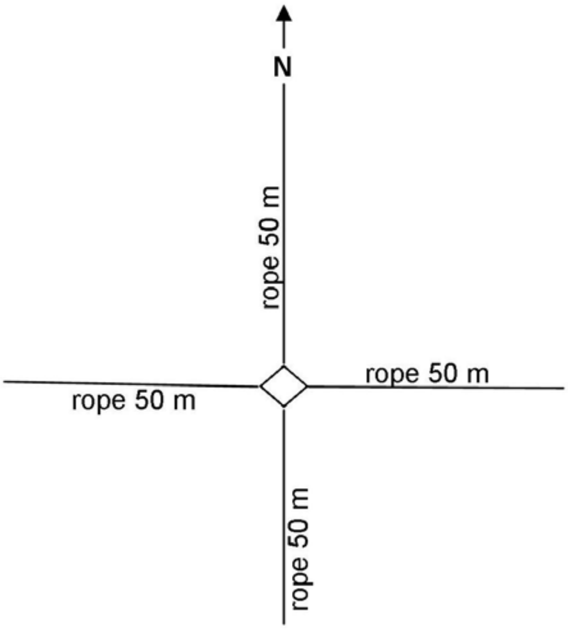

Figure 1: Graphic presentation of the method for monitoring the orchid populations' dynamics. Model of the *species sheet* (drawn up for every species from all 29).

Figure 2: *Orchis mascula* L. – poranici; in Romania, it is represented by *O. mascula* L. ssp. *signifera* (Vest) Soó.

Biological particularities: species coenology: glades, open woods and forest borders, scrubby areas and glades from the mountain regions stretching sometimes up to the alpine area, especially on the calcareous substrates according to "Flora of the Socialist Republic of Romania" (***, 1972); flowering period: IV – VI "Flora of the Socialist Republic of Romania" (***, 1972); biological form: geophyte (Ciocârlan, 2009); number of chromosomes: 2n = 42 (Ciocârlan, 2009).

Ecological particularities: phytogeographical element: sub-Mediterranean (Ciocârlan, 2009); requirements in respect to the climate and soil: mesophyte, light moderate acidophyle (Ciocârlan, 2009).

Status of the species: in the country: frequent (Ciocârlan, 2009).

Data from the scientific literature: Valea Mare – Moldova Nouă (Grigore and Coste, 1975); Moldova Nouă (Herbar Vlaicu N., Muzeul Naţional al Banatului, exs., Vlaicu, 1985).

Personal observation. Belobreşca area: Potok – Belobreşca (1994), road from Belobreşca to Zlatiţa (1998), Pantin Breg (1999), Ceroviţa (1999), Glavčina, Tavančić, Velika Lokva (1999); Ribiş-Divici (1995); Şuşca (1998); Piatra Albă – Radimna (1999); Divici (1999); Sviniţa area: Ielişova (2005), Trescovaţ – Mala Kukujova (2005), Tri Kule (2004); Plavişeviţa (2005); Mala Valley (2004), Ieşelniţa Valley (2005); Orşova area (2007), Alion Hill (2004, 2005); Mare Valley – Moldova Nouă (2006); Sasca Montană (2008); Ciucaru Mic – Dubova (2008); Vârciorova – Faţa Virului (2006); Sfânta Elena (2009); Oglănicului Valley (2008, 2009); Sirinia Valley (2009).

Table 2: Flowering period of *Orchis mascula* L. in "Iron Gates" Nature Park (table model acording to Savić, 2001).

Flowering period of the following species: *Orchis mascula* L.												
week one (1 – 7th day of the month)				+	+							
week two (8 – 14)				+								
week three (15 – 21)				+								
week four (22 – 30, 31)			+	+								
Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII

Table 3: Coenological affiliation of *Orchis mascula* L. occurence in the field (original); according to Sanda et al., 2008.

Area	Cenological affiliation
Western area	*Festuco (rubrae) – Agrostietum* Horv. 1951; *Quercetum petraeae-cerris* Soó 1957; *Querco petraea – Carpinetum* Soó and Pocs 1957; *Querco – Carpinetum orientalis* (Sancev 1961) Csűrös et al., 1968; *Tilio (argenteae) – Quercetum petraeae – cerris* Soó 1957; *Corno-Fraxinetum orni* Pop and Hodişan 1964; *Carpino – Fagetum* Paucă 1941 sas. *banaticum* (Borza 1958); *Phyllitidi – Fagetum* Vida 1959.
Central area	*Festuco (rubrae) – Agrostietum* Horv. 1951; *Tilio (argenteae) – Quercetum petraeae – cerris* Soó 1957; *Carpino – Fagetum* Paucă 1941 sas. *banaticum* (Borza 1958); *Phyllitidi – Fagetum* Vida 1959.
Eastern area	*Quercetum petraeae-cerris* Soó 1957; *Querco petraea – Carpinetum* Soó and Pocs 1957; *Querco – Carpinetum orientalis* (Sancev 1961) Csűrös et al. 1968; *Sedo maximi – Quercetum frainetto-cerridis* B. Jov 1986; *Corno – Quercetum pubescentis* Jakucs and Zólyomi ex Mathé and Kovács 1962; *Corno – Fraxinetum orni* Pop and Hodişan 1964; *Aremonio – Fagetum banatico – oltenicum* Boşcaiu 1970.

Area: "Iron Gates" Natural Park, western area;
MONITORING for *Orchis mascula* L.
Location subject to monitoring: Potok Valley (between Belobreşca and Divici villages);
Surface: 100 x 100 m;
Type of habitat: oak forest;
Vegetal association: *Quercetum petraeae-cerris*, Soó 1957;
Exposure and slope angle: southern, 45°.

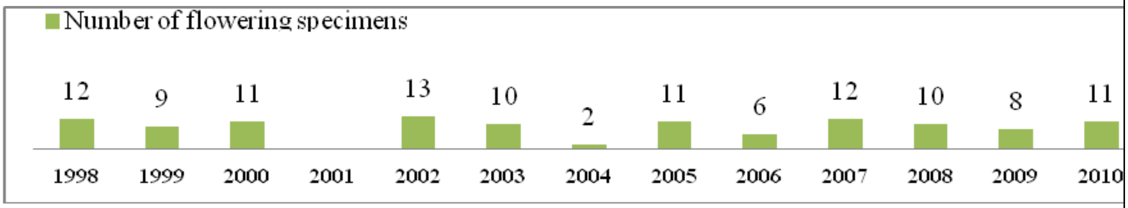

Figure 3a: Monitoring of *Orchis mascula* – in western area of the "Iron Gates".

Area: "Iron Gates" Natural Park, eastern area;
MONITORING for *Orchis mascula* L.
Location subject to monitoring: Vârciorova – Faţa Virului Mic;
Surface: 100 x 100 m;
Type of habitat: oak forest;
Vegetal association: *Corno-Quercetum pubescentis* Jakucs and Zólyomi ex Mathé and Kovács 1962;
Exposure and slope angle: south-western, 45°.

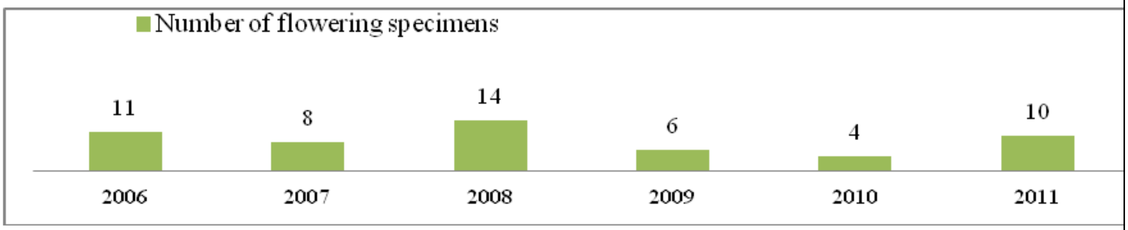

Figure 3b: Monitoring of *Orchis mascula* – in western area of the "Iron Gates.

In the analytical section dedicated to all orchid species found in the research area, I approached different aspects related to the sustainable preservation and protection of the orchid species from the two protected areas that are the subject of this study, as follows:

I presented the coenotaxonomic affiliation of the orchid species (a table-based presentation specifying the number of orchid species I found in the field for every vegetal association that has been described, followed by graphic representations, table 4);

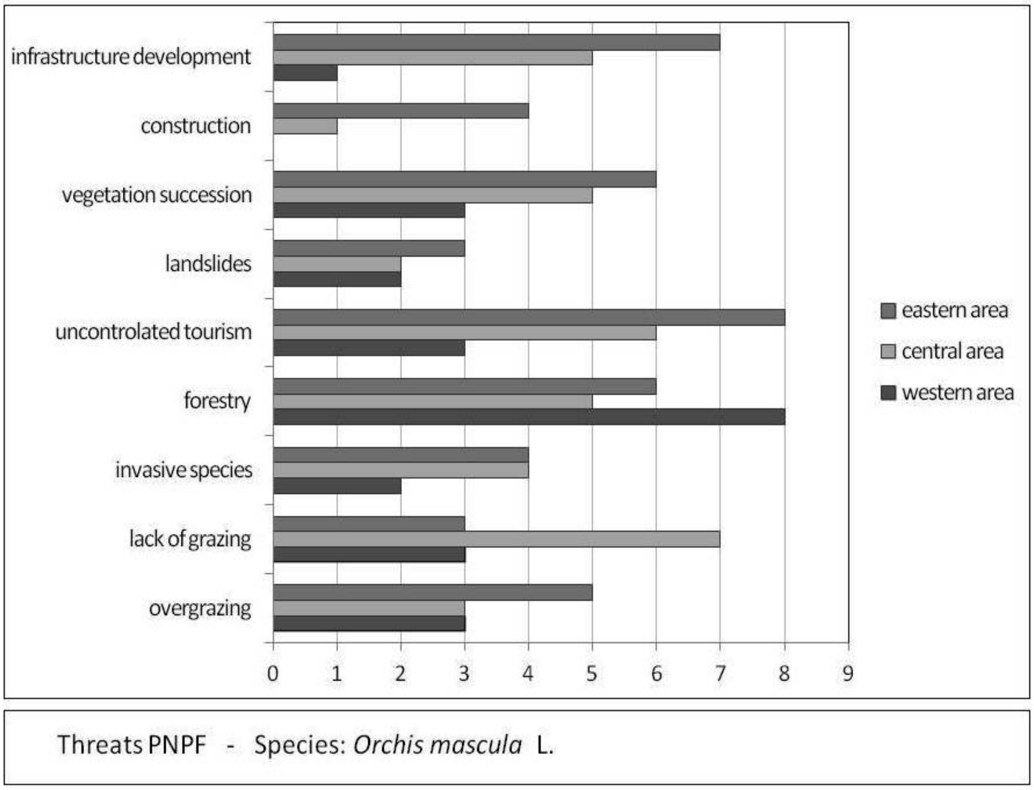

Figure 4: Threats for *Orchis mascula* L. – for "Iron Gates" Nature Park (original).

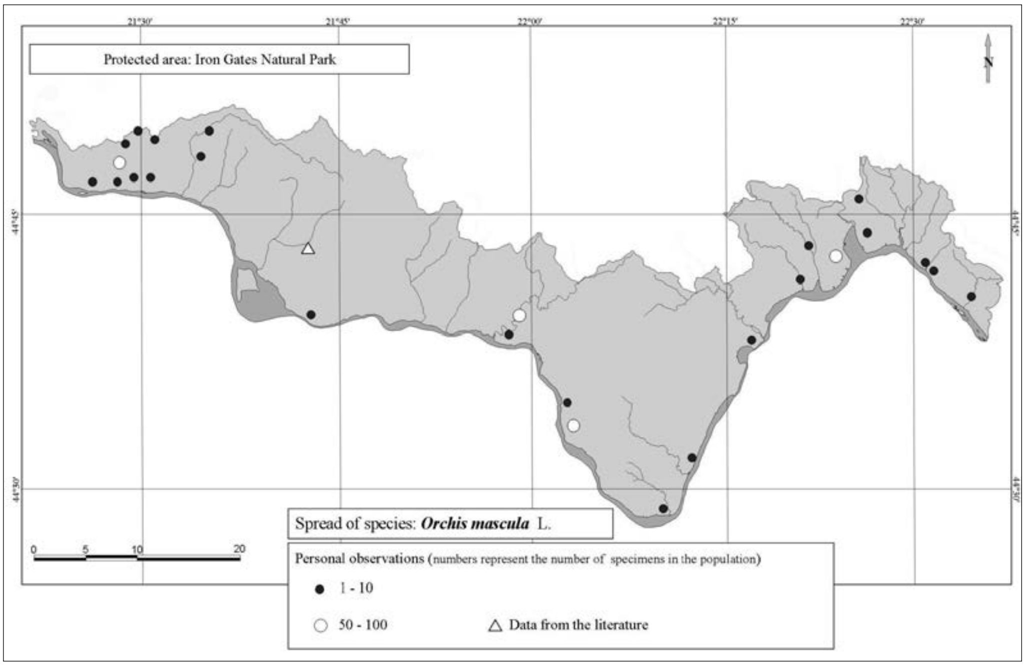

Figure 5: Distribution of the species *Orchis mascula* L. – "Iron Gates" Nature Park (original).

Table 4: Number of orchid species I found in the field for each vegetal association (original; acording to Sanda et al., 2008).

Vegetal association	No. of orchid species
Carpino – Fagetum Paucă 1941 sas. banaticum Borza, 1958	13
Danthonio – Chrysopogonetum Boşcaiu, 1972	9
Festucetum valesiaco – rupicolae Csűrös and Kovács, 1962	9
Festuco (rubrae) – Agrostietum Horv., 1951	9
Quercetum petraeae-cerris Soó, 1957	6
Danthonio-Brachypodietum pinnati Soó, 1946	5
Querco petraea – Carpinetum Soó and Pocs, 1957	5
Festucetum valesiacae (Danon 1962) Borisavljević et al., 1955	4
Phyllitidi – Fagetum Vida, 1959	4
Querco – Carpinetum orientalis (Sancev 1961) Csűrös et al., 1968	4
Medicagini minimae – Festucetum valesiacae Wagner, 1941	4
Chrysopogonetum grylli praemoesicum Roman, 1974	3
Corno-Fraxinetum orni Pop and Hodişan, 1964	3
Corno-Quercetum pubescentis Jakucs and Zólyomi ex Mathé and Kovács, 1962	3
Epipacteto – Fagetum Resmeriţă, 1972	3
Sedo maximi – Quercetum frainetto-cerridis B. Jov, 1986	3
Thymo pannonici – Chrysopogonetum grylli Doniţă et al., 1992	3
Filagini – vulpietum Oberd., 1938	2
Peucedano rocheliani – Molinietum caeruleae Boşcaiu, 1965	2
Quercetum farnetto – cerris Rudski 1949 sas. banaticum Pop I., 1967	2
Tilio (argenteae) – Quercetum petraeae – cerris Soó, 1957	2
Trifolio (repens) – Lolietum perennis Kripelova, 1968	2
Aremonio – Fagetum banatico – oltenicum Boşcaiu, 1970	1
Agrostio-Festucetum valesiacae Borisavljević et al., 1955	1
Cotino – Carpinetum orientalis Csűrös et al., 1968	1
Filipendulo – Geranietum palustris Koch, 1926	1
Geranio macrorrhizae – Fagetum (Borza, 1933) Soó, 1964	1
Hieracio pilosellae – Festucetum valesiaceae Vučković, 1991	1
Junco – Molinietum Preising, 1951	1
Scirpo – Phragmitetum Koch W., 1926	1

Vegetal associations and orchids in the research area

From the vegetation perspective, the orchids in the research area have not been sufficiently studied (Matacă, 2005, has found five species in the field and he refers to the cenological affiliation for 29 species), going no further than the alliance level; as for the Locvei Mountains, Coste, 1974, points to the presence of 15 orchid species (from which he managed to acknowledge only 11 species in the field), adding for most of the species the coenological affiliation up to the level of association.

The scanty data about the orchids may be linked to several factors, such as their scarcity and the small and scattered populations. Based on my personal observations (as well as the very few official data regarding the presence of the orchid species in different vegetal associations), the orchids have been found in 30 vegetal associations (Tab. 4).

Considering the size of the orchid populations, I have tried to provide a more accurate account regarding their exact number, according to the multi-annual data that have been gathered till now (there has been used the graphic simple presentation method, based on my personal determinations) (Figs. 6 and 7);

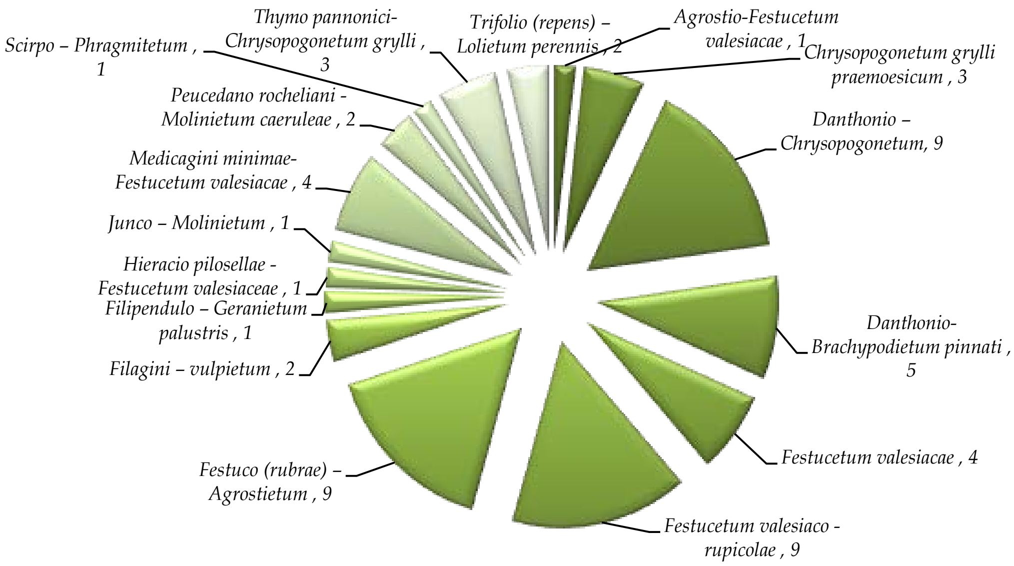

Figure 6: Number of the orchid species in certain habitats, such as grasslands and meadows in the Danube Canyon (vegetal associations according to Sanda et al., 2008).

Due to the fact that most orchid species blossom during the late spring or early summer, I have inserted two graphic representations that explain the number of species that blossom in the research area (graphic according to Savić, 2001, Fig. 8).

I have depicted, in a tabular manner, the most important threats for the orchid species which I found in the field, using a synthetic scale from one to five (in order to express the degree of influence) and I have also added several personal considerations regarding the threat status and the natural recovery process of the ecosystem (habitat) that has been affected; all the threats described in the table have been individually detailed for every protected area subject to my research, being also accompanied by numerous original photos (Tab. 5);

Taking into account the fact that most orchid species are rare, I drew up a table identifying their status, based on several criteria (according to IUCN; according to Oltean et al. (1994); according to Dihoru and Negrean (2009); their preservation status, according to the Management Plans applicable in the park; according to CITES) as well as their status and condition (based on an individual analysis), according to my personal opinion (Tab. 6).

After an analysis of the threats and the status of the species, I decided to set forth a number of sustainable preservation measures (for every area of the two parks subject to study, complementary to the measures presented by the PNPF administration in Management Plans).

Combining and analyzing the data collected in the field and the relevant information provided by the specialist literature (regarding the presence, the status of populations and the threats to the orchid species) I also put forth appropriate solutions for preservation, suggesting the inclusion of several areas from the "Iron Gates" Nature Park (which currently are not considered as such) into the integral protection area.

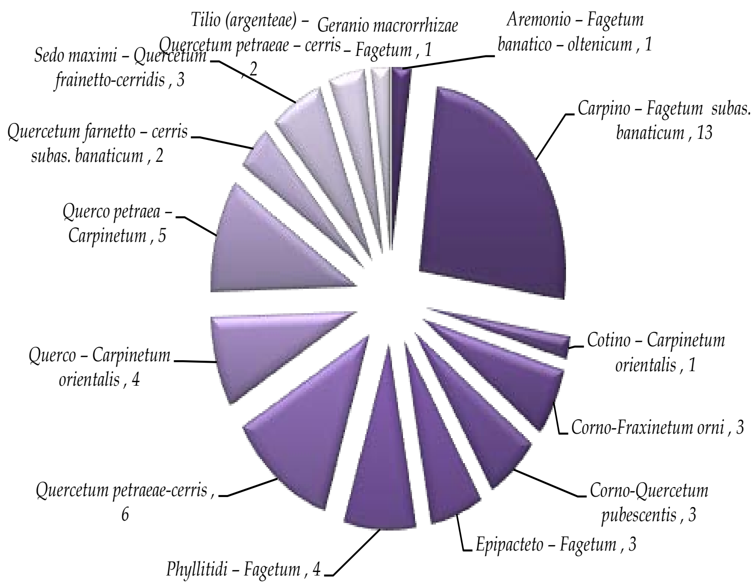

Figure 7: Number of the orchid species in certain habitats, such as forests and scrubby areas in the Danube Canyon (vegetal associations according to Sanda et al., 2008).

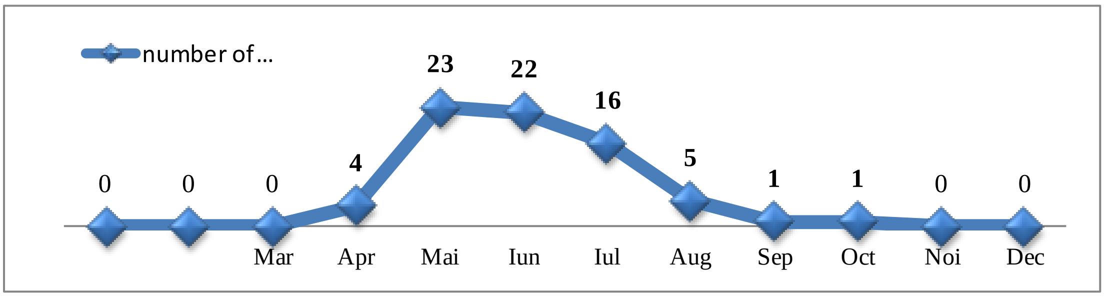

Figure 8: Flowering calendar for the orchid species in "Iron Gates" Natural Park (Savić, 2001).

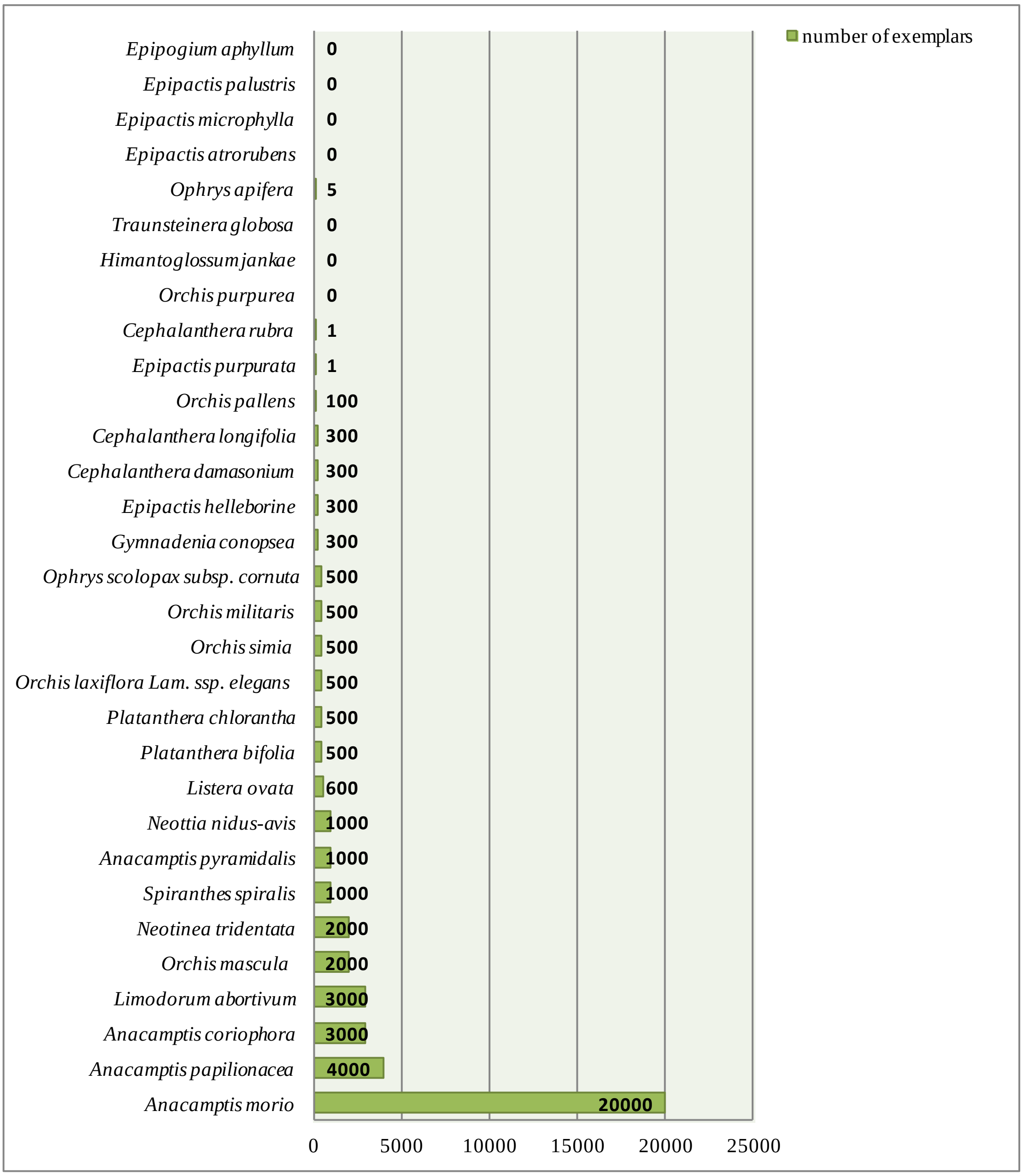

Figure 9: Estimated number of individuals
(average years of research from 1998 to 2014)
for the Danube Gorge.

Table 5: Threats to the (habitats) orchid species in “Iron Gates” Nature Park.

No.	Threat	Threat intensity (scale 1-5)	Recovery process of the ecosystems’ naturality	Threat status
1.	Modification of natural habitats by changing the use of lands			
	a. Legal and illegal construction works (expansion of the lands within the built-up area)	5	irreversible	critical
	b. Stone quarries	3	irreversible	critical
	c. Wind farms	2	irreversible	critical
2.	Legal and illegal clearings in park	4	long-term	alarming
3.	Development of infrastructure (roads, adjacent buildings)	3	irreversible	critical
4.	Abandonment of lands (grass lands, meadow lands, orchards)	2	long-term	alarming
5.	Uncontrolled (frantic) tourism	2	medium-long term	alarming
6.	Invasive species	2	long-term	alarming
7.	Illegal collecting	1 (potential 5)	long-term	alarming
8.	Other threats (fires, landslides)	1	short-long term	tolerable

Table 6: The status of the orchid species from the two protected areas, subject to this study; CR – critically endangered, EN – endangered, VU – vulnerable, V/R – vulnerable/rare, R – rare, NT – non-threatening, DD – insufficiently known; Legend (of the table): 1. IUCN 2011. IUCN Red List of Threatened Species. Version 2011.1., www.iucnredlist.org. Downloaded on 22 October 2011 (* – no information in the IUCN database); 2. Dihoru and Negrean (2009): The Red Data Book of Vascular Plants of Romania (Cartea Roşie a plantelor vasculare din România). Romanian Academy Publishing House, Bucharest; 3. Oltean et al., I/1994. The Red List of the Superior Plants from Romania (Lista Roşie a plantelor superioare din România). Romanian Academy – Institute of Biology, St. Sin. Doc. Ec., Bucharest; 4. ***, Administration of "Iron Gates" Natural Park (2008, 2011): Management Plan of the "Iron Gates" Natural Park, Orşova (brief data); 5. CITES, 2011. http://www.cites.org/eng/app/appendices.php accessed on October 25th 2011 (*, – protected); 7. Personal considerations (based on the data provided by the scientific literature and based on personal researches carried out over 15 years of study in the field); NRB – National red Book 2009, NRL – National Red List 1995, PC – Personal Considerations, PNPF – Statute PNPF.

	Species	1	2	3	4	5	6
1.	*Anacamptis coriophora* (L.) R. M. Bateman, Pridgeon and M. W. Chase	–	–	R	–	X	R
2.	*Anacamptis morio* (L.) R. M. Bateman, Pridgeon and M. W. Chase	–	–	R	–	X	NT
3.	*Anacamptis palustris* ssp. *elegans* (Heuff.) R. M. Bat., Pridg. and M. W. Chase	–	–	R	–	X	CR
4.	*Anacamptis papilionácea* (L.) R. M. Bateman, Pridgeon and M. W. Chase	–	LR	R	–	X	R
5.	*Anacamptis pyramidalis* (L.) Rich.	LC	–	V/R	R	X	R
6.	*Cephalanthera damasonium* (Mill.) Druce	–	–	R	–	X	R
7.	*Cephalanthera longifolia* (Huds.) Fritsch	–	–	R	–	X	R
8.	*Cephalanthera rubra* (L.) L. C. Rich.	–	–	V/R	R	X	EN
9.	*Epipactis atrorubens* (Hoffm.) Schult.	–	–	R	–	X	–
10.	*Epipactis helleborine* (L.) Crantz.	–	–	R	–	X	R
11.	*Epipactis microphylla* (Ehrh.) Sw.	–	–	R	–	X	–

Table 6 (continued): The status of the orchid species for "Iron Gates" Nature Park, subject to this study.

12.	*Epipactis palustris* (L.) Cranz	–	–	R	–	X	–
13.	*Epipactis purpurata* Sm.	–	–	R	–	X	EN
14.	*Epipogium aphyllum* (Schmidt) Sw.	–	–	R	–	X	DD
15.	*Gymnadenia conopsea* (L.) R. Br.	–	–	R	–	X	R
16.	*Himantoglossum hircinum* (L.) Spreng.	–	–	R	–	X	–
17.	*Limodorum abortivum* (L.) Sw.	–	–	R	–	X	V/R
18.	*Listera ovata* (L.) R. Br.	–	–	R	–	X	VU
19.	*Neotinea tridentáta* (L.) R. M. Bateman, Pridgeon and M. W. Chase	–	–	R	–	X	R
20.	*Neotinea ustulata* (L.) R. M. Bateman, Pridgeon and M. W. Chase	–	–	R	–	X	–
21.	*Neottia nidus-avis* (L.) L. C. Rich.	–	–	R	–	X	R
22.	*Ophrys apifera* Hudson	–	–	R	–	X	–
23.	*Ophrys scolopax* Cav. ssp. *Cornuta* (Steven) Soó	–	CR	R	–	X	VU
24.	*Orchis mascula* L.	–	–	R	–	X	R
25.	*Orchis militaris* L.	–	–	R	–	X	V/R
26.	*Orchis pallens* L.	–	CR	R	–	X	E
27.	*Orchis purpurea* Huds.	–	–	R	–	X	–
28.	*Orchis simia* Lam.	–	–	R	–	X	VU
29.	*Platanthera bifolia* (L.) L. C. Rich.	–	–	R	–	X	R
30.	*Platanthera chlorantha* (Cust.) Rchb.	–	–	R	–	X	V/R
31.	*Spiranthes spiralis* (L.) Chevall.	–*	–	R	–	X	R

The following abbreviations have been used within this study:

IGNP – "Iron Gates" Nature Park; IUCN – International Union for Conservation of Nature (in Romanian: Uniunea Internaţională pentru Conservarea Naturii); O. S. – Forest District; U. P. – Production Unit; MMP – Ministry of Environment and Forests.

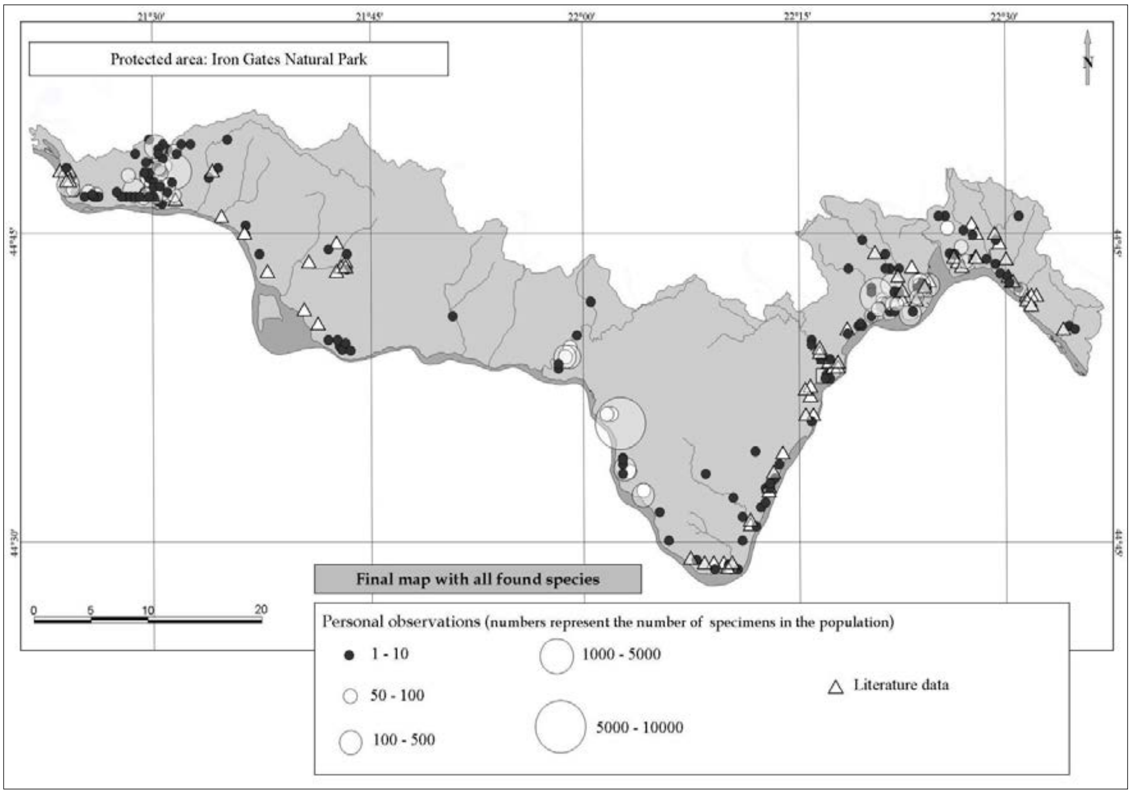

Figure 10: Distribution of orchid species and populations – "Iron Gates" Nature Park (original).

Measures proposed for the protection and sustainable preservation of the Orchidaceae L. species in the "Iron Gates" Nature Park

Consulting the Management Plan (2011) for the "Iron Gates" Nature Park, I found that only a relatively small area of the park benefits from integral protection measures (basically, the natural reservations within the park have been included).

A significant number of habitats of grasslands and forests, where I discovered a high number of orchid species (and implicitly, extensive populations) and other cohabiting floral and faunal elements, extremely important from the biodiversity preservation perspectives, are still not included in the integral protection areas.

Therefore, analyzing strictly the data collected in the field, I propose for evaluation and approval to the administration of the park (the Park Scientific Council, respectively), the following localities and areas which, from the biological diversity point of view, fully comply with the requirements for the integration into the integral protection areas, being thus able to have a proper status. A large part of these areas is currently subject to extreme severe anthropogenic disturbance (the area of the Sfânta Elena karst plateau, the area of Eşelniţa township).

Proposals for the expansion of the integral protection area (consisting in the proposed map – purple coloured areas, figure 11):

Western area of the "Iron Gates" Natural Park: a. dry grasslands from Topovište and Govedarište (area of Baziaş Village); **b.** grasslands and the underbrush and scrubs at the south of the Baziaş Natural Reservation, stretched over its entire length, up to the limit with DN 57A; besides the orchid species and other rare plants and the vegetal associations belonging to the sub-Mediterranean type, the area shows an important habitat for Horned Viper (*Vipera ammodytes*) and Hermann's Tortoise (*Testudo hermanni*); this area also fosters a significant number of *Paeonia officinalis* ssp. *banatica* specimens; **c.** semi-natural and natural grasslands at the north and east of Divici Village; **d.** grasslands and meadows between Potok Valley and Belobreşca Valley (Ceroviţa Hills); **e.** the beech and oak forests located in the Potok Valley (between Divici and Belobreşca Villages); **f.** grasslands and underbush and scrubs at the NE of Belobreşca Village (Tavančic, Mala Lokva Hills); **g**. grasslands and meadows at the north of Şuşca Village (Movila Strejerica Hill); **h.** the hill cliffs covered by dry grasslands, on the left exit road from Măceşti Village to Moldova Veche locality; **i.** grasslands and underbrush located on the Livadika limestone plateau (at the south of Sfânta Elena Village) close to "Feţele Dunării" cliff; **j.** grasslands and meadows in the sinkholes area of Sfânta Elena limestone plateau (currently, a large part of this area has been destroyed and transformed into a huge wind farm); **k.** wet grasslands on the left side of the Liuborajdea (Strenjak) Valley;

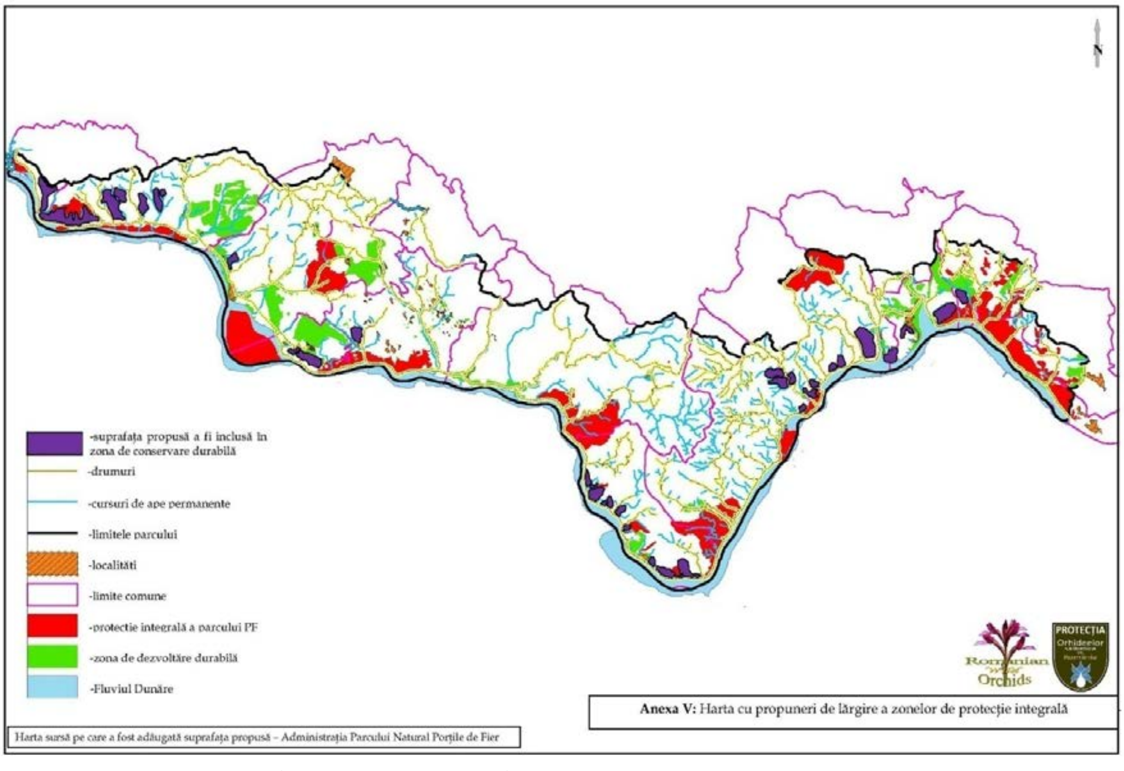

Figure 11: Proposals for the expansion of the integral protection area – "Iron Gates" Natural Park (map source: "Iron Gates" Nature Park Administration).

Central area of the "Iron Gates" Nature Park: a. grasslands and meadows, the ancient beech and oak forests in the Sirinia Valley (to Bigăr Village, already included into the integral protection area of the "Iron Gates" Nature Park); all grasslands (from the main peaks to DN 57) from the Polesava (Ielişova, respectively) creek up to the small valley of the Povalina Creek (including also the grasslands from the area of the Treskovac Peak); **c.** all grasslands and the scrub and underbrush (shiblyak type scrub) at the SE of Sviniţa township, Cioaca Boštica area, Tri Kule up to DN 57; **d.** beech forests, peaks covered by oak trees from the Mraconia Valley;

Eastern area of the "Iron Gates" Nature Park: a. all grasslands on the left banks of the Mrakonia Bay; the grasslands towards Vulcan Hill (at the north of the Cazanele Mici Reservation) from the built-up area of Eşelniţa township; **c.** the grasslands and scrub in the Mala area (Eşelniţa); **d.** the grasslands and scrub in the adjacent area of Eşelniţa township; **e.** the grasslands and oak forests from Eşelniţa township and Orșova municipality; **f.** the grasslands on Alion Hill (Orșova); **g.** the grasslands in the Ţarovaţ and Gârbovac Valley (Iloviţa Village).

CONCLUSIONS

This study aims to render a general exhaustive approach of all terrestrial orchid species that grow in Romania, starting from the morphological features to the particularities related to their biology and ecology, followed by a comprehensive study of the detailed orchid species found in the Danube Gorge ("Iron Gates" Nature Park) area.

In respect of the distribution (corology), ecology and preservation of the terrestrial orchid species growing in the South-West of Romania (the southern region of Banat, respectively), we can draw few conclusions.

Based on the data provided by the scientific literature, I determined that 39 orchid species are present in the southern region of Banat (29 are growing in the "Iron Gates" Nature Park, from the 58 species currently acknowledged in Romania).

During my personal researches conducted in the field for over 15 years, I acknowledged the presence of 23 orchid species in the Danube Gorge area ("Iron Gates" Nature Park).

I established the presence of new orchid species in the research area: two new species in the Danube Gorge area ("Iron Gates" Nature Park): *Epipactis purpurata* Sm. and *Listera ovata* (L.) R. Br.

I found orchid species in almost all existing types of natural habitats within the two research areas (except for the steep rocky habitats). An interesting aspect is the fact that no species belonging to the genus *Dactylorhyza* was found in the Danube Canyon area (no scientific data and no findings during the researches in the field).

The orchid species have been found in 30 vegetal associations, for the "Iron Gates" Nature Park.

The highest number of orchid species, characteristic of open habitats, such as the grasslands, is found in three representative vegetal associations: Danthonio – Chrysopogonetum (nine species), Festucetum valesiaco – rupicolae (nine species) and Festuco (rubrae) – Agrostietum (nine species). As for the various forest habitats, a significant abundance of orchid species was found in the: Carpino – Fagetum (13 species) vegetal association.

The orchids represent rare species (some very rare) in the area of "Iron Gates" Nature Park, subject to my research. For example, in the Danube Gorge, the largest representation (by number) is attributed to the species *Anacamptis morio*, with an estimate of 20,000 specimens, followed by *Anacamptis papilionacea* (4,000), *A. coriophora* and *Limodorum abortivum* with populations of about 3,000 specimens each (Fig. 9).

A major part of the orchid species present in the research area are in bloom from April until June.

Unfortunately, the actual status of the protection measures taken not only for the orchid species but for all other rare plants (including their habitats), and which are growing within the two protected areas can hardly be considered satisfying.

One of the most important problems that lead to the degradation of the natural habitats from the two protected areas, and which was observed in the field, was the change of land use (an irreversible change, in my opinion, by building holiday homes, wind farms, stone quarries, etc.) followed by the illegal collection of samples, even more destructive.

Taking into consideration the aspects described by this study, it is obvious that the preservation of orchids is not possible without the durable preservation of their natural habitats. In order to provide the proper protection of every separate orchid species found in the two areas subject to my research, the administrators of these areas should be contacted for setting forth the necessary steps to be followed for the integral preservation (as far as this is possible) of the habitats where these rare species are growing.

A significant number of habitats of grasslands and forests ("Iron Gates" Nature Park), where I found a large number of orchid species, does not yet benefit from integral protection measures. Therefore, after a thorough assessment of the data I collected in the field, I propose, for analysis and approval by the administration of the "Iron Gates" Natural Park, 21 new areas which I consider necessary to be included in the park's integral protection system.

In my opinion, the presence of orchids is a sign of a well-preserved habitat and, at the same time, a significant market of the proper state of preservation of the existing biodiversity (the undisturbed intra- and interspecific relationships).

The researches will continue especially due to my passion for studying this very interesting and exciting family of plants. Being fully aware of the orchid flora (presence and distribution) in the south-western part of Romania, I have all necessary arguments for the next stage: protection and durable preservation of the habitats where orchid species grow. I actively try, as far as I possibly can, to engage the attention of the public, to make a small contribution towards stirring public awareness regarding the necessity to protect not only this group of plants but the entire natural heritage of Romania, which is currently facing a potential irreversible downfall for the future generations who, hopefully, will be more responsible.

REFERENCES

1. Arditti J., 1992 – Fundamentals of Orchid Biology, New York, Wiley, 704
2. Boşcaiu N., Lupşa V., Resmeriţă I., Coldea G. and Schneider E., 1971 – Vegetaţia lemnoasă mezo-xerotermă (Orno-Cotinetalia) din Defileul Dunării, *Ocrotirea Naturii*, 15, 1, 49-55, Bucureşti. (in Romanian)
3. Braun-Blanquet J., 1965 – Plant Sociology: The Study of Plant Communities, London, Hafner, 439.
4. Buttler K. P., 1986 – Orchideen, die wildwachsenden Arten und Unterarten Europas, Vorderasiens und Nordafrikas, Mosaik Verlag, Munchen, 287. (in German)
5. Ciocârlan V., 2009 – Flora ilustrată a României, Pteridophyta et spermatophyte, Edit. Ceres, Bucureşti, 1141. (in Romanian)
6. Coste I., 1974 – Flora şi vegetaţia Munţilor Locvei, Teză de doctorat, Universitatea "Babeş-Bolyai" Cluj, Facultatea de Biologie – Geografie, unpublished. (in Romanian)
7. Csürös Ş., Pop I., Hodişan I. and Csürös-Kaptalan M., 1968 – Cercetări floristice şi de vegetaţie între Orşova şi Eşelniţa, *Contribuţii botanice*, 277-312, Cluj Napoca. (in Romanian)
8. Delforge P., 2006 – Orchids of Europe, North Africa and the Middle East, A & C Black, London, 640.
9. Dihoru G. and Negrean G., 2009 – Cartea roşie a plantelor vasculare din România, Edit. Academiei Române, Bucureşti, 630. (in Romanian)
10. Dressler R. L., 1981 – The orchids: natural history and classification, Cambridge, Massachusetts, Harvard University Press, 352.
11. Dressler R. L., 1993 – Phylogeny and classification of the orchid family, Dioscorides Press, 352.
12. Gladkova H. V. and Tahtadžan A. (eds), 1982 – Semenstvo orhidnie (Orchidaceae), *Žizn rastenii*, 6, 248-275. (in Russian)
13. Grigore S. and Coste I., 1974 – Aspecte botanice din rezervaţia naturală Valea Mare-Moldova Nouă, *Ocrotirea Naturii*, 18, 2, 159-166. (in Romanian)
14. Grigore S. and Coste I., 1975 – Flora Rezervaţiei Naturale Valea Mare – Moldova Nouă (Banat), *Tibiscus, Ştiinţe Naturale*, 69-81, Timişoara. (in Romanian)
15. Grigore S. and Coste I., 1978 – Cercetări asupra vegetaţiei dintre Moldova Veche şi Pescari (judeţul Caraş-Severin), *Banatica, Caiete de Ştiinţe naturale, Studiile Cercului de Geolgie Geografie şi Biologie*, 7, 173-189, Reşiţa. (in Romanian)
16. Heuffel J., 1858 – Enumeratio Plantarum in Banatu Temesiensi, Vindobonae, 208.
17. Jávorka S. and Csapody V., 1934 – A magyar flóra képekben, Studium, Budapest, 576. (in Hungarian)
18. Matacă S., 2005 – Parcul Natural Porţile de Fier, Flora, Vegetaţia şi Protecţia Mediului, Edit. Universitară, Craiova, 549. (in Romanian)
19. Milanovici S., 2003 – Rod Orchis na južnim padinama planine Lokva (Đerdapska Klisura – Porţile de Fier) Rumunija, Diplomski rad (Licence Paper), Univerzitet u Novom Sadu, PMF – Departman za Biologiju i Ekologiju, Novi Sad, Srbija, 60. (in Serbian)
20. Milanovici S., 2004 – Genul *Orchis* L. pe versanţii de sud-vest al Munţilor Locvei (Parcul Natural Porţile de Fier), *Drobeta, seria Ştiinţele Naturii*, XIV, 36-38, Drobeta Turnu Severin. (in Romanian)
21. Milanovici S., 2006 – Orchids from "Iron Gates" Natural Park area, distribution and conservation problems (Romania) Caesiana, *The Journal of the European Orchid Council*, Edit. Borgia, Roma, Padova, 99-104.
22. Milanovici S., 2009 – Considerations regarding conservation of orchid's species in "Iron Gates" Natural Parc area, *Drobeta, Seria Ştiinţele Naturii*, XIX, 29-43, Drobeta Turnu Severin.
23. Milanovici S., 2012 – Orhidee din sudul Banatului (English – Orchids from south-west side of Banat region), East-West Print, Timişoara, 406. (in Romanian)
24. Nilsson L. A., 1992 – Orchid Pollination Biology, *Trends in Ecology and Evolution*, 7, 8, 255-259.

25. Oltean M., Negrean G., Popescu A., Roman N., Dihoru G., Sanda V. and Mihăilescu S., 1994 − Lista Roşie a plantelor superioare din România, *Studii, sinteze, documentații de ecologie*, 1, Bucureşti, 54. (in Romanian)
26. Panţu Z., 1915 – Orchidaceele din România. Studiu Monografic, Edit. Acad. Rom., Bucureşti, 225. (in Romanian)
27. Pătroescu M., Chincea I., Pascovici N., Ioja C., Matacă S., Popa E. M., Florescu V., Dumitraşcu D., Vâlceanu C., Odorescu I., Popescu V., Rozylowicz L., Necşuliu R. and Sbîrcea Ş., 2004 – Planul de management al Parcului Natural Porţile de Fier în perspectiva dezvoltării durabile, *Drobeta, Muzeul Regiunii Porţile de Fier*, XIV, 64-92, Drobeta Turnu Severin. (in Romanian)
28. Rasmussen H. N., 1995 – Terrestrial orchids from seed to mycotrophic plant, Cambridge University Press, 460.
29. Roman N., 1974 – Flora şi vegetaţia din sudul Podişului Mehedinţi, Bucureşti, 222. (in Romanian)
30. Rochel A., 1828 - Plantae Banatus rariores iconibus et desarepteniobus illustratae, Pestini;
31. Sanda V., Öllerer K. and Burescu P., 2008 – Fitocenozele din România. Sintaxonomie, structură, dinamică şi evoluţie, Edit. Ars Docendi, Universitatea din Bucureşti, 570. (in Romanian)
32. Savić D., 2001 – Orhideje Fruške-Gore, Magitarski rad, Beograd, 221. (in Serbian)
33. Soó R., 1973 – A magyar flóra és vegetáció rendszertani – növényföldrajzi kézikonyve v. Akadémiai Kiadó, Budapest, 723. (in Hungarian)
34. Souche R., 2004 – Les Orchidees sauvages de France, Pelican, Montpellier, 340. (in French)
35. ***, 1964-1980 – Flora Europaea, I-V, Cambridge University Press, Cambridge, V-476.
36. ***, Flora R. S. R. – XII, 1972, Edit. Academiei R. S. R. (in Romanian)
37. ***, 2011 – Administraţia Parcului Natural Porţile de Fier, Planul de Management al Parcului Natural Porţile de Fier, Orşova, 320. (in Romanian)
38. Herbarium Vlaicu N., Muzeul National al Banatului, exs., Vlaicu, 1985
39. IUCN Red List of Threatened Species. Version 2011.1., www.iucnredlist.org. Downloaded on 22 October 2011
40. CITES, 2011. http://www.cites.org/eng/app/appendices.php accessed on October 25th 2011

PARTICULARITIES OF THE AQUATIC VEGETATION FROM "IRON GATES" NATURA 2000 SITE (BANAT, ROMANIA)

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KEYWORDS: Romania, Danube River, "Iron Gates", aquatic vegetation, natural habitats.

ABSTRACT

The paper presents the results of investigations on the aquatic vegetation, along the Romanian bank of the Danube River, in the area of Porţile de Fier ("Iron Gates"; Mehedinţi and Caraş-Severin counties), a Natura 2000 site. Twenty-three plant communities were identified from Lemnetea minoris and Potametea pectinati classes. The survey led to the identification of some newly described phytocoenotaxons in this protected area. All the plant communities in this paper are documented by phytosociologic tables, being accompanied by coenotaxonomic, phytogeographical, ecological and social strategies analysis, in order to assess their conservation status, as the main tool for management decisions.

ZUSAMMENFASSUNG: Die Besonderheiten der Gewässervegetation im Natura 2000-Gebiet „Porțile de Fier/Eisernes Tor".

Vorliegende Arbeit stellt die Ergebnisse der Untersuchungen betreffend die Gewässervegetation entlang der rumänischen Uferstrecke der Donau im Bereich des Natura 2000-Gebietes „Porţile de Fier/Eisernes Tor" (Verwaltungskreise Mehedinţi und Caraş-Severin) vor. Dabei wurden 23 Pflanzengesellschaften der Klassen Lemnetea minoris und Potametea pectinati festgestellt. Die Untersuchungen führten zur Identifikation und Beschreibung einiger für dieses Schutzgebiet neuer phytocoenologischer Einheiten. Alle in der Arbeit vorgestellten Pflanzengesellschaften sind mittels pflanzensoziologischer Tabellen dokumentiert und von coenotaxonomischen, pflanzengeographischen, ökologischen sowie sozial-strategischen Analysen begleitet, die der Bewertung des Erhaltungszustandes als wichtigstes Instrument für Management-Entscheidungen dienen.

REZUMAT: Particularităţile vegetaţiei acvatice din situl Natura 2000 „Porţile de Fier" (Banat, România).

Lucrarea prezintă rezultatele investigaţiilor efectuate asupra vegetaţiei acvatice de-a lungul malului românesc al Dunării, în zona sitului Natura 2000 Porţile de Fier (jud. Mehedinţi şi Caraş-Severin). Au fost identificate 23 asociaţii vegetale aparţinând claselor Lemnetea minoris şi Potamogetonetea (syn. Potametea) pectinati. Studiile au condus la identificarea unor fitocenotaxoni noi pentru aria protejată. Toate asociaţiile prezentate în lucrare sunt documentate prin tabele fitosociologice, fiind însoţite şi de analize cenotaxonomice, fitogeografice, ecologice şi ale strategiilor sociale, în scopul evaluării stării de conservare a acestora, ca principal instrument în luarea deciziilor manageriale.

INTRODUCTION

The complexity of aquatic communities is a result of topographic diversity (Vivian-Smith, 1997), of physical and chemical characteristics of the water and of human influences (Tetelea, 2005; Brönmark and Hansson, 2010).

Species diversity is dependent on habitat structure, the most complex habitats hosting a higher biodiversity (Bell et al., 1991). According to Williams et al. (2003), pounds are responsible for a higher diversity comparing to other aquatic communities, sheltering unique and rare species. Aquatic macrophytes play an important role for nitrogen (Saunders and Kalff, 2001) and detritus retention (Rooke, 1984), during the vegetation season. Moreover, higher structural complexity of habitats provides higher heterogeneity of algae and invertebrates colonization (Dudley, 1988; Melo et al., 2002; Takeda et al., 2003; Thorp et al., 1997).

A complex system of rivers, ponds, ditches, swamps, and flooded areas were formed as a result of the construction of one of the largest hydroelectric power plants in Europe, “Iron Gates” I, on the Danube River, in 1972. Both, the isle of Moldova Veche and Nera Delta are large areas flooded during the spring season. According to Blaustein and Schwartz, 2001 (in Dudley), temporary water host important species for global biodiversity and plays an important role for population dynamics and community structure studies.

The “Porţile de Fier” Natural Park was the subject of many botanical surveys, addressing all the plant communities, a highly diversified area, leading to a floristic inventory of 1,875 vascular plant species: among these 1,748 species, 120 subspecies and six varieties. Also, there have been registered 44 plant communities, framed in two suballiances, 22 alliances, 16 orders, and 13 classes of vegetation (Matacă, 2005). Aquatic and wetlands flora found along the Danube River, in the “Iron Gates” Natural Park, has been studied since the nineteenth century, by Grecescu (1898), Heuffel (1858), but especially in the last century (Borza, 1947-1949; Matacă, 2002; Roman, 1971; Călinescu and Iana, 1964; Raclaru and Alexan, 1972; Ciocârlan et al., 1969; Liţescu et al., 2003; Morariu et al., 1969; Sârbu et al., 2006, 2011; Ştefureac et al., 1971).

As a result of the newly designed navigation system in the “Porţile de Fier” area, the vegetation investigations increased (Matacă, 2002; Ştefureac, 1970; Grigore and Coste, 1978; Raclaru and Alexan, 1973; Resmeriţă et al., 1972; Şerbănescu and Sanda, 1970; Csűrös et al., 1968; Dihoru et al., 1973; Păun et al., 1968; Sanda et al., 1968, 1970; Todor et al., 1971).

The purpose of this study is a reappraisal of the previously identified aquatic communities, new plant communities in the area, and the analysis of their structure, primarily to highlight the conservation status of habitats, emphasizing the presence of invasive plant species. It was taken into account the fishermen complaint toward the explosive growth of fixed aquatic vegetation, especially those communities edified by the water chestnut (*Trapa natans*). This species is known as having a wide ecological spectrum, concerning nutrient and heavy metal concentration (Rai and Sinha, 2001), playing an important role in phytoremediation (Srivastava et al., 2014).

The surveys have been conducted mainly in the Natura 2000 site “ROSPA0026 Danube sector – Baziaş-Porţile de Fier”, largely overlapping the “Iron Gates” Natural Park. The above mentioned site has an area of 9,904 ha, and is located on the territory of Caraş-Severin (56%) and Mehedinţi (44%) counties (south-western part of Romania), in Continental biogeographical region. The altitude ranges from 28 to 192 m a.s.l. (O. M. 2387/2001; Planul de management al Parcului Natural Porţile de Fier, 2013) (Fig. 1).

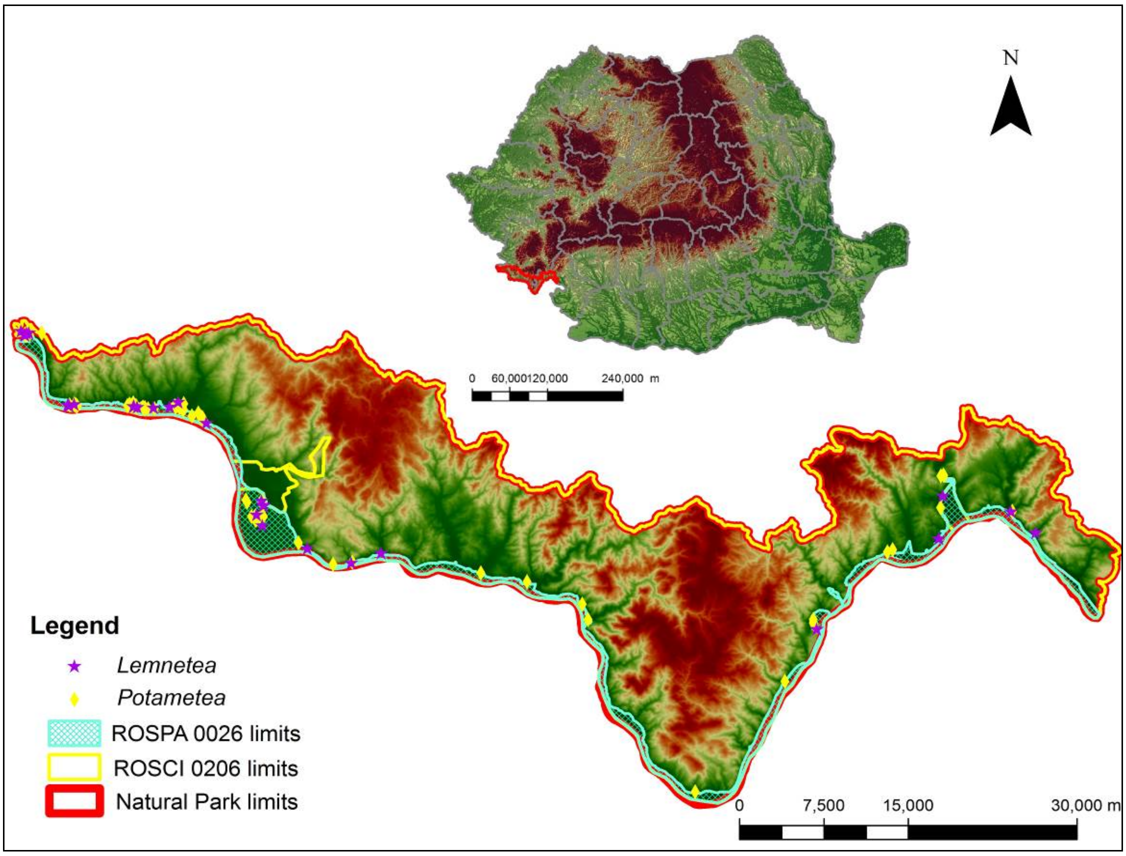

Figure 1: Map of the "Porţile de Fier" Natural Park.

Geology of the study area has a mosaic feature. The studied territory is the most picturesque section of the Danube River – the so-called areas "Cazanele Mari" and "Cazanele Mici". In addition to these, from a geological point of view there is the remarkable suspended synclinal called "Munteana", the fossiliferous outcrops at Sviniţa and Bahna, the Permian volcanic neck Trescovăţ, and also a variety of karst formations. In some areas, the loess deposits are exposed in the form of slopes, some including a status of nature reserves, for example "Râpa cu Lăstuni" (a nesting place for some species of swifts). The Moldova Veche isle was intended to become into a place to store the mining waste from the MoldaMin Company, which exploited copper in Moldova Nouă, and coal at Cozla, Baia Nouă and Bigăr.

The surveyed territory belongs to the "Iron Gates" Massif (Popp, 1971), which is crossed for 134 km by the Danube River, generating the most spectacular gorge sector in Europe (Călinescu et al., 1955; The Geological Map of Romania). Upon entering Romania, the riverbed is between 7.5 to 17.5 m in depth and has a width of up to 1,500 m. Between Coronini and Liuborajdea, the Danube passes through a limestone sector, the width decreases and reaches 36 m in depth. West of Liubcova, the Danube crosses a granite area, and toward Cozla rapids and transverse currents occur, due to substrate formed by gneisses of Ielova, conglomerates, porphyry and porphyrites. Downstream Cozla, the Danube cuts through another limestone area. The maximum depth is recorded in the "Cazane" area – about 100 m, and the width is 150-200 m. Beyond the "Cazane" area, the riverbed depth decreases and because of the lithology, represented by crystalline schists, rapids and submerged rocks appear.

Based on the calculated values for the period during 1970-2000, average annual temperatures in the "Iron Gates" Natural Park are: at Berzasca 11.4°C, at Orşova 11.6°C, at Sviniţa 11.5°C; the relative humidity of the air at Orşova is 76% and at Drobeta-Turnu Severin is of 74%. There were two periods recorded with the most rainfall, one in May-June and the second in November-December. At Orşova, the average yearly rainfall is of 586.3 mm, and at Drobeta-Turnu Severin is of 652.4 mm. The prevailing winds at Orşova are from the north-west, and at Drobeta-Turnu Severin those from west and north-west (Matacă, 2005).

From a pedologic point of view, the most widespread zonal soils are clay-illuvial podzolic series, the brown-acid soils, and intrazonal lito-morphic soils. The best soils that are presented in flooded areas are those weakly evolved soils, namely silt and alluvial soils, that vary in texture and evolution. On the high river meadow and lower terrace there is a succession of alluvial soils: sandy silt layered alluvials, the alluvial humiferous soils, and the brown alluvial soils. On alluvial cones and tributaries floodplains, soils are coarse, and in the calacareous skeleton occur branciogs. In some places, alluvial gleic soils and even swamps gleic soils are reported (Matacă, 2005; Glăvan and Geanana, 1972).

MATERIAL AND METHODS

The study of vegetation utilizes a basic coenotaxonomic unit the plant association, characterized into the field by the phytocoenoses (= individuals of association), which were analyzed on the basis of phytocenological relevés. The quantitative indices of abundance-dominance (AD) used are those from the Braun-Blanquet scale (Braun-Blanquet, 1964). Identification of plant associations was based on the characteristic species, taking into account the presence of the dominant species (Cristea, 1991, 1993; Cristea et al., 2004). In order to draw up the coenotaxonomic conspectus, various records have been consulted (Coldea, 1991, 1997; Grigore and Coste, 1978; Morariu and Danciu, 1970; Popescu and Ştefureac, 1976; Raclaru and Alexan, 1973; Şerbănescu and Sanda, 1970; Dihoru et al., 1973; Morariu et al., 1969; Popescu et al., 1997; Sanda et al., 1968, 1980, 1994; Todor et al., 1971), as well as other available European classifications.

The extent of the sampled surface was determined by the size of the phytocoenoses, ranging from 1 m^2 to 25 m^2.

Setting the location of the natural habitats were based on the characteristic phytocoenotaxons (associations, alliances, orders), as stated by the Romanian interpretation manual of habitats (Gafta and Mountford, 2008; Doniţă et al., 2005, 2006), in accordance with the European Union Habitat Directive 92/43/EEC (***, Manuel d'interpretation des habitats de l'UE).

The vascular flora nomenclature is in accordance with Flora Europaea (Tutin et al., 1964-1980; ***, http://ww2.bgbm.org/europlusmed/), and with some Romanian identification field books (Ciocârlan, 2000). We used the nomenclature of the algae suggested by Cărăuş (2012). Establishing the values of ecologic and floristic elements indexes were made after various reference publications (e.g. Popescu and Sanda, 1998; Sanda et al., 1983). The social behaviour and the degree of naturalness were analyzed after Borhidi (1995).

The coenotaxonomic classification was performed using the program SYNTAX 5.0 (Podani, 1993), using the UPGMA algorithm and also the Bray Curtis quantitative index.

RESULTS AND DISCUSSION

Twenty-three aquatic vegetal communities were identified in the area, all belonging in two classes, according to the following coenotaxonomic conspectus:

*new recorded associations in the studied area

LEMNETEA O. de Bolós and Masclans 1955

Lemnetalia minoris O. de Bolós and Masclans 1955

Lemnion gibbae R. Tx. and Schwabe-Braun in R. Tx 1974

1. Lemnetum gibbae Miyavaki and J. Tüxen 1960
2. Lemnetum minoris Oberd. ex T. Müller and Görs 1960
3. Lemno-Spirodeletum W. Koch 1954 (syn. Spirodeletum polyrhizae W. Koch 1954)
4. Salvinio-Spirodeletum polyrhizae Slavnič 1956
5. *Lemno-Salvinietum natantis Myawaki and Tx. 1960
6. *Lemno minoris-Azolletum filiculoides Br.-Bl. 1952

Lemno-Utricularietalia Passarge 1978

Utricularion vulgaris Passarge 1964

7. *Lemno-Utriculariteum vulgaris Soó (1928) 1947

Hydrocharietalia Rübel 1933

Hydrocharition morsus-ranae (Passarge 1964) Westhoff and den Held 1969

8. Hydrocharitetum morsus-ranae Van Langendonk 1935
9. Ceratophylletum demersi Corillion 1957

POTAMETEA PECTINATI R. Klika in Klika and Novák 1941

Potametalia pectinati W. Koch 1926

Potamion pectinati (W. Koch 1926) Görs 1977

10. *Potametum lucentis Hueck 1931
11. Myriophyllo-Potametum lucentis Soó 1934
    –*vallisnerietosum (syn. Potameto-Vallisnerietum Br.-B1 1931)
12. *Najadetum marinae Fukarek 1961
13. *Najadetum minoris Ubrizsy 1961
14. *Potametum pectinati (Hueck 1931) Carstensen 1955
15. Potametum pusilli Soó 1927
16. *Elodeetum nuttallii Ciocârlan et al. 1997
17. *Elodeetum canadensis (Pign. 1953) Pass. 1964

Nymphaeion albae Oberd. 1957

18. Nymphoidetum peltatae (All. 1922) Bellot 1951
19. Trapetum natantis Kárpáti 1963
20. Potametum natantis Soó 1927
21. *Potametum perfoliati Miljan 1933

Ranunculion aquatilis Passarge 1964

22. *Ranunculetum (syn. Batrachietum) trichophylli Soó (1927) 1971
23. Potametum nodosi Passarge 1964.

Class Lemnetea O. de Bolós and Masclans 1955 in the "Porţile de Fier" Natural Park is represented by nine plant communities, belonging to three orders and three alliances (Tab. 1).

Table 1: Plant communities from Class Lemnetea O. de Bolós and Masclans 1955.

Relevé no.	1	2	3	4	5	6	7	8	9	10
General coverage (%)	70	90	80	100	100	100	100	90	80	100
Relevé area (m^2)	9	9	4	9	2	1	5	9	1	25
Relevé code	Lmin_70	L_min_39	L_min_48	L_min135	L_gib138	L_gib139	L_Spi150	L_Spi137	L_Spi158	L_Spi163
Lemnion										
Lemna gibba	.	.	.	1	3	3-4	+	.	1	.
Spirodela polyrhiza	+	+-1	+	1	+	2	5	4	2	1-2
Hydrocharition										
Hydrocharis morsus-ranae	.	.	.	.	.	.	.	.	.	.
Utricularion										
Utricularia vulgaris	.	.	.	.	.	.	.	.	.	.
Lemnetalia and Lemnetea										
Azolla filiculoides	.	.	.	.	+	1	.	.	1	+
Lemna minor	4	4-5	4	5	3-4	3	1-2	2-3	3	3-4
Salvinia natans	.	.	.	.	.	.	+	+	+	+
Potamion										
Potamogeton acutifolius	.	.	.	.	.	.	.	.	.	.
Potamogeton acutifolius f. major	.	.	.	.	.	.	.	.	.	.
Potametalia and Potametea										
Najas marina	.	.	.	.	.	.	.	.	.	.
Najas minor	.	.	.	.	.	.	.	.	.	.
Potamogeton nodosus	.	.	.	.	.	.	.	.	.	.
Trapa natans	1	+	.	.	.	.	.	.	.	+
Ceratophyllum demersum	.	.	.	.	.	.	.	.	.	1
Elodea canadensis	.	.	.	.	.	.	.	.	.	.
Myriophyllum spicatum	.	.	.	.	.	.	.	.	.	.
Potamogeton crispus	.	.	.	.	.	.	.	.	.	+
Potamogeton natans	.	.	.	.	.	.	.	.	.	.
Potamogeton pectinatus	1	2	.	.	.	.	.	.	.	.
Potamogeton perfoliatus	.	.	.	.	.	.	.	.	.	+
Potamogeton pusillus	.	.	.	.	.	.	.	.	.	.
Elodea nuttallii	.	.	.	.	.	.	.	.	.	.
Phragmiti-Magnocaricetea										
Alisma plantago-aquatica	.	.	.	.	.	.	.	.	.	.
Schoenoplectus lacustris	.	.	.	.	.	.	.	.	.	.
Paspalum distichum	.	.	.	.	.	.	.	.	.	.
Varyae syntaxa										
Echinochloa crus-galli	.	.	.	.	.	.	.	.	.	.
Cladophora glomerata	.	.	2	.	.	.	.	.	.	+

Table 1 (continued): Plant communities from Class Lemnetea O. de Bolós and Masclans 1955.

Relevé no.	11	12	13	14	15	16	17	18	19	20
General coverage (%)	100	80	85	100	100	90	98	90	90	100
Relevé area (m^2)	2	9	9	9	9	9	9	1	9	9
Relevé code	L_Spi190	Sal_S112	L_Sal202	L_Sal209	L_Sal182	L_Sal181	L_Sal183	L_Azo210	L_Utr124	Hy_mr152
Lemnion										
Lemna gibba	+	.	.	.	.	.	.	.	.	.
Spirodela polyrhiza	2-3	2	.	+-1	+-1	+	+	+	.	+
Hydrocharition										
Hydrocharis morsus-ranae	.	.	.	.	.	.	.	.	.	3-4
Utricularion										
Utricularia vulgaris	.	.	.	.	.	.	.	.	5	1
Lemnetalia and Lemnetea										
Azolla filiculoides	+	.	1-2	1-2	+-1	1-2	1-2	3-4	.	.
Lemna minor	3-4	1-2	+	1-2	+	1-2	+	2	+	.
Salvinia natans	1	3-4	4	3-4	3-4	4	4-5	1-2	.	+
Potamion										
Potamogeton acutifolius	.	.	.	.	.	.	.	.	.	.
Potamogeton acutifolius f. major	.	.	.	.	.	.	.	.	.	.
Potametalia and Potametea										
Najas marina	.	.	+	.	.	.	.	.	.	.
Najas minor	.	.	.	.	.	.	.	.	.	.
Potamogeton nodosus	.	.	1	.	.	.	.	.	.	.
Trapa natans	1	.	.	.	+-1	.	1-2	.	.	.
Ceratophyllum demersum	.	.	.	.	.	.	.	.	.	2-3
Elodea canadensis	.	.	.	.	.	.	1-2	.	.	4
Myriophyllum spicatum	.	.	.	.	.	.	.	.	.	.
Potamogeton crispus	.	.	.	.	.	.	.	.	.	.
Potamogeton natans	.	.	.	.	.	.	.	.	+	.
Potamogeton pectinatus	.	.	.	.	.	.	.	.	.	.
Potamogeton perfoliatus	.	.	.	.	.	.	.	.	.	.
Potamogeton pusillus	.	.	.	.	.	.	.	.	.	.
Elodea nuttallii	.	.	.	.	.	.	.	.	.	.
Phragmiti-Magnocaricetea										
Alisma plantago-aquatica	.	.	.	.	.	.	.	.	1	.
Schoenoplectus lacustris	.	.	.	.	.	.	.	.	.	.
Paspalum distichum	.	.	.	3	3	.	.	1-2	.	.
Varyae syntaxa										
Echinochloa crus-galli	2	.	.	.	.	.	.	.	.	.
Cladophora glomerata	.	.	.	.	.	.	.	.	.	.

Table 1 (continued): Plant communities from Class Lemnetea O. de Bolós and Masclans 1955.

Relevé no.	21	22	23	24	25	26	27	28	29	30	31
General coverage (%)	60	50	100	100	100	70	85	65	90	90	100
Relevé area (m^2)	8	25	25	25	9	9	9	9	25	9	25
Relevé code	C_dem153	C_dem159	C_dem164	C_dem169	C_dem174	C_dem_1	C_dem_8	C_dem_54	C_dem139	C_dem141	C_dem142
Lemnion											
Lemna gibba	1	.	.	.	.	.	.	.	.	.	.
Spirodela polyrhiza	3-4	.	1-2	+	1-2	.	.	.	+	+	.
Hydrocharition											
Hydrocharis morsus-ranae	+	.	.	.	.	.	.	.	.	.	.
Utricularion											
Utricularia vulgaris	+	.	.	.	.	.	.	.	.	.	.
Lemnetalia and Lemnetea											
Azolla filiculoides	.	.	+	+	+-1	.	.	.	.	.	.
Lemna minor	.	.	3-4	1-2	3-4	.	.	.	+	.	+
Salvinia natans	.	.	+	+	+	.	.	.	.	.	.
Potamion											
Potamogeton acutifolius	.	.	1	.	.	.	.	.	.	1-2	+
Potamogeton a. f. major	.	.	1	.	.	.	.	.	.	1-2	+
Potametalia and Potametea											
Najas marina	.	.	.	+	+	.	.	.	+	2	+
Najas minor	.	.	.	.	.	.	.	.	.	1	+
Potamogeton nodosus	.	.	1	.	.	1-2	.	.	.	.	.
Trapa natans	.	.	1	1	+	.	.	.	.	+	1
Ceratophyllum demersum	4	2-3	4	5	4	3	4	4	5	3	4
Elodea canadensis	+	.	.	.	1-2	.	.	.	.	.	2
Myriophyllum spicatum	.	.	.	.	.	.	+	.	.	.	.
Potamogeton crispus	.	.	.	.	+	.	.	.	.	.	.
Potamogeton natans	.	.	.	.	.	.	.	.	.	.	.
Potamogeton pectinatus	.	.	+	.	.	1	.	+	.	.	.
Potamogeton perfoliatus	.	2	+	+	.	2-3	+	.	.	.	.
Potamogeton pusillus	.	.	.	.	.	.	+	+	.	.	.
Elodea nuttallii	.	.	.	+	.	.	.	.	.	.	.
Phragmiti-Magnocaricetea											
Alisma plantago-aquatica	.	.	.	.	.	.	.	.	.	.	.
Schoenoplectus lacustris	.	.	.	.	.	.	.	+	.	.	.
Paspalum distichum	.	.	.	.	.	.	.	.	.	.	.
Varyous syntaxa											
Echinochloa crus-galli	.	.	.	.	.	.	.	.	.	.	.
Cladophora glomerata	.	.	+	+	1	.	.	.	.	.	.

Data and place of relevés: Ass. Lemnetum minoris: **rel. 1-3**, 25.06.2012, Divici Pond, **rel. 4**, 31.07.2012, Calinovăţ Island; Ass. Lemnetum gibbae: **rel. 5-6**, 01.08.2012, Calinovăţ Island; Ass. Lemno-Spirodeletum: **rel. 7**, 01.08.2012, Nera Pond, **rel. 8**, 03.08.2012, Calinovăţ Island, **rel. 9**, 02.08.2012, Nera Pond, **rel. 10,** 03.08.2012, Liborajdea**, rel. 11**, 23.09.2012, Moldova Veche Island; Ass. Salvinio-Spirodeletum polyrhizae, **rel. 12**, 27.06.2012, Nera Pond; Ass. Lemno-Salvinietum natantis, **rel. 13**, 24.09.2012, Pojejena, **rel. 14**, 24.09.2012, Orşova, **rel. 15-17**, 23.09.2012, Moldova Veche Island; Ass. Lemno minoris-Azolletum filiculoides: **rel. 18**, 25.09.2012, Orşova; Ass. Lemno-Utriculariteum vulgaris: **rel. 19**, 31.07.2012, Moldova Veche Island; Ass. Hydrocharitetum morsus-ranae: **rel. 20**, 02.08.2012, Nera Pond; Ass. Ceratophylletum demersi: **rel. 21**, 02.08.2012, Nera Pond, **rel. 22,** 02.08.2012, Coronini**, rel. 23,** 03.08.2012, Liborajdea, **rel. 24,** 03.08.2012, Dubova, **rel. 25**, 05.08.2012, Orşova, **rel. 26**, 23.06.2012, Slătinicul Mare Valley, **rel**. **27**, 23.06.2012, Voditei Valley, **rel. 28**, 25.06.2012, Belobreşca Pond, **rel. 29**, 01.08.2012, Şuşca Pond, **rel. 30-31**, 01.08.2012, Pojejena.

Three plant communities are reported for the first time in this protected area. Class Lemnetea comprises of aquatic vegetation that is short in size, as well as scattered throughout lakes, ponds, and canals. These communities appear as free floating or initially fixed to the substrate, later roots break and become free, being carried by water currents. This is the reason why in the dendrogram (Fig. 4), communities of this class do not form distinct clusters. In the studied area, this vegetation type has a simple coenotic structure, with a well individualized coenotic core, usually represented by at least 50% of the characteristic species for class and the coenotaxonomic component units (in Lemnetea gibbae 100%), the other plant species being characteristic especially for Potametea class, with which is in contact. The vegetation cycle (growing season) is very short, only few weeks.

From a phytogeographical point of view (Fig. 2), the cosmopolitan and Eurasian species are thrive, especially the Mediterranean species, as a result of the climate influence in south-western Romania. In general, the plant communities within this class are poor in species. Ceratophylletum demersi is richer in species, moreover it is the most widespread plant community in the area, which is reflected by a greater variety of phytogeographical elements.

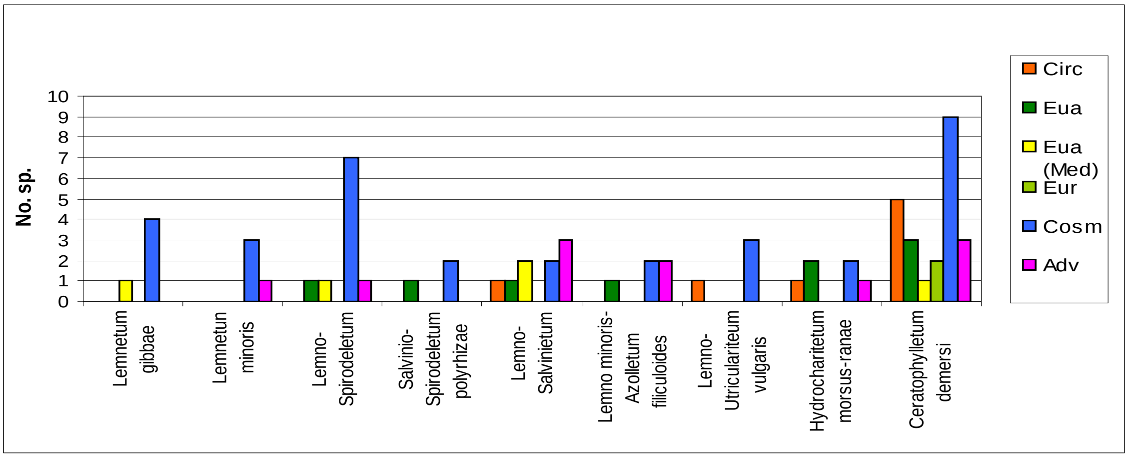

Figure 2: Phytogeographical spectrum
for the associations of the Lemnetea class.

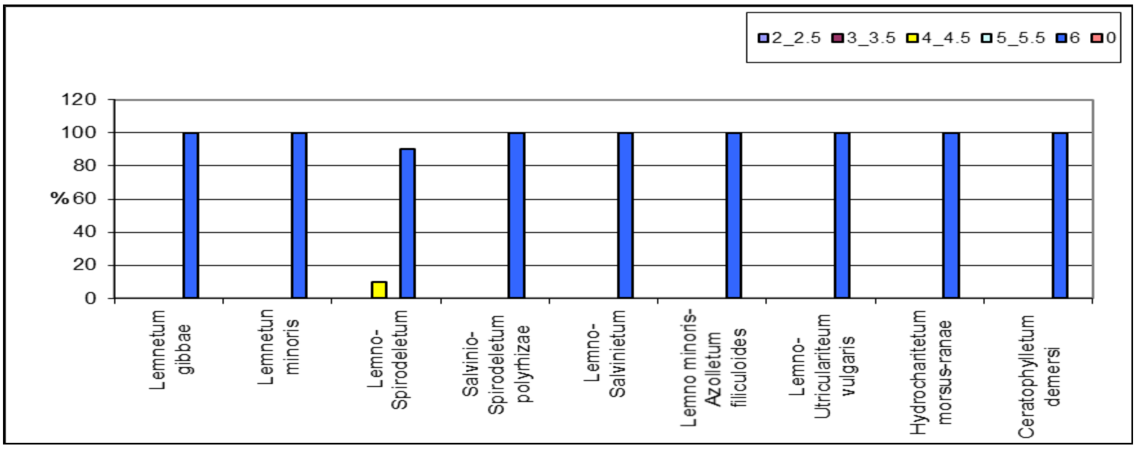

Figure 3: Ecological spectrum for humidity for the communities of the Lemnetea class.

Among the alien plant species in this class, the more common is *Azolla filiculoides*, on Moldova Veche Isle; along with this species, *Paspalum distichum* is also present.

The **ecological** spectrum shows the extreme characteristics of this habitat, 100% dominated by the hydrophilous plant species (U_6) (Fig. 3). The temperate climate is reflected by the predominance of micro-mesothermal species ($T_{3-3.5}$), and the influence of the Mediterranean climate is evidenced by the presence of the moderately thermophilous species ($T_{4-4.5}$) and thermophilous ones ($T_{5-5.5}$) (Fig. 5). Related to water pH (Fig. 6), the dominant species are those euri-ionics (R_0), as many of the cosmopolitan species are amfitolerant. Of the steno-ionics species, a large proportion is those acid-neutrophilic ($R_{3-3.5}$) or less acid-neutrophilous ($R_{4-4.5}$) ones.

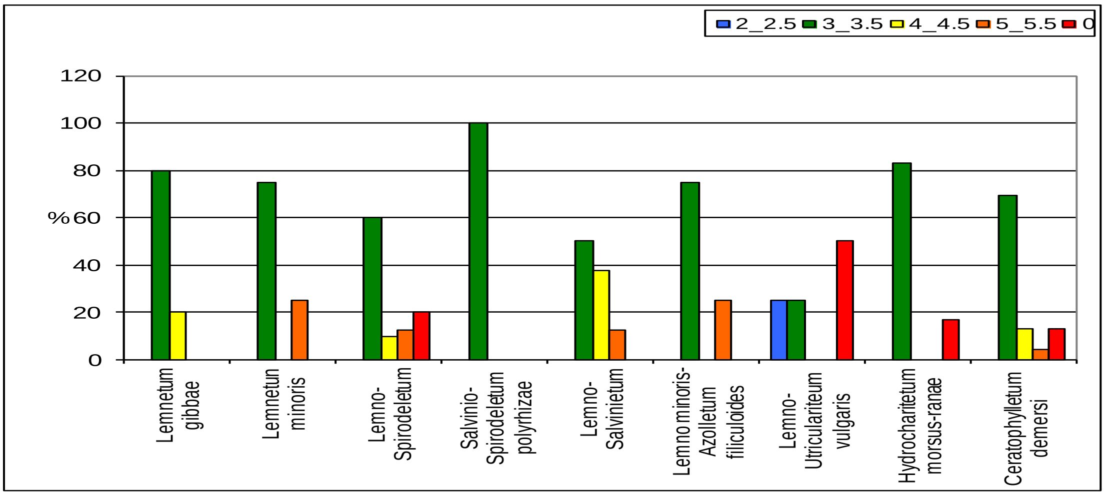

Figure 5: Ecological spectrum for temperature for the communities of the Lemnetea class.

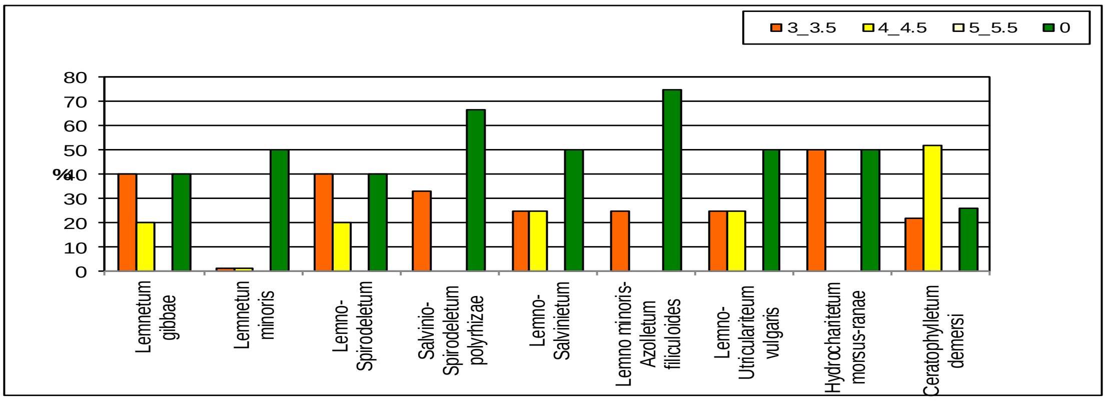

Figure 6: Ecological spectrum for water pH for the communities of the Lemnetea class.

In terms of social behaviour, the natural pioneer species dominate (NP, with a naturalness value of +3), while in the initial stages of the phytocoenogenesis process, with a high reproductive rate, being a species that are tolerant to the extreme environmental conditions, but demanding to nutrient content. Competitive species are well represented (C naturalness value of +5), stress-resistant species, especially into those phytocoenosis better knocked off. If phytocoenoses are more stabilized, there are also stress tolerant species, with a broad ecology (generalist species, G, with a naturalness value of +4) or even specialist species (S, with a naturalness value of +6). The latest are met only in the phytocoenosis of the plant community Ceratophylletumdemersi, for which the reisthemost diversified spectrum (Fig. 7). Moreover, they have the most complex structure in the Lemnetea class.

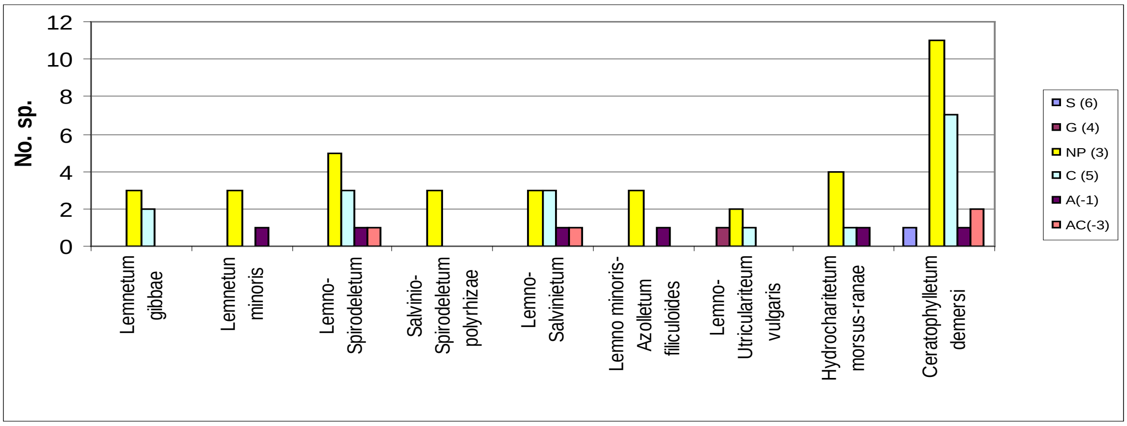

Figure 7: Social behaviour for the communities of the Lemnetea class.

Table 2: Plant communities from Class Potametea Tx. and Prsg. 1942, Aliance Potamogetonion pectinati (W. Koch 1926) Görs 1977.

Relevé no.	1	2	3	4	5	6	7	8	9	10	11
General coverage (%)	9	9	9	9	9	10	9	9	25	6	9
Relevé area (m^2)	95	100	60	65	95	80	100	80	100	70	70
Relevé code	P_luc_59	P_luc_60	P_luc_61	P_lu_61b	P_luc_23	P_luc_12	P_luc_45	MY_Po_81	MY_Po_84	MY_Po165	MY_Pot_7
Potamion											
Potamogeton acutifolius	+	+	.	.	.	.	.	.	.	.	.
Potamogeton acutifl. f. *major*	+	+	.	.	.	.	.	.	.	.	.
Potamogeton trichoides	.	+	.	+	.	.	.	.	.	.	.
Potametalia and Potametea											
Ceratophyllum demersum	1	1-2	.	.	+	.	.	+	+	3	2
Najas marina	.	.	.	.	.	.	.	+	.	1	.
Najas minor	.	.	.	.	.	.	.	.	.	.	.
Potamogeton nodosus	.	.	.	+	.	+	3	.	.	.	1
Vallisneria spiralis	.	.	.	.	.	.	.	.	.	.	.
Elodea canadensis	.	.	.	.	.	.	.	.	.	.	.
Elodea nuttallii	.	.	.	.	+	.	.	.	.	.	+
Myriophyllum spicatum	.	.	.	.	.	.	.	5	5	3-4	4
Potamogeton crispus	.	.	.	+	.	+	.	.	.	.	+
Potamogeton lucens	5	5	3-4	4	5	4-5	3-4	.	.	+	.
Potamogeton pectinatus	1	1	+	.	.	.	+	.	+	.	.
Potamogeton perfoliatus	.	.	.	+	.	.	.	.	.	+	2
Potamogeton pusillus	.	.	.	.	+	.	.	+-1	.	.	+
Ranunculus trichophyllus	.	.	.	.	.	.	.	.	.	.	.
Trapa natans	+-1	+	+	.	.	.	+	.	.	.	+
Lemnetea											
Azolla filiculoides	.	.	.	.	.	.	.	.	.	.	.
Lemna minor	+	+	+	+	.	.	+	.	.	.	.
Salvinia natans	.	.	.	.	.	.	.	.	.	.	.
Spirodela polyrhiza	.	.	+	+	.	.	.	.	.	.	.
Phragmiti-Magnocaricetea											
Schoenoplectus lacustris	.	.	.	.	.	.	.	.	.	.	.
Varyae syntaxa											
Chara foetida	.	.	.	.	.	.	.	.	.	.	.
Cladophora glomerata	.	.	.	.	.	.	.	.	.	.	.
Potamion											
Potamogeton acutifolius	.	.	.	.	.	+	.	.	.	.	3
Potamogeton acutifo. f. *major*	.	.	.	.	+	.	.	.	.	.	+
Potamogeton trichoides	.	.	.	.	.	+	+	.	.	.	+
Potametalia and Potametea											
Ceratophyllum demersum	.	1-2	.	.	.	.	.	.	+	2	+
Najas marina	.	.	.	1	.	+	3	3	1-2	.	+
Najas minor	.	.	.	.	+	2	.	.	.	4	3
Potamogeton nodosus	+	.	.	.	.	.	.	1-2	.	+	.
Vallisneria spiralis	.	5	4	3	4	2	.	.	3-4	.	1
Elodea canadensis	.	.	.	+	1	3	.	.	.	.	+
Elodea nuttallii	.	.	.	.	.	.	.	.	.	1	.
Myriophyllum spicatum	4	+	2	4	2	1-2	1	.	+	.	+
Potamogeton crispus	.	.	.	.	.	.	.	.	.	.	.
Potamogeton lucens	.	.	.	.	.	.	.	.	.	.	.

Table 2 (continued): Plant communities from Class Potametea Tx. and Prsg. 1942, Aliance Potamogetonion pectinati (W. Koch 1926) Görs 1977.

Relevé no.	1	2	3	4	5	6	7	8	9	10	11
General coverage (%)	9	9	9	9	9	10	9	9	25	6	9
Relevé area (m^2)	95	100	60	65	95	80	100	80	100	70	70
Relevé code	P_luc_59	P_luc_60	P_luc_61	P_lu_61b	P_luc_23	P_luc_12	P_luc_45	MY_Po_81	MY_Po_84	MY_Po165	MY_Pot_7
Potamogeton pectinatus	+	1	.	.	.	.	.	.	.	.	.
Potamogeton perfoliatus	.	.	+	.	.	+	+	.	+	.	.
Potamogeton pusillus	.	.	.	.	.	.	.	.	.	.	.
Ranunculus trichophyllus	.	.	.	.	.	.	.	.	.	.	.
Trapa natans	.	.	.	.	.	.	.	.	.	.	.
Lemnetea											
Azolla filiculoides	.	.	.	.	.	.	.	.	.	.	.
Lemna minor	.	.	.	.	.	.	.	+	.	.	.
Salvinia natans	.	.	.	.	.	.	.	.	.	+	.
Spirodela polyrhiza	.	.	.	.	.	.	.	.	.	+	.
Phragmiti-Magnocaricetea											
Schoenoplectus lacustris	.	.	.	.	.	.	.	1	.	.	.
Varyae syntaxa											
Chara foetida	.	.	.	.	.	.	.	.	.	.	.
Cladophora glomerata	.	.	.	.	.	.	1-2	.	.	.	.
Potamion											
Potamogeton acutifolius	.	.	.	.	.	.	.	.	.	.	.
Potamogeton acutif. f. *major*	.	.	.	.	.	.	.	.	.	.	.
Potamogeton trichoides	.	.	.	.	.	.	.	.	.	.	.
Potametalia and Potametea											
Ceratophyllum demersum	+	.	.	+	.	.	.	+	1-2	.	.
Najas marina	.	.	.	.	.	.	.	.	.	.	.
Najas minor	.	.	.	.	.	.	.	.	.	.	.
Potamogeton nodosus	.	.	.	+-1	+	+	.	.	.	2	+-1
Vallisneria spiralis	.	.	.	.	.	.	.	.	.	.	.
Elodea canadensis	.	.	.	.	.	.	.	.	.	.	.
Elodea nuttallii	.	.	.	.	.	.	.	.	.	.	.
Myriophyllum spicatum	.	.	.	.	.	.	.	.	.	.	.
Potamogeton crispus	.	.	.	.	.	.	.	.	.	.	.
Potamogeton lucens	.	.	.	.	+	.	.	.	.	.	.
Potamogeton pectinatus	3-4	4	4	5	5	5	5	4	4	4	5
Potamogeton perfoliatus	.	.	.	.	.	.	.	.	.	.	.
Potamogeton pusillus	.	.	.	.	.	.	.	.	.	+	.
Ranunculus trichophyllus	.	.	.	.	.	.	.	.	.	.	.
Trapa natans	1	1	+	1	+	+	+-1	1	1-2	.	.
Lemnetea											
Azolla filiculoides	.	.	.	.	.	.	.	.	.	.	.
Lemna minor	+-1	1	1	+	+	+	+	+	+	+	+
Salvinia natans	.	.	.	.	.	.	.	.	.	.	.
Spirodela polyrhiza	+	+	+	.	.	+	.	+-1	.	+	+
Phragmiti-Magnocaricetea											
Schoenoplectus lacustris	.	.	.	.	.	.	.	.	.	.	.
Varyae syntaxa											
Chara foetida	.	.	.	.	.	.	.	.	.	.	.
Cladophora glomerata	.	.	.	.	.	.	1	.	.	3	1-2
Potamion											
Potamogeton acutifolius	.	.	.	.	.	.	.	.	.	.	.

Table 2 (continued): Plant communities from Class Potametea Tx. and Prsg. 1942, Aliance Potamogetonion pectinati (W. Koch 1926) Görs 1977.

Relevé no.	1	2	3	4	5	6	7	8	9	10	11
General coverage (%)	9	9	9	9	9	10	9	9	25	6	9
Relevé area (m^2)	95	100	60	65	95	80	100	80	100	70	70
Relevé code	P_luc_59	P_luc_60	P_luc_61	P_lu_61b	P_luc_23	P_luc_12	P_luc_45	MY_Po_81	MY_Po_84	MY_Po165	MY_Pot_7
Potamogeton acutif. f. *major*	.	.	.	.	.	.	.	.	.	.	.
Potamogeton trichoides	.	+	.	.	.	.	.	.	.	.	1
Potametalia and Potametea											
Ceratophyllum demersum	.	.	.	+	+	+	1	+	+	.	.
Najas marina	.	.	.	.	.	.	.	.	.	.	.
Najas minor	.	.	1	.	.	.	.	.	.	.	.
Potamogeton nodosus	.	.	.	.	.	.	.	+	+	.	.
Vallisneria spiralis	.	.	.	.	.	.	.	.	.	.	.
Elodea canadensis	.	.	.	.	.	.	.	.	.	.	5
Elodea nuttallii	.	.	.	.	.	.	.	.	.	.	.
Myriophyllum spicatum	1	.	.	1-2	.	.	.	.	.	.	1
Potamogeton crispus	.	.	.	.	.	.	.	.	.	.	.
Potamogeton lucens	.	.	.	.	.	.	.	.	.	.	.
Potamogeton pectinatus	4	4	4	5	.	.	.	1	.	+	.
Potamogeton perfoliatus	.	.	1	.	.	.	2	+	+	+	.
Potamogeton pusillus	.	.	.	+	5	4-5	4	5	4-5	5	.
Ranunculus trichophyllus	.	+-1	.	.	.	.	.	.	.	.	.
Trapa natans	.	.	.	.	.	.	.	+	.	+	.
Lemnetea											
Azolla filiculoides	.	.	.	.	.	.	.	.	.	.	.
Lemna minor	.	+	.	.	+	1	.	.	.	.	.
Salvinia natans	.	+	.	.	.	.	.	.	.	.	.
Spirodela polyrhiza	.	+	.	.	+	+	.	.	.	.	.
Phragmiti-Magnocaricetea											
Schoenoplectus lacustris	.	.	.	.	.	.	.	.	.	.	.
Varyae syntaxa											
Chara foetida	+	.	.	.	.	.	.	.	.	.	.
Cladophora glomerata	.	.	.	.	.	2-3	.	.	.	.	3

Table 2 (continued): Plant communities from Class Potametea Tx. and Prsg. 1942, Aliance Potamogetonion pectinati (W. Koch 1926) Görs 1977.

Potamion						
Potamogeton acutifolius	.	.	.	.	.	.
Potamogeton acutifolius f. *major*	.	.	.	.	.	.
Potamogeton trichoides	+	+	+	.	.	.
Potametalia and Potametea						
Ceratophyllum demersum	+	+	.	2	.	.
Najas marina	+	.	.	+	.	.
Najas minor	.	.	.	+	.	.
Potamogeton nodosus	.	.	1	.	.	.
Vallisneria spiralis	+	+	.	.	.	.
Elodea canadensis	5	5	4	.	.	.
Elodea nuttallii	.	.	.	2	4	5
Myriophyllum spicatum	+	+	.	.	+-1	.
Potamogeton crispus	.	.	+	.	+	+
Potamogeton lucens	.	.	.	.	2	.
Potamogeton pectinatus	.	.	.	1-2	.	.
Potamogeton perfoliatus	.	.	.	.	.	2
Potamogeton pusillus	.	.	.	.	1	.
Ranunculus trichophyllus	.	.	.	.	.	.
Trapa natans	+	1-2	3	+	.	.
Lemnetea						
Azolla filiculoides	+	+	.	.	.	.
Lemna minor	+	+	+	+	.	.
Salvinia natans	+	+	2	+	.	.
Spirodela polyrhiza	.	.	.	+	.	.
Phragmiti-Magnocaricetea						
Schoenoplectus lacustris	.	.	.	.	.	.
Varyae syntaxa						
Chara foetida	.	.	.	.	.	.
Cladophora glomerata	.	.	.	.	.	.

Data and place of relevés: Ass. Potamogetonetum lucentis Hueck 1931: **rel. 1-2,** 25.06.2012, Şuşca Pond, **rel. 3-4,** 25.06.2012, Pojejena Pond, **rel. 5,** 24.06.2012, Sirinia Valley**, rel. 6,** 23.06.2012, Cerna Valley, **rel. 7,** 25.06.2012, Divici Pond; Ass. Myriophyllo-Potamogetonetum lucentis Soó 1934, **rel. 8-9,** 26.06.2012, Moldova Veche Island, **rel. 10,** 03.08.2012, Liubcova, **rel. 11,** 23.06.2012, Vodiţei Valley, **rel. 12,** 31.07.2012, Moldova Veche Island; ass. Myriophyllo-Potamogetonetum lucentis Soó 1934 sass. vallisnerietosum Coldea et al., 1997, **rel. 13-17**, 02.08.2012, Nera Pond; Ass. Potamogetonetum pectinati (Hueck 1931) Carstensen 1955, **rel. 18-23**, 25.06.2012, Divici Pond, **rel. 24,** 25.06.2012, Belobreşca Pond, **rel. 25-26,** 24/25.06.2012, Şuşca Pond, **rel. 27-28**, 25.06.2012, Calinovăţ Isl., **rel. 29**, **32.** 26.06.2012/31.07.2012, Moldova Veche Isl., **rel. 30-31**, 27.06.2012, Nera Pond; Ass. Potamogetonetum pusilli Soó 1927, **rel. 33-34,** 25.06.2012, Belobreşca Pond**, rel. 35-38,** 25.06.2012, Pojejena Pond; Ass. Najadetum marinae Fukarek 1961, **rel. 39**, 03.08.2012, Liubcova, **rel. 40**, 31.07.2012, Moldova Veche Island, **rel. 41,** 02.08.2012, Nera Pond; Ass. Najadetum minoris Ubriszy 1961, **rel. 42,** 01.08.2012, Şuşca Pond, **rel. 43**, 02.08.2012, Nera Pond; Ass. Elodeetum canadensis Eggler 1933, **rel. 44,** 03.08.2012, Cozla, **rel. 45-47**, 23.09.2012, Moldova Veche Island; Ass. Elodeetum nuttallii Ciocârlan et al., 1997, **rel. 48,** 01.08.2012, Pojejena, **rel. 49,** 23.06.2012, Cerna Valley, **rel. 50**, 23.06.2012, Vodiţei Valley.

Table 3: Associations from Class Potametea Tx. and Prsg. 1942, Aliance Nymphaeion albae Oberd. 1957.

Relevé no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
General coverage (%)	60	100	90	85	95	85	80	90	90	90	100	70	95	90	60
Relevé area (m^2)	9	25	9	9	25	9	9	25	25	9	9	9	9	9	9
Relevé code	Ny_p_197	Trap_14	Trap_15	Trap_16	Trap_18	Trap_26	Trap_27	Trap_28	Trap_29	Trap_30	Trap_31	Trap_32	Trap_36	Trap_37	Trap_50
Potamion															
Potamogeton acutifolius	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.
Potamogeton acutifolius f. *major*	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.
Potamogeton trichoides	.	.	.	1	+	.	.	.	.	.	.	.	.	.	.
Potametalia and Potametea															
Nymphoides peltata	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Trapa natans	+	4	5	3-4	5	5	4-5	3-4	3	5	5	4	5	4	3-4
Potamogeton natans	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Potamogeton perfoliatus	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.
Najas marina	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Potamogeton nodosus	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+
Ceratophyllum demersum	.	+-1	1	1-2	+	+	+	+	.	.	.	+	.	+	.
Elodea canadensis	1-2	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Myriophyllum spicatum	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Potamogeton crispus	.	.	.	+	.	+	.	.	.	.	.	.	.	.	.
Potamogeton lucens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Potamogeton pectinatus	.	+	+	+	.	+	1	2	2-3	+	+	+	1	1	1-2
Potamogeton pusillus	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.
Elodea nuttallii															
Lemnetea	.	2	3	.	+	.	.	.	.	.	.	.	.	.	.
Azolla filiculoides	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Salvinia natans	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.
Lemna minor	+	.	.	+	+	1	.	.	.	.	.	+-1	+-1	+	+
Lemna gibba	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Spirodela polyrhiza	+	.	+	+	+	+	.	.	.	.	.	+	+	+	.
Varyae syntaxa															
Chara foetida	.	.	.	.	.	.	.	2	1-2	.	.	.	.	.	.
Cladophora glomerata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Table 3 (continued): Associations from Class Potametea Tx. and Prsg. 1942, Aliance Nymphaeion albae Oberd. 1957.

Relevé no.	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
General coverage (%)	95	60	90	60	100	100	100	100	80	65	100	90	100	70	60	80
Relevé area (m^2)	9	9	25	25	25	25	25	25	9	25	25	25	9	9	9	9
Relevé code	Trap_58	Trap_63	Trap_136	Trap_140	Trap_162	Trap_170	Trap_171	Trap_172	Trap_192	Pnat131	Pper156	Pper157	Pper22	Pper25	Pper60	Pper25
Potamion																
Potamogeton acutifolius	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.
Potamogeton acutifolius f. *major*	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.
Potamogeton trichoides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.
Potametalia and Potametea																
Nymphoides peltata	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.
Trapa natans	5	5	5	4	5	5	5	5	+	.	.	.	.	+	+	.
Potamogeton natans	.	.	+	.	.	.	.	.	+	4	.	.	.	.	.	+
Potamogeton perfoliatus	.	+	.	+	.	.	.	.	.	.	4	5	5	5	3-4	4-5
Najas marina	.	.	.	+	.	.	.	.	.	1	+	.	.	.	.	.
Potamogeton nodosus	.	.	.	+	.	.	+	.	.	.	.	.	.	.	1-2	.
Ceratophyllum demersum	+	2	2	2	+	1-2	1-2	+	1-2	.	3	1	1-2	.	.	.
Elodea canadensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Myriophyllum spicatum	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.
Potamogeton crispus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.
Potamogeton lucens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.
Potamogeton pectinatus	+	.	.	+	.	.	.	.	.	.	.	.	2	+	.	+
Potamogeton pusillus	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	+
Elodea nuttallii																
Lemnetea	.	.	.	.	.	+	.	+	.	.	.	.	+	.	.	.
Azolla filiculoides	.	.	.	.	.	+	+	.	+	.	+	+	.	.	.	.
Salvinia natans	.	.	+	.	.	+	+	.	+	.	+	+	.	.	.	.
Lemna minor	+	.	1	.	+	1	.	1	+	.	+	+	.	+	+	.
Lemna gibba	.	.	.	.	.	.	+	.	+	.	.	.	.	.	.	.
Spirodela polyrhiza	+	.	+	.	+	.	+	+	+	.	+	+	.	.	+	.
Varyae syntaxa																
Chara foetida	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cladophora glomerata	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	+

Data and place of relevés: Ass. Nymphoidetum peltatae (All. 1922) Bellot 1951: **rel. 1,** 23.09.2012, Moldova Veche Island; Ass. Trapetum natantis Kárpáti 1963, **rel**. 2, 23.06.2012, Orşova, **rel. 3**, 23.06.2012, Mala Bay, **rel**. **4**, 24.06.2012, Dubova Bay, **rel. 5**, 23.06.2012**,** Grăniceri Valley, **rel. 6-14**, 25.06.2012, Divici Pond, **rel. 15**, 25.06.2012, Belobreşca Pond, **rel. 16** and **19**, 25.06.2012/01.08.2012, Şuşca Pond, **rel. 17**, 25.05.2012, Pojejena Pond, **rel. 18,** 31.07.2012, Calinovăţ Island, **rel. 20**, 03.08.2012, Liborajdea, **rel. 21-22**, 08.04.2012, Dubova, **rel. 23**, 08.04.2012, Eşelniţa, **rel. 24**, 23.09.2012, Moldova Veche Island; Ass. Potamogetonetum natantis Soó 1927, **rel. 25**, 31.07.2012, Moldova Veche Island; Ass. Potamogetonetum perfoliati Miljan 1933, **rel. 26-27,** 02.08.2012, Nera Pond, **rel. 28**, 24.06.2012, Tri-Kule, **rel. 29**, 25.06.2012, Divici Pond, **rel. 30-31,** 25.06.2012, Pojejena Pond.

Table 4: Plant communities from Class Potametea R. Tx. and Prsg. 1942, Alliance Ranunculion aquatilis Passarge 1964.

Relevé no.	1	2	3	4	5	6	7	8
General coverage (%)	1	9	9	9	9	9	9	9
Relevé area (m^2)	90	80	90	100	90	80	100	70
Relevé code	Batr_108	P_nod_41	P_nod_42	P_nod_46	P_nod_49	P_nod_69	P_nod_70	P_nod_71
Potamion								
Potamogeton obtus. f. *latifrons*	.	.	.	.	.	.	.	.
Potametalia and Potametea								
Najas marina	.	.	.	.	.	.	.	.
Potamogeton nodosus	.	4	3-4	3.4	3	3	3	4
Trapa natans	.	+	+-1	1	+	.	.	.
Ceratophyllum demersum	.	+	.	.	2	.	.	.
Myriophyllum spicatum	.	.	.	.	.	.	.	.
Potamogeton crispus	.	.	.	.	.	.	.	.
Potamogeton lucens	.	.	.	1-2	.	+	.	.
Potamogeton pectinatus	.	1	2-3	2-3	2	2	2-3	.
Potamogeton perfoliatus	.	.	.	.	.	+	+	+
Potamogeton pusillus	.	.	.	.	.	.	.	+
Ranunculus trichophyllus	5	.	.	.	.	.	.	.
Potamogeton trichoides	.	.	.	.	.	+	.	.
Lemnetea								
Azolla filiculoides	.	.	.	.	.	.	.	.
Salvinia natans	.	.	.	.	.	.	.	.
Lemna minor	+	+	1	+	2	1-2	+	.
Spirodela polyrhiza	+	+	.	.	+	1	.	+
Varyae syntaxa								
Chara foetida	.	.	.	.	.	.	.	.
Cladophora glomerata	.	.	.	.	.	1	1	1
Potamion								
Potamogeton obtus.s f. *latifrons*	.	.	.	.	.	.	+	.
Potametalia and Potametea								
Najas marina	.	.	.	1-2	.	.	.	.
Potamogeton nodosus	5	3	3	3-4	3	4	2	3-4
Trapa natans	+	.	.	.	.	.	.	.
Ceratophyllum demersum	.	.	.	+	.	.	2	2
Myriophyllum spicatum	.	.	.	.	.	.	.	1
Potamogeton crispus	.	.	.	.	.	.	+	+
Potamogeton lucens	.	.	2	.	1	.	.	.
Potamogeton pectinatus	+-1	.	1	+	+	.	.	.
Potamogeton perfoliatus	.	.	.	.	.	.	.	1-2
Potamogeton pusillus	.	2-3	.	.	.	.	.	.
Ranunculus trichophyllus	.	.	.	.	.	.	.	.
Potamogeton trichoides	.	.	.	.	.	.	1	.
Lemnetea								
Azolla filiculoides	.	.	.	.	.	+	.	.
Salvinia natans	.	.	.	.	+	+	+	.
Lemna minor	+	+	.	.	+	2	3	.
Spirodela polyrhiza	+	+	.	.	+	1-2	1-2	.
Varyae syntaxa								
Chara foetida	.	+	.	.	.	.	.	.
Cladophora glomerata	.	.	.	.	.	.	.	.

Data and place of relevés of table 4: Ass. Ranunculetum (Batrachietum) trichophylli Soó (1927) 1971: rel. 1, 27.06.2012, Nera Pond; Ass. Potamogetonetum nodosi Passarge 1964, rel. 2-4, 25.06.1012, Divici Pond, rel. 5, 25.06.2012, Belobreşca Pond; rel. 6 and 13, 25.06.2012/31.07.2012, Pojejena Pond, rel. 7-11, 25.06.1012, Calinovăţ Island, rel. 12, 31.07.2012, Moldova Veche Island, rel. 14, 02.08.2012, Coronini, rel. 15, 02.08.2012.

Class Potametea pectinati R. Tx. and Prsg. 1942 includes submerged aquatic vegetation or with floating leaves, fixed on substrate, which develop in standing, year-around waters. The vegetation is dominated by perennial species, with communities that tolerate a wide range of water depths. Unless the water levels dry up completely, some species survive periods of low water levels.

One order, three alliances and 14 plant communities (eight associations and one subassociation are newly identified in this protected area) were identified in the "Porţile de Fier" Natural Park (Tabs. 2, 3 and 4).

Over 60% of the component species belong to the coenotic core, which comprises a decent fraction of these communities in the area, as a consequence of the stable water conditions. This aspect is reflected by distinct clusters in our comparative analysis (Fig. 4).

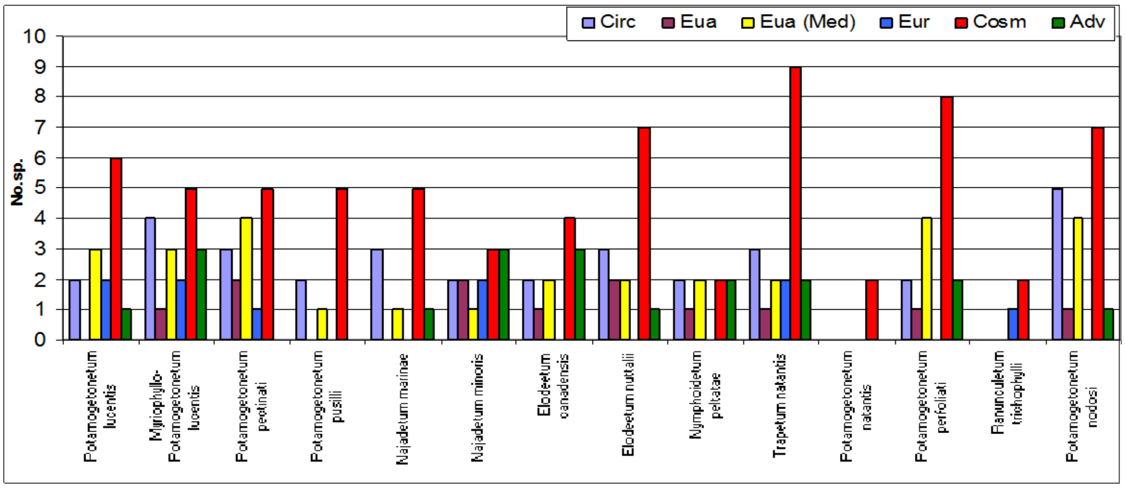

Figure 8: Phytogeografic spectrum for the communities of the Potamogetonetea class.

From a phytogeographical point of view (Fig. 8), the cosmopolitan, circumpolar and the Eurasian species are well represented (especially the Mediterranean ones). Compared with the phytocoenosis of Lemnetea class, the phytogeographical spectrum is more diversified here, as a consequence of a stronger stability of these phytocoenosis. The circumpolar species are present in most communities, benefiting from lower thermal amplitudes of the water. The adventitious species are: *Elodea nuttallii*, *E. canadensis*, *Vallisneria spiralis*, and *Azolla filiculoides*, the first three species exhibit invasive behavior in the studied area. Communities of *Elodea nuttallii* replace those of *E. canadensis*, and also other plant communities edified by indigenous species. Only few communities are devoid of invasive species, e.g. *Potametum pectinati* (occurs more frequently at the fringes of ponds along the Danube River, where the water current is faster), *Potametum pusilli*, *Potametum natantis* and *Ranunculetum* (*Batrachietum*) *trichophylli*. The last two communities are rare in the area.

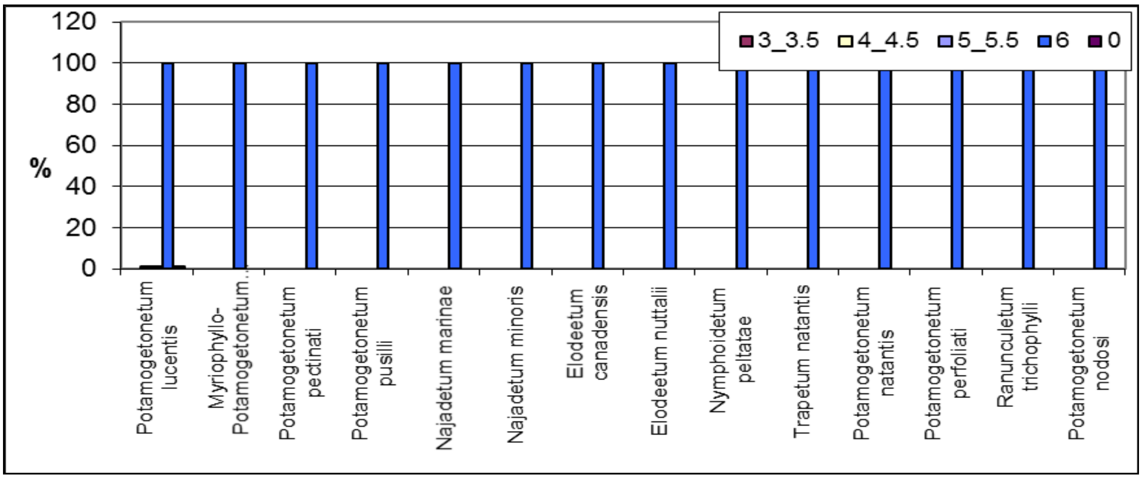

Figure 9: Ecological spectrum for humidity for the communities of the Potamogetonetea class.

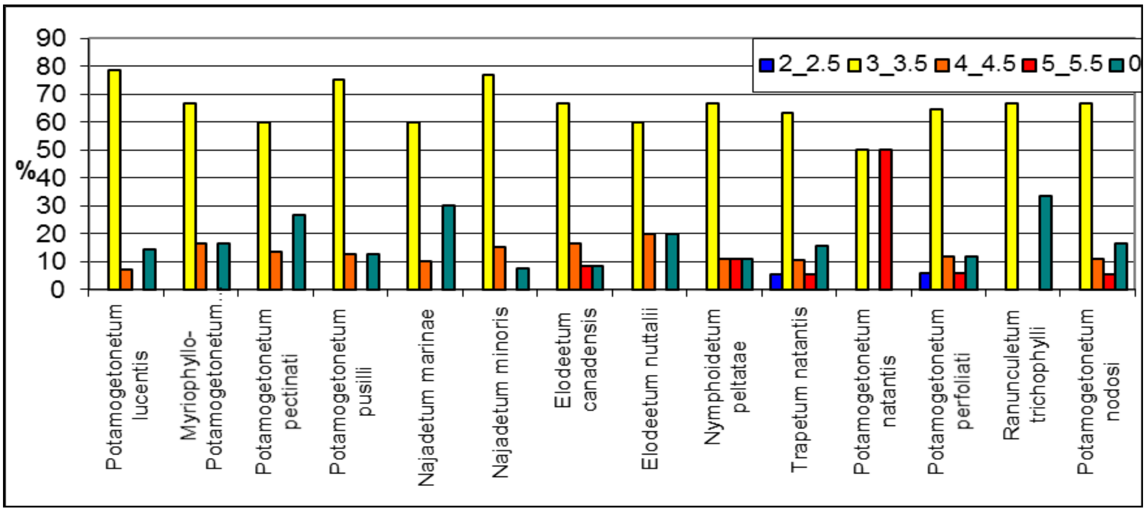

Figure 10: Ecological spectrum for temperature for the communities of the Potamogetonetea class.

The **ecological** spectra, related to humidity (Fig. 9) and temperature (Fig. 10) are similar to those of the Lemnetea class, prevailing hydrophilous (U_6) and the micro-mesothermal species ($T_{3\text{-}3.5}$); with a good occurrence of the moderate thermophilous species ($T_{4\text{-}4.5}$) and thermophilous ($T_{5\text{-}5.5}$) as a result of Mediterranean climate. Compared to water pH, among the steno-ionics species, the dominant are the weak acid-neutrophilous species ($R_{4\text{-}4.5}$), followed by acid-neutrophilous ($R_{3\text{-}3.5}$). The euri-ionics species (R_0), show a permanent disturbance of the habitat (Fig. 11).

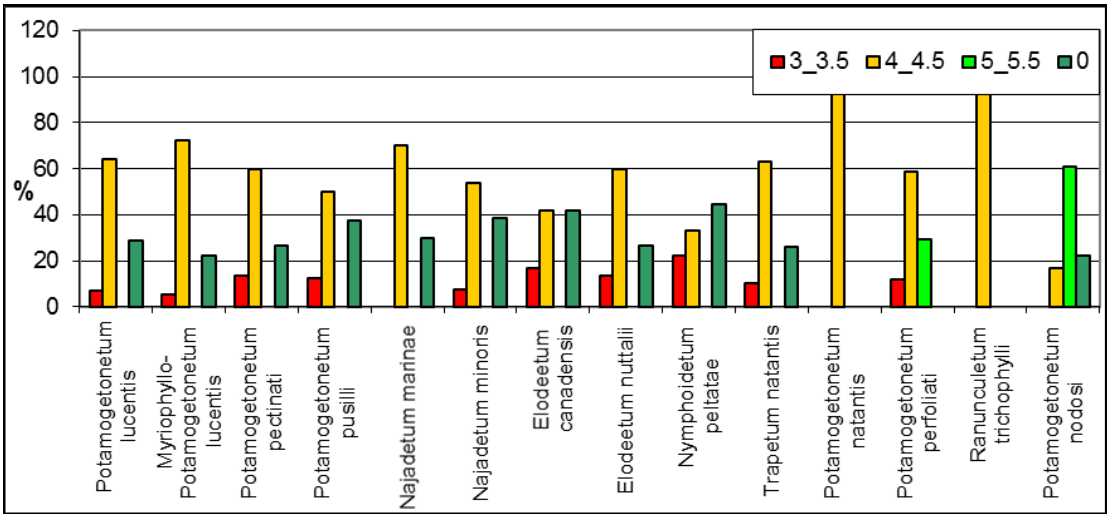

Figure 11: Ecological spectrum for water pH for the communities of the Potamogetonetea class.

In terms of **social behaviour**, the competitive species dominate (C with a naturalness value of +5), being stress-resistant species, are more present in a cohesive phytocoenosis. Natural pioneers are well represented (NP, with a naturalness value of +3), especially by those plant communities located in areas with strong currents (Potamogetonetum lucentis) or by the recently installed (Najadetum marinae). In the case of stabilized phytocoenoses, stress-tolerant plant species are also present, with a broad ecology (generalist G, with a naturalness value of +4). The presence of species with limited ecology (S, with a naturalness value of +6), in almost all plant communities is noteworthy, which indicates a constant, stable feature of phytocoenosis, a harmonized structure of the aquatic habitats with extreme conditions, a structure that was accomplished over time (Fig. 12). *Potamogetonetum natantis* and *Ranunculetum trichophylli* plant communities are exceptions, seldom appear in the investigated area. The plant communities of *Ranunculion aquatilis* (aquatic vegetation developed in shallow waters, smoothly flowing and sometimes temporarily) are in competition with large aquatic macrophytes, which is a reason why they are becoming fewer and fewer in southeastern Europe (http://www.sci.muni.cz/botany/vegsci/vegetace.php?lang=en&typ=VBD).

The characteristic species of this alliance is *Ranunculus trichophyllus*. It was identified in a single phytocoenosis only, in the mini delta of Nera, and only in June, during the flooding period. Two alien invasive species, *Elodea canadensis* and *E. nuttallii*, were recorded (Borhidi, 1995), but according to other references, *Vallisneria spiralis* is also an invasive plant species in Europe (Săvulescu, 1952-1976).

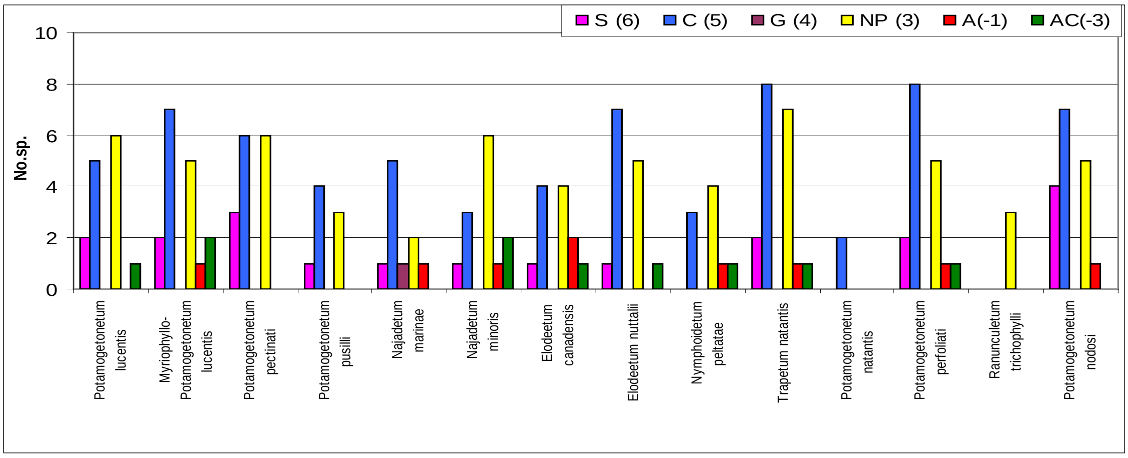

Figure 12: Social behaviour spectrum for the associations of the Potamogetonetea class.

Anthropogenic impact on natural habitats

Based on phytosociologic relevés and field investigations, there have been identified the following three types of natural habitats, namely: **3150** – Natural eutrophic lakes with vegetation of Magnopotamion or Hydrocharition, **3160** – Natural dystrophic lakes and ponds, and **3260** – Water courses lowland to mountain level, with vegetation from Ranunculion fluitantis and Callitricho-Batrachion. The habitat 3160 is the most widespread in the area, especially represented by Trapetum natantis plant communities, which cover large areas of the ponds, shallow waters and small bays. The massive development of this plant community is detrimental to other submerged or floating communities, up until September, when the area covered by this habitat is halved, as long as the dominant species begins to decompose. This situation, led to some difficulties during summer time, water crafts are slowed in their movement along the ponds; furthermore, this plant community slow the development of the fish fauna because of the low amount of oxygen in the water; on the other hand, it has a positive effect on birds, giving them peace, bringing environmental services by water denitrification (Tall et al., 2011), especially considering, where the terrain includes croplands.

These habitats host protected or threatened plant species, including those on the red lists, like: *Azolla filiculoides* (Dihoru and Negrean, 2009), *Potamogeton trichoides* (Oltean et al., 1994), *Salvinia natans* (Bern Convention, 1979; Dihoru and Negrean, 2009), *Elodea canadensis* (Boşcaiu et al., 1994), *Najas marina* (Boşcaiu et al., 1994) (in our opinion, it is a mistake to include in a red list/red book, those species which are aliens in a certain region, e.g. *Azolla filiculoides* or *Elodea canadensis* in Europe).

The plant communities of these habitats are dominated by natural pioneer species (especially floating species) and competitive species (mostly submerged species), as a result of habitat disturbance through seasonal water fluctuation. According to Zohary and Ostrovsky (2011), increasing water level affects the habitat diversity, species richness and abundance and favour the income and proliferation of allochtone generalists, with negative response in species richness. Some of the alien species have an invasive feature in natural habitats. *Elodea canadensis*, *Vallisneria spiralis*, and especially *Elodea nuttallii*, which eliminate other plants, represent a real problem. On the other hand, *Vallisneria spiralis* grows abundantly in Nera Pond, taking out the communities edified by *Najas marina* and *Najas minor*.

A permanent anthropogenic pressure is exerted on aquatic and swamp habitats from the "Porţile de Fier" Natural Park. The development of tourism, as an alternative to the economic downturn in the studied area, is reflected by a growing number of buildings (as hotels, holiday cottages, pontoon bridges, etc.), but mostly by leasing the banks of the Danube River to private persons or companies. All these lead to a decrease of the cover of spontaneous riparian vegetation and water eutrophication. In addition, each year, the Danube River and its tributaries, bring a significant amount of waste, the most affected area in this regard being the Nera Delta. This area is grazed by sheep, while the isle of Moldova Veche is grazed by horses, thus leading to a higher eutrophication. The answer of plant communities toward eutrophication is obvious through a higher representation of euri-ionic plant species.

CONCLUSIONS

The aquatic vegetation of the "Porţile de Fier" Natural Park has a mosaic-type appearance, mainly determined by the speed of water flow, and by the topography of the studied area. Thus, all the identified associations are concentrated in the area of Divici, Belobreşca, Şuşca, Pojejena, and Nera ponds, the golfs between Orşova and Dubova, and associated ponds and bays of the island of Calinovăţ and Moldova Nouă. Most of the plant communities have been recorded in the area of the Moldova Nouă Isle and Nera Pond, which require a special attention, as part of the integrated management of the Natura 2000 sites: "ROSPA0026 Cursul Dunării – Baziaş-Porţile de Fier" and "ROSCI0206 Porţile de Fier".

As a result of this study, eleven plant associations, and a sub-association, are newly-identified in the investigated area. The presence of all of these plant communities could be a consequence of vegetation succession after the construction of the dam. An increase of wealth of the aquatic communities involves diversification of the algal and invertebrate fauna components, as some authors have already concluded (Dudley, 1988; Melo et al., 2002; Takeda et al., 2003; Thorp et al., 1997). The structure of these plant communities is influenced by the flow regime, level fluctuation and nutrient concentration in the water.

While developing the management plan should take into account the surveillance of the spreading of invasive plants (especially *Elodea canadensis*, *Elodea nuttallii* and *Valisneria spiralis*) and a mechanical removal of them. On the other hand, opening up corridors through the aquatic vegetation and allowing a controlled eco-tourism, with small speed boats, is an occupational alternative in this area sought by tourists, while the mines were closed and fishing is strongly restricted in the area of the "Porţile de Fier" Natural Park.

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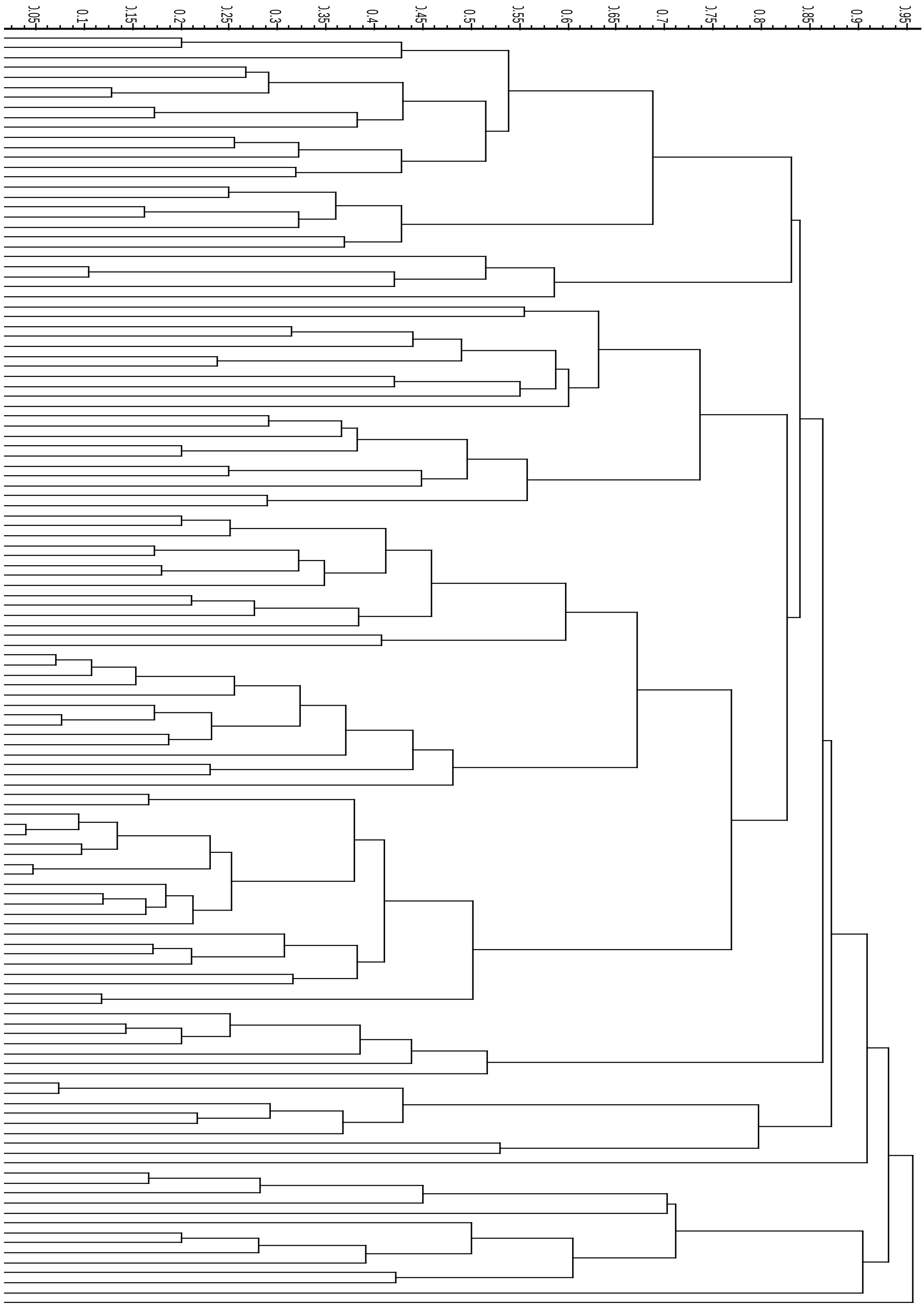

Figure 12: Aquatic communities' dendrogram (UPGMA, Bray Curtis Index).

REFERENCES

1. Bell S. S., McCoy E. D. and Mushinsky H. R., 1991 – Habitat structure: the physical arrangement of objects in space, Chapman and Hall, London.
2. Blaustein L. and Schwartz S. S., 2001 – Why study ecology in temporary pools? *Israel Journal of Zoology*, 47, 303-312.
3. Borhidi A., 1995 – Social behaviour types, their naturalness and relative ecological indicator values of the higher plants of the Hungarian flora, *Acta Botanica Hungarica*, 39, 97-182.
4. Borza A., 1947-1949 – Conspectus Florae Romaniae, Regionumque affinum, I-II, Tipografia „Cartea Românească", Cluj, 360.
5. Boşcaiu N., Coldea G. and Horeanu C., 1994 – Lista roşie a plantelor vasculare dispărute şi rare din flora României, *Ocrotirea Naturii și Mediului Înconjurător*, 38, 1, 45-46. (in Romanian)
6. Braun-Blanquet J., 1964 – Pflanzensoziologie, Springer Verlag, Berlin. (in German)
7. Brönmark C. and Hansson L. A., 2010 – The Biology of lakes and pounds, Second edition, Oxford University Press, 285.
8. Călinescu R., Coteţ P., Florea N., Iancu M., Martiniuc C., Savu A., Sârcu I. and Stoenescu Ş., 1955 – Geografia fizică a R. P. Române, Bucureşti. (in Romanian)
9. Călinescu R. and Iana S., 1964 – Consideraţiuni biogeografice asupra Defileului Dunării, *Analele Universităţii Bucureşti*, *Ştiințe Naturale*, 12, 1, 151-167. (in Romanian)
10. Cărăuş I., 2012 – Algae of Romania, A distributional checklist of actual algae, (Version 2.3), http://www.seaweedafrica.org/pdf/562DF96D13b4823893SWjO3A7893/50442.pdf, 809.
11. Ciocârlan V., Doniţă N. and Turcu G., 1969 – Contribuţii floristice din defileul Dunării, sectorul Cozla-Berzasca, *Studii și Cercetări de Biologie, Seria Botanică*, 21, 3, 205-208. (in Romanian)
12. Ciocârlan V., 2000 – Flora ilustrată a României, Pteridophyta et Spermatophyta, Bucureşti, Edit. Ceres, 1138. (in Romanian)
13. Coldea G., 1991 – Prodrome des associations végétales des Carpates du sud-est (Carpathes Roumaines), *Documents in Phytosociology*, Camerino, 13, 317-539. (in French)
14. Coldea G. (ed.), Sanda V., Popescu A. and Ştefan N., 1997 – Les associations végétales de Roumanie, 1, Les associations herbacées naturelles, Cluj-Napoca, 261. (in French)
15. Cristea V., 1991 – Fitosociologie şi vegetaţia României, Îndrumător de lucrări practice, Universitatea „Babeş-Bolyai", Cluj-Napoca. (in Romanian)
16. Cristea V., 1993 – Fitosociologie şi vegetaţia României, Universitatea „Babeş-Bolyai", Cluj-Napoca, 314. (in Romanian)
17. Cristea V., Gafta D. and Pedrotti F., 2004 – Fitosociologie, Edit. Presa Universitară Clujeană, Cluj-Napoca, 394. (in Romanian)
18. Csűrös Ş., Pop I., Hodişan I. and Csűrös-Káptalan M., 1968 – Cercetări floristice şi de vegetaţie între Orşova şi Eşelniţa, *Contribuții Botanice*, 277-312. (in Romanian)
19. Dihoru G., Cristurean I. and Andrei M., 1973 – Vegetaţia dintre Valea Mraconiei – Depresiunea Dubova, *Acta Botanica Horti Bucureşti*, 1972-1973, 353-423. (in Romanian)
20. Dihoru G. and Negrean G., 2009 – Cartea roşie a plantelor vasculare din România, Edit. Academiei Române, Bucureşti, 630. (in Romanian)
21. Doniţă N., Popescu A., Paucă-Comănescu M., Mihăilescu S. and Biriş I. A., 2005 – Habitatele din România, Edit. Tehnică Silvică, Bucureşti, 496. (in Romanian)
22. Doniţă N., Popescu A., Paucă-Comănescu M., Mihăilescu S. and Biriş I. A., 2006 – Habitatele din România, Edit. Tehnică Silvică, Bucureşti, 56. (in Romanian)
23. Dudley T. L., 1988 – The role of plant complexity and epiphyton in colonization of macrophytes by stream insects, *Verhandlungen der Internationalen Vereinigung für Limnologie*, 23, 1, 1153-8.

24. Gafta D., Mountford J. O. (eds), Alexiu V., Anastasiu P., Bărbos M., Burescu P., Coldea G., Drăgulescu C., Făgăraş M., Gafta D., Goia I., Groza G., Micu D., Mihăilescu S., Moldovan O., Nicolin L. A., Niculescu M., Oprea A., Oroian S., Paucă Comănescu M., Sârbu I. and Şuteu A., 2008 – Handbook for interpretation of Natura 2000 habitats from România, Cluj-Napoca, 101.
25. Glăvan V. and Geanana M., 1972 – Solurile, Atlasul complex „Porţile de Fier", Edit. Academiei Române, 142. (in Romanian)
26. Grecescu D., 1898 – Conspectul Florei României, Bucureşti. (in Romanian)
27. Grigore S. and Coste I., 1978 – Cercetări asupra vegetaţiei dintre Moldova Veche şi Pescari, *Studii și Cercetări de Geologie, Geografie, Biologie,* Reşiţa, 7, 173-189. (in Romanian)
28. Heuffel J., 1858 – Enumeratio Plantarum in Banatu Temesiensi, Vindabonae.
29. Liţescu S., Pascale G. and Sârbu A., 2003 – Aquatic flora and vegetation of semiflowing lakes Porţile de Fier I and Porţile de Fier II, *Studii și Cercetări de Biologie*, 8, 60-65, Bacău.
30. Matacă S. Ş., 2002 – Conspectul sistematic al plantelor vasculare din Parcul Natural Porţile de Fier (I), *Drobeta*, 11-12, 255-295. (in Romanian)
31. Matacă S. Ş., 2005 – Parcul Natural Porţile de Fier, Floră, vegetaţie şi protecţia naturii, Edit. Universitaria, Craiova, 550. (in Romanian)
32. Melo S. M., Takeda A. M. and Monkolski A., 2002 – Seasonal dynamics of Callibaetis willineri (Ephemeroptera, Baetidae) associated with Eichornia azurea (Pontederiaceae) in Guaraná Lake of the upper Paraná River, Brazil, *Hydrobiologia*, 470, 1-3, 57-62.
33. Morariu I., Danciu M. and Ularu P., 1969 – Date noi din flora Porţilor de Fier, *Studii și Cercetări de Biologie*, *Seria Botanică*, 21, 1, 17-22. (in Romanian)
34. Morariu I. and Danciu M., 1970 – In der Gegend der Eisernen Tores (Porţile de Fier) gemeldete Pflanzenassoziationen, *Revue Roumaine de Biologie – Botanique*, 15, 5, 419-429. (in German)
35. Oltean M., Negrean G., Popescu A., Roman N., Dihoru G., Sanda V. and Mihăilescu S., 1994 – Lista roşie a plantelor superioare din România, in Oltean M. (ed.) *Studii, sinteze, documentații de ecologie,* Academia Română – Institutul de Biologie, 1, 52, Bucureşti. (in Romanian)
36. Păun M., Cîrţu M., Cîrţu D. and Popescu G., 1968 – Materiale pentru flora dintre Berzeasca şi Pescari, judeţul Caraş-Severin, *Buletinul Științiific*, 10, 47-62, Craiova. (in Romanian)
37. Podani J., 1993 – SYN-TAX-PC, Computer Programs for mulivariate data analysis in ecology and systematics, version 5.0 – User's guide, Scientia Publication, Budapest.
38. Popescu A. and Ştefureac T., 1976 – Vegetations forschungen aus dem Sektor Sviniţa-Trikule Eisernes tor Rumäniens, *Acta botanica Horti Bucurestiensis,* 1975-1976, 341-368. (in German)
39. Popescu A., Sanda V. and Oroian S., 1997 – Vegetaţia Deltei Dunării, *Marisia*, 25, 3-126.
40. Popescu A. and Sanda V., 1998 – Conspectul florei cormofitelor spontane din România, *Acta botanica Horti Bucurestiensis*, 336. (in Romanian)
41. Popp N., 1971 – Principalele probleme de geografie fizică în opera lui Vâlsan G., Opere alese, Bucureşti, Edit. Ştiinţifică, 38-69 (in Romanian)
42. Raclaru P. and Alexan M., 1972 – Flora Defileului Dunării, Baziaş-Pojejena, *Analele Universității București*, *Biologie vegetală*, 21, 201-217. (in Romanian)
43. Raclaru P. and Alexan M., 1973 – Asociaţii vegetale palustre din Defileul Dunării, Baziaş-Pojejena, *Studii și Cercetări de Biologie, Seria Botanică*, 25, 2, 131-139. (in Romanian)

44. Rai U. N. and Sinha S., 2001 – Distribution of metals in aquatic edible plants: Trapa natans (Roxb.), *Environmental Monitoring and Assesment*, 79, 241-252.
45. Resmeriţă I., Vicol E. C., Coldea G. and Schneider E., 1972 – Cartarea vegetaţiei din sectorul Valea Eşelniţa, *Studii și Cercetări de Biologie, Seria Botanică*, 24, 3, 213-220. (in Romanian)
46. Roman N., 1971 – Elemente noi pentru caracterizarea fitogeografică a Porţilor de Fier, *Studii și Cercetări de Biologie, Seria Botanică*, 23, 6, 477-484. (in Romanian)
47. Rooke J. B., 1984 – The invertebrate fauna of four macrophytes in a lotic system, *Freshwater Biology*, 14, 507-513.
48. Sanda V., Şerbănescu G. and Zăvoianu I., 1968 – Aspecte ale florei şi vegetaţiei palustre din Clisura Cazanelor, *Studii și Cercetări de Biologie, Seria Botanică*, 20, 3, 217-224. (in Romanian)
49. Sanda V., Şerbănescu G., Raclaru P. and Alexan M., 1970 – Contribuţii la cunoaşterea staţiunilor cu Acorus calamus L., *Studii și Cercetări de Biologie, Seria Botanică*, 22, 6, 481-489.
50. Sanda V., Popescu A. and Doltu M. I., 1980 – Cenotaxonomia şi corologia grupărilor vegetale din România, *Studii și Comunicări, Ştiințe Naturale*, Sibiu, 24 (supl.), 1-172. (in Romanian)
51. Sanda V., Popescu A., Doltu M. I. and Doniţă N., 1983 – Caracterizarea ecologică şi fitocenologică a speciilor spontane din flora României, *Studii și Comunicări, Ştiințe Naturale*, Sibiu, 25 (supl.), 1-126. (in Romanian)
52. Sanda V., Popescu A. and Coldea G., 1994 – Asociaţiile vegetale din clasa Lemnetea minoris R. Tx. 1955 din România, *Contribuții Botanice*, 1993-1994, 5-11. (in Romanian)
53. Saunders D. L. and Kalff J., 2001 – Nitrogen retention in wetlands, lakes and rivers, *Hydrobiologia*, 443, 205-212.
54. Săvulescu T., (coord.), 1952-1976 – Flora Republicii Populare Române – Flora Republicii Socialiste România, I-XIII, Edit. Academiei Române. (in Romanian)
55. Sârbu A., Smarandache D., Janauer G. and Pascale G., 2006 – Elodea nuttallii (Planchon) St. John – a competitive hydrophyte in the Romanian Danube River corridors, *Proceedings 36th International Conference of IAD*, 4-8 September, Vienna.
56. Sârbu A., Janauer G., Schmidt-Mumm U., Filzmoser P., Smarandache D. and Pascale G., 2011 – Characterisation of the potamal Danube River and the Delta: connectivity determines indicative macrophyte assemblages, *Hydrobiologia*, 671, 75-93.
57. Srivastava S., Yadav A. and Shukla D. N., 2014 – Effects of lead and its phytoremediation potential in Trapa natans L., *Asian Journal of Research in Chemistry*, 4, 434.
58. Şerbănescu G. and Sanda V., 1970 – Cercetări asupra vegetaţiei de luncă şi dealuri între Cazanele Mari şi Plavişeviţa, *Studii și Cercetări de Biologie*, 22, 3, 171-178. (in Romanian)
59. Ştefureac T., 1970 – Cercetări asupra florei şi vegetaţiei de la Porţile de Fier, *Analele Universității Bucureşti, Biologie Vegetală*, 19, 193-204. (in Romanian)
60. Ştefureac T., Popescu A., Zitti R. and Mihai G., 1971 – Analiza cormofitelor din sectorul Şviniţa-Tricule (Clisura Dunării), *Comunicări Botanice*, 12, 111-131. (in Romanian)
61. Takeda A. M., Souza-Franco G. M., Melo S. M. and Monkolski A., 2003 – Invertebrados associados a macrófitas, in Thomaz S. M. and Bini L. M. (eds), *Ecologia e Manejo de Macrófitas Aquáticas*, 243-260, Maringá, Eduem. (in Portuguese)
62. Tall L., Caraco N. and Maranger R., 2011 – Denitrification hot spots: dominant role of invasive macrophyte Trapa natans in removing nitrogen, *Ecological Applications*, 21, 8, 3104-3114.
63. Tetelea C., 2005 – Potenţialul geoecologic al ecosistemelor acvatice din Parcul Natural Porţile de Fier, Rezumat teză doctorat, Universitatea din Bucureşti. (in Romanian)

64. Thorp A. G., Jones R. C. and Kelso D. P., 1997 – A comparison of water-column macroinvertebrate communities in beds of different submersed aquatic vegetation in the tidal freshwater Potomac River, *Estuaries*, 20, 1, 86-95.
65. Todor I., Gergely I. and Bârcă C., 1971 – Contribuţii la cunoaşterea florei şi vegetaţiei din zona Defileului Dunării, *Contribuții Botanice*, 203-256. (in Romanian)
66. Tutin T. G., Heywwood V. H., Burges N. A., Moore D. M., Valentine D. H., Walters S. M. and Webb D. A., 1964-1980 – Flora Europaea, Cambridge: Cambridge University Press, 1-5.
67. Vivian-Smith G., 1997 – Microtopographic heterogeneity and floristic diversity in experimental wetland communities, *Journal of Ecology*, 85, 71-82.
68. Williams P., Whitfield M., Biggs J., Bray S., Fox G., Pascale N. and Sear D., 2003 – Comparative biodiversity of rivers, streams, ditches and ponds in an agricultural landscape in Southern England, *Biological Conservation*, 115, 329-341.

GEOGRAPHIC ORIGINS OF INVASIVE ALIEN SPECIES IN "IRON GATES" NATURAL PARK (BANAT, ROMANIA)

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KEYWORDS: geographic origin, biogeographic dispersal, invasive alien species, "Iron Gates" Natural Park, Romania.

ABSTRACT

The paper presents an inventory and distribution of invasive alien species, in "Iron Gates" Natural Park, especially to highlight their origins, the most aggressive alien species, and their impact on conservation status of habitats, and indirectly their economic and sociological impact on the human communities.

This study may have an important role in improving the efficiency of conservation measures, offering valuable information to authorities involved in protected areas administration.

RESUMEN: Orígen geográfico de las especies invasoras en el Parque Natural "Puertas de Hierro" (Banat, Rumania).

En este trabajo se presenta un inventario de las especies invasoras y su distribución espacial en el Parque Nacional Puertas de Hierro, con el fin de establecer su origen geográfico, de identificar a las más agresivas así como también de establecer qué impacto tienen tanto en el estado de conservación de los hábitats del parque como en los aspectos socioeconómicos de las comunidades humanas que habitan el lugar.

Este estudio es potencialmente importante para mejorar la eficiencia de las medidas de manejo y conservación, y presenta información de utilidad a las autoridades involucradas en la administración de áreas protegidas.

REZUMAT: Apartenența areal geografică a speciilor invazive din Parcul Natural Porțile de Fier, România.

Lucrarea prezintă un inventar al speciilor invazive și distribuția acestora în Parcul Natural Porțile de Fier, în special pentru a sublinia apartenența areal geografică, cele mai agresive specii invazive și impactul acestora asupra stării de conservare a habitatelor, precum și impactul lor economic și sociologic asupra comunităților umane.

Acest studiu reprezintă un pas necesar în îmbunătățirea măsurilor de conservare și oferă informații valoroase autorităților implicate în administrarea ariilor protejate.

INTRODUCTION

Invasive alien species (IAS) pose a threat to global ecosystems, and they are a major environmental threat of the 21st Century (Mack et al., 2000). Impacts include loss of native species and habitat, economic suppression, reduced food and water security, and direct threats to human health.

For many centuries, humans have intentionally or accidentally moved organisms around the planet (Elton, 1958) which resulted in many changes within world ecosystems. This was possible due to self-sustaining species subsiding outside their native ranges (Richardson, 2011), but many introduced species became invasive and have negative effects on native species and habitat structure (Gaertner et al., 2009).

Invasive species are commonly non-native species that disseminate out of their natural range generally as a result of human activities. Are incapable to live in a foreign environment without anthropic intervention and eventually die off, but due to acclimatization, humans can cause significant changes on species' ranges (Evans et al., 2008). Some species adapt to new surroundings and establish in the local ecosystems, where they can cause ecological and economic damage.

The EC estimated in 2014 that in Europe there were already 12,000 alien species, of which 10-15% are invasive. They appear in all major taxonomic groups, ranging from mammals, amphibians, reptiles, fish, invertebrates and plants to fungi, bacteria and other micro-organisms. They are found in all habitats, both on land and in water seas. (EEA, 2014)

Terrestrial plants are the most common alien species, representing over half of all species presented in Europe (over 6,500 species), followed by terrestrial invertebrates (over 2,700 species). There are close to 1,000 alien aquatic species, on the other hand, terrestrial vertebrates are the less numerous alien species present in EU. (Daisie, 2009)

Invasive alien species can cause local extinction of indigenous species, through competition for limited resources (food and habitat), interbreeding or the spread of exotic diseases. The lack of studies and sustainable actions to conserve natural protected areas, can lead to invasive alien species impacting entire ecosystems, thus altering their structure and function, including their ability to proved valuable ecosystem services, such as water regulation, flood control or even pollination. (Kumschick et al., 2012)

Invasive alien species can also have a significant economic impact, by reducing yields from agriculture, forestry and fisheries, can damage infrastructure (decrease water availability, block waterways, clog pipes). They can also destroy bodies of water bodies and change landscapes by causing loss of protected areas or cultural heritage values. Other than this, invasive alien species can be a major issue for human health, triggering skin problems or allergies and acting as a vector for other dangerous pathogens and diseases. (Mack et al., 2000)

The cost management of taking measures to combat invasive alien species is a continuous growth process. Once an invasive alien species is out of their contained environment by natural or anthropogenic reasons, human and financial resources are needed in order to repair the damage they cause, and take measures to eradicate them or stop them from spreading further. It's obvious that sooner the measures are taken the better. The Regulation on Invasive Alien species established by EU in 2014 includes three types of measure for combating IAS: prevention, early warning and rapid response and management of already established invasive alien species. (EEA, 2014)

It is also significant to mention that not all alien species are problematic or invasive; some of them generate economic benefits, this being one of the reasons why they were introduced in different areas (Daleo et al., 2009; Donaldson et al., 2014).

The study was focused on "Iron Gates" Natural Park, located in the South-Western part of Romania, on the territory of Caraș-Severin and Mehedinți counties part of Continental biogeographical region. Considered the third largest protected area in Romania (1,156 km^2) it is recognized for its great diversity of ecosystems, wide variety of species and emblematic landscapes.

"Iron Gates" Natural Park area was the subject of numerous complex research studies increasing before and after construction of "Iron Gates" Navigation System – Hydro Power Plants (1965-1971) (Boiangiu, 2002; Călinescu and Iana, 1964; Boșcaiu et al., 1971; etc.). Due to its importance represented by high diversity of species and ecosystems, the latest research studies focused on the conservation of natural habitats and species (Matacă, 2005; Pătroescu et al., 2008; etc.).

According to Law 5/2000, to approve the National Territory Improvement Plan – Section III – protected area, M. O. 552/2003 of M.A.P.A.M., HG 2151/2004 and OUG 57/2007 in the "Iron Gates" Natural Park are 18 natural protected areas (national reserves and nature monuments). Also according to HG 1284/2007 on the territory of "Iron Gates" Natural Park, which established two Special Protection Areas (SPAs) as integrated parts of European Ecological network NATURA 2000 in Romania: ROSPA0026 – Danube water course Baziaș-"Iron Gates" and ROSPA0080 Almăj-Locvei Mountains. In 2007 according to the Ministry of Environment and Sustainable Development Ordinance no. 1964 was established ROSCI0206 "Iron Gates" as a Site of Community Interest (SCI) as an integrated part of European Ecological Network NATURA 2000.

Botanical surveys carried out in "Iron Gates" Natural Park lead to a floristic inventory of 1,875 vascular plant taxa, including 1,748 species, 120 subspecies and six varieties, distributed in 570 genera and 131 families (Matacă, 2005). This floristic inventory represents 49.97% of all floral species known in Romania (Matacă, 2005). The diversity of the vegetal associations is high, being identified 171 vegetal associations, from which 26 are endemic for Romania and 21 have community value. The number of endemic elements completes the large diversity of fitogeographic elements. Also 27 habitat types from the 29 total habitats identified are habitats of community interest, and are listed in the 1st Annex of the Habitat Directive (92/43/EEC). Moreover, five of these habitats are considered priority habitats and designated that the area needed special conservation (PM of PNPF, 2013).

Regarding the fauna of "Iron Gates" Natural Park the existent studies, reveal the presence of 5,205 taxa, of which 4,873 are invertebrates and 332 vertebrates. Among vertebrates, class Aves has the most representatives (205 taxa), followed by Pisces with 63 representatives, and class Amphibia with the lowest representativeness – only 12 taxa (PNPF Management Plan, 2013). Most of the reptiles, amphibians and birds species from the "Iron Gate" Natural Park are protected at an international and national level. The "Iron Gate" area represents also a passage corridor for birds with world importance.

Being an EU member, the alignment of EU legislation and policies is mandatory. At the present moment the studies in "Iron Gates" Natural Park on invasive alien species are poor, detailed observation and analyses being needed.

The purpose of this study is an inventory and distribution of invasive alien species, in "Iron Gates" Natural Park, especially to highlight their origins, the most aggressive alien species, and their impact on conservation status of habitats, and indirectly their economic and sociological impact on the human communities. The paper may have an important role in improving the efficiency of conservation measures, offering valuable information to authorities involved in protected areas administration.

MATERIAL AND METHODS

The observation and analysis of invasive plant species was made in different phoenological phases of the growing season, and by the botanical material collected, preserved and determined from May to September 2012. For a complex analysis of the flora were used chorological data from Romanian Flora, I-XII, bibliographical data extracted from monographic studies of the region and the herbarium sheets (Timișoara, Cluj) collected by various botanists.

Taxa nomenclature is given by Flora Europaea (***, http: //ww2.bgbm.org/europlusmed/), and with Romanian identification field books (Ciocârlan, 2000).

Observation and analyses on fauna were conducted for six years, in various field trips between 2008 and 2014, for Management Plan of "Iron Gates" Natural Park (2013) and also based on scientific literature targeting our study area.

The origin of invasive alien species was established using international databases as http://www.cabi.org/; http://www.invasiveplantatlas.or/; http://www.europe-aliens.org/ and http://www.nobanis.org. We considered it to be essential to represent graphically their native distribution around the world by biogeographical realms and continents of the world.

For a better understanding of the impact on native habitats and species in "Iron Gates" Natural Park a synthetic assessment was necessary. The assessment of the impact of invasive alien species was based on criteria including occurrence, aggressiveness upon native species, the potential to transform and possibly replace the native habitats, the impact on human health and environmental factors. In order to estimate the impact of invasive alien species we used a scale from one to five (1 – low occurrence, 2 – low impact, 3 – medium impact, 4 – strong impact and 5 – very high impact) and we managed to construct a list with the most aggressive species in our study area. Further we illustrated their distribution in "Iron Gates" Natural Park to highlight the most vulnerable areas.

RESULTS AND DISCUSSION

Based on our field observation, data provided by IAS international database and analyses we identified so far 43 invasive alien species (two mammals, seven aquatic invertebrates, four fish and 32 plants) and we synthesized in table 1 their origin, pathways of introduction and their impact in "Iron Gates" Natural Park.

Table 1: Invasive species of "Iron Gates" Nature Park – origin, pathways of introduction and their impact.

Invasive species	Origin – Biogeographi-cal Realm	Pathways of introduction in IGNP	Impact in IGNP	Impact assessment in IGNP 1-5 (low occurrence – high impact)
Mammals				
Myocastor coypus Molina, 1782	Neotropic (South America)	Anthropic – Fur exploitation	Habitat degradation, pest	2
Neovison vison Schreber, 1777	Neartic (North America, Central America)	Anthropic – Fur exploitation	Competitive species, voracious predator	3
Aquatic invertebrates				
Corbicula fluminea O. F. Müller, 1774	Indo-Malay, Australasia, Afrotropical (Asia, Australia, Africa)	Anthropic – ship ballast	Competitive species, infrastructure degradation	3
Dreissena polymorpha Pallas, 1771	Paleartic (Europe)	Anthropic – ship ballast	Competitive species, bioaccumulate pollutants	2
Eriocheir sinensis Milne-Edwards, 1854	Paleartic (Asia)	Anthropic – ship ballast	Competitive species, parasite host, infrastructure degradation	4
Eustrongylides sp.	worldwide	Natural – birds and fish parasite	Parasite	3
Hemimysis anomala G. O. Sars, 1907	Paleartic (Europe)	Anthropic – ship ballast	Habitat degradation	2
Katamysis warpachowskyi G. O. Sars, 1893	Paleartic (Europe)	Anthropic – ship ballast	Impacts on the zooplankton	2
Orconectes limosus Rafinesque, 1817	Neartic (North America)	Anthropic – ship ballast, aquaculture	Competitive species, disease-crayfish plague	2

Table 1 (continued): Invasive species of "Iron Gates" Nature Park – origin, pathways of introduction and their impact.

Invasive Species	Origin – Biogeographical Realm	Pathways of introduction in IGNP	Impact in IGNP	Impact assessment in IGNP 1-5 (low occurrence –high impact)
Fish				
Ameiurus nebulosus Lesueur, 1819	Neartic (North America)	Anthropic – aquaculture	Competitive species	4
Carassius auratus gibelio Bloch, 1782	Paleartic (Europe, Asia)	Anthropic – aquaculture	Degrading environmental conditions and reproductive competition	3
Lepomis gibbosus Linnaeus, 1758	Neartic (North America)	Anthropic – aquarium trade	Competitive species, reduce zooplankton	4
Pseudorasbora parva Temminck and Schlegel, 1846	Paleartic (Asia)	Anthropic – aquaculture	Competitive species, decrease or extinction of native cyprinids	2
Plants				
Acorus calamus L.	Indo-Malay (Asia)	Anthropic – plant trade	Replace native species	2
Ailanthus altissima (P. Mill) Swingle	Paleartic (Asia)	Anthropic – ornamental purposes	Displace native vegetation, competitive species which reduce biodiversity	5
Amaranthus retroflexus L.	Neartic, Neotropical (North America, Central America)	Anthropic – plant trade	Aggressive and competitive weed	2

Table 1 (continued): Invasive species of "Iron Gates" Nature Park – origin, pathways of introduction and their impact.

Invasive Species	Origin – Biogeographi-cal Realm	Pathways of introduction in IGNP	Impact in IGNP	Impact assessment in IGNP 1-5 (low occurrence – high impact)
Plants				
Ambrosia artemisiifolia L., 1828	Neartic (North America)	Anthropic – agriculture	Reduce biodiversity, replace native species, can be allergenic species, can host fungi and viruses responsible for crop diseases	3
Amorpha fruticosa L.	Neartic (North America)	Anthropic – ornamental purposes and significant importance for beekeeping	Competitive species, it has the potential to replace native vegetation	5
Asclepias syriaca Blanco, 1837	Neartic (North America)	Anthropic – plant trade	Aggressive weed, contains toxic substances that may cause poisoning	3
Azolla filiculoides Lam.	Neartic, Neotropical (North America, Central America, South America)	Anthropic – plant trade	Low occurrence in Lemnetea communities	2
Bidens frondosa L.	Neartic (North America, Central America)	Anthropic – plant trade	Ecosystem degradation, replace native species	2
Bidens vulgata Greene	Neartic (North America)	Anthropic – plant trade	Competitive species, replace native species	2

Table 1 (continued): Invasive species of "Iron Gates" Nature Park – origin, pathways of introduction and their impact.

Invasive Species	Origin – Biogeographi-cal Realm	Pathways of introduction in IGNP	Impact in IGNP	Impact assessment in IGNP 1-5 (low occurrence – high impact)
Plants				
Conyza canadensis (L.) Cronq.	Neartic (North America)	Anthropic – plant trade	Ecosystem degradation, affects crops, can host for some plant viruses, nematodes, fungi and insects	2
Cyperus odoratus L.	Neartic (North America)	uncertain	Displace native vegetation	2
Dysphania ambrosioides L.	Neartic, Neotropical (Central America, South America)	Anthropic – plant trade	Replace native species	1
Echinocystis lobata (Michx.) Torr. and A. Gray	Neartic (North America)	Anthropic – plant trade decorative purposes	Ecosystem degradation, replace native species	2
Elodea nuttallii (Planch.) H. St. John	Neartic (North America)	Anthropic – plant trade, aquarium	Reduce biodiversity, replace native species	5
Elodea Canadensis Rich. in Michx.	Neartic (North America)	Anthropic – plant trade, aquarium	Competitive species, it has the potential to replace native vegetation, reducing biodiversity	5
Erigeron annuus (L.) Pers	Neartic (North America)	Anthropic – plant trade decorative purposes	Ecosystem degradation, competitive species	2
Erigeron strigosus Muhl. ex Willd.	Neartic (North America)	Anthropic – plant trade	Low occurrence	1

Table 1 (continued): Invasive species of "Iron Gates" Nature Park – origin, pathways of introduction and their impact.

Invasive Species	Origin – Biogeographi-cal Realm	Pathways of introduction in IGNP	Impact in IGNP	Impact assessment in IGNP 1-5 (low occurrence – high impact)
Plants				
Euphorbia maculata	Neartic (North America)	uncertain	Aggressive weed, ecosystem degradation	1
Galinsoga parviflora Cav.	Neotropical (South America)	Antrhopic – plant trade, agriculture	Habitat degradation, reduce crops productivity	1
Hibiscus trionum L.	Paleartic (Asia Africa)	Anthropic – plant trade	Intoxication in livestocks, human allergies	1
Juncus tenuis Willd.	Neartic (North America)	Anthropic – plant trade	Low occurrence	1
Oenothera biennis L.	Neartic (North America)	Anthropic – hoticulture, medical purposes	Habitat destruction	2
Oenothera parviflora L.	Neartic (North America)	Anthropic – hoticulture, medical purposes	Habitat destruction	2
Panicum capilare L.	Neartic (North America)	Anthropic – plant trade	Aggressive weed, replace native species	2
Paspalum paspalodes (Michx) Scribn	Neartic, Afrotropical (North America, Africa)	Anthropic – plant trade	Competitive species, it has the potential to replace native vegetation, reduce biodiversity, can be alternative host for fungi, bacteria, viruses and nematodes	5
Polygonum orientale L.	Indo-Malay	Anthropic – plant trade	Low occurrence	1
Portulaca oleracea L.	Uncertain possibly Neartic	Anthropic – plant trade	Aggressive weed, ecosystem degradation	2

Table 1 (continued): Invasive species of "Iron Gates" Nature Park – origin, pathways of introduction and their impact.

Rhus typhina L.	Neartic (North America)	Natural – zoochoric Anthropic – plant trade, ornamental purposes	Habitat destruction	2
Robinia pseudoacacia L.	Neartic (North America)	Anthropic – horticulture	Competitive species, it has the potential to replace native vegetation	5
Sorghum halepense (L.) Pers	Paleartic (Europe, Asia)	Anthropic – plant trade	Aggressive and competitive weed in wetlands communities, can cause intoxication in livestocks, human allergies	1
Vallisneria spiralis Linnaeus	Paleartic, Indo-Malay (Europe, Africa, Asia)	Anthropic – plant trade, aqurium	Competitive species, it has the potential to replace native vegetation Negative impact on navigation, recreation and agriculture activities	4
Xanthium italicum Moretti	Neotropical (Central America, South America)	Anthropic – plant trade	Competitive species, replace native species, can cause poisoning and allergies; invades crops	3

The invasive alien species identified in "Iron Gates" Natural Park have origins in six of the biogeographical realms. The biggest proportion − 62.79% of identified alien species have a Neartic origin, followed by Palearctic biogeographical origin with 20.93%, Neotropical origin with 13.95%, Indo-Malay origin – 9.30%, Afrotropical origin − 4.65% and only 2.32% with an Australasian provenance (Fig. 1). We can also notice that only 2.32% have a worldwide origin and 2.32% an uncertain origin (Fig. 1).

The Neartic origin of the species highlights the trade route between North America and Europe, but also the similar ecological characteristics between these areas which permitted a rapid adaptation of alien species. The pathways of introduction are mainly anthropic (Tab. 1) and are favoured by hydrographic characteristic of the study area, the Danube River being an important artery of communication and transport between Orient and Occident. This fact also explains the Paleartic origins of invasive alien species identified in our study area.

The majority of alien species were transported unintentionally from their natural range to "Iron Gates" Natural Park by ship ballast (e.g. aquatic invertebrates) or plant trade with other plant species transported for economic purposes (e.g. weeds).

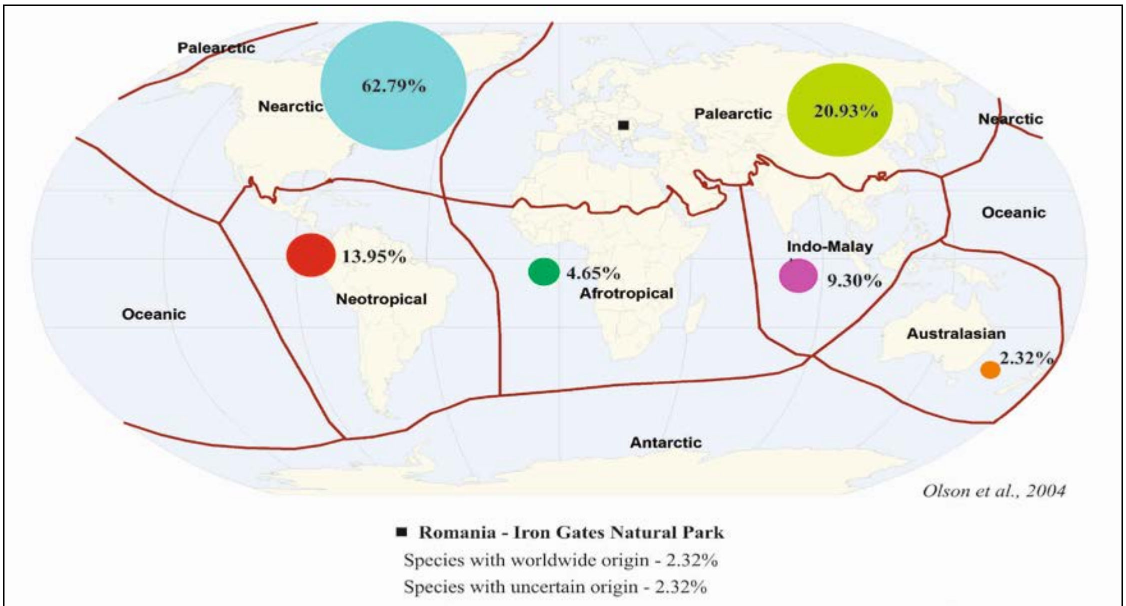

Figure 1: Invasive alien species origins of "Iron Gates" Natural Park by biogeographic realms.

Regarding the origin of invasive species identified in the study area by continents its obviously that the majority has a North American source with 62.79%, followed by Europe and Asia with 16.27% each, 13.95% Central America, 11.62% South America, 9.30% Africa, 2.32% Australia (Fig. 2). Only 2.32% of identified invasive species have a worldwide origin, represented by *Eustrongylides* sp. – wading birds (Cole, 1999) and freshwater fish parasite (Franson and Custer, 1994). Being a wide spread parasite it makes difficult to establish its accurate origin. We identified one species whose origin is uncertain (*Portulaca oleracea*), which represents 2.32% of all identified invasive alien species in "Iron Gates" Natural Park. It is possible for this species to have a Nearctic origin (Chapman et al., 1974).

Some of the identified species were introduced intentionally for use in aquaculture, horticulture and economic interests (e.g. *Nevison vision* for fur exploitation; *Ailanthus altissima* for ornamental purposes (Hu, 1979)).

Even thought alien species have been entering Europe for centuries, them have significantly risen in the last 50 years, mainly as a result of increased transportation, trade, travel and other components of globalization (Evangelista and Kumar, 2011; Mack et al., 2000). Studies estimate that the number of IAS in Europe has increased by as much as 76% since the 1970s (EEA, 2014). The number is likely to continue to grow unless major actions are taken to combat invasion.

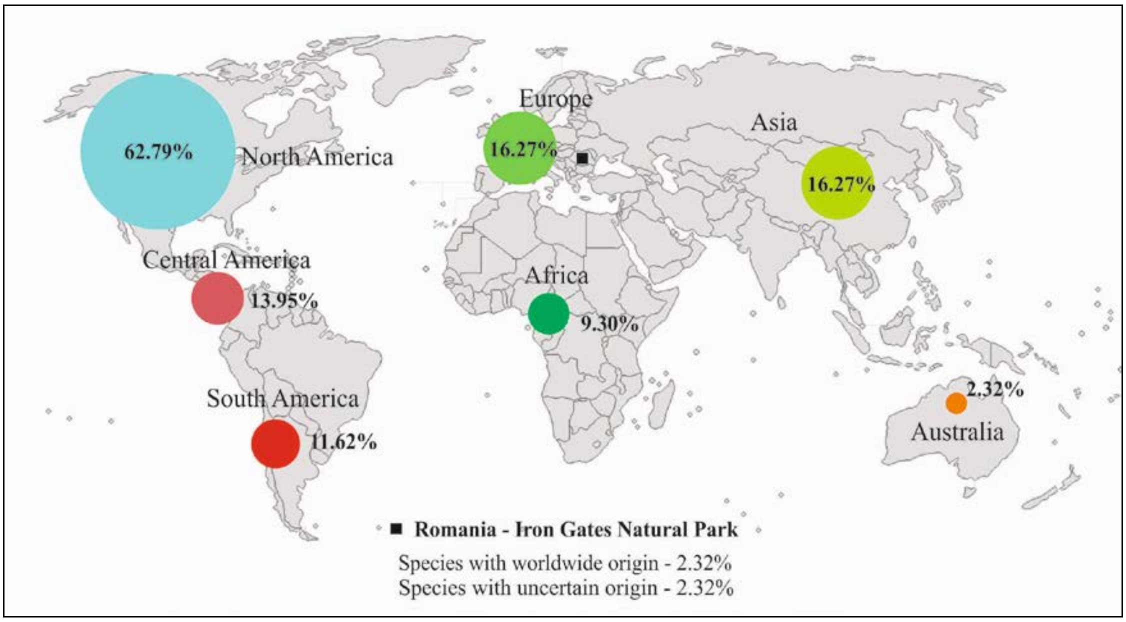

Figure 2: Invasive alien species origins of "Iron Gates" Natural Park by world continents.

In the absence of the data regarding the population of invasive alien species in "Iron Gates" Natural Park on a long period of time, we can only assume that the trend of IAS is similar to Europe.

It was estimated that only 0.1% introduced plants by humans outside their native area become invasive (Wiliamson, 1996; Williamson and Fitter, 1996). The invasive plants are naturalized plants that are able to spread to a considerable distance from the place of introduction (approximately > 100 m/50 years for plants that reproduce by seeds; > six m/three years for vegetative reproduction).

Assessing the impact of invasive alien species revealed 10 aggressive species with a high negative impact on the habitats of "Iron Gates" Natural Park: one aquatic invertebrate – *Eriocheir sinensis*, two fish – *Ameiurus nebulosus* and *Lemopis gibbosus*, and seven plants – *Ailanthus altissima*, *Amorpha fruticosa*, *Elodea nuttallii*, *Elodea canadensis*, *Paspalum paspalodes*, *Robinia pseudoacacia* and *Vallisneria spiralis* (Fig. 3). Their origins are mainly from Neartic biogeographical realm (70%), from North America. The other 30% have a Paleartic origin.

Aggressiveness of these 10 species are threatening the existence of native species from "Iron Gates" Natural Park and also the structure and functions of ecosystems because of their competitiveness regarding food and space (Josefsson and Andersson, 2001) and other adaptive mechanisms. One of this species is *Ailanthus altissima* that forms dense thickets that displace native vegetation and produce toxins that inhibit the growth of other plants. Also in riparian communities, lower plant species richness and phylodiversity were associated to the presence of *A. altissima* (Constán-Nava, 2012).

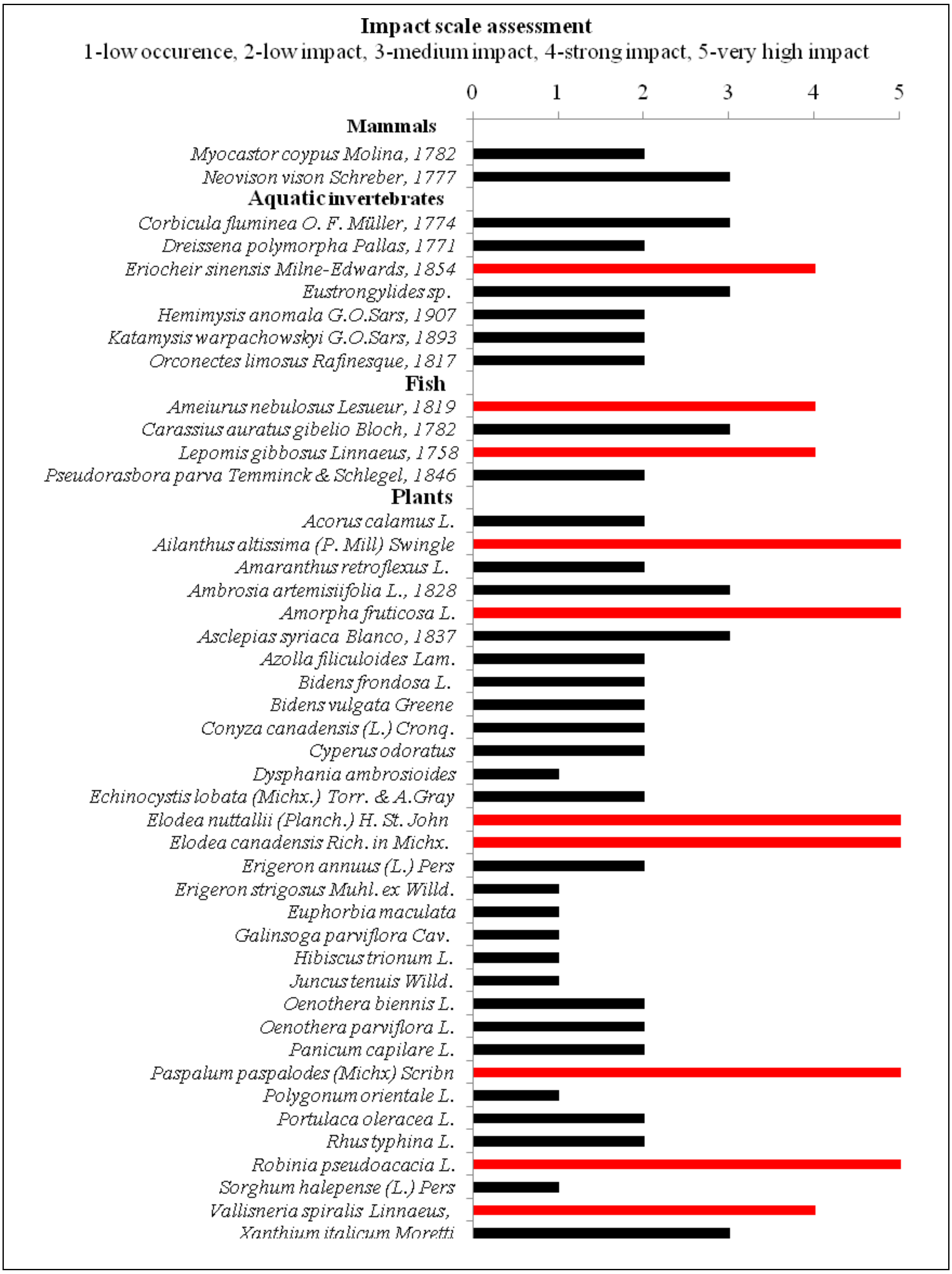

Figure 3: Impact assessment of invasive alien species in IGNP – highlighting the most aggressive IAS.

The main issue with invasive alien species, especially with terrestrial (*Ailanthus altissima*, *Amorpha fruticosa*, *Paspalum paspalodes*, *Robinia pseudoacacia*) and aquatic plants (*Elodea nuttallii*, *Elodea canadensis*, *Vallisneria spiralis*) is that they grow and reproduce rapidly, causing major disturbance to the areas in which they are present.

Due to their great adaptability, alien plant species compete with native species and creates significant transformations. For example, *Amorpha fruticosa* spreads along Danube watercourse and negatively effects native vegetation (*Salix alba*, *Phragmites australis).* It's a major threat for habitats of priority interest and affects protected bird species as *Phalacrocorax pygmeus* and *Aythya nyroca*.

The most vulnerable areas (Fig. 4) are the wetlands (Nera-Baziaş, Calinovăţ Island, Pojejena, Moldova Veche Island, Liborajdea-Berzasca, Eşelniţa Bay, Orşova Bay), usually dominated by cosmopolite species because they offer similar conditions all over the world.

Water is the most important vector for spreading the invasive species, fact also proved in the "Iron Gates" Natural Park. In high elevated areas where heatstroke is a higher risk and the soil is drier, the vegetation communities are cohesive giving no gaps to non-native species or eliminating them in some cases.

Invasive alien species are a significant and growing problem in all EU Member States, including the area of "Iron Gates" Natural Park. Certain aspects of invasive alien species are managed by a variety of existing laws targeting plant health and animal diseases, wildlife trade (CITES) or the use of alien or locally absent species in aquaculture (EEA, 2014), but the most important factor is to prevent their introduction and spread, especially in vulnerable habitats.

By knowing the origins and pathways of introduction of invasive alien species is an important step in having the right knowledge in order to establish measures of limiting their route of access especially by regulating trade (e.g. borders control). It is also important to raise public awareness by organizing extensive campaigns and given the fact that many of invasive alien species have economic importance, popularizing their use might contribute to economic exploitation purposes and in this way perhaps to their eradication (e.g. *Oenothera biennis, Oenothera parviflora* can be exploited for medical purposes).

In "Iron Gates" Natural Park have been identified so far 43 invasive alien species (two mammals, seven aquatic invertebrates, four fish and 32 plants) that cause significant changes in community structure of aquatic and terrestrial ecosystems and can also change the relations between indigenous and non-native producers and consumers. It is important to mention that only invasive terrestrial plants can change the habitats, because they have the potential to become part of the habitats for other organisms.

It has also been established a list of 10 aggressive species with a high negative impact on the habitats of "Iron Gates" Natural Park based on criteria as occurrence, aggressiveness upon native species, the potential to transform and possibly replace the native habitats, the impact on human health and environmental factors.

The origin of invasive alien species identified in "Iron Gates" Natural Park is predominantly Holartic, 62.79% have a Neartic origin, followed by a Paleartic provenance with 20.93%, showing the movements of species and the impact of human actions due to globalization process.

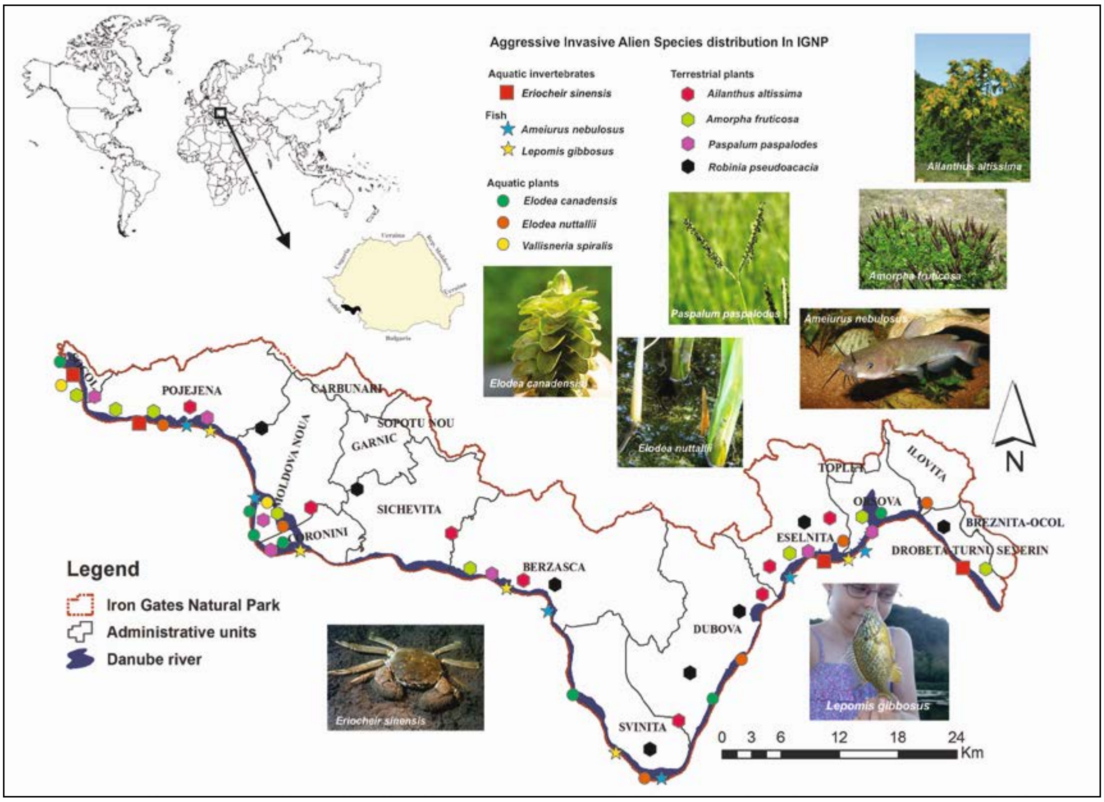

Figure 4: Spatial distribution of most aggressive invasive alien species in "Iron Gates" Natural Park.

A sustainable management of the protected area regarding invasive alien species definitely needs more accurate observations with a longer period of time. This will require more data collection, further detailed observation and analyses that should include observations in all phenological phases of growing season, surveys with professional fishermen, interviews with residents, bird watching and interdisciplinary approach. We highly recommend that the next Management Plan of "Iron Gates" Natural Park needs to establish concrete actions for monitoring invasive alien species, taking into account their diversity, the ecosystems within the park are identified and their aggressiveness. Also, a major objective of the Scientific Council and "Iron Gates" Natural Park Administration should be the emergence of new invasive alien species, and the current state assessment of ecosystems already affected by the their presence.

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REFERENCES

1. Boiangiu O., 2002 – Studiu climatic al bazinetului Orșova, *Drobeta*, XI-XII, 220-254, Drobeta Turnu Severin. (in Romanian)
2. Bostan C., Borlea F., Mihoc C. and Beceneaga A. M., 2014 – Spread of Ailanthus altissima species in new areal, *Research Journal of Agricultural Science*, 46, 1, 104-108.
3. Boşcaiu N., Lupşa V., Resmeriţă I., Coldea G. and Schneider E., 1971 – Vegetaţia lemnoasă mezo-xerotermă (Orno-Cotinetalia) din Defileul Dunării, *Ocrotirea naturii*, Bucureşti, 15, 1, 49-55. (in Romanian)
4. Călinescu R. and Iana S., 1964 – Consideraţiuni biogeografice asupra Defileului Dunării, *Analele Universităţii Bucureşti*, *Ştiințele naturii*, XII, 1, 151-167. (in Romanian)
5. Chapman J., Stewart R. B. and Yarnell R. A., 1974 – Archaeological evidence for pre-Columbian introduction of Portulaca oleracea and Mullugo verticillata into eastern North America, *Economy Botany*, 28, 411-412.
6. Ciocârlan V., 2000 – Flora ilustrată a României Pteridophyta et Spermatophyta, Edit. Ceres, Bucureşti, 14-1084. (in Romanian)
7. Cole R. A., 1999 – Chapter 29 – Eustrongylidosis, in Field Manual of Wildlife Diseases, General Field Procedures and Diseases of Birds, Biological Resources Division, 223-228.
8. Constán-Nava S., 2012 – Ecología de la especie invasora *Ailanthus altissima* (Mill.) Swingle: bases para su control y erradicación en espacios naturales protegidos, PhD Thesis summary, Spain: University of Alicante, http://rua.ua.es/dspace/handle/10045/24861, 4-148. (in Spanish)
9. Daisie (ed.), 2009 – Handbook of Alien Species in Europe, Invading Nature: Springer Series in Invasion Ecology, Springer, Dordrecht, the Netherlands, 133-265.
10. Daleo P., Alberti J. and Iribarne O., 2009 – Biological invasions and the neutral theory, *Diversity and Distributions*, 15, 547-553.
11. Donaldson J. E., Hui C., Richardson D. M., Robertson M. P., Webber B. L. and Wilson J. R. U., 2014 – Invasion trajectory of alien trees: the role of introduction pathway and planting history, *Global Change Biology*, 20, 1527-1537.
12. EEA, 2014 – Invasive Alien Species. A European response, EC, Belgium, 5-24.
13. Elton C. S., 1958 – The Ecology of Invasions by Animals and Plants, Methuen, UK, 196.
14. Evangelista P. and Kumar S., 2011 – Trade and transportation is changing the game, *Current Zoology*, II, 5, 57.
15. Evans J. M., Wilkie A. C. and Burkhardt J., 2008 – Adaptive management of non-native species: moving beyond the either- or through experimental pluralism, *Journal of Agricultural and Environmental Ethics*, 21, 521-539.
16. Franson J. C. and Custer T. W., 1994 – Prevalence of eustrongylidosis in wading birds from colonies in California, Texas, and Rhode Island, United States of America: Colonial Waterbirds, v, 17, 168-172.
17. Gaertner M., den Breeÿen A., Hui C. and Richardson D. M., 2009 – Impacts of alien plant invasions on species richness: a meta-analysis, *Progress in Physical Geography*, 33, 319-338.
18. Hu S. Y., 1979 – Ailanthus, *Arnoldia*, 39, 2, 29-50.
19. Josefsson M. and Andersson B., 2001 – The environmental consequences of alien species in the Swedish lakes Mälaren, Hjälmaren, Vänern and Vättern, *Ambio*, 30, 8, 514-521.
20. Kumschick S., Bacher S., Dawson W., Heikkilä J., Sendek A., Pluess T., Robinson T. B. and Kühn I., 2012 – A conceptual framework for prioritization of invasive alien species for management according to their impact, *NeoBiota*, 15, 69-100.
21. Mack R. N., Simberloff D., Lonsdale W. M., Evans H., Clout M. and Bazzaz F. A., 2000 – Biotic invasions: causes, epidemiology and control, *Ecological Applications*, 10, 689-710.
22. Matacă S. Ş., 2005 – Parcul Natural Porţile de Fier, Floră, vegetaţie şi protecţia naturii, Edit. Universitaria, Craiova, 550. (in Romanian)

LAND SNAIL FAUNA OF "PORŢILE DE FIER" ("IRON GATES") NATURE PARK (BANAT, ROMANIA)

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KEYWORDS: land snails, limestone, karst, "Iron Gates", Romania.

ABSTRACT

The paper presents an analysis of terrestrial mollusc fauna of the "Iron Gates" Nature Park. Various types of habitats (e.g. forests, rocks, riparian areas) and substrates (e.g. limestone, conglomerate, crystalline schist) were analyzed. A total of 45 species of terrestrial gastropods were identified in 17 sampling points, four of which are mentioned for the first time in the area. Six other species cited in the literature were not found. Limestone substrate allows the development of large populations of terrestrial gastropods, but the specific diversity is larger when it is associated with a forest habitat. The current legal and illegal exploitation of limestone threatens the mollusc communities associated with this type of habitat. The subsequent erosion process and the low mobility of these animals make their colonization of habitats difficult.

RÉSUMÉ: Note sur la faune des gastéropodes terrestres du Park Naturel "Portes de Fer" ("Porţile de Fier").

Ce travail présente une analyse de la faune des mollusques terrestres du Park Naturel "Portes de Fer". Différents types d'habitats (forêts, rochers, des zones riveraines) et de substrats (schistes calcaires, conglomérats, cristallins) ont été analysées. Un total de 45 espèces de gastéropodes terrestres ont été identifiées dans les 17 points de prélèvement, dont quatre sont mentionnées pour la première fois dans la région. Six autres espèces citées dans la littérature n'ont été pas retrouvées. Le substrat calcaire permet le développement d'importantes populations de gastéropodes terrestres, mais la diversité spécifique est supérieure quand celui-ci est associé à un habitat forestier. L'exploitation légale et illégale de matériaux de construction met en danger les communautés de mollusques terrestres associées à ce type d'habitat. De plus, la recolonisation est difficile à cause de l'érosion déclenchée après la fin des opérations et à la faible mobilité de ces animaux.

REZUMAT: Note asupra faunei de gastropode terestre din Parcul Natural „Porţile de Fier".

Lucrarea prezintă o analiză a faunei de moluşte terestre din Parcul Natural „Porţile de Fier". Diverse tipuri de habitate (păduri, stâncării, zone ripariene) şi de substrate (calcar, conglomerate, şisturi cristaline). Un număr de 45 specii de gastropode terestre au fost identificate în cele 17 puncte de colectare, patru dintre acestea fiind menţionate pentru prima oară în regiune. Alte şase specii citate în literatură nu au fost regăsite. Substratul calcaros permite dezvoltarea unor populaţii impresionante de gastropode terestre, diversitatea specifică fiind mai mare atunci când acesta este asociat cu un habitat forestier. Exploatarea materialelor de construcţii prin dezvoltarea carierelor legale şi ilegale, periclitează comunităţile de moluşte terestre asociate cu acest tip de habitat, iar procesele de eroziune declanşate după încetarea exploatării, precum şi mobilitatea redusă a acestor animale fac dificilă recolonizarea.

INTRODUCTION

The “Iron Gates” Nature Park is one of the most represented areas within the karstic relief of Romania. The substrate of crystalline schists is covered by Cretaceous limestone (e.g. Sirinia, Sviniţa, “Iron Gates”) and conglomerates on the line Sviniţa – Svinecea and sandstones, shales in the Sicheviţa in Danube Gorge (*, 1987; **, 1992). The warm climate of the region, enhanced by the presence of limestone, determines the prevalence of Balkanic, Mediterranean and sub-Mediterranean plant species (Pătroescu et al., 2007).

The karst areas are generally the source of large biodiversity due to the multitude of ecological niches generated by the complexity of the landscape and the variable climatic conditions. Also, high species endemism can occur on karsts (Culver et al., 2000). Among the outstanding groups populating these areas, are also those requiring large amounts of calcium like the snails. It is known that lime-rich habitats often support abundant and diverse land snail communities (Horsák, 2006; Nekola, 1999; Kerney and Cameron, 1979), due to their high metabolic calcium demands – not only for shell generation, but also for egg production (Gärdenfors, 1992). Snails contribute to the general biodiversity by developing large populations, therefore making them important contributors to the invertebrate biomass.

Previously, the land snail fauna from the concerned area was the object of several general or specific researches. The most comprehensive is the monograph of Romanian gastropods (Grossu, 1981, 1983, 1987), a valuable image of the country’s gastropod fauna for the 20th century. Other papers were more focused, describing the cave mollusc fauna (Negrea, 1962, 1963, 1964, 1966). More recently, Cameron et al. (2013) presents an analysis of the snail fauna from Banat including the “Iron Gates” and Dvořák (2002), analyzing some caves in the area and listing 12 species found there.

This work is meant to contribute to the assessment of biodiversity in the “Iron Gates” Nature Park, for a future management plan.

MATERIAL AND METHODS

The present paper is based on qualitative sampling during the summer of 2014, at 17 sampling stations (Fig. 1, Tab. 1). Samples were taken inside the “Iron Gates” Nature Park from limestone, conglomerates, and crystalline schist substrate. Calcareous rocks or conglomerates, exposed or located in deciduous forests, vertical walls, or wet riversides, were equally sampled in the eastern and the western part of the park. The location of the sampling points is presented in figure 1. Snails were collected by hand by three collectors during one hour in each sampling site, and additional leaf litter sample was taken. About 20 l. of leaf litter was sieved and the material was sorted and identified in the laboratory. Grossu (1981, 1983, 1986, 1987) and Welter-Schultes (2012) were used for species identification.

RESULTS AND DISCUSSION

A number of 45 land snail species were identified in the area, some of which are reported here for the first time. The other six species have been mentioned in previous works, raising the number of land snail species in the area to 51.

The systematic list of encountered species is presented below. Since most of the previous works are confined to restricted areas, as is the case of the researches regarding the land snail fauna from caves, or are scattered reports of some species in taxonomic reviews, we will only consider two references: the comprehensive work of Grossu (Gastropoda Romaniae, 1983, 1985, 1986, 1987), and the recent research concerning the malacofauna from Banat (Cameron et al., 2013).

Table 1: Location and description of sampling points.

No.	Location/habitat type/substrate	Coordinates
1.	Mraconia Valley – crystalline rocks in forest	44.659977 N, 22.267286 E
2.	Mraconia Valley – forest on schist substrate	44.651388 N, 22.272791 E
3.	Mraconia Valley – limestone wall	44.644716 N, 22.290091 E
4.	Ciucaru Mic – limestone rocks on the plateau	44.632530 N, 22.282391 E
5.	Ciucaru Mic – limestone rocks in the forest	44.638658 N, 22.284875 E
6.	Ciucaru Mare – limestone bare rocks on the top	44.605283 N, 22.264263 E
7.	Ciucaru Mare – limestone rocks in the forest	44.607397 N, 22.265233 E
8.	Plavişeviţa – forest on crystalline substrate	44.543872 N, 22.210364 E
9.	Sirinia Valley – limestone rocks in the forest	44.6498583 N, 22.066794 E
10.	Sirinia Valley – limestone wall	44.6433056 N, 22.0563472 E
11.	Sirinia Valley – wet side valley in forest with limestone	44.638688 N, 22.05275 E
12.	Drencova – open valley in forest	44.632794 N, 22.008113 E
13.	Liubotina – open valley near forest on crystalline substrate	44.553141 N, 22.218083 E
14.	Liborajdea – open valley near forest on crystalline substrate	44.671582 N, 21.775245 E
15.	Limestone rocks four km downstream Coronini	44.655069 N, 21.723382 E
16.	Limestone rocks near Gaura cu Muscă Cave	44.664647 N, 21.699533 E
17.	Limestone rocks in forest on a humid valley near Coronini	44.668841 N, 21.693097 E

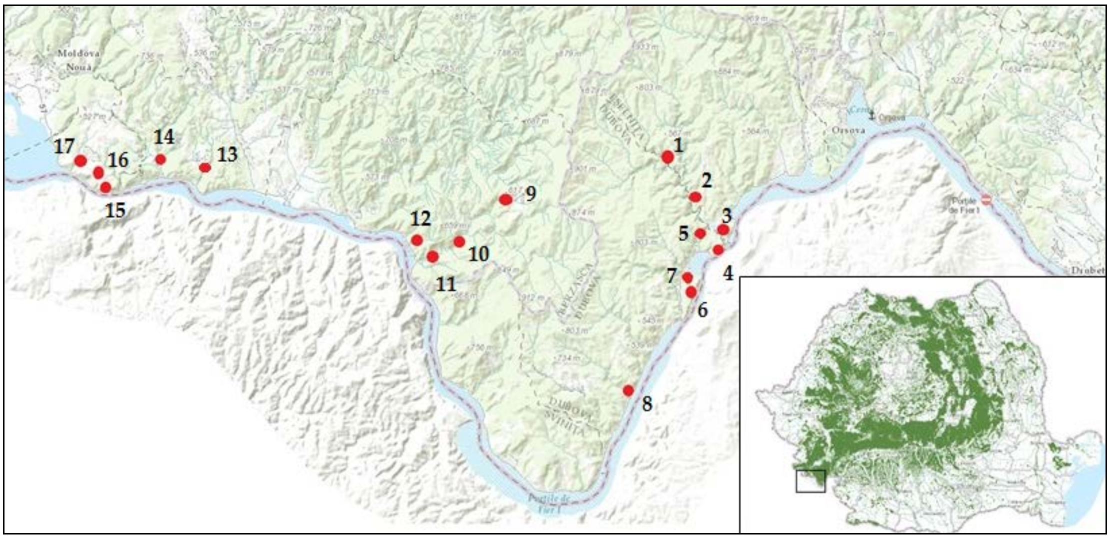

Figure 1: The location of sampling points.
Map source: http://geoportal.ancpi.ro/geoportal/viewer.

The systematic list of land snail species from "Iron Gates" Nature Park

1. *Platyla banatica* (Rossmässler, 1842): Grossu (1986); present work; in three sampling points in humid forest habitat.

2. *Pomatias rivularis* (Eichwald, 1829): Grossu (1986), Cameron et al. (2013); present work found in forests on limestone; locally develops large populations.

3. *Carychium* (*Saraphia*) *tridentatum* (Risso, 1826): Cameron et al. (2013); during the sampling in 2014 it was found only on Sirinia Valley.

4. *Cochlicopa lubricella* (Rossmässler, 1834): Grossu (1987); this work: found in four sampling points, on dry limestone walls or slopes of Ciucaru Mic, Ciucaru Mare, Coronini.

5. *Orcula dolium* (Draparnaud, 1801): Grossu (1987), Cameron et al. (2013); present work: a single shell was found on Sirinia Valley; the species known as calciphylous was probably transported from the cliffs by the rainfall.

6. *Agardhiella parreysii* (Pfeiffer, 1848): Grossu (1987), Cameron et al. (2013); present work: the species was found only on Mraconia Valley.

7. *Agardiella grossui* (Zilch, 1958): Grossu (1987); not found in the samples taken in 2014.

8. *Agardhiella licherdopoli* (Grossu, 1986): The species was described by Grossu from the deposits transported by the Danube at Giurgiu, and considered to come from the Danube Gorges. Not found during the current research.

9. *Sphyradium doliolum* (Bruguière, 1792): Grossu (1987); present work, only found on cliffs from Ciucaru Mic and Ciucaru Mare.

10. *Columella edentula* (Draparnaud, 1805): Grossu (1987); Cameron et al. (2013); not found during the sampling in 2014.

11. *Vallonia costata* (Müller, 1774): Grossu (1987); Cameron et al. (2013); present work: large populations on limestone cliffs on Ciucaru Mare and near Coronini.

12. *Acanthinula aculeata* (Müller, 1774): Grossu (1987); Cameron et al. (2013); present work, only a few shells from Sirinia Valley in forest habitat.

13. *Pupilla sterrii* (Forster, 1840): Cameron et al. (2013); present work, found on limestone cliffs in Ciucaru Mare and near Coronini.

14. *Pyramidula rupestris* (Draparnaud, 1801): Cameron et al. (2013); present work, found on limestone cliffs in Ciucaru Mare and near Coronini.

15. *Granaria frumentum* (Draparnaud, 1801): Grossu (1987); Cameron et al. (2013); present work, the most abundant species on limestone walls, cliffs, and rocks.

16. *Chondrina arcadica* (Reinhardt, 1881): Grossu (1987); Cameron et al. (2013); present work, also common on limestone cliffs and rocks; usually found together with *Granaria frumentum*, but less abundant.

17. *Truncatellina cylindrica* (Férussac, 1807): Grossu (1987); Cameron et al. (2013); present work, found in the leaf litter at the base of limestone cliffs and rocks.

18. M*erdigera obscura* (Müller, 1774): Cameron et al. (2013); present work, only a few specimens were found in a humid valley near Coronini.

19. *Zebrina detrita* (Müller, 1774): Not mentioned before by previous authors, but considered common by Grossu (1987); the species is calciphylous and was found in the samples from Ciucaru Mic and near Coronini.

20. *Chondrula tridens* (Müller, 1774): Not mentioned before, although Grossu (1981) consider it as a common species; present work, on Sirinia Valley.

21. *Herilla ziegleri dacica* (Pfeiffer, 1848): Grossu (1981); Cameron et al., (2013); present work, common mostly on limestone, mostly in open areas but can occur also in forests if limestone blocks are present.

22. *Cochlodina* (*Cochlodina*) *laminata laminata* (Montagu, 1803): Grossu (1981), Cameron et al. (2013); present work, common species, both on limestone and schist substratum, mostly in the forest.

23. *Ruthenica filograna* (Rossmässler, 1836): Not mentioned before; present work, only on Sirinia Valley.

24. *Clausilia pumila* Pfeiffer 1828: Grossu (1981); not found in samples taken in 2014.

25. *Laciniaria plicata* (Draparnaud, 1801), Grossu (1981), Cameron et al. (2013); present work, common species, both on limestone and schist substratum, mostly in forest.

26. *Alinda biplicata* (Montagu, 1803): Grossu (1981); Cameron et al. (2013); present work, one of the most common species, both in open areas and forest mostly the eastern part of the Park (Mraconia, Ciucaru Mare, Ciucaru Mic), highly variable.

27. *Bulgarica* (*Bulgarica*) *rugicollis pagana* (Rossmässler, 1842): Grossu (1981); Cameron et al. (2013); present work, one of the most abundant species, mostly in open areas; highly variable.

28. *Bulgarica* (*Strigilecula*) *vetusta* (Rossmässler, 1836): Grossu (1981); Cameron et al. (2013); present work, locally abundant, on limestone mostly in the forest.

29. *Cecilioides* (*Cecilioides*) *acicula* (Müller, 1774): Not mentioned before. It was found in litter samples taken at the base of limestone cliffs near Coronini.

30. *Punctum* (*Punctum*) *pygmaeum* (Draparnaud, 1801): Grossu (1983); Cameron et al. (2013); present work, in leaf litter samples from Sirinia Valley and near Coronini.

31. *Vitrea crystallina* (Müller, 1774): Not recorded before, found in leaf litter samples near Coronini.

32. *Vitrea contracta* (Westerlund, 1871): Not recorded before, found on Sirinia Valley and near Coronini.

33. *Carpathica (Ilyrica) langhi* (Pfeiffer, 1848): Cameron et al. (2013); present work, found in a single sample on Sirinia Valley.

34. *Oxychilus glaber* (Rossmässler, 1835): Grossu (1983); Cameron et al. (2013); present work, found both in forests and on limestone rocks.

35. *Oxychilus montivagus* (Kimakowicz, 1890): Grossu (1983); not found in our samples.

36. *Aegopinella epipedostoma* Fagot, 1879: Cameron et al. (2013); present work, in the forest from Sirinia Valley and near Coronini.

37. *Aegopinella minor* (Stabile, 1864): Cameron et al. (2013); present work, the forest on Sirinia Valley.

38. *Aegopinella pura* (Alder, 1830): Cameron et al. (2013); present work, litter samples from forest near Coronini.

39. *Oligolimax annularis* (Studer, 1820): Grossu (1983); Cameron et al. (2013); present work, on calcareous substrate, rock rubble habitat on Mraconia Valley, Ciucaru Mic and Ciucaru Mare.

40. *Fruticicola fruticum* (Müller, 1774): Grossu (1983); Cameron et al. (2013); present work, mostly in forest edges, both on calcareous and silica substrate, not very abundant.

41. *Euomphalia strigella* Draparnaud, 1801: Grossu (1983); Cameron et al. (2013); present work, present in 12 of the 17 sampling points, mostly in forests of forest edges.

42. *Monacha* (*Monacha*) *cartusiana* (Müller, 1774); not mentioned before, but according to Grossu (1983) is a common species; as for other common species, he did not mentioned all the records; present work, the species was found in samples from bare limestone cliffs and forest edges, near Coronini, in the western part of the park.

43. *Xerocampylaea zelebori* (Pfeiffer, 1853): Grossu (1983); Cameron et al. (2013); present work, abundant locally, on bare rocks or on herbaceous vegetation.

44. *Xerolenta obvia* (Menke, 1828): Grossu (1983); present work, locally very abundant; found on bare limestone rocks near Coronini.

45. *Monachoides vicinus* Rossmässler, 1842: Grossu (1983); present work, a single record in a forest near Drencova.

46. *Monachoides bacescui* Grossu 1979: Grossu (1983); Cameron et al. (2013); present work, on both substrates mainly in the forest.

47. *Soosia diodonta* Férussac, 1832: Grossu (1983), mentioned the species in the western part of the park, near Moldova Nouă; not found in our samples.

48. *Cattania trizona* (Rossmässler, 1835); Grossu (1983); Cameron et al. (2013); present work, on Mraconia Valley, Ciucaru Mic and Ciucaru Mare.

49. *Faustina illyrica* (Stabile, 1864): Grossu (1983), consider the species from “Iron Gates” as *Campylaea planospira*, most probably refers to *F. illyrica*; present work, the species was found in forests, under the leafs on the ground or on the rocks in Mraconia and Sirinia Valleys, but also on Ciucaru Mic, near Mraconia.

50. *Cepaea* (*Austrotachea*) *vindobonensis* (Pfeiffer, 1828): not specifically mentioned by Grossu (1983) due to its wide distribution; Cameron et al. (2013); present work, a common species, present almost everywhere in the area.

51. *Helix* (*Helix*) *pomatia* Linnaeus, 1758: not specifically mentioned by Grossu (1983), but common; Cameron et al. (2013); present work, mostly in forests, in the eastern part of the area.

CONCLUSIONS

Land snails are among of the most important invertebrate groups in the “Iron Gates” Nature Park. The generosity of the landscape, combined with the calcareous substrate in the karst areas, allows the presence of large snail population. Although the diversity is not particularly high, some of these species can develop very large populations. The rock crevices or limestone slabs are shelter for many species. Exposed rock can provide vertical surfaces and crevices that are preferred by some snails as *Granaria frumentum* and *Chondrina arcadica*. Others, such as the *Cattania trizona*, are calciphylous and are often observed crawling directly on the vertical surfaces of limestone and rock outcrops in forests – known to be good snail habitats. Among the 44 species found during the sampling in 2014, *Cecilioides acicula*, *Vitrea contracta*, *Vitrea crystalina* and *Ruthenica filograna* are recorded for the first time in the area. They have a restricted distribution in the park and the small species were only found in leaf litter sampling, so it might be possible that they may have been missed in previous collections. In Regards to the six species that are listed in Grossu, but were not found during the sampling in 2014, most of them are small species, and/or with restricted distribution as *Agardiella grossui, Agardhiella licherdopoli, Soosia diodonta* and *Columella edentula*.

One of the main threats for the land snail populations is the mining of mineral resources due to the accessibility of the limestone quarry. The legal and illegal exploitations are disturbing the snail communities related to this type of habitat, which actually represents the most important part of the park’s malacofauna. The limited mobility and the continuous landscape change, even after the cessation of exploitation due to the erosion of the limestone walls, makes difficult the decolonization in these areas.

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REFERENCES

1. Cameron R. A. D., Pokryszko B. M., Gheoca V. and Horsak M., 2013 – At the Central European – Balkan transition: forest land snail faunas of the Banat contrasted with those of the Carpathian chain, *Acta Biologica Cracoviensia Series Botanica*, 55 (Suppl. 1), 21-21. WOS:000325510300007.
2. Culver D. C., Master L. L., Christman M. C. and Hobbs H. H., 2000 – Obligate Cave Fauna of the 48 Contiguous United States, *Conservation Biology*, 14, 386-401, DOI:10.1046/j.1523-1739. 2000.99026.x.
3. Dvořák L., 2002 – Contribution to the knowledge of snails (Gastropoda) of limestone caves near Moldova Nouă (SW Romania, Banat), *Nachrichtenblatt der Ersten Vorarlberger Malakologischen Gesellschaft*, 10, 43-47.
4. Gärdenfors U., 1992 – Effects of artificial liming on land snail populations, *Journal of Applied Ecology*, 29, 50-54.
5. Grossu A. V., 1981 – Gastropoda Romaniae, 3, Ordo Stylommatophora: Suprafamiliile Clausiliacea şi Achatinacea, Bucureşti, 1-248. (in Romanian)
6. Grossu A. V., 1983 – Gastropoda Romaniae, 4, Ordo Stylommatophora, Suprafamiliile: Arionacea, Zonitacea, Ariophantacea şi Helicacea, Edit. Litera, Bucureşti, 1-538. (in Romanian)
7. Grossu A. V., 1986 – Gastropoda Romaniae, 1, Prosobranchia și Opistobranchia, Edit. Litera, Bucureşti, 195-207. (in Romanian)
8. Grossu A. V., 1987 – Gastropoda Romaniae, 2, Subclasa Pulmonata, Ord. Basommatophora şi Ord. Stylommatophora: Suprafam. Succineacea, Cochlicopacea, Pupillacea, Edit. Litera, Bucureşti, 1-388. (in Romanian)
9. Horsák M., 2006 – Mollusc community patterns and species response curves along a mineral richness gradient: a case study of fens, *Journal of Biogeography*, 33, 98-107.
10. Kerney M. P. and Cameron R. A. D., 1979 – Field guide to the land snails of the British Isles and northwestern Europe, London, Collins Press, 1-288.
11. Negrea A., 1962 – Contribuție la studiul moluștelor din peșterile din R. P. România (Nota II), – *Comunicările Academiei R. P. R., Seria Biologie Animală*, 12, l, 37-43, București. (in Romanian)
12. Negrea A., 1963 – Contribuție la studiul moluștelor din peșterile din R. P. România, III, *Studii și Cercetări de Biologie, Academia R. P. România, Seria Biologie Animală*, XV, 3, 333-342, București. (in Romanian)
13. Negrea A., 1964 – Contribuție la studiul moluștelor din peșterile din R. P. România, Nota IV, *Lucrările Institutului de Speologie „Emil Racoviță"*, 3, 361-366. (in Romanian)
14. Negrea A., 1966 – Gasteropodele (Mollusca – Gastropoda) din peșterile României, *Lucrările Institutului de Speologie „Emil Racoviță"*, 5, 125-139. (in Romanian)
15. Nekola J. C., 1999 – Terrestrial gastropod richness of carbonate cliff and associated habitats in the Great Lakes region of North America, *Malacologia*, 41, 231-252.
16. Welter-Scultes F. W., 2012 – European non-marine molluscs, a guide for species identification, Planet Poster Editions, Göttingen, 1-679.
17. * 1987 – Geografia României III, Carpații și Depresiunea Transilvaniei, Edit. Academiei, București, 647. (in Romanian)
17. **, 1992 – Geografia României, Regiunile pericarpatice, Edit. Academiei, București. (in Romanian)

DE GRUYTER OPEN

PRELIMINARY DATA ON THE ECOLOGICAL REQUIREMENTS OF THE INVASIVE SPINY-CHEEK CRAYFISH IN THE LOWER DANUBE

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KEYWORDS: *Orconectes limosus*, expansion, tributaries, water quality, Romania.

ABSTRACT

Water quality and properties of the riverbed often shape the community structure of aquatic ecosystems, occasionally sustaining the expansion of non-native species. This study aims to provide preliminary data on the ecological preferences of the invasive species *Orconectes limosus*, its control, and the protection of the native stock is an European priority. In order to assess the species ability to colonize small river systems, relevant tributaries in the invaded Danube sector were monitored. Statistical test indicates a preference for deep and warm rivers, low water velocity and also high concentrations of calcium.

RÉSUMÉN: Los datos preliminares sobre las exigencias ecológicas del cangrejo invasivo (espinoso-mejilla) en el bajo Danubio.

La calidad del agua y las propiedades del cauce del río a menudo dan forma a la estructura de la comunidad de ecosistemas acuáticos y, ocasionalmente, sostienen la expansión de especies no-nativas. El objetivo de este estudio es proporcionar datos preliminares sobre las preferencias ecológicas de la especie invasiva *Orconectes limosus*, su control y protección de la población nativa siendo una prioridad europea. A fin de evaluar la habilidad de la especie en colonizar pequeños sistemas fluviales, afluentes relevantes en el sector invadido del Danubio fueron monitorizados. El test estadístico indicó la preferencia hacía ríos profundos y cálidos, con baja velocidad del agua y también altas concentraciones de calcio.

REZUMAT: Date preliminare asupra cerinţelor ecologice ale speciei invazive racul dungat pe cursul inferior al Dunării.

Calitatea apei și caracteristicile albiei modelează frecvent structura comunităților ecosistemelor acvatice, ocazional susținând expansiunea speciilor non-native. Prezentul studiu are drept scop furnizarea de date preliminare cu privire la preferințele ecologice ale speciei invazive *Orconectes limosus*, controlul acesteia și protecția stocului nativ fiind o prioritate la nivel european. În vederea evaluării capacității speciei de a coloniza sisteme acvatice de tipul râurilor de talie mică au fost monitorizați anumiți afluenți ai Dunării în sectorul deja populat de specia țintă. Analizele statistice sugerează preferința acesteia pentru apele adânci și calde, cu viteză de curgere redusă și concentrații ridicate de calciu.

INTRODUCTION

The invasive species represent one of the most serious threats to global biodiversity due to their successful competivity and their major impact on the local native aquatic communities (Galil, 2007; Clavero et al., 2009; Peay and Füreder, 2011). The uncontrolled introduction of non-indigenous crayfish species (NICS) played a fundamental role in the current distribution of the indigenous crayfish species (ICS) (MEA, 2012). NICS rapid spread (Diéguez-Uribeondo, 2006; Gherardi, 2006; Souty-Grosset et al., 2006) caused significant economic losses (EC, 2008; EC, 2012).

Five ICS reside in Europe, namely *Astacus astacus*, *A. leptodactylus* and *A. pachypus*, respectively *Austropotamobius torrentium* and *A. pallipes* (Holdich et al., 2010). The introduction of NICS is known for commercial purposes starting in the nineteenth century, being identified more than ten species (Holdich et al., 2010).

In Romania, there have been three reported ICS: *Astacus astacus, A. leptodactylus* and *Austropotamobius torrentium* (Băcescu, 1967; Pârvulescu, 2010). Also, since 2008, the presence of *Orconectes limosus* (Rafinesque, 1817) has been confirmed for the first time in the Danube River (Pârvulescu et al., 2009). *O. limosus* shows tolerance towards the habitat conditions and rapid life cycle, being also the carrier of *Aphanomyces astaci* Schikora 1906, a disease to which native species do not have resistance (Unestam, 1969; Lindqvist and Huner, 1999; Söderhäll and Cerenius, 1999). The spread of this species was demonstrated in large aquatic habitats (Buřič et al., 2009; Panov et al., 2009), but its ability to invade small rivers and streams is still poorly documented (Petrusek et al., 2006). In its original habitats this species usually lives in small streams (McAlpine et al., 1991). The contact between this species and *A. astacus* and *A. torrentium* has not been reported so far in Romania.

This study aimed to provide preliminary data on the ecological limitations of *O. limosus* in small tributaries, with the goal of sensitive *A. astacus* and *A. torrentium* long term conservation success.

MATERIAL AND METHODS

Crayfish capture

The sampling sites are geographically located in the "Iron Gates" Nature Park (PM, 2010). To assess the specific colonizing ability of *O. limosus* in small river systems, 10 sampling sites were surveyed, corresponding to eight tributaries which are flowing in the invaded Danube sector: Eșelnița (S1), Mraconia (S2), Liubotina (S3), Tisovița (S4), Sirinia (S5), Berzasca downstream (S6) and upstream (S7), Gornea downstream (S8) and upstream (S9), Radimna (S10). Subsequently, two tributaries were monitored: Gornea (SS1) and Berzasca (SS2) (Fig. 1) using the index of catch per unit effort (CPUE) (Paaver and Hurt, 2009), defined by the number of crayfish individuals captured on a river stretch of 100 m length. For SS1 and SS2 a transect method was used (Sîrbu and Benedek, 2004) by dividing the studied sector into 13 equal sections for SS1, and six sections for SS2, respectively. The transects were distributed both in the invaded and non-invaded river sectors.

The sampling was carried out seasonally in three successive years between 2011 and 2013. In the case of SS1 and SS2 tributaries, data collection was carried out in the summer and autumn seasons corresponding to the same period.

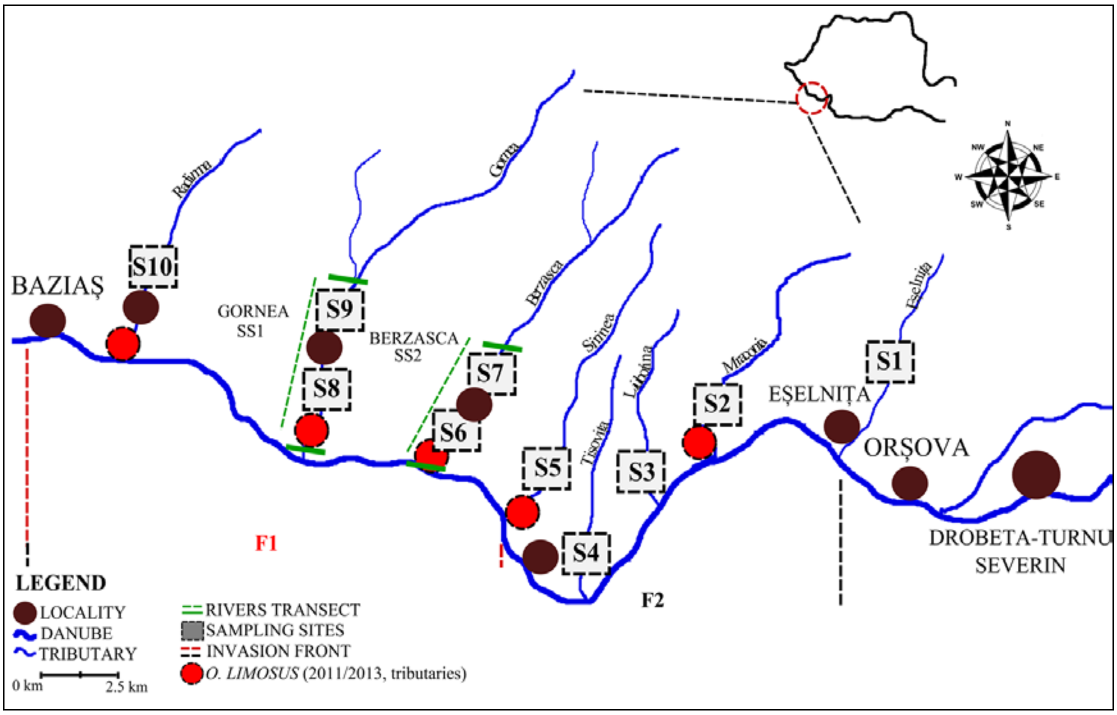

Figure 1: Sampling sites in the Baziaş-Orşova Danube sector, 2011-2013.

Physical and chemical water parameters

In order to draw an overall picture of the preferences of the species *O. limosus*, we measured the following water parameters: average width and depth of the bed/water; water velocity (m/s); dissolved oxygen (mg/l); conductivity (µS/cm); and pH and water temperature (°C). The velocity of the water corresponding to each transect was determined by establishing the average value resulting from five readings per site using the floating object method described by Boyer (1964). The content of dissolved oxygen, conductivity, pH, and water and air temperature were determined using Hach-Lange HQ40D multiparameter as the average of five readings per site.

The following chemical parameters of the water were also measured: nitrite ($N\text{-}NO_2$), nitrate ($N\text{-}NO_3$), phosphate ($P\text{-}PO_4^{3-}$), ammonium ($N\text{-}NH_4^+$) (mg/l), total hardness (°dH) calcium (Ca^{2+}) and magnesium (Mg^{2+}) (mg/l). To determine these parameters, one reading per site was performed using a HACH-Lange DR2800 spectrophotometer.

Statistical analyses

The annual average values corresponding to the water parameters were computed. The non-parametric Mann-Whitney test was used in order to compare the differences in the physical-chemical parameters among the sites where the species was present or absent. The test was considered significant for p-values lower than 0.05. Box-plots were further used to reflect the potential ecological preferences of the species *O. limosus* in relation to its presence/absence. We showed this representation exclusively for p-values ≤ 0.05, respectively for those parameters for which significant differences were established during the entire study. Statistical analyses were performed using Statistica 7.

RESULTS AND DISCUSSION

During this study 488 adult and juvenile individuals of *O. limosus* were captured, of which 103 from SS1 and 385 from SS2. Data processing was performed according to the annual change of the species invasion front on the Danube River as follows: summer 2011 – spring 2012 period the invaded sector of Danube F1 included three tributaries corresponding to a number of two sites where the species was present (S6, S8) and three sites where it was absent (S7, S9-10). The sites located in the control area were not taken into account (S1-4): during summer 2012 – spring 2013 period, the invaded sector of Danube F2 included eight tributaries corresponding to four sites with presence (S2, S5-6, S8) and six with absence (S1, S3-4, S7, S9-10) (Fig. 1).

Table 1: Mann-Whitney results of the physico-chemical parameters over the presence/absence sites for the species *O. limosus*, 2011-2013.

Physico-chemical parameters	2011-2012	2012-2013
	p-level	
average width	0.137	0.505
average depth	0.008	0.016
water temperature	0.000067	0.036
water velocity	0.371	0.009
oxygen content	0.557	0.190
pH	0.867	0.615
conductivity	0.175	0.693
$N\text{-}NO_2$	0.063	0.193
$N\text{-}NO_3$	0.084	0.547
phosphate	**0.046**	0.155
ammonium	0.221	0.771
total hardness	0.076	0.730
Ca	**0.023**	**0.041**
Mg	0.063	0.571

Table 2: Mann-Whitney results of the physico-chemical parameters over the presence/absence SS1 and SS2 transects for the species *O. limosus*, 2011-2013.

Physico-chemical parameters	SS1	SS2
	p-level	
average width	0.132	0.200
average depht	0.021	0.003
water temperature	0.004	0.0005
water velocity	0.0001	0.022
oxygen content	0.041	0.113
pH	0.445	0.071
conductivity	0.464	0.403
$N\text{-}NO_2$	0.289	0.606
$N\text{-}NO_3$	0.722	0.468
phosphate	0.082	1.000
ammonium	0.428	0.808
total hardness	0.081	0.301
Ca	0.007	0.003
Mg	0.069	0.202

The Mann-Whitney test shows the differences in the physical-chemical parameters among the sites were the species was present or absent, the results being presented according to tables 1 and 2. In the case of the eight tributaries in which the presence or absence of the species *O. limosus* was considered, significant differences were obtained for parameters such as river depth and water temperature, along with the concentration of calcium. The phosphate concentration and the water velocity remained below the significance level for the period 2011-2012 and 2012-2013, respectively (Tab. 1). For SS1 and SS2, significant differences were found corresponding to the river depth, water temperature, and velocity, along with calcium and dissolved oxygen, with the exception that the last parameter was found significant exclusively for SS1 (Tab. 2).

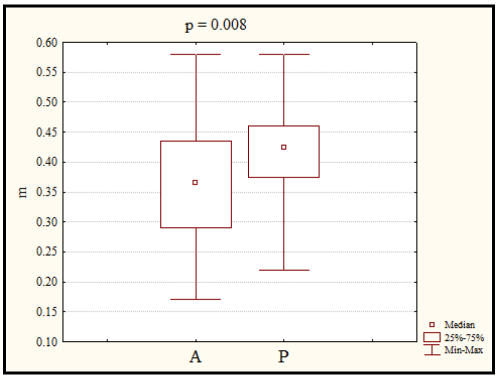

Figure 2a: Box-plots showing the average annual values of water depth (m) corresponding to the presence (P)/absence (A) of the species *O. limosus*, 2011-2012 (a).

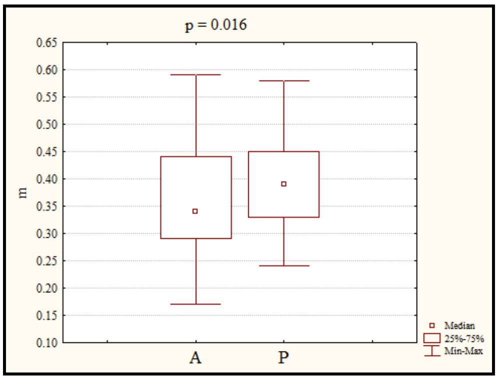

Figure 2b: Box-plots showing the average annual values of water depth (m) corresponding to the presence (P)/absence (A) of the species *O. limosus*, 2012-2013.

Considering all eight tributaries, the box-plots indicate the preference for deep river systems and warm water temperature (Figs. 2 and 3) as well as a high concentration of calcium (Fig. 4). The pattern is similar for SS1 and SS2 with significant differences for all three parameters (Figs. 5, 6 and 8). p-values ≤ 0.05 were established also in terms of the water velocity indicating a preference for its lowest values (Tab. 1, Fig. 7), similarly with the pattern for the eight tributaries, but only in 2012-2013 (Tab. 2). The species particularly inhabits aquatic habitats with ecological characteristics different from those of small streams or springs, being encountered in the last two categories particularly in the downstream area (Aklehnovich and Razlutskij, 2013; Petrusek et al., 2006).

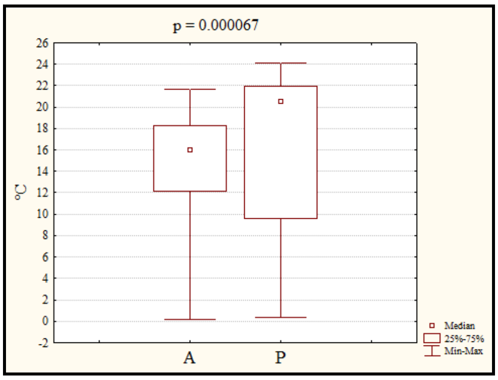

Figure 3a: Box-plots showing the average annual values of water temperature (°C) corresponding to the presence (P)/absence (A) of the species *O. limosus*, 2011-2012.

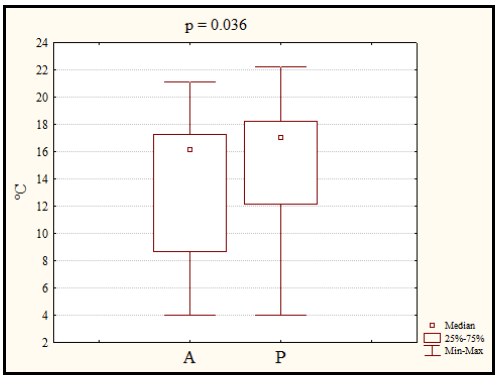

Figure 3b: Box-plots showing the average annual values of water temperature (°C) corresponding to the presence (P)/absence (A) of the species *O. limosus*, 2012-2013 (b).

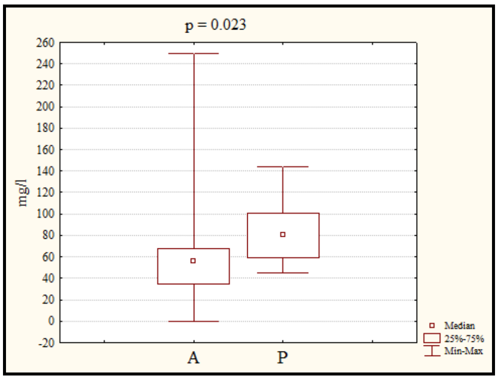

Figure 4a: Box-plots showing the average annual values of calcium (mg/l) corresponding to the presence (P)/absence (A) of the species *O. limosus*, 2011-2012.

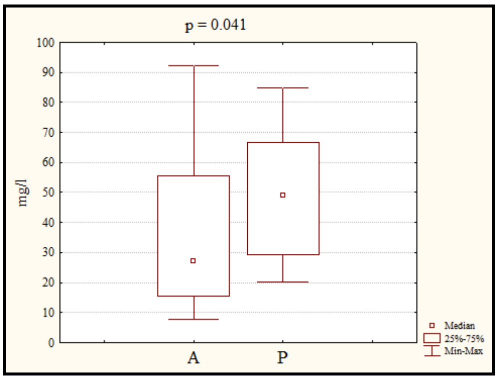

Figure 4b: Box-plots showing the average annual values of calcium (mg/l) corresponding to the presence (P)/absence (A) of the species *O. limosus*, 2012-2013.

In the habitats of origin, *O. limosus* is known to occupy a variety of aquatic ecosystems, with preference for those with low water velocity and substrate consisting mainly of sand and silt deposits (Ortmann, 1906). However, Aklehnovich and Razlutskij (2013) reported its presence both in lakes and rivers, the latter being the channels with muddy and hard substrate (rocks, stones, gravel).

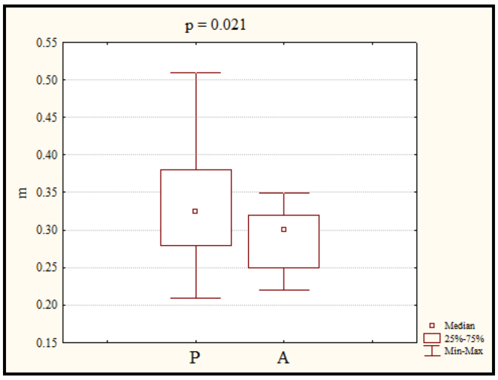

Figure 5a: Box-plots showing the average annual values of water deph (m) corresponding to the presence (P)/absence (A) of the species *O. limosus* in SS1 2011-2013.

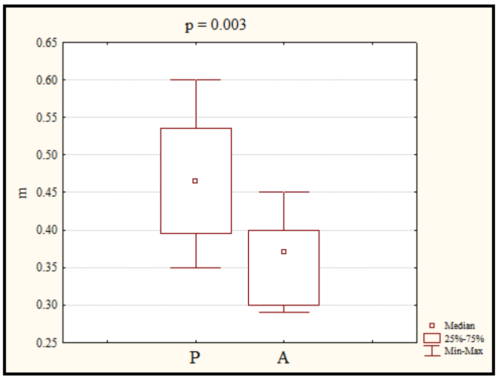

Figure 5b: Box-plots showing the average annual values of water deph (m) corresponding to the presence (P)/absence (A) of the species *O. limosus* in SS2, 2011-2013.

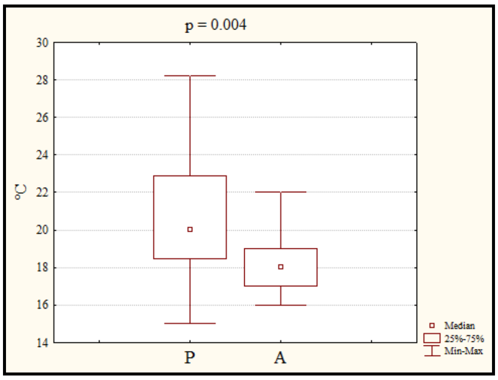

Figure 6a: Box-plots showing the average annual values of water temperature (°C) corresponding to the presence (P)/absence (A) of the species *O. limosus* in SS1, 2011-2013.

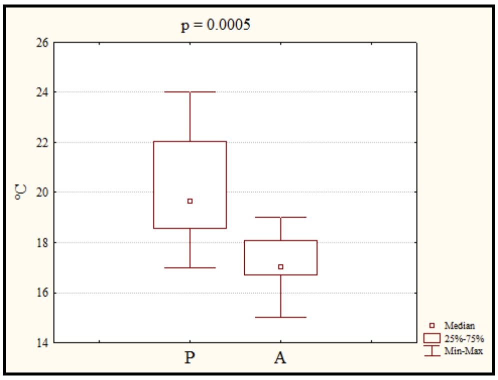

Figure 6b: Box-plots showing the average annual values of water temperature (°C) corresponding to the presence (P)/absence (A) of the species *O. limosus* in SS2, 2011-2013.

In the case of the chemical water parameters, a certain pattern of preference was not identified with the exception of calcium, suggesting a potential preference for its higher values (Figs. 4 and 8). An explanation can be found in the calcium need of crustaceans in various important physiological processes as well as that of moulting (Ueno and Mizuhira, 1984).

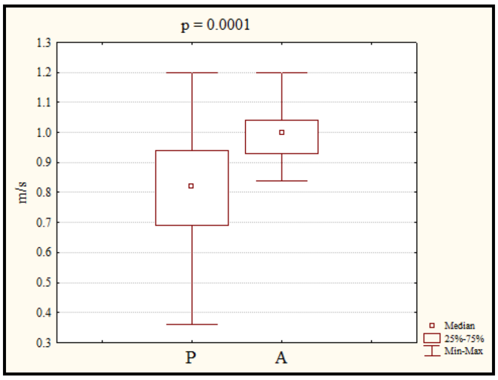

Figure 7a: Box-plots showing the average annual values of water velocity (m/s) corresponding to the presence (P)/absence (A) of the species *O. limosus* in SS1, 2011-2013.

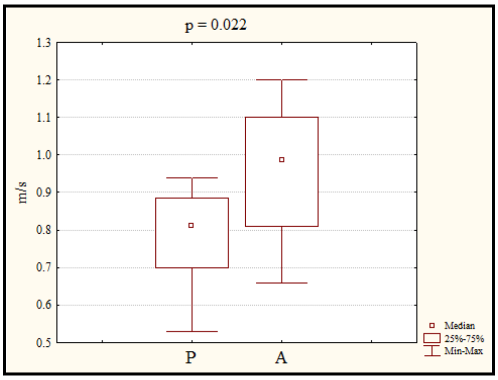

Figure 7b: Box-plots showing the average annual values of water velocity (m/s) corresponding to the presence (P)/absence (A) of the species *O. limosus* in SS2, 2011-2013.

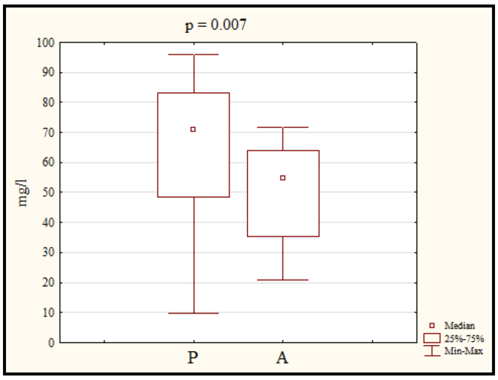

Figure 8a: Box-plots showing the average annual values of calcium (mg/l) corresponding to the presence (P)/absence (A) of the species *O. limosus* in SS1, 2011-2013.

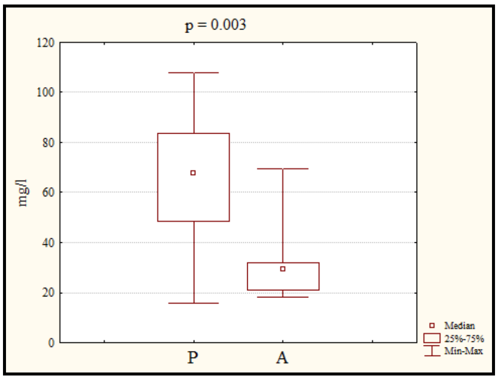

Figure 8b: Box-plots showing the average annual values of calcium (mg/l) corresponding to the presence (P)/absence (A) of the species *O. limosus* in SS2, 2011-2013.

The *O. limosus* ecological tolerance and also its presence in various habitats (Ortmann, 1906; Aklehnovich and Razlutskij, 2013) can represent a future threat for the ICS (Pârvulescu, 2009; Söderbäck, 1995; Buřič et al., 2009) with the risk of coming into contact with the protected species, among which includes *A. torrentium* and *A. astacus*, the former being frequently found in tributaries of the Danube (Pârvulescu and Petrescu, 2010). However, the impact caused by its presence in a small natural ecosystem cannot be predicted accurately, therefore detailed studies are needed.

CONCLUSIONS

O. limosus was identified both in the Lower Danube and in the downstream sector of its five studied tributaries.

Results of statistical analyses indicate a preference for deep and warm rivers, and low velocity. A similar pattern was identified for the calcium concentration indicating its preference for high values.

REFERENCES

1. Aklehnovich A. and Razlutskij V., 2013 – Distribution and spread of spiny-cheek crayfish Orconectes limosus (Rafinesque, 1817) in Belarus, *BioInvasions Records*, 2, 3, 221-225.
2. Băcescu M. C., 1967 – The fauna of the S. R. Romania – Crustacea, Decapoda, S. R. Romania Publishing House, Bucharest, 4.
3. Boyer M. C., 1964 – Streamflow measurement, in Chow V. T. (ed.), Handbook of Applied Hydrology, Edit. McGraw-Hill, New York, 15-41.
4. Buřič M., Kouba A. and Kozák P., 2009 – Spring mating period in Orconectes limosus: the reason for movement, *Aquatic Science*, 71, 473-477.
5. Clavero M., Brotons L., Pons P. and Sol D., 2009 – Prominent role of invasive species in avian biodiversity loss, *Biological Conservation*, 142, 10, 2043-2049.
6. Diéguez-Uribeondo J., 2006 – The dispersion of the Aphanomyces astaci carrier Pacifastacus leniusculus by humans represents the main cause of disappearance of the indigenous crayfish *Austropotamobius pallipes* in Navarra, *Bulletin Français de la Pêche et de la Pisciculture*, 380-381, 1303-1312.
7. EC, European Commission, 2008 – Towards an EU strategy on invasive species, http://ec.europa.eu/environment/nature/invasivealien/docs/1ENACTpart1v6.pdf, accessed in March, 2014.
8. EC, European Commission, 2012 – European Commission, DG Environment – LIFE Unit, http://ec.europa.eu/life/, accessed in September, 2012.
9. Galil B. S., 2007 – Loss or gain? Invasive aliens and biodiversity in the Mediterranean Sea, *Marine Pollution Bulletin*, 55, 7-9, 314-322.
10. Gherardi F., 2006 – Crayfish invading Europe – the case study of Procambarus clarkia, *Marine and Freshwater Behaviour and Physiology*, 39, 175-191.
11. Holdich D. M., Reynolds J. D., Souty-Grosset C. and Sibley P. J., 2010 – A review of the ever increasing threat to European crayfish from non-indigenous crayfish species, *Knowledge and Management of Aquatic Ecosystems*, 11, 394-395.
12. Lindqvist O. V. and Huner J. V., 1999 – Life history characteristics of crayfish: what makes some of them good colonizers? in Crayfish in Europe as alien species. How to make the best of a bad situation? Gherardi F. and Holdich D. M. (eds), Rotterdam, Brookfield, http://www.amazon.co.uk/Crayfish-Europe-Alien-Species-Crustacean/dp/9054104694, accessed in May, 2012, 299.
13. McAlpine D., Hogans W. E. and Fletcher T. J., 1991 – Orconectes limosus (Crustacea, Cambaridae) an addition to the crayfish fauna of New Brunswick, *Canadian Field-Naturalist*, 105, 386-387.
14. MEA, Millennium Ecosystem Assessment, 2012 – http://www.maweb.org/en/index.aspx, accessed in July, 2012.
15. Ortmann A. E., 1906 – The crayfishes of the state of Pennsylvania, *Memoirs of the Carnegie Museum*, 2, 34.
16. Paaver T. and Hurt M., 2009 – Status and management of noble crayfish Astacus astacus in Estonia, *Knowledge and Management of Aquatic Ecosystems*, 18, 394-395.
17. Panov V. E., Alexandrov B. and Arbaciauskas K., 2009 – Assessing the risks of aquatic species invasions via European inland waterways: the concepts and environmental indicators, *Integrated Environmental Assessment and Management*, 5, 110-126.
18. Pârvulescu L., 2009 – Illustrated guide to identify the species of crayfish in Romania, Oradea University Press, Oradea, 28. (in Romanian)
19. Pârvulescu L., Paloş C. and Molnar P., 2009 – First record of the spiny-cheek crayfish Orconectes limosus (Rafinesque, 1817) (Crustacea: Decapoda: Cambaridae) in Romania, *North-Western Journal of Zoology*, 5, 2, 424-428.
20. Pârvulescu L., 2010 – Crayfish field guide of Romania, Edit. Bioflux, Cluj-Napoca, 26.

21. Pârvulescu L. and Petrescu I., 2010 – The distribution of stone crayfish Austropotamobius torrentium (Schrank, 1803) (Crustacea: Decapoda: Astacidae) in the south-west Romanian mountain and sub-mountain area, *Travaux du Museum National d'Histoire Naturelle "Grigore Antipa"*, 53, 103-113.
22. Peay S. and Füreder L., 2011 – Two indigenous European crayfish under threat – how can we retain them in aquatic ecosystems for the future? *Knowledge and Management of Aquatic Ecosystems*, 401, 33.
23. Petrusek A., Filipová L., Ďuriš Z., Horká I., Kozák P., Policar T., Štambergová M. and Kučera Z., 2006 – Distribution of the invasive spiny-cheek crayfish (Orconectes limosus) in the Czech Republic, Past and present, *Bulletin Français de la Pêche et de la Pisciculture*, 380-381, 903-918.
24. PM, Management plan, 2010 – http://www.pnPorţiledefier.ro/, accessed in March, 2011.
25. Sîrbu I. and Benedek A. M., 2004 – Practical ecology, "Lucian Blaga" University Press, 254. (in Romanian)
26. Souty-Grosset C., Reynolds J. D., Gherardi F., Schulz R., Edsman L., Fureder L., Taugbol T., Noel P., Holdich D., Smietana P., Mannonen A. and Carral J., 2006 – CRAYNET, achievements in scientific management of European crayfish: the way forward and future challenges, *Bulletin Français de la Pêche et de la Pisciculture*, 380-381, 1395-1405.
27. Söderbäck B., 1995 – Replacement of the native crayfish Astacus astacus by the introduced species Pacifastacus leniusculus in a Swedish lake: possible causes and mechanisms, *Freshwater Biology*, 33, 291-304.
28. Söderhäll K. and Cerenius L., 1999 – The crayfish plague fungus: history and recent advances, *Freshwater Crayfish*, 12, 11-35.
29. Ueno M. and Mizuhira V., 1984 – Calcium transport mechanism in crayfish gastrolith epithelium correlated with the molting cycle, *Histochemistry*, 80, 3, 213-217.
30. Unestam T., 1969 – Resistance to the crayfish plague in some American, Japanese and European crayfishes, *Report of the Institute of the Freshwater Research Drottningholm*, 49, 202-209.

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BENTHIC MACROINVERTEBRATE COMMUNITIES IN THE NORTHERN TRIBUTARIES OF THE "IRON GATES" GORGE (DANUBE RIVER)

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KEYWORDS: macroinvertebrates, Berzasca, Sirinia, Liubcova, Mraconia.

ABSTRACT

The paper presents the structure of the benthonic macro-invertebrates communities in the Berzasca, Sirinia, Liubcova, and Mraconia rivers. The results are based on quantitative benthos samples (95 samples), collected in July 2014 from 19 sampling stations within the study area. In longitudinal profile, the benthonic macro-invertebrate communities of the Sirinia, Liubcova and Berzasca rivers displays relatively large structural variability, while the communities of the Mraconia River displays smaller structural variability. The structure of the benthonic macro-invertebrate communities correlated with the biotope characteristics indicates the good ecological status of the analysed rivers, with the exception of the Berzasca River sector downstream of the town of Berzasca and immediately upstream of the Danube junction, a sector with moderate ecological status due to negative effects from man-made modifications in the lotic biotope of the sector.

RĖSUMĖ: Les communautés de macroinvertébrés benthiques des affluents nord du Danube, dans la région des Portes de Fer.

L'article décrit la structure des communautés de macroinvertébrés benthiques des rivières de Berzasca, Sirinia, Liubcova et Mraconia. Les résultats obtenus sont basés sur des échantillons quantitatifs de benthos (95 échantillons) collectés en juillet 2014 sur 19 stations d'échantillonnage situées dans la zone de référence. En profil longitudinal, les communautés de macroinvertébrés benthiques des rivières de Sirinia, Liubcova et Berzasca présentent une variabilité structurelle assez importante, alors que les communautés de la rivière de Mraconia présentent une moindre variabilité structurelle. La structure des communautés de macroinvertébrés benthiques corrélée aux caractéristiques du biotope relèvent du bon état écologique des rivières analysées, à l'exception de la rivière de Berzasca en aval de la ville de Berzasca, juste avant la confluence avec le Danube, secteur présentant un état écologique modéré, dû à la modification anthropique du biotope lotique dans ce secteur.

REZUMAT: Comunităţile de macronevertebrate bentonice din afluenţii nordici ai Dunării, în zona Porţile de Fier.

Lucrarea prezintă descrierea structurii comunităţilor de macronevertebrate bentonice din râurile Berzasca, Sirinia, Liubcova şi Mraconia. Rezultatele se bazează pe probe cantitative de bentos (95 probe), colectate în iulie 2014 din 19 staţii de colectare situate în zona de referinţă. În profil longitudinal, comunităţile de macronevertebrate bentonice din râurile Sirinia, Liubcova şi Berzasca prezintă variabilitate structurală relativ mare, iar cele din râul Mraconia prezintă variabilitate structurală mai mică. Structura comunităţilor de macronevertebrate bentonice în corelaţie cu caracteristicile biotopului relevă faptul că râurile analizate prezintă o stare ecologică bună, cu excepţia sectorului râului Berzasca situat aval de localitatea Berzasca, imediat amonte de confluenţa cu Dunărea, care prezintă stare ecologică moderată, în acest sector biotopul lotic este modificat antropic.

INTRODUCTION

Construction of the "Iron Gates" I (1972) for hidroenergy and navigation complex modified the hydrological regime of the Danube and its tributaries at the confluence with the newly-created reservoir lake (Ujvari, 1959). After the dam was constructed across the Gura Valley, and the reservoir lake was formed, the river mouths of all Danube tributaries became flooded and turned into bays.

Considering these aspects, this study aims to analyze the longitudinal dynamics of the benthic macroinvertebrate communities of the Danube tributaries flowing from the left side, from the "Iron Gates" area (Fig. 1): Berzasca River, with a catchment area of 229 km²; Sirinia, with a catchment area of 74.2 km², and Mraconia, with a catchment area of 113 km² (Tetelea, 2014).

These rivers have their sources in the Almăj Mountains and cross some sparse settlements at the confluence with the Danube. The study area is part of the "Iron Gates" Natural Park.

These analyzed rivers are classified as western Carpathian type, characterised by flood waters during spring and winter, while winter leakage is more important, due to Mediterranean climate influences which induces the early melting of snow. Rivers are short with large slopes and relatively high flow rates, resulting in a large volume of alluvial material dislocated from the riverbed (Ujvari, 1959).

Studies of the invertebrate communities in northern Danube tributaries of the "Iron Gates" were conducted during 1959 to 1970, before the dam construction and reservoir filling: Botoşănenu (1959) studied fauna of caddisflies, Prunescu-Arion (1968) recorded data on benthic fauna, Antonescu et al. (1969) carried out hydrobiological research on rivers Berzasca and Sirinia, Brezeanu, Prunescu-Arion, and Popescu Marinescu (in Buşniță et al., 1970) studied the taxonomic structure of macroinvertebrate communities in the rivers: Bozneaţca, Varada, Sicolovăţ, Alibeg, Liuborajdea, Cruşovăţ, Cameniţa, Oraviţa, Berzasca, Sirinia, Elişeva, Povalina, Tisova, Plavişevița, Mraconia, Eşelniţa, Cerna, Vodiţa, Bahna, and Dubova. (Badea et al. 1983; Posea, 1982; Roşu, 1980).

MATERIAL AND METHODS

The results are based on quantitative benthic macroinvertebrate samples (95 samples) taken in July 2014 from 19 stations of the reference areas, located at approximately five km intervals along the four studied Danube tributaries (Fig. 2).

In each station, quantitative samples were taken from five separate points, in order to highlight the specific diversity of local micro-habitats. The sampling was carried out with an 887 cm^2 surface Surber Sampler, with a 250 µm mesh net. The sampled biological material was fixed in 4% formaldehyde solution and was analyzed in the laboratory with an Olympus (150X) stereomicroscope. The invertebrates were identified to order except Oligochaeta, Hirudinea and Chironomidae and the counts were converted to number of individuals per square meter (ind./m^2). For the quantitative structure description of the macroinvertebrate communities we used relative abundance (A%) and mean density (Ds) measures.

The assessed biotope variables were: altitude, slope, riverbed width, depth, substratum types, channel modification (expressed as a percentage in comparison to the natural state), riverine vegetation and water physico-chemical characteristics (pH, total dissolved solids – TDS, dissolved oxygen – DO). The substratum types (mud, sand, gravel, pebbles, cobbles, and boulders) were expressed as percentages of the transversal section surface (20 m length).

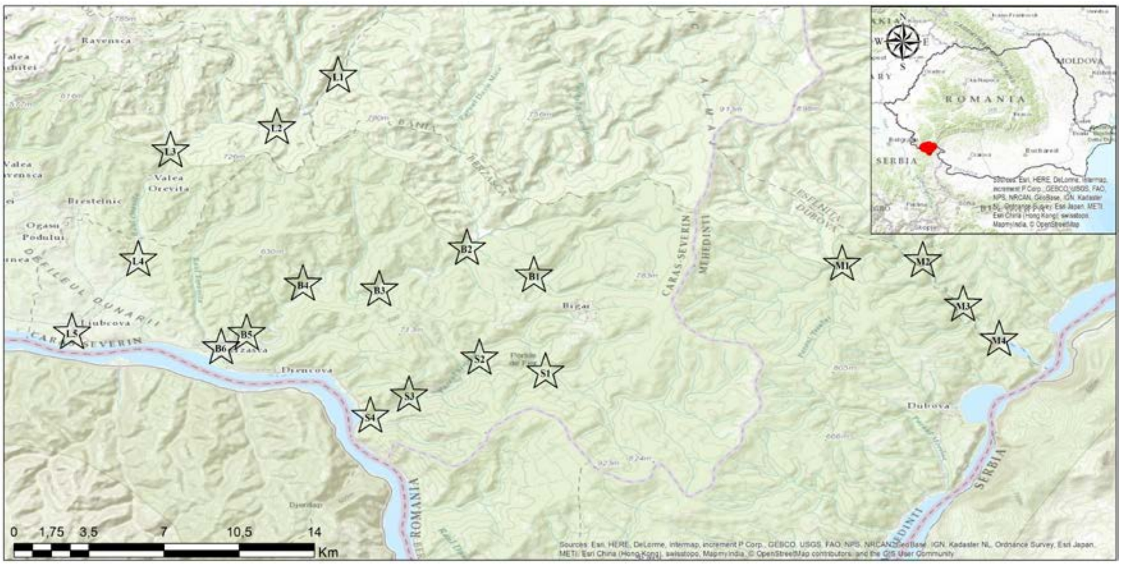

Figure 1: The sampling stations location on the studied rivers: Berzasca (B1 – B6), Sirinia (S1 – S4), Liubcova (L1 – L5), Mraconia (M1 – M4).

RESULTS AND DISCUSSION

The benthic macroinvertebrate groups with the largest distribution in the reference area are Ephemeroptera, Plecoptera, Trichoptera, and Chironomida, present in all the analysed river sectors. Groups with a more restricted distribution included the Tricladida, Gastropoda, Oligochaeta, Hydracarina, Amphipoda, Odonata, Heteroptera, Coleoptera, and Dipterans other than Chironomidae Family (Tab. 1).

The similarity analysis of the benthic macroinvertebrate communities in the six lotic sectors studied on the Berzasca River, based on the relative abundance values of the present taxa, reveals the fact that they can be classified into five groups (Fig. 3; Tab. 1): I. communities dominated numerically by Ephemeropterans, accompanied by the Planaria, the Trichopterans and the Chironomids, with relative abundances between 10% and 13%, present in B1; II. communities dominated numerically by Ephemeropterans and Trichopterans, accompanied by the Oligochetes and the Plecopterans with relative abundances between 15% and 20%, present in B3; III. communities dominated numerically by Ephemeropterans and Plecopterans, in which Oligochetae present relative abundances comprised between 15% and 20%, present in B2 and B4; IV. communities dominated numerically by Ephemeropterans and Plecopterans, accompanied by Trichopterans and Chironomids with relative abundances between 13% and 19%, present in B5; V. communities dominated numerically by Chironomids, present in B6. A relatively large structural difference was found between communities from the sectors B1 – B5 and that of sector B6 – upstream of the Danube confluence, an area where the lotic habitat is modified by humans and impacted by pollution from waste water and domestic waste generated by the village of Berzasca.

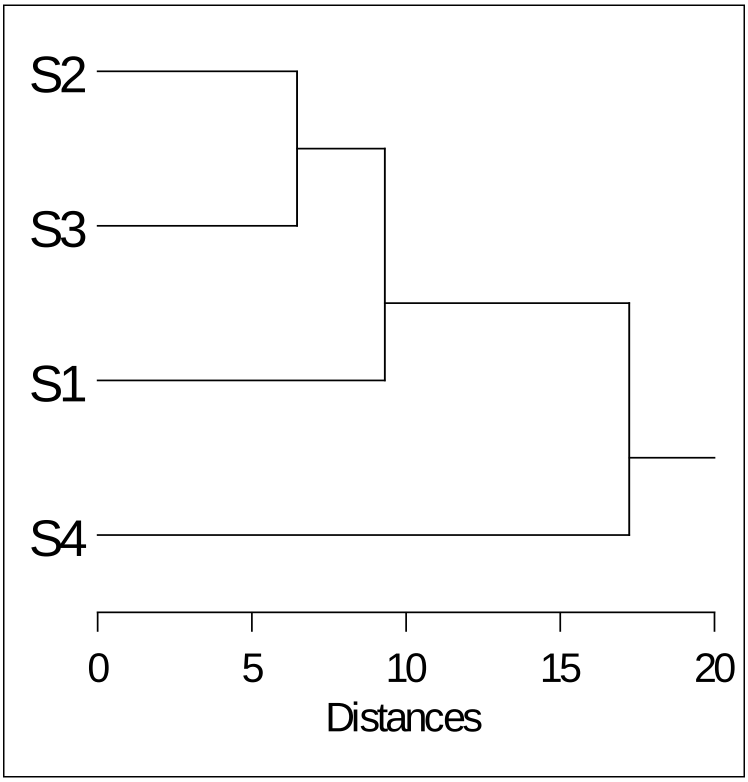

Figure 2: Cluster analysis based on the benthic macroinvertebrate systematic groups relative abundence (A%), of the four analysed lotic sectors of the Sirinia River (euclidian distances, S1 – S4 sampling stations).

The benthic macroinvertebrate communities of **Sirinia River** present a relatively high structural variability along the river (Fig. 2, Tab. 1).

In the upper river sector – sector S1 – the numerically dominant taxa are the Ephemeroptera and the Trichoptera, followed by Chyronomida. In this sector, Plectoperans have a relative abundance smaller than 10%, Amphipods and Dipterans have relative abundances between 12% and 20%; sector S2 is numerically dominated by Ephemeropterans, Oligochetae and Dipterans, and, with relative abundances less than 10%, Plecopterans, Trichopterans, Turbelariatae and Coleopterans; downstream, sector S3 is numerically dominated by Ephemeropterans and Dipterans, with lower abundances of Trichopterans (18.64%) and Plecopterans (13.28%), and, with relative abundances under 7%, by Oligochetae, Coleopterans, Amfipods, Turbelariates and Hydracarians; in the lower sector – sector S4 – the Chironomids dominate in numbers, followed by Oligochaeta with relative abundances of 17.23%, with Ephemeropterans, Plecopterans, Trichopterans, Turbelariates, Amfipodes and Hydracarians also being present.

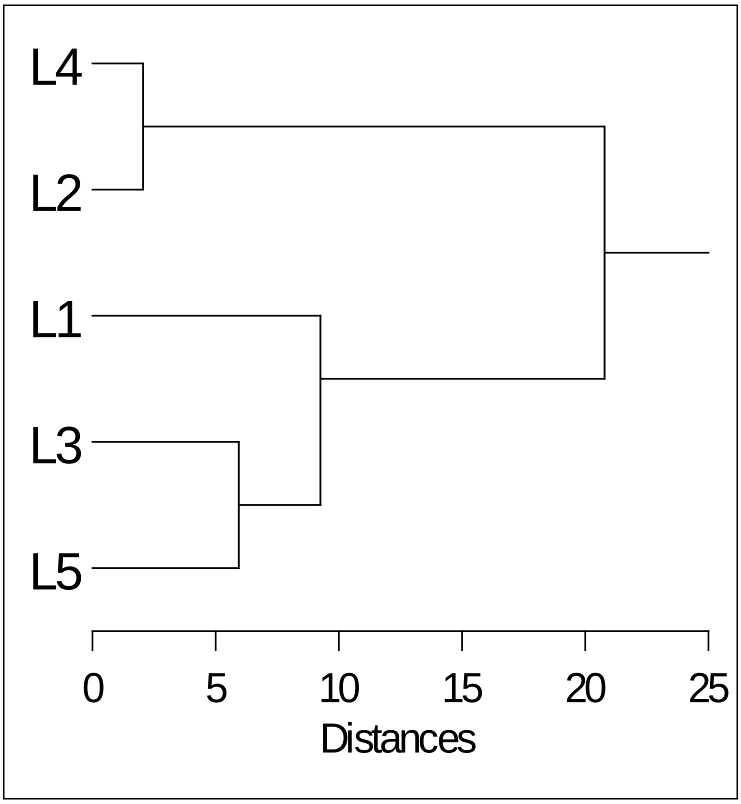

Figure 3: Cluster analysis based on the benthic macroinvertebrate systematic groups relative abundence (A%), of the five analysed lotic sectors of the Liubcova River (euclidian distances, L1 – L5 sampling stations).

Based on the values of relative abundances of the present taxa, the benthic macroinvertebrate communities of the five river sectors analysed along the **Liubcova River** can be classified in three groups (Fig. 3, Tab. 1): I. Communities dominated numerically by Amphipodes, with Plecopterans and Ephemeropterans present at abundances between 7% and 15%, and Trichopterans, Oligochetae and the Dipterans present in relative abundances under 5%, all present in L2 and L4; II. Communities dominated numerically by Ephemeropterans, with Amphipodes and Plecopterans at lower abundances, and Dipterans, Trichopterans and Oligochetae in relative abundances under 4%, present in L1; III. Communities dominated by Ephemeropterans and Oligochetae, accompanied in variable proportions by Dipterans, Plecopterans, Coleopterans and Amfipodes, present in L3 and L5.

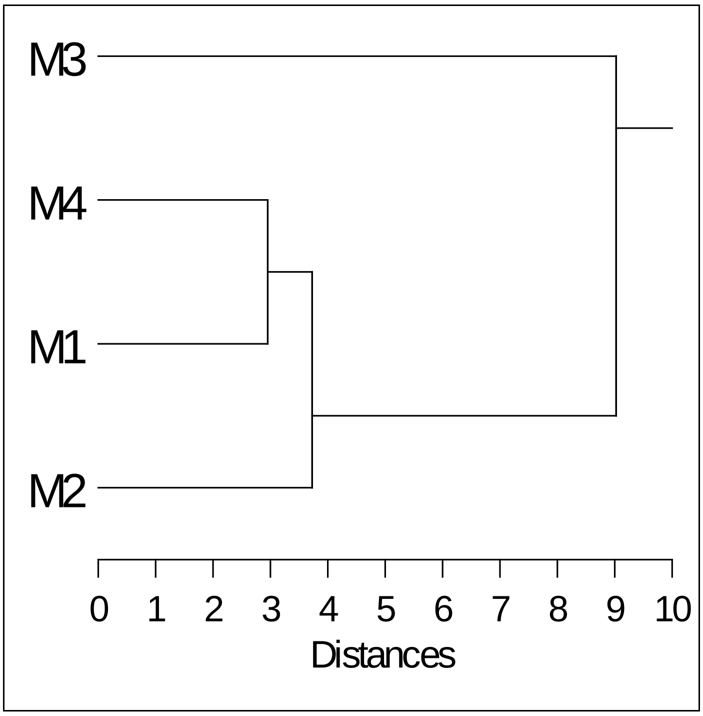

Figure 4: Cluster analysis based on the benthic macroinvertebrate systematic groups relative abundence (A%), of the four analysed lotic sectors of the Mraconia River (euclidian distances, M1 – M4 sampling stations).

Benthic macroinvertebrate communities of all four studied sectors along **Mraconia River** have a relatively small structural variability (Fig. 4, Tab. 1), and they can be grouped in two classes: I. Communities in which Ephemeropterans and Plecopterans are numerically co-dominant, with Oligochaetes and Dipterans present in relative abundances ranged between 10% and 19%, and Trichopterans, Coleopterans and Amphipods present in abundances smaller than 10%, present in M1, M2 and M4; II. Communities in which Dipterans and Ephemeropterans are numerically co-dominant, with Oligochaetes and Plectopterans present in small abundances (10.59% and 8.84% respectively), and Trichopterans, Amphipods, Coleopterans and water mites present with relative abundances smaller than 5%, present in M3.

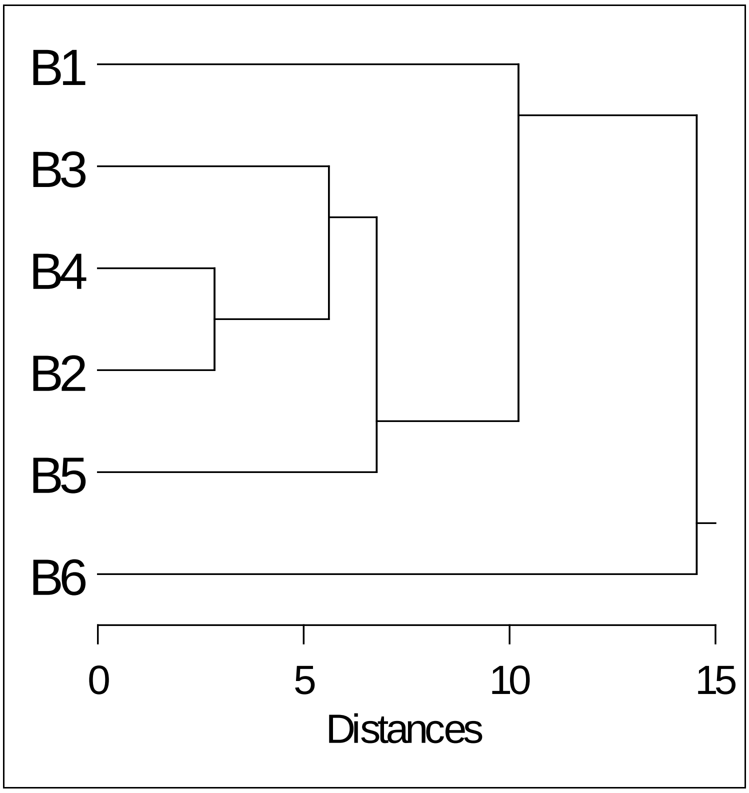

Figure 5: Cluster analysis based on the benthic macroinvertebrate systematic groups relative abundence (A%), of the six analysed lotic sectors from the Berzasca River (euclidian distances, B1 – B6 sampling stations).

In the reference area, the highest density of benthic macroinvertebrates was recorded in **Berzasca River** (Fig. 5, Tab. 1), within the sector placed at 5.5 km upstream of the confluence with the Danube (B5).

High density of Plecopterans is associated with river sectors with a fast flow and a substratum predominantly formed of cobbles and boulders; Ephemeropterans develop populations with a large number of individuals in most of the river sectors, except the sectors in which sedimentary substratum is prevalent – sand and mud. In the case of the other benthic sectors, a dependence pattern of the density on the prevalent substratum type cannot be described in a certain sector.

In terms of biotope conditions, although they occur at relatively low altitudes (under 375 m), the studied rivers have a mountain character up to about 5-6 km upstream the confluence with the Danube, with well oxygenated waters, slightly basic pH and a content of total dissolved solids ranging between 207 mg/l (in M1) and 364 mg/l (in L4 and L5) (Tab. 1).

Table 1: Benthic macroinvertebrate community structure in Berzasca River (B1 – B6), Sirinia River (S1 – S4), Liubcova River (L1 – L5) and Mraconia River (M1 – M4), (Ds – mean density, A% – relative abundance) and riverbed characteristics (Wm – minimum width, WA – average width, WM – maximum width, Dm – minimum depth, DA – average depth, DM – maximum depth, m – mud, s – sand, g – gravel, p – pebbles, c – cobbles, b – boulders, g + m – gravel covered with thin layer of mud).

Sampling station/position, altitude, biotope characteristics	Benthic macroinvertebrate community structure		
	Taxonomic groups	Ds (ind./m^2)	A (%)
B1 N 44°40’616’’, E 22°04’904’’, 304 m DO = 104.2%, pH = 8.26, TDS = 286 mg/l Wm = 1.5 m, WA = 2.5 m, WM = 3.5 m Dm = 0.05 m, DA = 0.3 m, DM = 0.4 m p – 10%, c – 10%, b – 80%	Tricladida	126.27	10.04
	Gastropoda (*A. fluviatilis*)	13.53	1.08
	Oligochaeta	13.53	1.08
	Amphypoda	6.76	0.54
	Ephemeroptera	651.63	51.79
	Plecoptera	63.13	5.02
	Trichoptera	153.33	12.19
	Coleoptera	11.27	0.90
	Chironomidae	162.34	12.90
	other Diptera	56.37	4.48
B2 N 44°41’302’’, E 22°03’205’’, 228 m DO = 104.1%, pH = 8.15, TDS = 240 mg/l Wm = 5 m, WA = 7 m, WM = 9 m Dm = 0.1 m, DA = 0.3 m, DM = 1.2 m s – 3%, p – 7%, c – 40%, b – 50%	Tricladida	22.55	1.83
	Oligochaeta	200.68	16.30
	Hydracarina	11.27	0.92
	Amphypoda	29.31	2.38
	Ephemeroptera	405.86	32.97
	Plecoptera	266.07	21.61
	Trichoptera	105.98	8.61
	Coleoptera	54.11	4.40
	Chironomidae	101.47	8.24
	other Diptera	33.82	2.75
B3 N 44°40’287’’, E 22°01’021’’, 156 m DO = 106.1%, pH = 8.34, TDS = 248 mg/l Wm = 6 m, WA = 10 m, WM = 15 m Dm = 0.2 m, DA = 0.4 m, DM = 1.4 m p – 20%, c – 60%, b – 20%	Oligochaeta	205.19	18.24
	Hydracarina	2.25	0.20
	Amphypoda	6.76	0.60
	Ephemeroptera	311.16	27.66
	Plecoptera	209.7	18.64
	Trichoptera	304.4	27.05
	Coleoptera	2.25	0.20
	Chironomidae	60.88	5.41
	other Diptera	22.55	2.00

Table 1 (continued): Benthic macroinvertebrate community structure in Berzasca River (B1 – B6), Sirinia River (S1 – S4), Liubcova River (L1 – L5) and Mraconia River (M1 – M4), (Ds – mean density, A% – relative abundance) and riverbed characteristics (Wm – minimum width, WA – average width, WM – maximum width, Dm – minimum depth, DA – average depth, DM – maximum depth, m – mud, s – sand, g – gravel, p – pebbles, c – cobbles, b – boulders, g + m – gravel covered with thin layer of mud).

Sampling station/position, altitude, biotope characteristics	Benthic macroinvertebrate community structure		
	Taxonomic groups	Ds (ind./m^2)	A (%)
B4 N 44°40'404'', E 21°59'108'', 119 m DO = 104.6%, pH = 8.39, TDS = 259 mg/l Wm = 7 m, WA = 12 m, WM = 15 m Dm = 0.2 m, DA = 0.4 m, DM = 1.2 m g – 5%, p – 20%, c – 60%, b – 15%	Tricladida	2.25	0.17
	Gastropoda (*A. fluviatilis*)	94.7	7.08
	Oligochaeta	263.81	19.73
	Hydracarina	18.04	1.35
	Amphypoda	18.04	1.35
	Ephemeroptera	372.04	27.82
	Odonata	4.51	0.34
	Plecoptera	302.14	22.60
	Trichoptera	119.5	8.94
	Coleoptera	18.04	1.35
	Chironomidae	101.47	7.59
	other Diptera	22.55	1.69
B5 N 44°39'182'', E 21°57'701'', 93 m DO = 107.1%, pH = 8.55, TDS = 258 mg/l Wm = 9 m, WA = 15 m, WM = 17 m Dm = 0.15 m, DA = 0.35 m, DM = 1.3 m s – 3%, p – 35%, c – 45%, b – 17%	Gastropoda (*A. fluviatilis*)	27.06	1.02
	Oligochaeta	105.98	4.01
	Hydracarina	36.08	1.37
	Amphypoda	4.51	0.17
	Ephemeroptera	671.93	25.43
	Plecoptera	868.09	32.85
	Heteroptera	6.77	0.26
	Trichoptera	358.51	13.57
	Coleoptera	36.08	1.37
	Chironomidae	496.05	18.77
	other Diptera	38.33	1.45
B6 N 44°38'882'', E 21°57'098'', 78 m DO = 100.4%, pH = 8.42, TDS = 260 mg/l Wm = 21 m, WA = 21 m, WM = 22 m Dm = 0.25 m, DA = 0.4 m, DM = 1.8 m s – 7%, g +m – 90%, b – 3%	Gastropoda (*A. fluviatilis*)	11.27	1.37
	Oligochaeta	74.41	9.04
	Hydracarina	18.04	2.19
	Ephemeroptera	196.17	23.84
	Odonata	2.25	0.27
	Plecoptera	42.84	5.21
	Trichoptera	15.78	1.92
	Coleoptera	6.76	0.82
	Chironomidae	450.96	54.80
	other Diptera	4.51	0.55

Table 1 (continued): Benthic macroinvertebrate community structure in Berzasca River (B1 – B6), Sirinia River (S1 – S4), Liubcova River (L1 – L5) and Mraconia River (M1 – M4), (Ds – mean density, A% – relative abundance) and riverbed characteristics (Wm – minimum width, WA – average width, WM – maximum width, Dm – minimum depth, DA – average depth, DM – maximum depth, m – mud, s – sand, g – gravel, p – pebbles, c – cobbles, b – boulders, g + m – gravel covered with thin layer of mud).

S1 N 44°38’335’’, E 22°05’184’’, 312 m DO = 104.3%, pH = 8.18, TDS = 214 mg/l Wm = 3 m, WA = 4 m, WM = 5 m Dm = 0.05 m, DA = 0.4 m, DM = 0.8 m s – 3%, c – 30%, b – 67%	Amphypoda	36.08	4.09
	Ephemeroptera	266.07	30.18
	Plecoptera	78.92	8.95
	Trichoptera	286.36	32.48
	Chironomidae	198.42	22.51
	other Diptera	15.78	1.79
S2 N 44°38’594’’, E 22°03’534’’, 227 m DO = 104.2%, pH = 8.45, TDS = 296 mg/l Wm = 4 m, WA = 6 m, WM = 7 m Dm = 0.3 m, DA = 0.5 m, DM = 1.5 m g – 3%, p – 2%, c – 15%, b – 80%	Tricladida	13.53	3.41
	Oligochaeta	49.61	12.50
	Hydracarina	2.25	0.57
	Ephemeroptera	180.38	45.45
	Plecoptera	31.57	7.96
	Trichoptera	31.57	7.96
	Coleoptera	9.02	2.27
	Chironomidae	33.82	8.52
	other Diptera	45.1	11.36
S3 N 44°37’672’’, E 22°01’779’’, 110 m DO = 99.1%, pH = 8.35, TDS = 316 mg/l Wm = 3 m, WA = 5 m, WM = 6 m Dm = 0.01 m, DA = 0.25 m, DM = 1.5 m c – 30%, b – 70%	Tricladida	4.51	0.57
	Oligochaeta	51.86	6.50
	Hydracarina	2.25	0.28
	Amphypoda	4.51	0.57
	Ephemeroptera	239.01	29.94
	Plecoptera	105.98	13.28
	Trichoptera	148.82	18.64
	Coleoptera	22.55	2.83
	Chironomidae	45.1	5.65
	other Diptera	173.62	21.75
S4 N 44°37’158’’, E 22°00’811’’, 81 m DO = 98.8%, pH = 8.21, TDS = 330 mg/l Wm = 10 m, WA = 12 m, WM = 14 m Dm = 0.02 m, DA = 0.3 m, DM = 1.5 m s – 5%, g – 32%, p – 60%, c – 3%	Oligochaeta	173.62	17.23
	Amphypoda	13.53	1.34
	Ephemeroptera	99.21	9.84
	Plecoptera	74.41	7.38
	Trichoptera	22.55	2.24
	Coleoptera	9.02	0.89
	Chironomidae	613.3	60.85
	other Diptera	2.25	0.22

Table 1 (continued): Benthic macroinvertebrate community structure in Berzasca River (B1 – B6), Sirinia River (S1 – S4), Liubcova River (L1 – L5) and Mraconia River (M1 – M4), (Ds – mean density, A% – relative abundance) and riverbed characteristics (Wm – minimum width, WA – average width, WM – maximum width, Dm – minimum depth, DA – average depth, DM – maximum depth, m – mud, s – sand, g – gravel, p – pebbles, c – cobbles, b – boulders, g + m – gravel covered with thin layer of mud).

L1 N 44°45'532'', E 21°59'953'', 375 m DO = 101.6%, pH = 7.97, TDS = 291 mg/l Wm = 2 m, WA = 3 m, WM = 3.5 m Dm = 0.01 m, DA = 0.15 m, DM = 0.6 m s – 15%, g – 50%, p – 35%	Tricladida	2.25	0.30
	Oligochaeta	9.02	1.20
	Amphypoda	162.34	21.62
	Ephemeroptera	401.35	53.45
	Plecoptera	135.29	18.02
	Trichoptera	9.02	1.20
	Chironomidae	29.31	3.90
	other Diptera	2.25	0.30
L2 N 44°44'268'', E 21°58'410'', 270 m DO = 102.9%, pH = 8.19, TDS = 333 mg/l Wm = 6 m, WA = 6 m, WM = 7.5 m Dm = 0.01 m, DA = 0.15 m, DM = 0.5 m s – 10%, g – 30%, p – 45%, c – 10%, b – 5%	Oligochaeta	13.53	1.54
	Amphypoda	622.32	70.95
	Ephemeroptera	124.01	14.14
	Plecoptera	103.72	11.83
	Trichoptera	11.27	1.28
	Chironomidae	2.25	0.26
L3 N 44°43'686'', E 21°55'738'', 264 m DO = 106.1%, pH = 8.43, TDS = 358 mg/l Wm = 3 m, WA = 5 m, WM = 6 m Dm = 0.15 m, DA = 0.2 m, DM = 0.5 m s – 1%, c – 50%, b – 49%	Oligochaeta	133.04	18.55
	Amphypoda	40.59	5.66
	Ephemeroptera	299.89	41.81
	Plecoptera	65.38	9.12
	Trichoptera	115	16.03
	Coleoptera	15.79	2.20
	Chironomidae	18.18	2.53
	other Diptera	29.32	4.09
L4 N 44°40'999'', E 21°54'919'', 124 m DO = 102.5%, pH = 8.31, TDS = 364 mg/l Wm = 4.5 m, WA = 6 m, WM = 7 m Dm = 0.1 m, DA = 0.15 m, DM = 1 m s – 5%, g – 85%, p – 10%	Oligochaeta	29.31	1.50
	Amphypoda	1379.93	70.51
	Ephemeroptera	153.33	7.83
	Plecoptera	257.05	13.13
	Trichoptera	87.94	4.49
	Chironomidae	36.08	1.84
	other Diptera	13.53	0.69
L5 N 44°39'218'', E 21°53'258'', 75 m DO = 98.5%, pH = 8.41, TDS = 364 mg/l Wm = 6 m, WA = 8 m, WM = 9 m Dm = 0.15 m, DA = 0.35 m, DM = 0.8 m m – 5%, s – 35%, g – 60%	Oligochaeta	347.24	18.58
	Amphypoda	2.25	0.12
	Ephemeroptera	899.66	48.13
	Plecoptera	112.74	6.03
	Trichoptera	139.8	7.48
	Chironomidae	363.02	19.42
	other Diptera	4.51	0.24

Table 1 (continued): Benthic macroinvertebrate communitystructure in Berzasca River (B1 – B6), Sirinia River (S1 – S4), Liubcova River (L1 – L5) and Mraconia River (M1 – M4), (Ds – mean density, A% – relative abundance) and riverbed caracteristics (Wm – minimum width, WA – average width, WM – maximum width, Dm – minimum depth, DA – average depth, DM – maximum depth, m – mud, s – sand, g – gravel, p – pebbles, c – cobbles, b – boulders, g + m – gravel covered with thin layer of mud).

M1 N 44°40'892'', E 22°12'614'', 298 m DO = 106.2%, pH = 8.28, TDS = 207 mg/l Wm = 2.5 m, WA = 3.5 m, WM = 6 m Dm = 0.1 m, DA = 0.2 m, DM = 1 m p – 9%, c – 30%, b – 61%	Oligochaeta	250.28	12.82
	Amphypoda	38.33	1.96
	Ephemeroptera	744.08	38.11
	Plecoptera	387.82	19.86
	Trichoptera	126.27	6.47
	Coleoptera	31.57	1.62
	Chironomidae	320.18	16.40
	other Diptera	54.11	2.77
M2 N 44°40'983'', E 22°14'638'', 208 m DO = 106.1%, pH = 8.42 TDS = 253 mg/l Wm = 5 m, WA = 5 m, WM = 6 m Dm = 0.1 m, DA = 0.3 m, DM = 0.4 m p – 20%, c – 50%, b – 30%	Oligochaeta	121.76	16.88
	Amphypoda	2.25	0.31
	Ephemeroptera	306.65	42.50
	Plecoptera	117.25	16.25
	Trichoptera	63.13	8.75
	Coleoptera	36.08	5.00
	Chironomidae	51.86	7.19
	other Diptera	22.55	3.13
M3 N 44°39'884'', E 22°15'638'', 136 m DO = 104.9%, pH = 8.46, TDS = 246 mg/l Wm = 2.5 m, WA = 6 m, WM = 10 m Dm = 0.1 m, DA = 0.25 m, DM = 2.5 m g – 10%, p – 20%, c – 50%, b – 20%	Oligochaeta	218.71	10.59
	Hydracarina	2.25	0.11
	Amphypoda	27.06	1.31
	Ephemeroptera	534.39	25.87
	Plecoptera	182.64	8.84
	Trichoptera	90.19	4.37
	Coleoptera	15.78	0.76
	Chironomidae	717.02	34.72
	other Diptera	277.34	13.43
M4 N 44°39'037'', E 22°16'526'', 52 m DO = 106%, pH = 8.52, TDS = 249 mg/l Wm = 9 m, WA = 9 m, WM = 10 m Dm = 0.05 m, DA = 0.15 m, DM = 1 m g – 5%, p – 20%, c – 30%, b – 45	Oligochaeta	124.01	10.93
	Amphypoda	6.76	0.60
	Ephemeroptera	426.16	37.57
	Plecoptera	311.16	27.44
	Trichoptera	103.72	9.15
	Coleoptera	9.02	0.80
	Chironomidae	112.74	9.94
	other Diptera	40.59	3.58

CONCLUSIONS

Longitudinally, benthic macroinvertebrate communities of the rivers Sirinia, Liubcova and Berzasca have a relatively high structural variability, and those of the Mraconia River have a lower structural variability.

In the case of the rivers Berzasca and Sirinia, a significant difference is clear between the structure of the communities of the river sector from 50 m upstream of the confluence with the Danube and the upstream communities. This difference is most likely due to the transition from the mountain lentic habitats upstream, and the habitats downstream, closer to the Danube confluence.

The structure of the benthic macroinvertebrate communities, in correlation with the biotope features, reveals that the studied rivers have a good ecological state, with the exception of the sector of the Berzasca River situated directly downstream from Berzasca Village and immediately upstream from the confluence with the Danube, which has a moderate condition, as a result of anthropic modification of the lotic biotope.

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REFERENCES

1. Antonescu C. S., Udrescu M. and Oltean C., 1969 – Rezultate preliminare asupra cercetării râurilor Berzasca și Sirinea, *Hidrobiologia*, 10, 307-309. (in Romanian)
2. Badea L., (ed.), 1983 – Geografia României, I, Geografia Fizică, Edit. Academiei Române, 662. (in Romanian)
3. Botoşănenu L., 1959 – Cercetări asupra trichopterelor din Masivul Retezat și Munții Banatului, Edit. Academiei Române, 165. (in Romanian)
4. Buşniţă T., Brezeanu G., Oltean M., Popescu-Marinescu V. and Prunescu-Arion E., 1970 – Monografia zonei Porţile de Fier. Studiu hidrobiologic al Dunării şi al afluenţilor săi, Edit. Academiei R. S. România, 266. (in Romanian)
5. Posea G., (ed.), 1982 – Enciclopedia Geografică a României, Edit. Ştiinţifică şi Enciclopedică, Bucureşti, 847. (in Romanian)
6. Prunescu-Arion E., 1968 – Contributions to the study of bentonic fauna of certain rivers of the zone of the future “Iron Gates” Dam lake, *Travaux du Muséum National d’Histoire Naturelle “Grigore Antipa”*, 8, 1, 143-161.
7. Roşu A., 1980 – Geografia Fizică a României, Edit. Didactică şi Pedagogică, Bucureşti, 484. (in Romanian)
8. Tetelea C., 2014 – Morphometric analysis to extrapolate geoecological potential of the rivers in the “Iron Gates” Natural park (Banat, Romania), *Transylvanian Review of Systematical and Ecological Research*, (in printing).
9. Ujvari I., 1972 – Hidrografia Republicii Populare Române, Edit. Ştiințifică, București, 577. (in Romanian)

THE "PORŢILE DE FIER/IRON GATES" NATURE PARK (ROMANIA) SOME DANUBE NORTHERN TRIBUTARIES FISH FAUNA

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KEYWORDS: Berzasca, Sirinia, Liubcova and Mraconia rivers, fish fauna.

ABSTRACT

The relative larger size of the Berzasca River, respectively the relatively constant environmental conditions, with relatively stenotopic ichthyocenosis, suffered small qualitative and quantitative fish fauna modifications in time, compared to the smaller rivers such as Sirinia, Liubcova/Oreviţa and Mraconia. The Danube "Iron Gates" I Lake influences the lower sectors of the studied rivers in term of fish species exchange. The accidental droughts in the karstic zones of the studied lotic sectors have a negative influence on the spatial continuity of the local fish fauna, and the climate change can increase these influence in the future. All the studied rivers play an important role for the near Danube "Iron Gates" I Lake lotic fish species of small-medium size, as reproduction and shelter habitats.

RESUMEN: Ictiofauna de algunos tributarios del norte del Danubio en el Parque Natural "Puertas de Hierro" (Rumania).

El tamaño del Río Berzasca, que es relativamente grande, sus condiciones ambientales, que son mas o menos constantes y su ictiofauna, que es básicamente estenotípica, sufrieron cambios cualitativos y cuantitativos en el tiempo, en comparación con ríos más pequeños como el Sirinia, Liubcova/Oreviţa y el Mraconia. En términos de intercambio de la ictiofauna, el Parque Natural Las "Puertas de Hierro" I, en el Lago Danubio, tiene una gran influencia en los sectores bajos de los ríos aquí estudiados. Las sequías accidentales en la parte cárstica de estos sectores lóticos tienen una influencia negativa sobre la continuidad íctica local y los cambios climáticos pudieran incrementar esa influencia en el futuro. Todos los ríos estudiados juegan un papel importante como hábitat reproductivo y de refudio para los peces medianos del Danubio en el Parque Nacional "Puertas de Hierro".

REZUMAT: Ihtiofauna unora dintre tributarii nordici ai Dunării din Parcul Natural "Porțile de Fier" (România).

Datorită dimensiunii relativ mari a râului Berzasca, respectiv condiţiilor relativ constante de mediu, ihtiocenozele relativ stenotopice ale acestui râu, au suferit modificări calitative şi cantitative reduse în timp, în comparaţie cu râurile mai mici cum ar fi Sirinia, Liubcova/Oreviţa şi Mraconia. Lacul Porţile de Fier I influenţează sectoarele inferioare ale râurilor studiate din punctul de vedere al schimburilor de specii. Secetele accidentale din zonele carstice ale sectoarelor lotice studiate au influenţe negative asupra continuităţii spaţiale ale faunei ihtiologice locale, şi schimbările climatice pot creşte aceste influenţe în viitor. Toate râurile studiate joacă un rol important pentru speciile de peşti de dimensiuni mici-medii din lacul Porţile de Fier I din proximitate, ca habitate de reproducere şi adăpost.

INTRODUCTION

In the last century the Lower Danube River, Danube Delta and North-West Black Sea area experienced significant decreases in habitat heterogeneity and quality, fish diversity and stock abundance (Antipa 1909, 1941; Bănărescu, 1964; Bănăduc et al., 2014). The “Iron Gates” Danube area is in the same situation (Bănăduc et al., 2014). The complex topography and history of this area, combining a natural gorge relief and extensive anthropogenic impacts ranging from pollution, hydrotechnical works, fish overexploitation and poaching, create obstacles for the lotic fish species of the Danube tributaries in this area, leading to changes in population and diversity. This paper identify some of the modifications to ichthyocenoses structure in some of the northern Danube tributaries, updating the knowledge of this area since the previous work around fifty years ago (Bănărescu, 1964; Bușniță et al., 1970).

This study focuses on four Danube tributaries, the Berzasca, Sirinia, Liubcova/Oreviţa and Mraconia, considering their input of water from the West Carpathian range. Relatively high flows and floods are not unusual in winter and spring, with over 50% of the flows coming from rain and snow. Some karst also contribute to subterranean water sources. Based on water flow quantities, the Berzasca River can be considered as a big mountain river, and Sirinia, Liubcova/Oreviţa and Mraconia are small mountain rivers. (Ujvari, 1972) The predominantly mountainous relief of the river basin areas induces high speed sediments flow, the majority being coarse dragged material (e.g. gravel and boulders) and a minority of sediments being in suspension. These tributary sectors of the Danube River are no longer influenced by the natural hydrological regime (variations in flow and groundwater levels) of the Danube, a relationship that existed even before the formation of the “Iron Gates” Lake I (Ujvari, 1959). Qualitatively speaking these lotic systems are negatively influenced only in the lower course sectors, where organic pollution is present and also some semi-lenitic eutrophic sectors appear, formed in the proximity of the confluences with the “Iron Gates” I Lake at relatively high water.

In the lower segments of these tributaries in the above mentioned confluence areas there is a man-made trend of increased water levels with large oscillations, turbidity and reduced water current speeds, an increase of sedimentation, increase of phytoplankton mass and a decrease of the litho-rheophile benthic fauna – all a consequence of the impact of the higher water level in the “Iron Gates” I Lake. In general, more or less significant differences can be observed between the structures of the benthic macroinvertebrate communities upstream and downstream of the confluence with the Danube, a result of the different features of the lentic habitat downstream and upstream, the latter having predominantly mountain river characteristics (Curtean-Bănăduc, 2014). Generally, in these confluence areas, the transition from litho-rheophile, psamo-rheophile, and psamo-pelo-rheophile habitat sections to psamo-semistagnophile, and psamo-pelo-semistagnophile habitat sectors is noticeable.

The variety of the landscape, the specificity of the climate, the proximity of the Danube and least, but not last, the human impact in the region raise the question of whether the studied tributaries represent a sheltered enclave for the specific fish fauna in the medium term, or whether they represent lotic sub-systems indirectly influenced by the Danube River.

This research aims to analyse the potential changes due to natural and anthropogenic factors on the fish communities of certain Danube River tributaries of the „Iron Gates” area (Fig. 1): Berzasca, Sirinia, Liubcova/Oreviţa and Mraconia. The available ichthyofauna elements in the studied four Danube tributaries were evaluated through comparison of the half century old data (Bănărescu, 1964) and the present paper author’s field data.

MATERIAL AND METHODS

Fish samples for this study were collected in 2010-2012, in Berzasca, Sirinia, Liubcova, and Mraconia rivers (Fig. 1). The fish was identified and immediately released in situ: *Salmo trutta fario*, *Thymallus thymallus*, *Esox lucius*, *Squalius cephalus*, *Phoxinus phoxinus*, *Tinca tinca*, *Scardinius erithrophthalmus*, *Aspius aspius*, *Alburnus alburnus*, *Alburnoides bipunctatus*, *Blicca bjoerkna*, *Abramis brama*, *Vimba vimba*, *Chondrostoma nasus*, *Rhodeus sericeus amarus*, *Gobio gobio obtusirostris*, *Gobio alpininnatus*, *Barbus barbus*, *Barbus meridionalis*, *Cyprinus carpio*, *Carasius gibelio*, *Orthrias barbatulus*, *Misgurnus fosilis*, *Cobitis taenia*, *Sabanejewia aurata balcanica*, *Sabanejewia aurata bulgarica*, *Silurus glanis*, *Lota lota*, *Lepomis gibosus*, *Perca fluviatilis*, *Acerina cernua*, *Gobius fluviatilis*, *Gobius kessleri* and *Cottus gobio*.

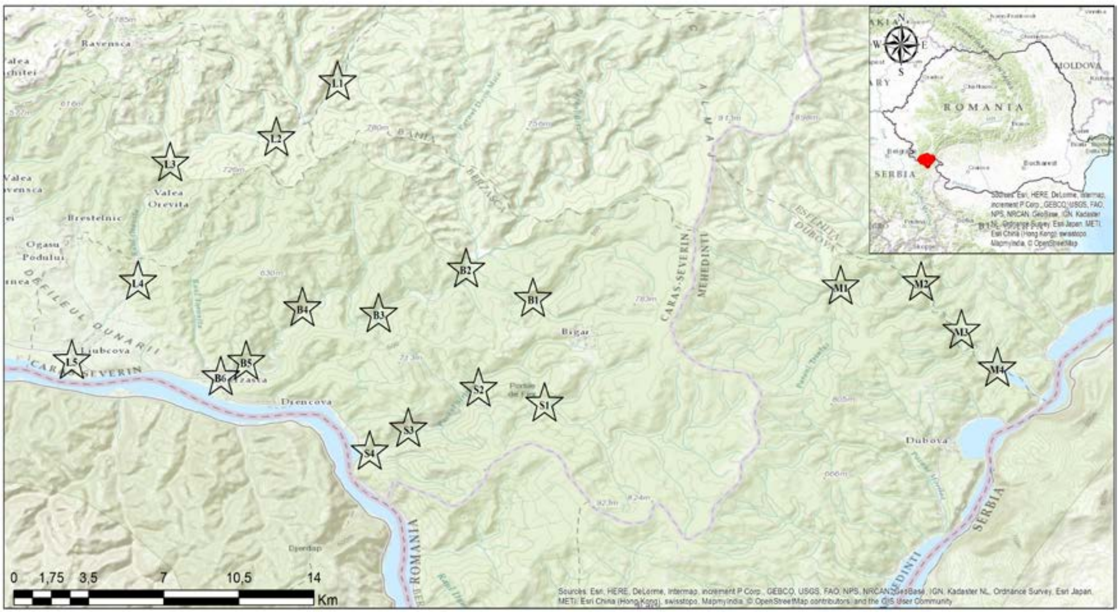

Figure 1: The location of sampling stations on the studied rivers: Berzasca (B1 – B6), Sirinia (S1 – S4), Liubcova/Oreviţa (L1 – L5), and Mraconia (M1 – M4).

RESULTS AND DISCUSSION

Berzasca River

Berzasca is a perennial river that never runs dry even in the hottest summer. It falls into the river category characterised by an area of watershed between 200 and 1,500 km^2, length of the river between 30 and 100 km and mean discharge between 0.5 and 15 m^3/s (Tetelea, 2014).

The ichthyofauna of the Berzasca River is characterized by the presence of *Salmo trutta fario* (Fig. 2) in the studied area, an unexpected species that was possibly introduced to the river by humans (Paşovschi, 1956). Fish species that would be expected, but which are missing from the characteristic ichthyologic trout zone include: *Cottus gobio* and *Phoxinus phoxinus*. The brown trout dominates in the upstream section until around 30 km sector and it is considered an indicator of a steady situation in the river over the last half of century in this section. In the Merridionnal barbel and Grayling zone. *Barbus meridionalis* is one of the most successful and abundant fish species of this river, although *Thymallus thymallus* continues to be absent, as was observed in the earlier work on the river. *Orthrias barbatulus* and *Alburnoides bipunctatus* appear to have a good and stable population in this river, reflecting the earlier study's finding. The populations of *Chondrostoma nasus* and *Vimba vimba* in the Danube still have positive influences in the lower sector of Berzasca River, especially during the reproduction season. *Squalius cephalus* also has an abundant stable population.

Figure 2: A *Salmo trutta fario* individual captured during sampling and immediately released after identification.

A significant structural modification appeared in sector B6, upstream of the Berzasca-Danube confluence, between collection of the historic data (Bănărescu, 1964) and the new data presented here. The sector is an area where the lotic habitat is modified to a semi-lenitic habitat and impacted by local organic pollution from the nearby Berzasca Village. In the lower sector of the river, many species improved their presence in time and space in comparison with the older data: *Gobio gobio obtusirostris* had a stronger population than in the past. *Sabanejewia aurata bulgarica, Lota lota, Gobio alpininnatus, Aspius aspius, Rutilus rutilus carpathorosicus, Alburnus alburnus, Barbus barbus, Blicca bjoerkna, Abramis brama, Cyprinus carpio, Esox lucius, Perca fluviatilis, Silurus glanis, Scardinius erithrophthalmus, Cobitis taenia, Lepomis gibosus, Acerina cernua, Rhodeus sericeus amarus, Carasius gibelio, Tinca tinca, Misgurnus fosilis, Gobius fluviatilis, Gobius kessleri* were all found occasionally in the lower B6 sector.

Sirinia River

Sirinia is a small mountainous river with a watershed area category between 100 and 200 km^2, a length of between 20 and 50 km and a mean discharge between 0.2 and 5 m^3/s (Tetelea, 2014).

As in the Berzasca River, *Salmo trutta fario* is present in the studied lotic sector, again apparently introduced by humans in the past (Pașovschi, 1956). There was no presence in the ichthyologic trout zone of *Cottus gobio* and *Phoxinus phoxinus*. In one part of the Meridional barbell and Grayling zone, *Barbus meridionalis* remains one of the most abundant fish species of the studied river, although *Thymallus thymallus* is missing. *Orthrias barbatulus* have a relatively low abundance. *Alburnoides bipunctatus* appear to have a good and stable population along the time in this river. *Sabanejewia aurata balcanica, Sabanejewia aurata bulgarica, Squalius cephalus* and *Gobio albipinatus* are present in the S4 lower sector, with particularly high populations in summer. Occasional individuals of *Gobio gobio obtusirostris, Rhodeus sericeus amarus, Alburnus alburnus, Carasius gibelio*, and *Perca fluviatilis* can be found in the same lower sector.

Mraconia River

Mraconia is a small mountainous river with a watershed area category between 100 and 200 km^2, a length of between 20 and 50 km and a mean discharge between 0.2 and 5 m^3/s (Tetelea, 2014).

As in the Berzasca and Sirinia Rivers, *Salmo trutta fario* is present in the studied lotic sector, again apparently introduced by humans in the past (Pașovschi, 1956). There was no presence in the ichthyologic trout zone for: *Cottus gobio* and *Phoxinus phoxinus*. In the Meridional barbell and Grayling zone, *Barbus meridionalis* remains one of the most abundant fish species, although *Thymallus thymallus* is missing. *Orthrias barbatulus* has a relatively low abundance. *Alburnoides bipunctatus* has a good and stable population here. *Sabanejewia aurata balcanica*, *Sabanejewia aurata bulgarica*, *Squalius cephalus* and *Gobio albipinatus* in the summer period are present in the S4 lower sector. Occasional individuals in the same lower sector can be found from the following species: *Gobio gobio obtusirostris, Rhodeus sericeus amarus, Alburnus alburnus, Carasius gibelio* and *Perca fluviatilis.*

Liubcova/Oreviţa River

Liubcova/Oreviţa River is a small mountainous river with a watershed area category between 100 and 200 km^2, a length of between 20 and 50 km and a mean discharge between 0.2 and 5 m^3/s (Tetelea, 2014).

It was not previously studied by Bănărescu (1964). The following fish species were identified in the present study: *Barbus meridionalis, Orthrias barbatulus, Alburnoides bipunctatus, Sabanejewia aurata balcanica,* and *Squalius cephalus.* In the summer period *Gobio gobio obtusirostris, Rhodeus sericeus amarus, Alburnus alburnus, Carasius gibelio* and *Perca fluviatilis* are present in the L5 lower sector.

CONCLUSIONS

The relative larger size of the Berzasca River and constant environmental conditions, with relatively stenotopic ichthyocenosis, suffered small qualitative and qualitative changes in time, compared to the smaller rivers such as Sirinia, Liubcova/Oreviţa and Mraconia. Our findings indicate that the effects of anthropogenic impacts and natural topography cause variations in the ichthyofauna of the studied rivers. The Berzasca River, experienced less change, a relatively stenotopic ichthyocenosis and smaller qualitative and quantitative changes over time when compared to the smaller rivers of Sirinia, Liubcova/Oreviţa and Mraconia.

The discharge regime is a condition for the presence of migratory and semi-migratory fish species upstream or downstream into the studied lotic sectors, and it is contributing to the decrease or increase of fish diversity and changes in fish population size. The accidental droughts in the karstic sectors of the studied lotic sectors have a negative influence on the local fish fauna continuity, and it seems likely that climate change will increase these influences in the future.

The relative small dimensions of Sirinia, Liubcova/Oreviţa and Mraconia rivers can make them sensitive to future human impact.

All these rivers play an important role for the near Danube "Iron Gates" I Lake lotic fish species of small-medium size, as reproduction and shelter habitats.

A permanent seasonal fish fauna monitoring system is needed for all the northern Danube River tributaries in the Danube "Iron Gates" I Lake area.

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1. Antipa G., 1909 – Fauna ihtiologică a României, Publicaţiile Fondului Adamachi, 294.
2. Antipa G., 1941 – Marea Neagră, I, Oceanografia, Bioeconomia şi Biologia generală a Mării Negre, 30, Academia Română publicaţiunile Fondului Adamachi, X, LV. (in Romanian)
3. Bănărescu, P., 1964 – Fauna Republicii Populare Române, Pisces-Osteichthyes, XIII, Edit. Academiei R. P. Române, Bucureşti, 962.
4. Bănăduc D., Bănăduc A., Lenhardt M. and Guti G., 2014 – "Porţile de Fier/Iron Gates" area (Danube) fish fauna, *Transylvanian Review of Systematical and Ecological Research*, 16, (in printing).
5. Buşniţă T., Brezeanu T., Oltean M., Popescu-Marinescu V., Prunescu-Arion E., Bănărescu P. M., Bogatu D., Gheracopol O., Péterfi L. Ş. and Vasiliu G. A., 1970 – Monografia zonei Porţilor de Fier, Studiul hidrobiologic al Dunării şi al afluenţilor săi, Edit. Academiei R. S. România, 266. (in Romanian)
6. Curtean-Bănăduc A., 2014 – "Iron Gates" Gorges (Danube River), northern tributaries benthic macroinvertebrate communities, *Transylvanian Review of Systematical and Ecological Research*, 16, (in printing).
7. Paşovschi S., 1956 – Câteva consideraţiuni biogeografice asupra munţilor Banatului, *Ocrotirea naturii*, 2. (in Romanian)
8. Tetelea C., 2014 – Morphometric analysis to extrapolate geological potential of the rivers in the "Iron Gates" Natural Park (Banat, Romania), *Transylvanian Review of Systematical and Ecological Research*, 16, (in printing), 29-46.
9. Ujvari I., 1972 – Hidrografia Republicii Populare Române, Edit. Ştiinţifică, Bucureşti, 577. (in Romanian)

"PORŢILE DE FIER/IRON GATES" GORGES AREA (DANUBE) FISH FAUNA

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KEYWORDS: Danube, human impact, habitat changes, fish fauna.

ABSTRACT

An important fisheries sector of the Danube, the "Iron Gates" area, was studied by famous naturalists along the history like Marsigli, Haeckel, Kner, Antipa and Bănărescu. After more than half a century after the last main publication in this area, the "Iron Gates" Danube sector suffered significant human impact, and an assessment of the fish fauna was needed. The paper summarizes the trend of fish species along the XIX to XXIst centuries, and reveals the appearance of new species. The study includes data from about 65 fish species, belonging to: Acipenseridae, Polyodontidae, Clupeidae, Salmonidae, Esocidae, Cyprinidae, Cobitidae, Siluridae, Ictaluridae, Anguillidae, Lotidae, Gasterosteidae, Syngnathidae, Centrarchidae, Percidae, Gobiidae, Odontobutidae, and Cottidae. The major hidrotechnical works along with pollution, overexploitation and poachery, induced major changes in the ichthyofauna structure.

RESUMEN: Ictiofauna de la región "Puertas de Hierro" (Danubio).

A lo largo de la historia, destacados naturalistas como Marsigli, Haeckel, Kner, Antipa and Bănărescu han estudiado el área del Danubio denominada como "Puertas de Hierro", que representa un importante sector pesquero regional. En virtud de que el área "Puertas de Hierro" ha sufrido impactos antropogénicos sustanciales y más de medio siglo después de haberse publicado la principal obra sobre aspectos básicos de diversidad regional, surge la necesidad de realizar una nueva evaluación. En este artículo se resume la tendencia de las especies ícticas del siglo XIX al XXI y se revela la aparición de nuevas especies. También se incluyen datos de 65 especies de peces pertenecientes a las siguientes familias: Acipenseridae, Polyodontidae, Clupeidae, Salmonidae, Esocidae, Cyprinidae, Cobitidae, Siluridae, Ictaluridae, Anguillidae, Lotidae, Gasterosteidae, Syngnathidae, Centrarchidae, Percidae, Gobiidae, Odontobutidae, Cottidae. La estructura de la fauna íctica ha sido considerablemente alterada por las enormes construcciones hidrotecnicas, la sobreexplotación y la pesca furtiva.

REZUMAT: Fauna de peşti a zonei „Porţile de Fier" (Dunăre).

O zonă importantă a Dunării pentru pescuit, zona „Porţile de Fier", a fost studiată de-a lungul istoriei de naturalişti faimoşi ca Marsigli, Haeckel, Kner, Antipa şi Bănărescu. După mai mult de jumătate de secol de la ultima publicaţie importantă despre această arie, în condiţiile în care sectorul Dunării „Porţile de Fier" a suferit un impact antropic semnificativ, a fost necesară o evaluare a ihtiofaunei. Lucrarea prezintă evoluția ihtiofaunei de-a lungul secolelor XIX la XXI şi relevă apariţia unor specii noi. Studiul include date referitoare la 65 de specii de peşti, aparţinând la: Acipenseridae, Polyodontidae, Clupeidae, Salmonidae, Esocidae, Cyprinidae, Cobitidae, Siluridae, Ictaluridae, Anguillidae, Lotidae, Gasterosteidae, Syngnathidae, Centrarchidae, Percidae, Gobiidae, Odontobutidae şi Cottidae. Amenajările hidrotehnice majore, poluarea, supraexploatarea şi braconajul au indus modificări majore în structura ihtiofaunei.

INTRODUCTION

Fish communities cannot be understood if we don’t have long term data records about their dynamics, especially in terms of major ecosystems changes.

The Danube River is the second biggest European river, one of the most relevant in natural view for this continent. The length of the Danube is 2,826 km and its watershed includes parts of 19 nations from the Black Forest springs to the Black Sea. The Danube watershed expands up to 801,093 km^2. (Tockner et al., 2009) This river fish diversity is superior to other rivers of Europe. The present 115 indigenous fish species, which are about 20% of the European freshwater fish fauna (Kottelat and Freyhof, 2007), induce a high fish richness for Danube. This fact is dependent of the considerable dimensions, great variability of habitats and east to west movement corridor for migration of the Danube River.

The studied Danube sector cover over 200 km, between the Romanian localities Baziaş (km 1,072.2) and Gruia (km 851) or Ram (km 1,077) and Radujevac (km 852) localities in Serbia. The upper and middle part belong to the “Iron Gates” Natural Park/Parcul Natural “Porţile de Fier” on the Romanian Danube northern bank and Djerdap National Park on the Danube southern Serbian bank, and is one of the most spectacular Danube sectors, in terms of climate, geomorphology, hydrology, hydrobiology, zoogeography, aquatic, semiaquatic and riverine habitats and communities (Banu, 1967a, b; Băcescu, 1944; Bănărescu, 1957, 1993, 2004; Berg, 1932; Brînzan, 2012, 2013; Călinescu, 1946; Pașovschi, 1956; Posea, 1964; Ujvari, 1959, 1972; Badea and Bugă, 1992; Oancea and Velcea, 1987; Sanda et al., 1968), in comparison with other sectors.

Within the “Iron Gates” Gorge, the Danube shrinks to 150 meters in width and is flanked by limestone cliffs that go up to 300 meters. After exiting the gorge, the river widens again as it enters the Orşova Valley, where its slope is about 3-4 $cm.km^{-1}$. Within the gorge, the slope of the river bed was much higher, 240 $cm.km^{-1}$ between the 947-945 river km (Tőry, 1952). Regarding to the specific hydrogeological characteristics of the “Iron Gate” Gorge, the cascade section could be an insurmountable barrier for weak swimming smaller fish species, as the Ponto-Caspian gobies for a long period (Guti, 2000).

The interest Danube sector was well known as very rich in fish and as a consequence very important for fisheries (Giurescu, 1964). Fossils of big sturgeons were found in Palaeolithic, Mesolithic and Early Neolithic archaeological locations along the “Iron Gates” Gorge (Balon, 1964, 2004; Bartosiewicz, 1997; Dinu, 2010; Guti, 2006; Bartosiewicz and Bonsall, 2004). These evidences demonstrate the importance of fish in general and of the sturgeons in primeval diet approximately since 9,000 years ago to the antiquity. In the Middle Ages, in the 11th to 15th centuries period, sturgeon fishing also thrived in the area of interest. Numerous historic fishing locations were found in the proximity of the spawning places of anadromous sturgeon species (Guti, 2006). Moreover, the archaeological evidences of fish in the Middle Danube sectors are defined by osseous matter of big-size fish, predominantly *Cyprinus carpio*, *Silurus glanis* and *Esox lucius*, also numerous not well preserved smaller cyprinids (Dinu, 2010; Arratia and Mayden, 2004; Bartosiewicz and Bonsall, 2004; Gallik et al., 2015). It is obvious that all these fish species constituted important food and trade elements for the local communities.

The oldest fish data in the study area, are those of Marsigli (1726), Marsilius (1726) which studied the fish species of the disappeared now Ada-Kaleh Island; Haeckel and Kner (1858) describes the local fish species; Antipa (1909) studied also the local fish fauna; Bușniţă (1937) describe the local ichthyocenoses zone; Bănărescu (1964) comprehensive data including from this area.

Building and using of barrages on lotic systems is one of the major accomplishment of humans in river metamorphosis and the uppermost perturbation to streams' structures and functions, including in respect of fish fauna, both in the dam lakes and downstream lotic sectors (Olopade, 2013; Dynesius and Nilsson 1994; Humphries and Winemiller, 2009; Olopade and Rufai, 2014; Voicu and Merten, 2014; Voicu and Bănăduc, 2014; Morita et al., 2009; Normando et al., 2014; Schiemer et al., 2004). On the contrary, despite the fact that fish communities' structure is usually altered, there are cases where a decrease on fish diversity is not demonstrated (Travnichek and Maceina, 1994; Gourène et al., 1999).

The Danube is a major waterway for international trade, but the "Iron Gates" Gorge created torrents and whirlpools that made navigation difficult for centuries in the past. In 1831 a plan had already been drafted to make the passage navigable, but the engineering project was finalised in 1898. Rocks were cleared by explosion over a two km stretch in order to create an 80 m wide and three m deep navigation channel. The results of these efforts were less effective. The currents in the channel were so strong that, ships had to be dragged upstream by locomotive until the creation of the reservoir of the "Iron Gates" Dam (Tőry, 1952).

The "Iron Gates/Porţile de Fier" major hidro-energetic and navigation complex construction (1964-1972), in an important Danube sector, with a very specific fish fauna, is intriguing if induced fish fauna changes. In this respect an overview is appropriate after a half of a century of last significant data about this area.

The improvement of the upstream navigation in the "Iron Gates" Gorge in the 19th century and the construction of the reservoirs provided a migration access for the smaller Ponto-Caspian fish species to the Middle Danube (Guti, 2000).

MATERIAL AND METHODS

Historical maps and river engineering plans were evaluated to describe the geomorphologic conditions in the pristine pre-regulation conditions in the "Iron Gates" Gorge. The long-term changes on the fish fauna and occurrence of species were evaluated by scientific literature data. Acceptable records are available from the end of XVIIIth century (Antipa, 1909; Bușniţă, 1937; Herman, 1887; Marsigli, 1726; Vutskits, 1918).

Original unpublished data obtained in different projects by the authors of this paper were used: the bilateral Slovakian-Serbian project "Harmonization of methods for the monitoring of qualitative and quantitative composition of the fish stock of large rivers", 2012-2013; the Romanian "South-western Carpathian Wilderness and Sustainable Development Initiatives", 2014-2016, co-financed by a Swiss grant through the contribution to the enlarged European Union; "Fish behaviour preparatory study at "Iron Gates" Hydropower dams and reservoirs" financed by European Investment Bank, 2015; "Fishes as water quality indicators in open waters of Serbia" financed by Ministry of Education, Science and Technological Development of the Republic of Serbia, 2011-2016.

Fish samples for these projects were collected by beach seining, electrofishing, gillnets, and net traps. Fisherman captures were identified and acoustic telemetry was used for fish tracking. The captured fish were released after their identification.

RESULTS AND DISCUSSION

Each element of the fish fauna in the area of interest were evaluated by the indication of the long-term population dynamics, having regard to the major impacts of the hydroenergetic and navigation complex of the “Iron Gates/Porţile de Fier/Derdap” area.

Huso huso (Linnaeus, 1758), (Actinopterygii, Acipenseriformes, Acipenseridae, Acipenserinae), a critically endangered marine, freshwater, brackish, benthopelagic, anadromous, native fish species in the Danube Basin. It is protected under Bern Convention, Habitats Directive, CITES, CMS and IUCN (Antipa, 1909, 1910; Bănărescu, 1964, 2004; CITES, 2013; Frimodt, 1995; IUCN, 2014; Oțel, 2007; Baensch and Riehl, 1991; Kottelat and Freyhof, 2007; Liška et al., 2015).

Until the XIX century the beluga was a common species in the studied sector, but regular sturgeon fishery was terminated in the upstream (Hungarian) sector of the Danube in the XIXth century. Beluga catches started to decline along the Middle Danube from the XVIIth century due to overfishing and it disappeared at the end of the XXth century. (Antipa, 1909, 1934; Antonescu, 1934, 1957; Bacalbașa-Dobrovici, 1991, 1995; Bănărescu, 1964, 2005; Bușniță, 1960, 1964, 1994b, 2004; Guti, 2008, 2014; Karaman, 1936, 1952; Manea, 1980; Niculescu-Duvăz, 1961, 1965; Oțel, 2007; Ristic, 1963; Vasiliu, 1959; Vutskits, 1918; Bacalbașa and Petcu, 1969; Bușniță et al., 1970; Ciolac et al., 2003; Gheracopol et al., 1968; Schiemer et al., 2004). From the beginning of the XXIst century no data is available about beluga catches along the upstream of the “Iron Gates” dams due to absence of fish passages. The increasingly intense navigation on the Danube could be another disturbing factor on sturgeon migration. The beluga was harvested downstream of the “Iron Gates” II Dam by commercial fishermen in Serbia, Romania and Bulgaria till 2006 when Romania proclaimed 10 years ban on sturgeon catches, followed by Serbia and Bulgaria. Beluga still migrates to the “Iron Gates” II, fact that was confirmed by acoustic telemetry (Suciu et al., 2015) and there is information about sturgeon poaching activity.

Acipenser nudiventris Lovetsky, 1828, (Actinopterygii, Acipenseriformes, Acipenseridae, Acipenserinae) criticaly endangered species, it is in the Danube River basin a freshwater, potamodromous, migratory, native fish species in the Danube Basin. This species is protected under Habitats Directive, CITES, CMS and IUCN. (Antipa, 1910; Bauchot, 1987; Bănărescu, 1964, 2005; CITES, 2013; IUCN, 2014; Oțel, 2007; Riede, 2004)

Till the XIXth century it occurred in the studied sector, including its upstream and lower sectors of some big tributaries, as the Prut and Siret rivers. In the beginning of the XXth century it started to decrease significantly. (Antipa, 1909, 1934; Antonescu, 1934, 1957; Bacalbașa-Dobrovici, 1991; Bănărescu, 1964, 2005, 1994b; Bușniță, 1960, 1964; Guti, 2008; Karaman, 1936, 1952; Manea, 1980; Niculescu-Duvăz, 1961, 1965; Oțel, 2007; Ristic, 1963; Vasiliu, 1959; Vutskits, 1918; Bacalbașa and Petcu, 1969; Bușniță et al., 1970; Gheracopol et al., 1968; Moshu et al., 2006; Radu et al., 2008) In the XXIst century there were no more observations in the study area, the only catches were in the Middle Danube, where the last catch was recorded in a wintering hole in the vicinity of Mohács in Hungary on 2nd December 2009, it was a male specimen with body weight of 22 kg. The main reasons of the population decline were the historical overfishing, and the extensive river engineering for improvement of navigability, the river pollution and last but not least the fragmentation of the longitudinal connectivity by dam constructions (“Iron Gates” dams I and II and several other dams in the larger tributaries) without proper fish passages from the beginning of the XXth century.

Acipenser ruthenus Linnaeus, 1758, (Actinopterygii, Acipenseriformes, Acipenseridae, Acipenserinae) it is a vulnerable freshwater, brackish, benthic, potamodromous, and native fish species in the Danube Basin. This species is protected under Bern Convention, Habitats Directive, CITES, CMS and IUCN. (Antipa, 1909, 1910; Bănărescu, 1964, 2005; Birstein, 1993; CITES, 2013; Dimitriu, 1938; IUCN, 2014; Manea, 1980; Oțel, 2007; Kottelat and Freyhof, 2007; Gesner et al., 2010)

Till the XIXth century it was a common species between Coronini and Orșova localities in the sector of our scientific interest, including upstream sectors and in some big tributaries lower courses areas, for example in Mureș, Someș, Jiu, Olt, Argeș, Siret and Prut rivers. In the beginning of the XXth century it remained in the studied sector a dominant species but start to decrease in abundance at the end of this century, being still present not only in the Danube but in the lower Prut and Mureș rivers too (Antipa, 1909, 1934; Antonescu, 1934, 1957; Bacalbașa, 1991; Bănărescu, 1964, 2005; Bușniță, 1960, 1964; Karaman, 1936, 1952; Manea, 1980; Niculescu-Duvăz, 1961, 1965; Oțel, 2007; Ristic, 1963; Vasiliu, 1959; Vutskits, 1918; Bacalbașa and Petcu, 1969; Bușniță et al., 1970; Gheracopol et al., 1968; Radu et al., 2008). After the construction of the "Iron Gates" I, mass migrations of sterlet adults have been observed toward upstream regions with faster river flow rates where sedimentation processes are much less extensive than in the reservoir itself. Sterlets migrated intensively to the Danube tributaries, as the Velika Morava and the Sava River, and especially to the Tisza (Jankovic et al., 1994). Abundance of sterlet decreased in the study area mainly due to dam constructions, pollution and the extensive river engineering for development of navigation routes.

Acipenser gueldenstaedtii Brandt and Ratzeburg, 1833, (Actinopterygii, Acipenseriformes, Acipenseridae, Acipenserinae) it is a critically endangered marine, freshwater, brackish, demersal, anadromous, autochthonous fish species in the Danube Basin. This species is protected under Habitats Directive, CITES, CMS and IUCN. (Antipa, 1909, 1910; Bănărescu, 1964, 2005; CITES, 2013; IUCN, 2014; Oțel, 2007; Reide, 2004; Sokolov and Berdicheskii, 1989; Gesner et al., 2010)

Till the XIXth century this species was often found in the sector of our interest, including upstream stretch, and in the lower sectors of some tributaries for example Prut, Siret, Olt, Jiu, Someș and Mureș rivers. From the end the XIXth century its populations started to have a decreasing trend (Antipa, 1909, 1934; Antonescu, 1934, 1957; Bacalbașa-Dobrovici, 1991, 1995; Bănărescu, 1964, 1994b, 2005; Bușniță, 1960, 1964; Karaman, 1936, 1952; Manea, 1980; Niculescu-Duvăz, 1961, 1965; Oțel, 2007; Ristic, 1963, 1967; Vasiliu, 1959; Vutskits, 1918; Bacalbașa and Petcu, 1969; Buşniţă et al., 1970; Ciolac et al., 2003; Gheracopol et al., 1968). This species occurance was not observed along the upstream of "Iron Gates" II from the beginning of the XXIst century due to dam ("Iron Gates" I and II) constructions and lakes formation. It should to be noted also the fact that most of the important spawning and wintering habitats of this species, as well of other sturgeons were heavily modified in the "Iron Gates" sector of the Danube. The wastewater loads and the developments of the navigation way are also threatening factors for this species.

Acipenser sturio Linnaeus, 1758 (Actinopterygii, Acipenseriformes, Acipenseridae, Acipenserinae) it is a critically endangered marine, freshwater, brackish, demersal, amphihaline anadromous, autochthonous fish species in the Danube Basin. This species is protected under Bern Convention, Habitats Directive, CITES, CMS and IUCN. (Bănărescu, 1964, 2005; CITES, 2013; Oțel, 2007; Gesner et al., 2010; Rochard et al., 1997)

Till the XIXth century there was only sporadic information about its occurrence in the Danube Basin, but more precise data are available about its presence in the Danube Delta and at the shoreline of the Black Sea. In the XXth century the last catch was recorded in 1954 in Serbian part in the study area (Ristic, 1963) and from 1960 to 1965 in Romanian part (Manea, 1980; Jaric et al., 2009). Recently it is very rare in the Danube Delta and the Black Sea (Antipa, 1909, 1934; Antonescu, 1934, 1957; Antoniu-Murgoci, 1936; Bacalbașa-Dobrovici, 1995; Bănărescu, 1964, 2005; Bușniță, 1960, 1964; Karaman, 1936, 1952; Murgoci, 1936; Oțel, 2007; Ristic, 1963; Vasiliu, 1959; Vutskits, 1918; Bacalbașa and Petcu, 1969; Buşniţă et al., 1970; Ciolac et al., 2003; Gheracopol et al., 1968; Niculescu-Duvăz, 1961, 1965). In the XXIst century it was observed only in the Georgian area of the Black Sea and in the Rioni River (Kolman, 2011).

Acipenser stellatus Pallas, 1771, (Actinopterygii, Acipenseriformes, Acipenseridae, Acipenserinae) it is a critically endangered marine, freshwater, brackish, demersal, anadromous, autochthonous fish species in the Danube Basin. This species is protected under Bern Convention, Habitats Directive, CITES, CMS and IUCN. (Antipa, 1909; Bănărescu, 1964, 2005; Gesner et al., 2010; Oțel, 2007; Riede, 2004; Romero, 2002)

Till the XIXth century it was a common species in the studied sector, including its upstream stretch and the lower Prut River but it was relatively rare along the Middle Danube. Its populations started to decline during the second half of the XXth century (Antipa, 1909, 1934; Antonescu, 1934, 1957; Bacalbașa-Dobrovici, 1991, 1995; Bănărescu, 1964, 1994b, 2005; Bușniță, 1937, 1960, 1964; Karaman, 1936, 1952; Manea, 1980; Niculescu-Duvăz, 1961, 1965; Oțel, 2007; Ristic, 1963; Vasiliu, 1959; Vutskits, 1918; Bacalbașa and Petcu, 1969; Buşniţă et al., 1970; Ciolac et al., 2003; Gheracopol et al., 1968; Radu et al., 2008). In the XXIst century there was not recorded catches of stellate sturgeon along the upstream of the "Iron Gates" II hydroelectric dam, but there was some acoustic telemetry data about migratory behaviour of stellate sturgeon at the downstream of the "Iron Gates" II Dam. The reasons of the decreasing abundance were the historical overfishing, the river pollution and the extensive river engineering for navigation. One catch was only registered in the upper part of the Hungarian section of the Tisa River, at Tiszajenő in 2005. Origin of this specimen is questionable, because it was about two-three years old – younger than spawning migrants.

Polyodon spathula (Walbaum, 1792), (Actinopterygii, Acipenseriformes, Polyodontidae) it is a vulnerable freshwater, demersal, potamodromous, allochthonous fish species with origin from North America (CITES, 2013; Riede, 2004; Robins et al., 1991; Simonovic et al., 2006).

The first appearance of the Mississippi paddlefish in the Danube was reported in the Serbian side of the study (Simonovic et al., 2006) was in the beginning of the XXIst century, most likely the specimens that escaped from Romanian fish ponds during floods (Lenhardt et al., 2006). It occurs most frequently in deeper, low current areas such as free-flowing river sections, side channels, backwaters lakes, and tail waters below dams.

Alosa immaculata Bennett, 1835, (Actinopterygii, Clupeiformes, Clupeidae, Alosinae) it is a vulnerable marine, freshwater, brackish, pelagic-neritic, anadromous, autochthonous fish species in the Danube Basin. This species is protected under Bern Convention, Habitats Directive and IUCN. (Antipa, 1909; Bănărescu, 1964; CITES, 2013; Kotelat, 1997; Oțel, 2007; Romero, 2002; Riede, 2004)

Till the XIXth century the Pontic shad was a common species in the studied sector to Baziaș sector and upstream, at the middle of the XXth century it started to decrease drastically in the studied area (Antipa, 1909; Antonescu, 1934, 1957; Bacalbașa-Dobrovici, 1995; Bănărescu, 1964; Borcea, 1934, 1937; Bușniță, 1953; Karaman, 1936, 1952; Oțel, 2007; Năvodaru, 1992, 1998; Niculescu-Duvăz, 1961, 1965; Vasiliu, 1959; Vutskits, 1918; Bacalbașa and Petcu, 1969; Bușniță et al., 1970; Cautiș et al., 1957; Gheracopol et al., 1968; Năvodaru et al., 1994; Schiemer et al., 2004). In the XXIst century this species individuals regularly migrate till "Iron Gates" II Dam and sometimes some specimens went through ship locks upstream. The main reason of the decreasing trend of this species in the studied Danube sector can be the dams ("Iron Gates" I and II) construction without proper fish passages.

Alosa tanaica (Grimm, 1901), (Actinopterygii, Clupeiformes, Clupeidae, Alosinae) it is a least concern marine, freshwater, brackish, pelagic-neritic, anadromous, autochthonous fish species in the Danube Basin. Is protected under Habitats Directive, CITES and IUCN. (Bănărescu, 1964; Berg, 1962; CITES, 2013; Oțel, 2007; Riede, 2004)

Till the XIX century the Black Sea shad was present in the studied sector, in the XXth. century it was found only accidentally in the study sector and in Prut River and in relatively high abundance in the lower Romanian Danube downstream the Călărași (Antipa, 1909; Antonescu, 1934, 1957; Bacalbașa-Dobrovici, 1995; Bănărescu, 1964; Borcea, 1937; Bușniță, 1953; Leonte, 1943; Moshu et al., 2006; Niculescu-Duvăz, 1961, 1965; Oțel, 2007; Vasiliu, 1959; Vutskits, 1918; Bacalbașa and Petcu, 1969; Bușniță et al., 1970; Cautiș et al., 1957; Gheracopol et al., 1968; Schiemer et al., 2004). In the XXIst century nor the authors of this paper neither other ichthyologists nor the local fisherman's did not find this species anymore. The reason can be the dams ("Iron Gates" I and II) construction without fish passages.

Salmo trutta Linnaeus, 1758, (Actinopterygii, Salmoniformes, Salmonidae, Salmoninae) a freshwater autochthonous species in the Danube Basin (Bănărescu, 1964; Svetovidov, 1984).

Until the first half of the XXth century brown trout was present only accidentally in the studied sector, at the confluences of tributaries, during periods of high floods from the local northern/Romanian tributaries (Nera, Berzasca, Sirinia, Mraconia, Eșelnița, Cerna, and Slătinicu Mare rivers) (Buşniţă et al., 1970), and also on the southern Serbian tributaries in 2007 (Marić et al., 2006). It was apparently stocked in the majority of the tributaries (Pașovschi, 1956; Marić et al., 2006). Since the dam constructions it appears sometimes in this sector in some periods of year.

Hucho hucho (Linnaeus, 1758), (Actinopterygii, Salmoniformes, Salmonidae, Salmoninae) it is an endangered freshwater, benthopelagic, potamodromous, autochthonous fish species in the Danube Basin. This species is protected under Habitats Directive, CITES and IUCN. (Antipa, 1909; Bănărescu, 1964, 2005; CITES 2013; Bănărescu and Bănăduc, 2007; Kottelat and Freyhof, 2007)

At the beginning of the XXth century the huchen was present in the studied area especially in the sectors with rapids, but since the second half of the XXth century it has disappeared in the slow flowing dammed section of the Danube (Antipa, 1909; Bănărescu, 1964; Homei, 1956; Schiemer et al., 2004).

Esox lucius Linnaeus, 1758, (Actinopterygii, Esociformes, Esocidae) it is a freshwater, benthopelagic, autochthonous fish species in the Danube Basin (Antipa, 1909; Bănărescu, 1964; Buşniţă, 1967; Crossman, 1996; Oţel, 2007).

The pike is a common species in the studied sector (Antipa, 1909; Antonescu, 1934; Bănărescu, 1964; Buşniţă, 1967, 1964; Niculescu-Duvăz, 1961, 1965; Simonović, 2006; Vasiliu, 1959; Bacalbaşa and Petcu, 1969; Buşniţă and Alexandrescu, 1971; Buşniţă et al., 1970; Gheracopol et al., 1968) and its population thrived in the dammed river section in the last third of the XXth century.

Rutilus rutilus (Linnaeus, 1758), (Actinopterygii, Cypriniformes, Cyprinidae, Leuciscine) it is a freshwater, brackish, benthopelagic, autochthonous fish species in the Danube Basin (Antipa, 1909; Bănărescu, 1964; Oţel, 2007; Riede, 2004; Romero, 2002).

The roach is one of the common fish species in the studied sector (Antipa, 1909; Antonescu, 1934; Bănărescu, 1964; Buşniţă, 1960, 1964; Niculescu-Duvăz, 1961, 1965; Vasiliu, 1959; Bacalbaşa and Petcu, 1969; Buşniţă and Alexandrescu, 1971; Gheracopol et al., 1968; Schiemer et al., 2004; Buşniţă et al., 1970). It prefers the new slow flowing and stagnant habitats since the operation of the dams.

Squalius cephalus (Linnaeus, 1758), (Actinopterygii, Cypriniformes, Cyprinidae, Leuciscine) it is a freshwater, brackish, benthopelagic, potamodromous, autochthonous fish species in the Danube Basin (Antipa, 1909; Bănărescu, 1964; Baensch and Riehl, 1991).

The chub is a frequent species in the studied area (Antipa, 1909; Antonescu, 1934; Bănărescu, 1956a, 1964; Buşniţă, 1960, 1964; Oţel, 2007; Niculescu-Duvăz, 1961, 1965; Simonović, 2006; Vasiliu, 1959; Bacalbaşa and Petcu, 1969; Buşniţă and Alexandrescu, 1971; Buşniţă et al., 1970; Gheracopol et al., 1968; Schiemer et al., 2004). It has adapted to the new slow flowing and stagnant habitats, as well as to mesotrophy.

Leuciscus idus (Linnaeus, 1758), (Actinopterygii, Cypriniformes, Cyprinidae, Leuciscine) it is a freshwater, brackish, benthopelagic, autochthonous fish species in the Danube Basin (Antipa, 1909; Bănărescu, 1964; Oţel, 2007; Popescu et al., 1960; Romero, 2002).

The ide is one of the frequent fish species in the studied area (Antipa, 1909; Antonescu, 1934; Bănărescu, 1956a, 1964; Buşniţă, 1960, 1964; Niculescu-Duvăz, 1961, 1965; Schiemer et al., 2004; Vasiliu, 1959; Bacalbaşa and Petcu, 1969; Buşniţă and Alexandrescu, 1971; Buşniţă et al., 1970; Gheracopol et al., 1968). It prefers the new slow flowing habitats along the dammed river section.

Tinca tinca (Linnaeus, 1758), (Actinopterygii, Cypriniformes, Cyprinidae, Tincinae) it is a freshwater, brackish, demersal, autochthonous fish species in the Danube Basin (Antipa, 1909; Bănărescu, 1964; Oţel, 2007; Romero, 2002; Riede, 2004).

The tench was a common species in the studied area, in spite of the fact that is well adapted to the new stagnant water habitats with muddy sediments, its population has declined since the middle of the XXth century apparently due to pollution and eutrophication (Antipa, 1909; Antonescu, 1934; Bănărescu, 1964; Buşniţă, 1960, 1964; Vasiliu, 1959; Bacalbaşa and Petcu, 1969; Buşniţă and Alexandrescu, 1971; Buşniţă et al., 1970; Gheracopol et al., 1968; Niculescu-Duvăz, 1961, 1965; Schiemer et al., 2004).

Scardinius erythrophthalmus (Linnaeus, 1758), (Actinopterygii, Cypriniformes, Cyprinidae, Leuciscinae) it is a freshwater, brackish, benthopelagic, autochthonous fish species in the Danube Basin (Bănărescu, 1964; Oțel, 2007).

The rudd is a common species in the studied area (Antipa, 1909; Antonescu, 1934; Bănărescu, 1964; Buşniţă, 1960, 1964; Niculescu-Duvăz, 1961, 1965; Vasiliu, 1959; Bacalbaşa and Petcu, 1969; Buşniţă and Alexandrescu, 1971; Buşniţă et al., 1970; Gheracopol et al., 1968; Schiemer et al., 2004). It prefers the new stagnant aquatic habitats, along the impoundments.

Leuciscus aspius (Linnaeus, 1758), (Actinopterygii, Cypriniformes, Cyprinidae, Leuciscinae) it is a freshwater, brackish, benthopelagic, potamodromous, autochthonous fish species in the Danube Basin (Antipa, 1909; Bănărescu, 1964; Oțel, 2007; Riede, 2004; Romero, 2002; Vostradovsky, 1973; Bănărescu and Bănăduc, 2007).

The asp is a frequent species in the studied area (Antipa, 1909; Antonescu, 1934; Bănărescu, 1964; Buşniţă, 1960, 1964; Vasiliu, 1959; Bacalbaşa and Petcu, 1969; Buşniţă and Alexandrescu, 1971; Buşniţă et al., 1970; Gheracopol et al., 1968; Niculescu-Duvăz, 1961, 1965; Schiemer et al., 2004). It is a semi-reophilic species, and its population has been stable.

Alburnus chalcoides (Güldenstädt, 1772) (Actinopterygii, Cypriniformes, Cyprinidae, Alburninae) it is a freshwater, brackish, pelagic, potamodromous, autochthonous fish species in the Danube Basin. This species is protected under Bern Convention, Habitats Directive, CITES and IUCN. (Bănărescu, 1964, 1994b, 2005; Oțel, 2007; Romero, 2002; Riede, 2004)

The Danube bleak was a rare species in the east part of the studied area till the second half of the XXth century, but its occurrence has not been reported since the beginning of the XXIst century. The reason of its regress could be the change of water quality and the construction of the hydroelectric dams. (Antipa, 1909; Antonescu, 1934; Bănărescu, 1961, 1964, 1994b, 2005; Buşniţă, 1960, 1964; Niculescu-Duvăz, 1961, 1965; Vasiliu, 1959; Buşniţă and Alexandrescu, 1971; Gheracopol et al., 1968; Schiemer et al., 2004) Additional problems are the general population decline in the Black Sea tributaries (Oţel, 2007), as well as the deterioration of the river ecological status along its migratory way (pollution and dams).

Alburnus alburnus (Linnaeus, 1758) (Actinopterygii, Cypriniformes, Cyprinidae, Alburninae) it is a freshwater, brackish, benthopelagic, autochthonous fish species in the Danube Basin (Antipa, 1909; Bănărescu, 1964; Oțel, 2007; Romero, 2002).

The bleak is abundant in the studied area. (Antipa, 1909; Antonescu, 1934; Bănărescu, 1964; Buşniţă, 1960, 1964; Niculescu-Duvăz, 1961, 1965; Vasiliu, 1959; Buşniţă and Alexandrescu, 1971; Buşniţă et al., 1970; Schiemer et al., 2004; Gheracopol et al., 1968). It is a neutrophilic species, and changes of the aquatic habitats did not threat its population.

Alburnoides bipunctatus (Bloch, 1782) (Actinopterygii, Cypriniformes, Cyprinidae, Alburninae) it is a freshwater, benthopelagic, autochthonous fish species in the Danube Basin. This species is protected under IUCN. (Antipa, 1909; Bănărescu, 1964; Romero, 2002)

Till the first half of the XXth century it accidentally occurred in the studied sector, at the confluences of the northern/Romanian tributaries (Berzasca, Radimna, Sirinia, Elişeva, Plavişeviţa, Mraconia, Eşelniţa, Cerna, Bahna, Cameniţa and Liuborajdea) and the southern/Serbian tributaries (Mlava, Pek, Porečka reka, Vratna, Zamna, Rečka), when tributaries were flooded. It has not been observed in the impounded section of the Danube. (Antipa, 1909; Antonescu, 1934; Bănărescu, 1964; Buşniţă, 1960, 1964; Niculescu-Duvăz, 1961, 1965; Vasiliu, 1959; Buşniţă and Alexandrescu, 1971; Schiemer et al., 2004; Buşniţă et al., 1970; Gheracopol et al., 1968)

Blicca bjoerkna (Linnaeus, 1758) (Actinopterygii, Cypriniformes, Cyprinidae, Leuciscinae) it is a freshwater, brackish, demersal, potamodromous, autochthonous fish species in the Danube Basin (Antipa, 1909; Bănărescu, 1964; Oțel, 2007).

The white bream is abundant in the studied area. (Antipa, 1909; Antonescu, 1934; Bănărescu, 1964; Bușniţă, 1960, 1964; Niculescu-Duvăz, 1961, 1965; Vasiliu, 1959; Bușniţă and Alexandrescu, 1971; Buşniţă et al., 1970; Gheracopol et al., 1968; Schiemer et al., 2004). It prefers the new slow flowing and stagnant aquatic habitats, created by the impoundments.

Abramis brama (Linnaeus, 1758) (Actinopterygii, Cypriniformes, Cyprinidae, Leuciscinae) it is a freshwater, brackish, benthopelagic, autochthonous fish species in the Danube Basin (Antipa, 1909; Bănărescu, 1964; Oțel, 2007; Vostradovsky, 1973).

The freshwater bream was abundant in the studied area in the XIXth and XXth centuries, and still is in the XXIst century (Antipa, 1909; Bănărescu, 1964; Bușniţă, 1960, 1964; Niculescu-Duvăz, 1961, 1965; Vasiliu, 1959; Bușniţă and Alexandrescu, 1971; Bușniţă et al., 1970; Gheracopol et al., 1968; Schiemer et al., 2004). It is a neutrophilic species, and the aquatic habitat modifications resulted its more intensive growth and earlier sexual maturation in the dammed river section (Janković, 1980). This species found favourable conditions in the newly formed reservoirs and showed increase in catch (Lenhardt et al., 2004).

Ballerus sapa (Pallas, 1814) (Actinopterygii, Cypriniformes, Cyprinidae, Leuciscinae) freshwater, brackish, benthopelagic, autochthonous species in the Danube Basin (Oțel, 2007).

The white-eye bream is a frequent species in the study area (Antipa, 1909; Antonescu, 1934; Bănărescu, 1964; Bușniţă, 1960, 1964; Niculescu-Duvăz, 1961, 1965; Vasiliu, 1959; Bușniţă and Alexandrescu, 1971; Bușniţă et al., 1970; Gheracopol et al., 1968; Schiemer et al., 2004). It prefers the slow flowing river sections.

Ballerus ballerus (Linnaeus, 1758) (Actinopterygii, Cypriniformes, Cyprinidae, Leuciscinae) it is a freshwater, brackish, benthopelagic, potamodromous, autochthonous fish species in the Danube Basin (Antipa, 1909; Bănărescu, 1964; Oțel, 2007).

It is frequent in the study area (Antipa, 1909; Antonescu, 1934; Bănărescu, 1964; Bușniţă, 1960, 1964; Niculescu-Duvăz, 1961, 1965; Vasiliu, 1959; Bușniţă et al., 1970; Gheracopol et al., 1968; Schiemer et al., 2004). It uses the slow flowing habitats.

Vimba vimba (Linnaeus, 1758) (Actinopterygii, Cypriniformes, Cyprinidae, Leuciscinae) it is a freshwater, brackish, benthopelagic, autochthonous fish species in the Danube Basin (Antipa, 1909; Bănărescu, 1964; Oțel, 2007; Bănărescu et al., 1963).

The vimba bream is abundant in the study area (Antipa, 1909; Antonescu, 1934; Bănărescu, 1964; Bușniţă, 1960, 1964; Niculescu-Duvăz, 1961, 1965; Vasiliu, 1959; Bănărescu et al., 1963; Bușniţă et al., 1970; Gheracopol et al., 1968; Schiemer et al., 2004). It is a semi-reophilic species, and its population has been stable since the dam constructions.

Pelecus cultratus (Linnaeus, 1758) (Actinopterygii, Cypriniformes, Cyprinidae, Leuciscinae) it is a freshwater, brackish, pelagic, anadromous, autochthonous fish species in the Danube Basin (Balon, 1956; Bănărescu, 1964; Bănărescu and Bănăduc, 2007; Oțel, 2007).

It can be permanently found in the studied area (Antipa, 1909; Antonescu, 1934; Balon, 1956; Bănărescu, 1964; Bușniţă, 1960, 1964; Niculescu-Duvăz, 1961, 1965; Vasiliu, 1959; Bușniţă and Alexandrescu, 1971; Bușniţă et al., 1970; Gheracopol et al., 1968; Schiemer et al., 2004). It is a semi-reophilic species, preferring large rivers sectors and big lakes. The aquatic habitat changes along the dammed river section have not created problems.

Chondrostoma nasus (Linnaeus, 1758) (Actinopterygii, Cypriniformes, Cyprinidae, Leuciscinae) it is a freshwater, benthopelagic, potamodromous, autochthonous fish species in the Danube Basin (Antipa, 1909; Bănărescu, 1964; Oțel, 2007; Simonović, 2006).

The nase is frequent in the study area, but have a decreasing trend in the XXIst century (Antipa, 1909; Antonescu, 1934; Bănărescu, 1964; Bușniță, 1960, 1964; Niculescu-Duvăz, 1961, 1965; Vasiliu, 1959; Bușniță and Alexandrescu, 1971; Bușniță et al., 1970; Gheracopol et al., 1968; Schiemer et al., 2004). It is a reophilic species, and impacts of the river engineering negatively affected its population.

Hypophthalmichthys molitrix (Valenciennes, 1844) (Actinopterygii, Cypriniformes, Cyprinidae, Xenocyprinae) it is a freshwater, benthopelagic, potamodromous, allochtonous fish species with its origin from Far East (Oţel, 2007; Riede, 2004; Skeleton, 1993; Staraș and Oţel, 1999).

The silver carp was introduced for aquaculture in Romania in the second half of the XXth century (in 1960 and 1962). It succeeded to spread in the Danube including the studied sector (Gavriloaie, 2007; Oţel, 2007; Staraș and Oţel, 1999; Schiemer et al., 2004). It prefers the slow flowing and stagnant water habitats. This species found favourable conditions in the newly formed reservoirs and showed increase in catch (Lenhardt et al., 2004).

Hypophthalmichthys nobilis (Richardson, 1845) (Actinopterygii, Cypriniformes, Cyprinidae, Xenocyprinae) it is a freshwater, benthopelagic, potamodromous, allochtonous fish species with its origin from Far East (Gavriloaie, 2007; Kottelat, 2001; Oţel, 2007; Romero, 2002).

The bighead carp was introduced for aquaculture in Romania in the second half of the XXth century (in 1960 and 1962). It is kept in aquaculture from the second half of the XXth century (in 1960 and 1962), and it successfully established in the Danube including the studied sector (Gavriloaie, 2007; Oţel, 2007; Schiemer et al., 2004). It prefers the slow flowing and lenitic habitats. This species found favourable conditions in the newly formed reservoirs and showed increase in catch (Lenhardt et al., 2004).

Ctenopharyngodon idella (Vallenciennes, 1844) (Actinopterygii, Cypriniformes, Cyprinidae, Squaliobarbinae) it is a freshwater, demersal, potamodromous, allochtonous species with Far East origin (Gavriloaie, 2007; Oţel, 2007; Riede, 2004; Schiemer et al., 2004).

The grass carp was introduced for aquaculture purposes in Romania in the second half of the XXth century (in 1960 and 1962) (Gavriloaie, 2007) and in Serbia in 1963 and spread into the Danube, but even there was one record of one year old specimens in the Danube River in investigated sector in 1991 (Jankovic, 1998) there is assumption that only acclimatization of adults is possible with no possibility for natural spawning. This species found favourable conditions in the newly formed reservoirs and showed increase in catch (Lenhardt et al., 2004).

Rhodeus sericeus (Pallas, 1776) (Actinopterygii, Cypriniformes, Cyprinidae, Acheilognathinae) it is a freshwater, benthopelagic, autochthonous fish species in the Danube Basin. This species is protected under Bern Convention, Habitats Directive, CITES and IUCN. (Antipa, 1909; Bănărescu, 1964; Romero, 2002; Oțel, 2007; Bănărescu and Bănăduc, 2007)

The bitterling was missing in the XIXth and the first part of the XXth centuries and was registered in the second part of the XXth and first part of the XXIst centuries in the studied area (Antipa, 1909; Antonescu, 1934; Bănărescu, 1964; Bușniţă, 1960; Niculescu-Duvăz, 1961, 1965; Vasiliu, 1959; Bușniţă and Alexandrescu, 1971; Gheracopol et al., 1968; Schiemer et al., 2004). It is advantaged by stagnant water habitats with sandy and muddy substrata along the impounded section of the Danube.

Romanogobio albipinnatus (Lukasch, 1933) (Actinopterygii, Cypriniformes, Cyprinidae, Gobioninae) it is a freshwater, benthopelagic, autochthonous fish species in the Danube Basin. This species is protected under Bern Convention, Habitats Directive, CITES and IUCN. (Bănărescu, 1964; Nowak et al., 2006; Oțel, 2007; Bănărescu and Bănăduc, 2007)

The white-finned gudgeon was and is a common species in the studied area in the XIXth, XXth and XXIst centuries (Bănăduc, 2003; Bănărescu, 1952, 1956b, 1964, 1994a; Niculescu-Duvăz, 1961, 1965; Balon et al., 1988; Buşniţă et al., 1970; Gheracopol et al., 1968; Schiemer et al., 2004). It prefers the low water flow with sandy substrata habitats.

Pseudorasbora parva (Temminck and Schlegel, 1846) (Actinopterygii, Cypriniformes, Cyprinidae, Gobioninae) it is a freshwater, benthopelagic, allochtonous fish species with origin from Far East (Bănărescu, 1964; Oțel, 2007; Kottelat and Freyhof, 2007).

The stone moroko was missing in the XIXth and in the XXth centuries in the studied area, it was accidentally introduced in the Danube Basin in the 1960s and found here in the XXIst century (Bănărescu, 1964; Cakić et al., 2004; Gavriloaie, 2007; Gheracopol et al., 1968; Schiemer et al., 2004). This invasive species was accidentally introduced in the Danube Basin in 1960s. Is advantaged by stagnant and low speed flowing water habitats, and tolerates the eutrophic water quality.

Barbus barbus (Linnaeus, 1758) (Actinopterygii, Cypriniformes, Cyprinidae, Barbinae) it is a freshwater, benthopelagic, potamodromous, autochthonous fish species in the Danube Basin. This species is protected under CITES and IUCN. (Bănărescu, 1964; Oțel, 2007; Romero, 2002)

The barbel was and is abundant in the studied area in the XIXth, XXth and XXIst centuries (Antipa, 1909; Antonescu, 1934; Bănărescu, 1964; Niculescu-Duvăz, 1961, 1965; Simonović, 2006; Bușniță and Alexandrescu, 1971; Buşniţă et al., 1970; Gheracopol et al., 1968; Schiemer et al., 2004). It prefers the deep and moderately water flowing sectors of rivers.

Barbus meridionalis Risso, 1827, (Actinopterygii, Cypriniformes, Cyprinidae, Barbinae) it is a freshwater benthopelagic, autochthonous fish species in the Danube Basin (Bănărescu, 1964; Romero, 2002; Bănărescu and Bănăduc, 2007).

Till the first part of the XXth century the Mediterranean barbel was present only accidentally in the studied sector, in the confluences with tributaries areas, coming at high floods from the local northern/Romanian tributaries (Berzasca, Sirinia, Elişeva, Tişoviţa, Plavişeviţa, Mraconia, Eşelniţa, Cerna, and Bahna rivers) (Buşniţă et al., 1970). After that period such captures in the new Danube lake environment were no more registered, both on the Romanian and Serbian banks. Its reophilic and good water oxygenation preferences explain its missing in the area of interest after the two big lakes appearances.

Cyprinus carpio Linnaeus, 1758 (Actinopterygii, Cypriniformes, Cyprinidae) it is a freshwater, brackish, benthopelagic, potamodromous, autochthonous species in the Danube Basin (Bănărescu, 1964; Gavriloaie, 2007; Oțel, 2007; Riede, 2004).

The common carp was and is frequent in the studied area in the XIXth, XXth and XXIst centuries (Antipa, 1909; Antonescu, 1934; Bănărescu, 1964; Niculescu-Duvăz, 1961, 1965; Simonović, 2006; Bușniță and Alexandrescu, 1971; Bușniţă et al., 1970; Gheracopol et al., 1968; Schiemer et al., 2004). The decreasing in many river sectors of the water flowing speed and the increasing of the water depth and temperature was an advantage for this species.

Carassius carassius (Linnaeus, 1758) (Actinopterygii, Cypriniformes, Cyprinidae, Cyprinae) it is a freshwater, brackish, demersal, autochthonous fish species in the Danube Basin (Bănărescu, 1964, 2005; Oțel, 2007; Riede, 2004; Romero, 2002).

The crucian carp was present in the studied area in the XIXth century and the first part of the XXth century with a decreasing trend in the second part of the XXth century and in the XXIst century. The concurrence of this species with *Carassius gibelio*, water eutrophication which induced the decreasing of aquatic vegetation, useful as food and for reproduction (Antipa, 1909; Bănărescu, 1964, 1994b, 2005; Bușniță, 1938; Stănicioiu, 1978; Buşniţă et al., 1970; Schiemer et al., 2004). Its decreasing trend can be explained by the competition pressure of the *Carassius gibelio* and eutrophication.

Carassius gibelio (Bloch, 1782) (Actinopterygii, Cypriniformes, Cyprinidae, Cyprinae) it is a freshwater, brackish, benthopelagic, allochtonous fish species (Bănărescu, 1964; Gavriloaie, 2007; Oțel, 2007; Riede, 2004; Romero, 2002).

The Prussian carp was missing in the studied area in the XIXth century, and appeared in XXth century and extended in the XXIst century (Antipa, 1909; Bănărescu, 1964; Bușniță, 1938; Bușniță and Cristian, 1958; Schiemer et al., 2004). The new slow flowing and stagnant habitats created by impoundments advantaged this fish species.

Phoxinus phoxinus Linnaeus, 1758, (Actinopterygii, Cypriniformes, Cyprinidae, Leuciscinae) it is a freshwater, demersal and autochthonous fish species in the Danube Basin (Riede, 2004; Romero, 2002; Buşniţă et al., 1970).

Till the first half of the XXth century the Eurasian minnow was present only accidentally in the studied sector, washed from Cerna River, in the confluence area with this tributary. After that period such captures in the new Danube lake environment were no more registered, both on the Romanian and Serbian banks. The increasing of the water temperature and the decreasing of the water oxygen content did not favourise this species after the lakes formation. Since the dams construction this species disappeared along the study area, due to significant changes of fluvial habitats.

Misgurnus fossilis (Linnaeus, 1758) (Actinopterygii, Cypriniformes, Cobitidae, Cobitinae) it is a freshwater, demersal and autochthonous fish species in the Danube Basin area (Bănărescu, 1964; Oțel, 2007; Riede, 2004; Bănărescu and Bănăduc, 2007; Buşniţă et al., 1970).

The weatherfish was and still is present in the studied area in the XIXth, XXth and XXIst centuries (Antipa, 1909; Antonescu, 1934; Bănărescu, 1964; Bușniță and Alexandrescu, 1971; Buşniţă et al., 1970; Schiemer et al., 2004). This fish species is advantaged by the presence of stagnant or slow flowing water habitats with dense aquatic vegetation and muddy substrata.

Cobitis taenia Linnaeus, 1758 (Actinopterygii, Cypriniformes, Cobitidae, Cobitinae) it is a freshwater, demersal, autochthonous fish species in the Danube Basin (Bănărescu, 1964; Nalbant, 1963, 1994b; Riede, 2004; Romero, 2002; Vostradovsky, 1973; Bănărescu and Bănăduc, 2007).

The spined loach was and still is present in the "Iron Gates" researched area in the XIXth and XXth centuries, with a decreasing trend in the XXIst century (Bănărescu, 1964; Buşniţă et al., 1970; Nalbant, 1963, 1994). This fish species prefer usually the slow-flowing and still water habitats with soft fine sandy substrate, being advantaged by the new lenitic habitats.

Sabanejewia bulgarica (Drensky, 1928) (Actinopterygii, Cypriniformes, Cobitidae, Cobitinae) it is a freshwater and demersal, autochthonous fish species in the Danube Basin (Bănărescu, 1964; Nalbant, 1963, 1994; Oțel, 2007; Baensch and Riehl, 1991, 1995; Buşniţă and Băcescu, 1946; Buşniţă et al., 1970).

This species was and still is frequent in the studied area in the XIXth and XXth centuries, with a decreasing trend in XXIst century (Bănărescu, 1964; Nalbant, 1963, 1994). This species prefer deep sectors and flowing river stretches with sandy gravel substrate.

Silurus glanis Linnaeus, 1758 (Actinopterygii, Siluriformes, Siluridae) it is a freshwater, brackish, benthopelagic, non-migratory, autochthonous fish species in the Danube Basin (Antipa, 1909; Bănărescu, 1964; Frimodt, 1995; Oțel, 2007; Romero, 2002).

The wels catfish was and still is frequent in the studied area in the XIXth, XXth and XXIst centuries (Antonescu, 1934; Bănărescu, 1964; Niculescu-Duvăz, 1961, 1965; Simonović, 2006; Bușniță and Alexandrescu, 1971; Buşniţă et al., 1970; Gheracopol et al., 1968; Schiemer et al., 2004). It prefers the deep sectors along free flowing impounded sectors.

Ameiurus melas (Rafinesque, 1820) (Actinopterygii, Siluriformes, Ictaluridae) is a freshwater, demersal, allochtonous fish species with origin from North America which first introduction in Europe occured in the second half of the XX century (1871) (Bănărescu, 1964; Gavriloaie, 2007).

Due to the fact that this species prefers standing and muddy water, the construction of dams and formation of reservoirs contribute to the black bullhead spreading in the studied sector of the Danube River.

Anguilla anguilla (Linnaeus, 1758), (Actinopterygii, Anguilliformes, Anguillidae) it is a marine, freshwater and brackish (eurihaline), demersal, catadromous, autochthonous fish species in the Danube Basin (Antipa, 1909; Bănărescu, 1964; Oțel, 2007; Riede, 2004).

The European eel was and it is still present in the studied area in the XIXth, XXth and XXIst centuries (Antonescu, 1934; Bănărescu, 1964; Zinevici, 1967; Schiemer et al., 2004). It was also introduced to several water bodies in the Danube Basin during the second half of the XXth century. It can be found both in flowing and stagnant waters and migratory individuals may come from the upstream of the study area.

Lota lota (Linnaeus, 1758) (Actinopterygii, Gadiformes, Lotidae) it is a freshwater, brackish, demersal, potamodromous, autochthonous fish species in the Danube Basin (Antipa, 1909; Bănărescu, 1964, 2005; Oțel, 2007; Romero, 2002; Cohen et al., 1990).

The burbot was and is still present in the researched area in the XIXth, XXth and XXIst centuries. Its abundance is decreasing probably due to impoundments, water pollution and poaching. (Antonescu, 1934; Bănărescu, 1964, 1994a, 2005; Bușniță, 1960; Niculescu-Duvăz, 1961, 1965; Gheracopol et al., 1968; Schiemer et al., 2004) In the studied area it occurs in slow flowing deep sectors of the free flowing and the impounded river sections.

Pungitius platigaster (Kessler, 1859) (Actinopterygii, Gasterosteiformes, Gasterosteidae) it is a marine, freshwater, brackish, benthopelagic, autochthonous fish species in the Danube Basin (Bănărescu, 1964; Oțel, 2007; Romero, 2002).

The southern ninespine stickleback was present in the studied area in the XIXth century and the first half of the XXth century with no registrations in the second half of the XXth century and in the XXIst century (Bănărescu, 1964; Schiemer et al., 2004). This species prefers shallow stagnant water habitats.

Syngnathus abaster Risso, 1827 (Actinopterygii, Syngnathiformes, Syngnathidae) it is a marine, brackish, freshwater, autochthonous fish species in the Danube Basin (Nelson, 1994; Oțel, 2007).

The black-striped pipefish was absent in the XIXth century in the area of interest, but was found by the authors of this paper in the XIX and XX centuries, in 1997 and 1998 in Serbian part of investigated sector, when 57 specimens were caught in Tekija (km 956), Kladovo (km 934), Korbovo (km 910) and downstream of the "Iron Gates" II on km 862 and in Romanian sector in 2015 upstream of the "Iron Gates" II. (Antipa, 1909; Bănărescu, 1964; Sekulić et al., 1999; Second Joint Danube Survey Expedition)

Lepomis gibbosus (Linnaeus, 1758) (Actinopterygii, Perciformes, Centrarchidae) it is a freshwater, brackish, benthopelagic, potamodromous, allochtonous fish species with origin from North America, it was introduced in Europe as ornamental species in 1877 in France and in 1881 in Germany (Bănărescu, 1964; Riede, 2004; Romero, 2002; Buşniţă et al., 1970; Gavriloaie et al., 2007; Oțel, 2007).

The pumpkinseed was absent in the XIXth century and the first part of the XXth century and was introduced to the Middle Danube Basin at the end of the XIXth century, appeared in the studied area in the second half of the XXth century and it is present with significant abundance in the XXIst century (Antipa, 1909; Buşniţă et al., 1970; Gavriloaie et al., 2007).

Perca fluviatilis Linnaeus, 1758 (Actinopterygii, Perciformes, Percidae, Percinae) it is a freshwater, brackish, demersal and autochthonous fish species in the Danube Basin (Antipa, 1909; Bănărescu, 1964; Oțel, 2007; Riede, 2004).

The European perch was and is frequent in the studied area in the XIXth, XXth and XXIst centuries (Antonescu, 1934; Bănărescu, 1964; Bușniță, 1960; Niculescu-Duvăz, 1961, 1965; Simonović, 2006; Bușniță and Alexandrescu, 1971; Gheracopol et al., 1968; Schiemer et al., 2004). This neutrophilic fish species can be found in medium and large size lowland rivers characterised especially by low flow velocity and in several types of stagnant waters.

Gymnocephalus cernua (Linnaeus, 1758) (Actinopterygii, Perciformes, Percidae, Percinae) it is a freshwater, brackish, demersal and autochthonous fish species in the Danube Basin (Antipa, 1909; Bănărescu, 1964; Oțel, 2007; Riede, 2004; Romero, 2002; Buşniţă et al., 1970).

The ruffe was and is frequent in the studied area in the XIXth, XXth and XXIst centuries (Bănărescu, 1964; Niculescu-Duvăz, 1961, 1965; Gheracopol et al., 1968; Schiemer et al., 2004). This species prefers still freshwater of slow-flowing rivers with fine sediments, it can tolerate eutrophic waters.

Gymnocephalus schraetser (Linnaeus, 1758) (Actinopterygii, Perciformes, Percidae, Percinae) it is a freshwater, demersal and autochthonous fish species in the Danube Basin (Bănărescu, 1964, 1994a, 2005; Oțel, 2007; Romero, 2002; Bănărescu and Bănăduc, 2007; Holčik and Hensel, 1974).

The schraetzer was and is present in the studied area in the XIXth, XXth and XXIst centuries. This species was negatively affected by the water pollution and extensive river engineering (Bănărescu, 1964, 1994a, 2005; Holčik and Hensel, 1974; Schiemer et al., 2004). It is a reophilic species and avoids the stagnant water.

Gymnocephalus baloni Holčic and Hensel, 1974 (Actinopterygii, Perciformes, Percidae, Percinae) it is a freshwater, benthopelagic and autochthonous fish species in the Danube Basin (Bănărescu, 1994b, 2005; Oțel, 2007; Romero, 2002; Bănărescu and Bănăduc, 2007; Holčik and Hensel, 1974).

The Danube ruffe was identified in the studied area at the end of the XXth century and at the beginning of the XXIst century, but probably it was continuously present (Bănărescu, 2005; Oţel, 2007; Schiemer et al., 2004). It is reophilic and prefers the flowing fluvial habitats.

Sander lucioperca (Linnaeus, 1758) (Actinopterygii, Perciformes, Percidae, Luciopercinae) it is a freshwater, brackish, pelagic, potamodromous, autochthonous fish species in the Danube Basin (Antipa, 1909; Bănărescu, 1964; Oţel, 2007; Riede, 2004).

The pike-perch was and is frequent in the studied area in the XIXth, XXth and XXIst centuries (Bănărescu, 1964; Bușniță, 1960; Niculescu-Duvăz, 1961, 1965; Simonović, 2006; Bușniță and Alexandrescu, 1971; Buşniţă et al., 1970; Gheracopol et al., 1968; Schiemer et al., 2004). It is a neutrophilic species, and prefers the higher turbidity in the lowland rivers and eutrophic lakes.

Sander volgensis (Gmelin, 1789) (Actinopterygii, Perciformes, Percidae, Luciopercinae) it is a freshwater, brackish, demersal, autochthonous fish species in the Danube Basin (Antipa, 1909; Bănărescu, 1964; Oţel, 2007).

Occurrence of the Volga pike-perch was and is present in the studied area in the XXth and XXIst centuries, but probably it was continuously present in the study area including in the XIXth century too. It is sensitive to habitat modifications and deterioration, of water quality. (Antipa, 1909; Bănărescu, 1964, 2005; Oţel, 2007)

Zingel streber (Siebold, 1863) (Actinopterygii, Perciformes, Percidae, Luciopercinae) it is a freshwater, demersal and autochthonous fish species in the Danube Basin (Bănărescu, 1964, 2005; Bănărescu and Bănăduc, 2007; Oțel, 2007; Romero, 2002).

The Danube streber species was and is relatively frequent in the studied area in the XIXth and XXth centuries, with a decreasing trend in the XXIst century (Antipa, 1909; Bănărescu, 1964, 1994b, 2005; Bușniță, 1960; Bănărescu and Nalbant, 1979; Buşniţă et al., 1970; Schiemer et al., 2004). It is negatively affected by water pollution and extensive river engineering.

Zingel zingel (Linnaeus, 1766) (Actinopterygii, Perciformes, Percidae, Luciopercinae) it is a freshwater, demersal and autochthonous fish species in the Danube Basin (Bănărescu, 1964, 2005; Oțel, 2007; Romero, 2002; Bănărescu and Bănăduc, 2007; Buşniţă et al., 1970).

The zingel was and is present in the studied area in the XIXth, XXth and XXIst centuries (Antipa, 1909; Bănărescu, 1964, 1994b, 2005; Bușniță, 1960; Schiemer et al., 2004). This fish species it is negatively influenced by the water pollution and extensive river engineering.

Benthophilus stellatus (Sauvage, 1874) (Actinopterygii, Perciformes, Gobiidae, Gobiinae) it is a freshwater, brackish, demersal and autochthonous species in the Danube Basin (Oţel, 2007; Romero, 2002).

The stellate tadpole-goby was absent in the XIXth and XXth centuries in the area of interest, but the first specimen was found in the XXIst century by the authors of this paper (Antipa, 1909; Bănărescu, 1964). It is a neutrophilic species, which prefers soft muddy substrate.

Neogobius fluviatilis (Pallas, 1814) (Actinopterygii, Perciformes, Gobiidae, Gobiinae) it is a freshwater, brackish, benthopelagic, autochthonous species in the Danube Basin (Oţel, 2007; Romero, 2002).

The monkey goby was absent in the XIXth and XXth centuries in the area of interest, but the first specimen was found in the XXIst century by the authors of this paper, and his spreading in the middle Danube Basin has been known since the 1970s (Antipa, 1909; Bănărescu, 1964; Djikanović et al., 2013; Marković et al., 2015). It is a neutrophilic species, which prefers the lowland rivers and lakes with sandy bottom.

Ponticola kessleri (Günther, 1861) (Actinopterygii, Perciformes, Gobiidae, Gobiinae) it is a freshwater, brackish, benthopelagic, autochthonous fish species in the Danube Basin (Bănărescu, 1964; Oţel, 2007; Buşniţă et al., 1970).

The bighead goby was and is present in the studied area in the XIXth, XXth and XXIst centuries (Antipa, 1909; Bănărescu, 1964; Oţel, 2007; Buşniţă et al., 1970; Marković et al., 2015; Schiemer et al., 2004). It is a neutrophilic species, which prefers lowland rivers and lakes with average water depths, and rocky or gravel substrata.

Neogobius melanostomus (Pallas, 1814) (Actinopterygii, Perciformes, Gobiidae, Gobiinae) it is a marine, freshwater, brackish, demersal, amphidromous and autochthonous species in the Danube Basin (Kottelat, 1997; Kvach and Skóra, 2006; Marković et al., 2015).

The round goby was absent in the studied area in the XIXth century and the first part of the XXth century and appeared in the last part of the XXth century. It is still present. (Oţel, 2007; Marković et al., 2015; Schiemer et al., 2004) It is a neutrophilic species and prefers lowland rivers and lakes with different types of substrates from sandy gravel to rocks.

Babka gymnotrachelus (Kessler, 1857) (Actinopterygii, Perciformes, Gobiidae, Gobiinae) it is a freshwater, brackish, benthopelagic and autochthonous species in the Danube Basin (Oţel, 2007).

The authors (unpublished data) collected racer goby in October 2012 upstream of "Iron Gates" I and downstream of "Iron Gates" II. Its spreading in the studied area was induced by its preference for slow flowing habitats with muddy substrata and alteration on the riverine environment by damming (Oţel, 2007).

Perccottus glenii Dyubowski, 1877 (Actinopterygii, Perciformes, Odontobutidae) is allochthonous, freshwater, brackish, demersal and allochtonous species with Asian origin (Hegediš et al., 2007).

The Chinese sleeper first introduction in Europe dates from the XX century in 1912 (Reshetnikov, 2004), spread downstream from the Tisza River tributaries to the Tisza River and consequently, along the Danube River reach the Romanian, Serbian and Bulgarian part of the Danube (Hegediš et al., 2007; Nalbant et al., 2004; Zorić et al., 2014). Due to its preferences to stagnant water with silty substrata and dense vegetation (Nikolskii, 1956) there are records of this species in the studied area at river kilometre 1,047 (Šipoš et al., 2004).

Cottus gobio Linnaeus, 1758, (Actinopterygii, Scorpaeniformes, Cottidae) it is a freshwater, brackish, demersal and in the Danube Basin autochthonous fish species (Antipa, 1909; Bănărescu, 1964; Riede, 2004; Romero, 2002; Bănărescu and Bănăduc, 2007).

Till the first part of the XXth century the bullhead was present accidentally, washed from Cerna River, in the confluence area with this tributary. After that period such captures in the new Danube lake environment were no more registered, due to the lenitic and semi-lenitic aquatic habitats replacing the lenitic ones after the dams' construction. (Buşniţă et al., 1970)

CONCLUSIONS

In the last century, the Lower Danube aquatic environment diverseness, conservative and economic valuable fish variety and stocks abundance diminished in a considerable way and there were no signs that this tendency will end in the near future (Bănăduc et al., 2016).

The "Porţile de Fier/Iron Gates" Lower Danube sector is not an exception, at least from the qualitative point of view, the aquatic habitats and their fish fauna were seriously modified by hidrotechnical works, pollution, fish populations overexploitation and last but not least poachery.

One of the most important changes in the "Iron Gates" sector ichthyofauna is represented by the decrease of autochthonous economically and culturally important anadromous fish species (sturgeons and shads) and increase in catch of allochthonous fish species.

The "Porţile de Fier/Iron Gates" Gorge Danube area fish fauna can be still considered as a rich and complex one (65 fish species, belonging to: Acipenseridae, Polyodontidae, Clupeidae, Salmonidae, Esocidae, Cyprinidae, Cobitidae, Siluridae, Ictaluridae, Anguillidae, Lotidae, Gasterosteidae, Syngnathidae, Centrarchidae, Percidae, Gobiidae, Odontobutidae and Cottidae) with a high dynamic in the last centuries, and significant changes in this respect.

The major hidrotechnical works, pollution, fish populations overexploitation and poachery, induced drastically changes in the fish communities structure. This fact is revealed obviously by the transformation of the past lotic sterlet subzone of the carp zone (Buşniţă et al., 1970) to an actual barbell subzone of the carp zone. In this respect, the dominant species in the "Iron Gates" Gorge, the high rheophilic *Acipenser ruthenus*, was replaced by the moderate rheophilic *Barbus barbus*.

The initial significant differences among the fish communities of the "Iron Gates" area and the upstream and downstream Danube sectors of the area of interest are uniformised, in the detriment of the accentuated rheophilic species.

Improvements can be realised if the national and international authorities in this field of activities will became efficient in fish communities monitoring and management, including their habitat management.

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REFERENCES

1. Antipa G., 1909 – Fauna ihtiologică a României, Publicaţiile Fondului Adamachi, 294. (in Romanian)
2. Antipa G., 1910 – Regiunea inundabilă a Dunării. Starea ei actuală şi mijloacele de a o pune în valoare, Bucureşti, XII, 318. (in Romanian)
3. Antipa G., 1934 – Les Sturions de la Mer Noire, 16, 67-83. (in French)
4. Antonescu C., 1934 – Peştii apelor interioare din România, Bucureşti, 80. (in Romanian)
5. Antonescu C., 1957 – Peştii din apele R. P. Române, Bucureşti, Edit. Agrosilvică, 213. (in Romanian)
6. Antoniu-Murgoci A., 1936 – Observations concernant l'Acipenser sturio de la Mer Noire, 109-116. (in French)
7. Arratia G. and Mayden R. L., 2004 – Implications for the phylogenetic reconstruction of relationships of Cypriniformes using combined fossil and recent evidence, XI European Congress of Ichthyology, Abstract, 101.
8. Atkins C. G. and Foster N., 1874 – Obstructions to the upward movement of fishes in streams, and the remedy, in US Commission of Fish and Fisheries, II, Report of the Commissioner for 1872 and 1873, appendix E, XXIII and XXIV, Government Printing Office, Washington, DC, 589-621.
9. Bacalbaşa N. and Petcu A., 1969 – Pescuitul cu sacoviştea în zona viitorului lac de acumulare de la Porţile de Fier, *Hidrobiologia,* 10. (in Romanian)
Bacalbaşa-Dobrovici N., 1991 – Fish population evolution (1985-1988) in the last Danube built Reservoir Iron Gates II, *Verhandlungen des Internationalen Verein Limnologie*, 24, 2524-2527.
10. Bacalbaşa-Dobrovici N., 1995 – Este cazul să se construiască trecători pentru speciile migratoare şi migratoare pe Dunăre şi Siret? *Analele Ştiinţifice ale Institutului Delta Dunării*, VI, 1, 2015-218. (in Romanian)
11. Badea L. and Bugă D. (coord.), 1992 – Geografia României, IV, Regiunile pericarpatice, Edit. Academiei Române, Bucureşti, 580. (in Romanian)
12. Baensch H. A. and Riehl R., 1991 – Aquarien atlas, Bd. 3. Melle: Mergus, Verlag für Natur-und Heimtierkunde, Germany, 1104. (in German)
13. Baensch H. A. and Riehl R., 1995 – Aquarien Atlas, Band 4. Mergus Verlag GmbH, Verlag für Natur-und Heimtierkunde, Melle, Germany, 864. (in German)
14. Balon E. K., 1964 – Verzeichnis und ökologische Charakteristik der Fische der Donau, *Hydrobiologia*, 24, 441-451. (in German)
15. Balon E., 1956 – Prispevok k systematike, ekológii, morfológii, veku, raštu a počtu ikier u săble krivočiarej (Pelecus cultratus L.) z Dunaja pri Medvedove, 61-88. (in Slovak)
16. Balon E., Crawford S. and Lelek A., 1988 – Is the occurrence of Gobio albipinnatus Lukasch 1933 in the upper Danube a result of upriver invasion or sympatric speciation? *Senckenbergiana biologica*, 68, 4, 6, Frankfurt am Main, 275-299.
17. Balon E. K., 2004 – About the oldest domesticates among fishes, *Journal of Fish Biology*, 65 (Supplement A), 1-27.
18. Banu A. C., 1967a – Date geografice şi geologice asupra bazinului şi cursului inferior al Dunării, în Limnologia sectorului românesc al Dunării – Studiu monographic, Edit. Academiei Române, Bucureşti. (in Romanian)
19. Banu A. C., 1967b – Caractere climatice în Limnologia sectorului românesc al Dunării – Studiu monographic, Edit. Academiei Române, Bucureşti, 652. (in Romanian)
20. Bartosiewicz L., 1997 – Őskori vizahalászat a Duna vaskapui szakaszán. (Prehistoric sturgeon fishing in the "Iron Gates" Gorge), *Halászatfejlesztés,* 30, 92-104. (in Hungarian)
21. Bartosiewicz L. and Bonsall C., 2004 – Prehistoric fishing along the Danube, *Antaeus*, 27, 253-272.

22. Bauchot M. L., 1987 – Fiches FAO d'identification pour les besoins de la pêche, Poissons osseux, 891-1421 in Fischer W., Bauchot M. L. and Schneider M. (eds), (rev. 1), Méditerranée et mer Noire, Zone de pêche 37, II, Commission des Communautés Européennes and FAO, Rome. (in French)
23. Băcescu M., 1944 – Urme de faună marină în apele Dunării la Cazanele şi Porţile de Fier, *Revista Ştiinţifică „Vasile Adamachi"*, Iaşi, 30. (in Romanian)
24. Bănăduc D., 2003 – Contribuţii la morfologia şi biologia speciilor genului Gobio (Gobioninea, Cyprinidae, Pisces) în România, PhD thesis, 225. (in Romanian)
25. Bănărescu P. M., 2005 – Pisces (Peşti), in Cartea Roşie a Vertebratelor din România/The Red Book of Vertebrates of Romania, Botnariuc N., and Tatole V. (eds), Bucureşti, 215-255. (in Romanian)
26. Bănărescu P. M., 1952 – Studiu biometric şi sistematic al ciprinidului Gobio albipinnatus Lukas (inclusiv G. belingi Slast.) din bazinul Dunării, *Studii şi Cercetări Ştiinţifice*, III, 1-2, 246-263. (in Romanian)
27. Bănărescu P. M., 1956a – Genul Leuciscus (Pisces, Cyprinidae) în apele româneşti, *Analele Ştiinţifice ale Instututului de Cercetare şi Pescuit*, I, IV, 273-287. (in Romanian)
28. Bănărescu P. M., 1956b – Importanţa speciilor de Gobio ca indicatori de zone biologice în râuri, *Buletinul Institutului de Cercetare şi Pescuit*, 15, 3, 53-56. (in Romanian)
29. Bănărescu P. M., 1957 – Analiza zoogeografică a faunei ihtiologice a R. P. România, *Probleme de zoogeografie*, 5, 199-215. (in Romanian)
30. Bănărescu P. M., Papadopol M. and Müller G., 1963 – Le genre Vimba (Pisces, Cyprinidae) dans le bassin du Danube, *Travaux du Muséum National d'Histoire Naturelle "Grigore Antipa"*, 4, 381-400. (in French)
31. Bănărescu P., 1964 – Fauna Republicii Populare România, Pisces-Osteichthyes, XIII, Edit. Acad. Republicii Populare România, Bucureşti, 962. (in Romanian)
32. Bănărescu P. M. and Bănăduc D., 2007 – Habitats Directive (92/43/EEC) fish species (Osteichthyes) on the Romanian territory, *Acta Ichtiologica Romanica*, II, 43-78.
33. Bănărescu P. and Nalbant T., 1979 – Zingel streber nerensis subspecies nova, from South Banat, Romania, *Travaux du Muséum National d'Histoire Naturelle "Grigore Antipa"*, 20, 361-366.
34. Bănărescu P. M., 1993 – Considerations on the threatened freshwater fishes of Europe, *Ocrotirea Naturii şi a Mediului Înconjurător*, 37, 2, 87-98.
35. Bănărescu P. M., 1994a – On the presumed origin of Gobio albipinnatus Lukash, in the upper Danube by simpatric speciation, *Senckenbergiana biologica*, 73, 1-2, 49-55, Frankfurt am Main.
36. Bănărescu P. M., 1994b – The present-day conservation status of the freshwater fish fauna of Romania, *Ocrotirea Naturii şi a Mediului Înconjurător*, 38, 1, 1-16.
37. Bănărescu P. M., 2004 – Situaţia actuală a ihtiofaunei de apă dulce a României sub aspect faunistic, taxonomic şi al protecţiei, *Studia Universitatis Vasile Goldiş Arad, Seria Ştiinţele Vieţii*, 14, 43-49. (in Romanian)
38. Berg L. S., 1932 – Übersicht der Verbreitung der Süsswasserfische Europas, *Zoogeographica*, 1, 107-208. (in German)
39. Berg L. S., 1962 – Freshwater fishes of the U.S.S.R. and adjacent countries, 1, 4th edition, Israel Program for Scientific Translations Ltd, Jerusalem. (Russian version published in 1948).
40. Birstein V. J., 1993 – Sturgeons and paddlefishes: threatened fishes in need of conservation, *Conservation Biology*, 7, 773-787.
41. Borcea I., 1934 – Les Clupeides de la region littorale roumanie de la Mer Noir et des eaux interieures, *Annales Scientifiques de Université de Jassy*, 22, 306-344. (in French)

42. Borcea I., 1937 – Les Caspialoses de la Mer Noire, *Compte endus de l'Academie des Science Roumanie*, 1, 26-28. (in French)
43. Brînzan T. (ed.), 2012 – Natura 2000 în România, 256. (in Romanian)
44. Brînzan T. (ed.), 2013 – Catalogul habitatelor, speciilor și siturilor Natura 2000 în România, 784. (in Romanian)
45. Bușniță T., 1937 – Ihtiofauna, în Limnologia sectorului Românesc al Dunării – Studiu monographic, Edit. Academiei, Bucureşti. (in Romanian)
46. Buşniţă T., 1938 – Genul Carassius în apele României, Jub. Grigore Antipa, Hommage à son ceuvre, Bucureşti, 119-131. (in Romanian)
47. Buşniţă T. and Băcescu M., 1946 – Cobitis bulgarica Drensky, un poisson nouveau pour la faune de la Roumanie, *Notationes biologicae*, 4. (in French)
48. Bușniță T., 1953 – Problema sturionilor și clupeidelor din Marea Neagră, 12, 4, 5-12. (in Romanian)
49. Buşniţă T. and Cristian A., 1958 – Variaţia carasului argintiu (Carassius auratus gibelio) în apele româneşti şi cauzele care o determină, *Studii şi Cercetări de Biologie, Seria Biologie Animală*, 10, 4, 299-319. (in Romanian)
50. Bușniță T., 1960 – Modificările ihtiofaunei Dunării de jos în ultimii 100 de ani, *Revue Roumaine de Biologie*, 5, 4. (in Romanian)
51. Bușniță T., 1964 – Modificările ihtiofaunei Dunării în eventualele lacuri de baraj care se vor construi în sectorul românesc, *Hidrobiologia*, 5. (in Romanian)
52. Bușniță T., Brezeanu T., Oltean M., Popescu-Marinescu V., Prunescu-Arion E., Bănărescu P. M., Bogatu D., Gheracopol O., Péterfi L. Ș. and Vasiliu G. A., 1970 – Monografia zonei Porților de Fier, Studiul hidrobiologic al Dunării și al afluenților săi, Edit. Academiei R. S. România, 266. (in Romanian)
53. Bușniță T. and Alexandrescu I., 1971 – Atlasul peștilor din apele R. S. România, Edit. Ceres, București, 132. (in Romanian)
54. Cakić P., Lenhardt M., Kolarević J., Mićković B. and Hegediš A., 2004 – Distribution of the Asian cyprinid Pseudorasbora parva in Serbia and Montenegro, *Journal of fish Biology*, 65, 5, 1431-1434.
55. Cautiş I., Iliescu M. and Maximov A., 1957 – Problema fondului de caspialose din Marea Neagră, *Buletinul Institutului de Cercetare şi Pescuit*, 16, 1, 47-56. (in Romanian)
56. Călinescu R., 1946 – Introducere în biogeografia României, București. (in Romanian)
57. Ciolac A., Răzlog G. and Cristea V., 2003 – Ecological aspects regarding marin migratory sturgeons in Romanian Danube River, Universitatea din Bacău, *Studii și Cercetări, Biologie*, 8, 109-113.
58. CITES, 2013 – Appendices I, II and III valid from 12 June 2013, UNEP.
59. Cohen D. M., Inada T., Iwamoto T. and Scialabba N., 1990 – Gadiform fishes of the world (Order Gadiformes), An annotated and illustrated catalogue of cods, hakes, grenadiers and other gadiform fishes known to date, FAO Fisheries Synopsis, 125, 10, Rome, FAO, 442.
60. Crossman E. J., 1996 – Taxonomy and distribution, in Craig J. F. (ed.) Pike biology and exploration, Chapman and Hall, London, 298, 1-11.
61. Dimitriu M., 1938 – Contribution à l'étude de la nourriture des sterlets (Acipenser ruthenus) du Danube, *Annalele Institutului Naţional de Zootehnie*, 6, 1-12. (in French)
62. Dinu A., 2010 – Mesolithic fish and fishermen of the Lower Danube ("Iron Gates"), *Documenta Praehistorica*, 37, 299-310.
63. Djikanović V., Marković G. and Skorić S., 2013 – New record of Neogobius fluviatilis (Pallas, 1814) (Gobiidae) in the Danube River basin (Serbia), *Archives of Biological Science Belgrade*, 65, 4, 1469-1472.
64. Dynesius M. and Nilsson C., 1994 – Fragmentation and floe regulation of river systems in the Northern third of the World, *Science*, 266, 5186, 753-762.

65. Frimodt C., 1995 – Multilingual illustrated guide to the world's commercial coldwater fish, Fishing News Books, Osney Mead, Oxford, England, 215.
66. Galik A., Haidvogl G., Bartosiewicz L., Guti G. and Jungwirth M., 2015 – Fish remains as a source to reconstruct long-term changes of fish communities in the Austrian and Hungarian Danube, *Aquatic Science*, 77, 3, 337-354.
67. Gavriloaie I., Meşter L. and Falka I., 2007 – Romanian researches on the species Lepomis gibbosus (Linnaeus, 1758) (Pisces, Centrarchidae), *Acta Ichtiologica Romanica*, I. 103-110
68. Gesner J., Freyhof J. and Kottelat M., 2010 – Acipenser gueldenstaedtii, Acipenser sturio, Acipenser ruthenus, Acipenser nudiventris, Huso huso, The IUCN Red List of Threatened Species (Version 2015, www.iucnredlist).
69. Gheracopol O., Selin M. and Gabriela M., 1968 – Ihtiofauna Dunării româneşti în porțiunea Baziaş (km 1075) – Orşova (km 966) – zona viitorului lac de acumulare Porțile de Fier, Edit. Academiei Republicii Socialiste România – Grupul de cercetări complexe Porțile de Fier (Craiova). (in Romanian)
70. Giurescu C. C., 1964 – Istoria pescuitului şi a pisciculturii în România, I, 389. (in Romanian)
71. Gourene G., Teugels G. G., Hugueny B. and Thys van den Audenaerde D. F. E., 1999 – Evaluation de la diversite' ichtyologique d'un bassin Ouest-African apre's la construction d'un barrage, *Cybium*, 23, 147-160. (in French)
72. Guti G., 2000 – A ponto-kaszpikus gébfélék (Gobiidae) terjedése a Közép-Duna térségében, *Hidrológiai Közlöny*, 80, 5-6, 303-305. (in Hungarian)
73. Guti G., 2006 – Past and present status of sturgeons in Hungary, in *Proceedings 36th International Conference of IAD*, Austrian Committee Danube Research/IAD, Vienna, 143-147.
74. Guti G., 2008 – Past and present status of sturgeons in Hungary and problems involving their conservation, *Fundamental and Applied Limnology/Archiv für Hydrobiologie*, Supplement 162, *Large Rivers*, 18, 1-2, 61-79.
75. Guti G., 2014 – Can Anadromous Sturgeon Populations be Restored in the Middle Danube River? *Acta Zoologica Bulgarica*, Supplement 7, 63-67.
76. Heckel R. and Kner R., 1858 – Die Süsserwasserfische der Österreichischen Monarchie mit Rücksicht an die angrezenden Länder, Leipzig W. Engelmann, 338. (in German)
77. Hegediš A., Lenhardt M., Mićković B., Cvijanović G., Jarić I. and Gačić Z., 2007 – Amur sleeper (Perccottus glenii Dubowski, 1877) spreading in the Danube River basin, *Journal of Applied Ichthyology*, 23, 705-706.
78. Herman O., 1887 – A magyar halászat könyve, I-II, A. K. M. Természettud, Társulat, Budapest, 860. (in Hungarian)
79. Holčik J. and Hensel K., 1974 – A new species og Gymnocephalus (Pisces: Percidae) from the Danube, with remarks on the Genus, *Copeia*, 2, 471-486.
80. Homei V., 1956 – Lostriţa (Hucho hucho) în apele noastre, *Ocrotirea naturii*, 2, 101-109. (in Romanian)
81. Humphries P. and Winemiller K. O., 2009 – Historical impacts on river fauna, shifting baselines, and challenges for restoration, *Bioscience*, 59, 8, 673-684.
82. IUCN, 2014 – IUCN Red List of Threatened Species, Version 2014.1., IUCN 2014. IUCN Red List of Threatened Species, Downloaded in June 2014.
83. Jancović D., 1958 – Ekologija dunavske kečige (Acipenser ruthenus L.), Biološki institut, Narodna Republika Srbija, 2. (in Serbian)
84. Janković D., 1980 – Ichthyofaunal situation in Djerdap artificial lakes and their better use for fishery, *Vodoprivreda*, 12, 93-95.
85 Jankovic D., Krpo J., Lenhardt M. and Hegediš A., 1994 – Ecological characteristics of the Danube fish species, in The Danube in Yugoslavia, Jankovic D. and Jovicic M., (eds), 159-173.

86. Jankovic D., 1998 – Natural reproduction by Asiatic herbivorous fishes in the Yugoslav section of the River Danube, *Italian Journal of Zoology*, 65, 2, 227-228.
87. Jaric I., Lenhardt M., Cvijanovic G. and Ebenhardt T., 2009 – Acipenser sturio and Acipenser nudiventris in the Danube – extant or extinct? *Journal of Applied Ichthyology*, 25, 137-141.
88. Karaman S., 1936 – Beitrag zur Kenntnis der Süsswasserfische Jugoslaviens, *Bulletin of Society of Science Skoplje, Natural Sciences*, 17, 5, 55-64. (in German)
89. Karaman S., 1952 – Beitrag zur Kenntnis der Süsswasserfische Jugoslaviens, Prir. Istrariveje Jugoslavie Akademija, 125-128. (in German)
90. Kolman R., 2011 – European Sturgeon, Acipenser sturio in Georgia.
91. Kottelat M., 1997 – European freshwater fishes, *Biologia*, 52, Supplement 5, 1-271.
92. Kottelat M., 2001 – Freshwater fishes of northern Vietnam, A preliminary check-list of the fishes known or expected to occur in northern Vietnam, Environment and Social Development Unit, East Asia and Pacific Region, The World Bank, 123.
93. Kottelat M. and Freyhof J., 2007 – Handbook of European freshwater fishes, Publications Kottelat, Cornol and Freyhof, Berlin, 646.
94. Kvach Y. and Skora K. E., 2006 – The comparative analysis of infection parameters of the round goby Neogobius melanostomus (Pallas) (Gobiidae: Osteichthyes) in the Gulf of Gdansk, Baltic Sea, Poland and the nortwestern Black Sea, Ukraine, *Acta Ichtiologica Romanica*, I, 141-152.
95. Lenhardt M., Cakić P. and Kolarević J., 2004 – Influence of the HEPS Djerdap I and Djerdap II dam construction on catch of economically important fish species in the Danube River, *Ecohydrology and Hydrobiology*, 4, 499-502.
96. Lenhardt M., Hegedis A., Mickovic B. and Visnjic-Jeftic Z., 2006 – First record of the North American paddlefish (Polyodon spathula Walbaum, 1792) in the Serbian part of the Danube River, *Archivs of Biological Science Belgrade*, 58, 27-28.
97. Leonte V., 1943 – Einige Bemerkungen yur Biologie der Speyies Alosa nordmanni Antipa, 2, 273-280. (in German)
98. Liška I., Wagner F., Sengl M., Deutsch K. and Slobodnik J. (eds), 2015 – Joint Danube Survey 3, A comprehensive Abalysis of Danube Water Quality, 369.
99. Manea G., 1980 – Sturionii (Acipenseridae), Edit. Ceres, București, 244. (in Romanian)
100. Marić S., Susnik S., Simonoviś P. and Snoj A., 2006 – Phylogeographic study of brown trout from Serbia, based on mitochondrial DNA control region analysis, *Genetics, Selection, Evolution*, 38, 411-430.
101. Marković G., Marinović Z. and Lujić J., 2015 – Recent status of Neogobio sp. (Gobiidae) in Serbian watercourses, *Acta Oecologica Carpatica*, VIII, 163-168.
102. Marsigli L. F., 1726 – Danubius pannonico-misycus, Hagae et Amstelodami.
103. Marsilius A. F., 1726 – Danubius pannonico-mysicus, observationi – bus geographicis, astronomicis, hydrographicis, historicis, physicis perlustratus et in sex Tomos digested, IV, De piscibus in aquis Danubii viventibus, Hagae Comitum, Amstelodami, 92, 89.
104. Morita K., Morita S. H. and Yamamoto S., 2009 – Effects of habitat fragmentation by damming on salmonid fishes: lessons from the white-spotted charr in Japan, *Ecological Research*, 24, 4, 711-722.
105. Moshu A. J., Davideanu G. G. and Cebanu A. S., 2006 – Elements on the ichthyofauna diversity of Prut River basin, *Acta Ichtiologica Romanica*, I, 171-184.
106. Murgoci A., 1936 – Observation concernant Acipenser sturio de la Mer Noir, *Annales Scientifiques de Université de Jassy*, 23, 109-116.
107. Nalbant T., 1963 – A study of the genera of Botiinae and Cobitinae (Pisces, Ostariophysi, Cobitidae), *Travaux du Museum National d'Histoire Naturelle "Grigore Antipa"*, 4, 343-379.
108. Nalbant T., 1994 – Studies on loaches (Pisces: Ostariophysi: Cobitidae), I, An evaluation of the valid genera od Cobitinae, *Travaux du Museum National d'Histoire Naturelle "Grigore Antipa"*, XXXIV, 375-380.

109. Nalbant T., Battes K., Pricope F. and Ureche D., 2004 – First record of the Amur sleeper Perccottus glenii (Pisces: Perciformes: Odontobutidae) in Romania, *Travaux du Museum National d'Histoire Naturelle „Grigore Antipa"*, 47, 279-284.
110. Năvodaru I., 1992 – Prolificitatea scrumbiei de Dunăre, *Analele Şiinţifice ale Institutului Delta Dunării*, 183-186. (in Romanian)
111. Năvodaru I., Staraș M. and Cernâșencu I., 1994 – Influenţa regimului hidrologic al Dunării asupra variaţiei anuale a capturilor de scrumbie de Dunăre (Alosa pontica Eichwald), *Analele Şiinţifice ale Institutului Delta Dunării*, III, 1, 215-221. (in Romanian)
112. Năvodaru I., 1998 – Migraţia scrumbiei de Dunăre (Alosa pontica) şi factorii de mediu, *Analele Şiinţifice ale Institutului Delta Dunării*, IV, 1, 149-152. (in Romanian)
113. Nelson J. S., 1994 – Fishes of the world, Third edition, John Wiley and Sons, Inc. New York, 600.
114. Niculescu-Duvăz M., 1961 – Ichtiofauna și producțiile anuale de pești ale Dunării de jos și modificările lor în ipoteza barării fluviului, *Industria alimentară (producţia animală*), 11. (in Romanian)
115. Niculescu-Duvăz M., 1965 – Economia piscicolă în cadrul sistemului hidroenergetic și de navigație Porțile de Fier, *Natura, Seria biolgie*, 5. (in Romanian)
116. Nikolskii G. V., 1956 – Ryby basseina Amura, Isdatelstvo ANSSR, 551. (in Russian)
117. Normando F. T., Santiago K. B., Gomes M. V. G., Rizzo E. and Bazzoli N., 2014 – Impact of Três Marias on the reproduction of the forage fish Astyanax bimaculatus and Astyanax fasciatus from the São Francisco River, downstream from the dam, southern Brazil, *Environmental Biology of Fishes*, 3, 309-319.
118. Nowak M., Popek W. and Epler P., 2006 – The genus Gobio in Poland – Historical Review and present status (Teleostei, Cyprinidae), *Acta Ichthiologica Romanica*, I, 203-214.
119. Oancea D. and Velcea V. (coord.), 1987 – Geografia României, III, Carpații şi Depresiunea Transilvaniei, Edit. Academiei, București, 647. (in Romanian)
120. Olopade O. A., 2013 – Preliminary observations on the Family Mormyridae in Oyan Dam lake (Nigeria), *Transylvanian Review of Systematical and Ecological Research*, *The Wetlands* Diversity, 15.1, 33-48.
121. Olopade O. A. and Rufai O. P., 2014 – Composition, abundance and diversity of the family Cichlidae in Oyam Dam, Ogun State, Nigeria, *Transylvanian Review of Systematical and Ecological Research*, *The Wetlands Diversity*, 16.2, 97-106.
122. Oțel V., 2007 – Atlasul peștilor din Rezervația Biosferei Delta Dunării, Edit. Centrul de Informare Tehnologică Delta Dunării, Tulcea, 482. (in Romanian)
123. Pașovschi S., 1956 – Câteva considerațiuni biogeografice asupra munților Banatului, *Ocrotirea naturii*, 2. (in Romanian)
124. Popescu E., Ziemiankowski V. and Rotaru A., 1960 – Contribuţii la cunoaşterea biologiei văduviţei (Leuciscus idus) din cursul inferior al Dunării, *Studii şi Cercetări, Institutul de Cercetare şi Pescuit*, 2, 5, 7-33. (in Romanian)
125. Posea G., 1964 – Defileul Dunării, *Natura, Seria Geografie, Geologie*, 16, 1. (in Romanian)
126. Radu G. A., Meliceanu I. and Patriche I., 2008 – Ichthyofauna, an important heritage of the lower Prut floodplain, *Acta Ichtiologica Romanica*, III, 137-1146.
127. Reshetnikov A. N., 2004 – The fish Perccottus glenii: history of introduction to western regions of Eurasia, *Hydrobiologia*, 522, 349-350.
128. Riede K., 2004 – Global register of migratory species – from global to regional scales, Final Report of the R & D – Projekt 808 05 081, Federal Agency for Nature Conservation, Bonn, Germany, 329.
129. Ristic M., 1963 – Biological differentiation of winter and spring sturgeon morphs within species Acipenser gueldenstaedtii Brandt in Yugoslavian part of the Lower Danube, *Ribarstvo Jugoslavije*, 2, 25-36. (in Serbian)

130. Ristic M., 1967 – Fishery biological study of Acipenseridae of Yugoslavian part of the Lower Danube, *Ribarstvo Jugoslavije*, 2, 48-58. (in Serbian)
131. Robins C. R., Bailey R. M., Bond C. E., Brooker J. R., Lachner E. A., Lea R. N. and Scott W. B., 1991 – Common and scientific names of fishes from the United States and Canada, *American Fishery Society Special Publications*, 20, 183.
132. Rochard E., Lepage M. and Meauzé L., 1997 – Identification et caractérisation de l'aire de répartition marine de l'esturgeon européen Acipenser sturio à partir de déclarations de captures, *Aquatic Living Resources*, 10, 101-109. (in French)
133. Romero P., 2002 – An etymological dictionary of taxonomy, Madrid, unpublished.
134. Sanda V., Şerbănescu G. and Zăvoianu I., 1968 – Aspecte ale florei şi vegetaţiei palustre din clisura Cazanelor, *Studii şi Cercetări de Biologie, Seria Botanică*, 20, 3. (in Romanian)
135. Schiemer F., Guti G., Keckeis H. and Staraş M., 2004 – Ecological status and problems of the Danube River and its fish fauna: a review, *Proceedings of the second International Symposium on the Management of Large Rivers for Fisheries*, I, Sustaining livelihoods and biodiversity in the new millennium, RAP Publication (FAO), 16, 273-299.
136. Sekulić N., Cakić P., Lenhardt M., Vučić D. and Budakov L. J., 1999 – Short-snouted pipefish Szngnathusabaster (Acanthopterygii: Syngnathidae) in the Yugoslav section of the Danube, *Ichthyologia*, 31, 1, 79-82.
137. Simonović P., 2006 – The Fishes of Serbia, 2nd edition, NNK International, School of Biology, Belgrade, 247.
138. Simonović P., Marić S. and Nikolić V., 2006 – Occurrence of paddlefish Polyodon spathula (Walbaum, 1792) in the Serbian part of the lower River Danube, *Aquatic Invasions*, 1, 3, 183-185.
139. Šipoš Š., Miljković B. and Pejčić L. J., 2004 – The first record of Amur sleeper (Perccottus glenii Dybowski, 1877, fam. Odontobutidae) in the Danube River, *International Association for Danube Research*, 35, 509-510.
140. Skelton P. H., 1993 – A complete guide to the freshwater fishes of southern Africa, Southern Book Publishers, 388.
141. Sokolov L. I. and Berdicheskii L. S., 1989 – Acipenseridae, in Holcík J. (ed.), The freshwater fishes of Europe, 1, II, General introduction to fishes Acipenseriformes, AULA-Verlag Wiesbaden, 469, 150-153.
142. Staraş M. and Oţel V., 1999 – Primele dovezi asupra reproducerii speciei Hypophthalmychthys molitrix (Pisces: Cyprinidae) în mediul acvatic natural din România, *Analele Ştiinţifice ale Institutului Deltei Dunării*, VII, 183-188. (in Romanian)
143. Stăncioiu S., 1978 – Contribuţii la studiul carasului argintiu (Carassius auratus gibelio-Bloch) din bazinele situate în Câmpia Râmnicului şi Siretului inferior în vederea creşterii fondului piscicol, Rezumat teză de doctorat, Universitatea Galaţi, 85. (in Romanian)
144. Suciu et al., 2015 – Monitoring Strategy of Sturgeon Behaviour to Ensure Functionality of Future Fish Passes: The "Iron Gates" II Case in the Danube River.
145. Svetovidov A. N., 1984 – Salmonidae, in Whitehead P. J. P., Bauchot M.-L., Hureau J.-C., Nielsen J. and Tortonese E. (eds), Fishes of the north-eastern Atlantic and the Mediterranean, UNESCO, Paris, 1, 373-385.
146. Tockner K., Robinson C. T. and Uehlinger U., 2009 – Rivers of Europe ISBN-13: 978-0-12-369449-2, first edition.
147. Tőry K., 1952 – A Duna és szabályozása, Akadémiai Kiadó, Budapest, 454. (in Hungarian)
148. Travnichek V. H. and Maceina M. J., 1994 – Comparison of flow regulation effects on fish assemblages in shallow and deep water habitats in the Tallapoosa river, Alabama, USA, *Journal of Freshwater Ecology*, 9, 207-216.
149. Ujvari I., 1959 – Hidrografia R. P. România, Edit. Ştiinţifică, Bucureşti, 288. (in Romanian)
150. Ujvari I., 1972 – Geografia apelor României, Edit. Ştiinţifică, Bucureşti, 577. (in Romanian)
151. Vasiliu G. D., 1959 – Peştii apelor noastre, Bucureşti, Edit. Ştiinţifică. (in Romanian)

152. Voicu R. and Bănăduc D., 2014 – Restoring longitudinal connectivity of the Someşul Mic River near the dam in Mănăstirea Village (Transylvania, Romania), *Acta Oecologica Carpatica*, VII, 149-168.
153. Voicu R. and Merten E., 2014 – Creating a system for upstream – downstream fish migration over the first and the second discharge sills downstream of Mănăştur Dam on the Someşul Mic River, Cluj-Napoca, Transylvania, Romania), *Transylvanian Review of Systematical and Ecological Research*, *The Wetlands Diversity*, 16.2, 163-182.
154. Vostradovsky J., 1973 – Freshwater fishes, The Hamlyn Publishing Group Limited, London, 252.
155. Vutskits G., 1918 – Pisces, in Fauna Regni Hungariae, A. K. M. Természettudományi Társulat, Budapest, 42.
156. Zinevici V., 1967 – Consideraţii asupra răspândirii anghilei (Anguilla anguilla L.) în sectorul românesc al Dunării şi la gurile sale, *Hidrobiologia*, 8. (in Romanian)
157. Zorić K., Simonović P., Đikanović V., Marković V., Nikolić V., Simić V. and Paunović M., 2014 – Checklist of non-indigenous fish species of the river Danube, *Archives of Biological Science Belgrade*, 66, 629-639.

ANALYSING LANDSCAPE FRAGMENTATION AND CLASSIFYING THREATS FOR HABITATS OF COMMUNITY INTEREST IN THE "IRON GATES" NATURAL PARK (ROMANIA)

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ABSTRACT

Our study aims at evaluating the ecological impact of landscape fragmentation, identifying, and classifying the threats affecting habitats of community interest in the "Iron Gates" Natural Park. We used landscape metrics for assessing the fragmentation process, results expressing decreases in the values of three metrics (MPS, ED, SDI) and increases for two metrics (NumP and IJI). We observed an insignificant increase in landscape fragmentation related to a reduced decrease of its landscape diversity for the 1990-2006 timeframe. We classified the main anthropic threats to habitats of community interest in three main categories: diversification and densification of buildings and transportation infrastructures, land use and industrial activities.

RÉSUMÉ: Analyse de la fragmentation du paysage et classification des menaces pour les habitats d'intérêts communautaires dans le Parc Naturel des "Portes de Fer" (Roumanie).

L'étude réalise une évaluation de l'impact écologique des activités humaines sur les habitats et les espèces d'importance communautaire dans le Parc National "Portes de Fer". Une des conséquences majeurs de ces activités que nous avons analyse est la fragmentation de paysages, quantifie en utilisant les métriques paysagères. Les donnes obtenues montrent une baisse des valeurs pour trois indicateurs (MPS, ED, SDI) et une hausse des valeurs pour deux (NumP et IJI). Entre 1990-2006, la fragmentation du paysage a légèrement augmenté, entent que la diversité du paysage a diminué. Les formes de pression humaine sur les habitats ont été groupées en trois catégories: densification résidentielle et des voies de circulation, utilisation du terrain et activités industrielles.

REZUMAT: Analiza fragmentării peisajului şi clasificarea ameninţărilor pentru habitatele de interes comunitar în Parcul Natural „Porţile de Fier".

Studiul îşi propune să evalueze impactul ecologic indus de fragmentarea peisajelor asupra habitatelor și speciilor de importanță comunitară din Parcul Natural „Porțile de Fier". Fragmentarea peisajului a fost cuantificată utilizând analiza metricilor peisajului. Rezultatele evidențiază scăderi ale valorilor în cazul a trei metrici (MPS, ED, SDI) şi creşteri pentru doi metrici (NumP şi IJI). La nivelul arealului s-a înregistrat o creștere nesemnificativă a fragmentării peisajului, coroborată cu o ușoară diminuare a diversității peisajului în intervalul 1990-2006. Formele de presiune umană au fost grupate în trei categorii: diversificarea şi creşterea densităţii construcţiilor şi a căilor de transport, modul de utilizare a terenurilor şi activităţile industriale.

INTRODUCTION

The establishment of the European network of protected areas – Natura 2000 – was an important step towards biodiversity conservation at European level (Evans, 2012; Primack et al., 2008). The network was established based on the legal provision of the core Directives of nature conservation: Habitats and Birds Directive (Pullin et al., 2009). The Directives have in their annexes a detailed list of European habitats that present a community interest, mainly due to their ecological characteristics.

A wide variety of studies focus on the habitats of community interest as part of the Natura 2000 network, but only a small proportion approach the social and political implications determining a reduced correspondence between the ecologic and social domains (Popescu et al., 2014). Ecological studies are more frequent, a furthermore proof of the fact that the enforcement of the Habitats and Birds Directives are focused on the conservation of habitats of community interest (Evans, 2012; Popescu et al., 2014).

Research on the conservation of biological diversity revealed that the main threats affecting protected areas networks are the degradation and destruction of habitats, overexploitation, invasive species, pollution or the inadequate spatial planning of the network (Ioja et al., 2010; Primack et al., 2008).

The human impact inside protected areas is amplified by changes in the land use, environmental degradation, the expansion of constructed surfaces and transportation infrastructures, the main effects being represented by the destruction and fragmentation of habitats (Fischer et al., 2007).

Current environmental threats induced by the new consumption models of population – densification of settlements, human induced landscapes and the diversification of economic activities (Antrop, 2004) should be evaluated as synergic process at local or global level (Chincea et al., 2014).

The social and economic vulnerability determined by the amplification of the human pressures imposes a system of sustainable management and territorial planning that consider the new environmental modifications, landscape characteristics and the need for resource consumption (Ioja, 2013; Lindenmayer et al., 2006).

The new directions of analysis should approach conflicts between conservation and development objectives at local, regional and global level (inside the protected areas from Natura 2000 network) (Popescu et al., 2014), with emphasis on the conflicts between agricultural practices and habitats (Pe'er et al., 2014) or the densification of built-up surfaces and the conservation of habitats and species of community interest.

Evaluations of the status of species and habitats inside a protected area can be realized using landscape metrics as an indicator of their dynamic under the influence of anthropic factors (dynamic of the fragmentation degree and landscape structure) (Niculae and Pătroescu, 2011; McGarigal and Marks, 1994; Turner and Meyer, 1994; McGarigal et al., 2002; Pătru-Stupariu et al., 2011; Turner et al., 2001).

Landscape ecology represents a new direction in landscape research that focuses on the structure, composition, functions and the role of human communities in creating and modifying the landscape pattern (Farina, 1998; Forman, 1997; Burel and Baudry, 1999; Forman and Godron, 1986).

In time, the intervention of human factors in the "Iron Gates" Natural Park manifested at different spatial scales and magnitudes, but had a significant role in the spatial and territorial dynamic of habitats of community interest. Species and habitats are differently affected by landscape fragmentation. In the study area among the factors found in the literature are the densifications of built-up surfaces, transportation infrastructures, landscape modification, etc.

The study assessed the ecological impacts induced on the habitats of community interest from the "Iron Gates" Natural Park by anthropic threats and subsequent landscape fragmentation. The research objectives are: a) to quantify landscape fragmentation for the 1990-2006 period using landscape metrics and evaluate its effects on habitats of community interest and b) to identify and classify the main categories of threats and prioritize the areas where they generate environmental conflicts in relation to habitats of community importance.

MATERIAL AND METHODS

Study area

The "Iron Gates" Natural Park is situated in the south-western part of Romania, on the border with Serbia, overlapping the territory of the Mehedinţi and Caraş-Severin counties (Pătroescu and Rozylowicz, 2000; Cucu et al., 2013a, b) and including 20 territorial administrative units. This park was established through Law 5/2000, Section III – Protected areas (Guvernul României, 2013) and is now included in the V category IUCN, managed especially for the conservation of terrestrial landscapes and recreation (IUCN, 2014).

Vegetation includes vascular plants with 1,749 species, 120 subspecies, 570 genus and 131 families (50% of the number of species in Romania) (Matacă, 2005).

The "Iron Gates" Natural Park includes 18 reserves of avifauna, botanical, paleontological, forestry or mixed interest, established under legal provisions and presented in the management plan of the protected area: Balta Nera – Dunăre, Baziaş, Insula Calinovăţ, Râpa cu lăstuni, Divic-Pojejena, Valea Mare, Peştera cu apă din Valea Polevii, Ostrovul Moldova Veche, Locul fosilifer Sviniţa, Cazanele Mari and Cazanele Mici, Bahna, Dealul Duhovna, Gura Văii-Vârciorova, Faţa Virului, Cracul Crucii, Dealul Vărănic, Valea Oglănicului, Cracul Găioara (Guvernul României, 2013; Pătroescu et al., 2004).

The "Iron Gates" Natural Park includes two Special Protection Areas, components of the Natura 2000 network: ROSPA0026 Cursul Dunării-Baziaş-Porţile de Fier and ROSPA0080 Munţii Almăjului-Locvei (Guvernul României, 2011). In 2007 the entire surface of the Park was designated as a Site of Community Importance (ROSCI0206 Porţile de Fier), included in the Natura 2000 network (Ministerul Mediului şi Pădurilor, 2011) (Fig. 1).

In the Site of Community Importance ROSCI0206 "Porţile de Fier"/"Iron Gates" 29 habitats of community interest have been identified according to Annex I of the Habitats Directive (Directiva 92/43/CEE), their conservation requiring the designation of special areas. From the 29 identified habitats (Tab. 1), seven are priority habitats for conservation (Ministerul Mediului şi Pădurilor, 2011).

In addition, a large number of species of community interest form Annex II of the Habitats Directive have been identified in the "Iron Gates" Natural Park, including 15 mammal species (of which one priority species – *Canis lupus*), four species of amphibians and reptiles, 12 fish species, 16 invertebrate species (of which two priority species, *Osmoderma eremita* and *Rosalia alpina*) and 12 species of plants (Ministerul Mediului şi Pădurilor, 2011). The two Special Protection Areas include species from Annex I of the Birds Directive: ROSPA0026 Cursul Dunării-Baziaş-Porţile de Fier – 13 species and ROSPA0080 Munţii Almăj – 21 species (Guvernul României, 2011).

Table 1: Habitats of community interest in the "Iron Gates" Natural Park; *priority habitat types.

3130	Oligotrophic to mesotrophic standing waters with vegetation of the Littorelletea uniflorae and/or of the Isoëto-Nanojuncetea
3140	Hard oligo-mesotrophic waters with benthic vegetation of Chara ssp.
3150	Natural eutrophic lakes with Magnopotamion or Hydrocharition – type vegetation
3260	Water courses of plain to montane levels with the Ranunculion fluitantis and Callitricho-Batrachion vegetation
3280	Constantly flowing Mediterranean rivers with Paspalo-Agrostidion species and hanging curtains of Salix and Populus alba
40A0*	Subcontinental peri-Pannonic scrub
6110*	Rupicolous calcareous or basophilic grasslands of the Alysso-Sedion albi
6190	Rupicolous pannonic grasslands (Stipo-Festucetalia pallentis)
6210*	Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco-Brometalia) (* important orchid sites)
6260*	Pannonic sand steppes
6430	Hydrophilous tall herb fringe communities of plains and of the montane to alpine
8120	Calcareous and calcshist screes of the montane to alpine levels (Thlaspietea rotundifolii)
8210	Calcareous rocky slopes with chasmophytic vegetation
8220	Siliceous rocky slopes with chasmophytic vegetation
8230	Siliceous rock with pioneer vegetation of the Sedo-Scleranthion or of the Sedo albi-Veronicion dillenii
8310	Caves not open to the public
9110	Luzulo-Fagetum beech forests
9130	Asperulo-Fagetum beech forests
9150	Medio-European limestone beech forests of the Cephalanthero-Fagion
9170	Galio-Carpinetum oak-hornbeam forests
9180*	Tilio-Acerion forests of slopes, screes and ravines
91AA*	Eastern white oak woods
91E0*	Alluvial forests with Alnus glutinosa and Fraxinus excelsior (Alno padion, Alnion incanae, Salicion albae)
91K0	Illyrian Fagus sylvatica forests (Aremonio-Fagion)
91L0	Illyrian oak-hornbeam forests (Erythronio-Carpinion)
91M0	Pannonian-Balkanic turkey oak – sessile oak forests
91Y0	Dacian oak and hornbeam forests
92A0	Salix alba and Populus alba galleries
9530*	(Sub-) Mediterranean pine forests with endemic black pines

Landscape fragmentation

For quantifying and analysing landscape fragmentation we used the spatial database established by the EEA in the CORINE Land Cover Project for the years 1990 and 2006 (Bossard et al., 2000; Feranec et al., 2010; Heymann et al., 1994), in a grid format with a resolution of 100*100 meters, which we projected in the Stereo 1970 system.

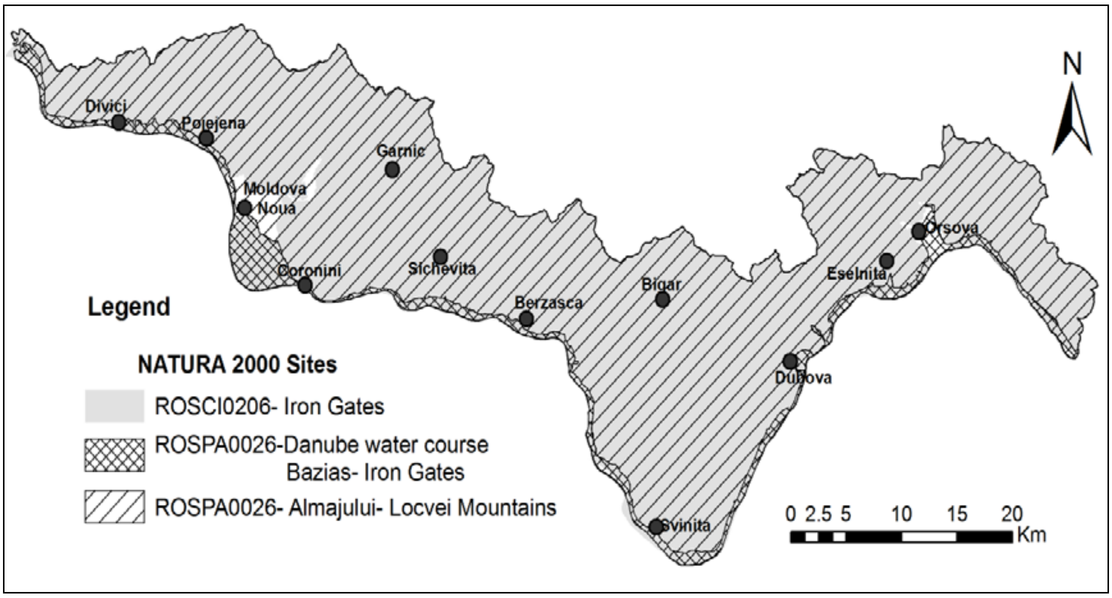

Figure 1: Natura 2000 sites in the "Iron Gates" Natural Park.

The interval corresponds to the Romanian post-communist period characterized by a transition economy. We aggregated land use and land cover classes extracted from the CORINE database (19 classes) in nine main classes (Tab. 2) according to the CLC nomenclature system level II (Eiden et al., 2000) accounting for the particularities of the protected area and the objectives of our study.

Regarding the evaluation of the landscape pattern and the fragmentation of habitats we used five landscape metrics (Eiden et al., 2000; Niculae, 2012), based on the number, size, diversity and the overlap of units in the landscape pattern (Tab. 3).

We calculated landscape metrics using the software Patch Analyst 5.0 (Rempel et al., 2012) and its function Spatial Statistics, developed by the Centre for Northern Forest Ecosystem Research, Lakehead University, Ontario.

Threats analysis

The identification and classification of anthropic threats upon habitats of community interests, and the prioritization of areas with environmental conflicts was done based on the observations and field collection of data, as well as interviews with local actors from the protected area (Cucu et al., 2013a; Primack et al., 2008).

In addition, we consulted a large body of literature (articles, proceedings, reports, management plans) on the topic of environmental conflicts determined by human activities on habitats and species. We validated the data with information from aerial images and cartographic materials.

For prioritizing threats, we used diverse criteria such as the number of landscape components influenced by human activities, environmental impact assessment for different land uses and the proximity to habitats of community interest. Land uses have a spatial and temporal evolution determined by the local and regional development, densification of built-up surfaces and the need to increase the accessibility of the protected area (CCMESI, 2014).

The identification and prioritization of areas with environmental conflicts was realized according to the relation between the densification of built-up and industrial surfaces and habitats of community interest from the "Iron Gates" Natural Park.

Table 2: Classes obtained from reclassification.

Name of CLC classes (level 2)	CLC Code level 2 (level 3)	Name of reclassified classes	Code
Built-up surfaces	11 (112)	Artificial surfaces	1
Industrial and commercial units	12 (121; 123)		
Mines, dumps and sites for construction materials	13 (131; 132)		
Agricultural fields	21 (211)	Arable lands	2
Permanent crops	22 (221; 222)	Permanent crops	3
Pastures	23 (231)	Pastures	4
Heterogeneous agricultural fields	2.4 (242; 243)	Heterogeneous agricultural fields	5
Forests	31 (311; 313)	Forests	6
Shrubs and/or grass vegetation	32 (321; 324)	Natural vegetation	7
Reduced or no vegetation	33 (332; 333)	Unproductive lands	8
Water bodies	51 (511; 512)	Water bodies	9

Table 3: Landscape metrics used in the analysis (McGarigal and Marks, 1994).

Indicator	Formula*/Description	Measure/ Values
Number of patches (NumP)	$NP = n$ The value is 1 when the entire landscape has a single patch. n = total number of landscape patches, without background units	NumP ≥ 1, no limits
Mean patch size (MPS)	$MPS = \frac{A}{N}\left(\frac{1}{10{,}000}\right)$ Values range by the limits of the resolution, scales and the minimum size of the unit. Final value can be divided by 10,000 to convert in ha. A = total landscape surface (m^2); N = total number of patches	ha MPS > 0, no limits
Edge density (ED)	$ED = \frac{E}{A}(10{,}000)$ Sum of lengths for all edge segments in the landscape in relation to the total surface. Final value can be divided by 10,000 to convert in ha. E = total lenght (m) of edge segments; can include the landscape limit; A = total surface of the landscape (m^2)	m/ha ED ≥ 0, no limits

Table 3 (continued): Landscape metrics used in the analysis.

Indicator	Formula*/Description	Measure/ Values
Shannon diversity index (SHDI)	$SHDI = -\sum_{i=1}^{m} \left(Pi \circ \ln Pi \right)$ The value equals 0 when the landscape contains a single unit (no diversity) and increases with the number of classes and/or the balanced distribution between surfaces. The value is equal to minus the sum of the proportional abundance for each type of patch and their proportion. M = number of patches for the *i* class with close neighbours; i = 1,…, m, types of landscape classes; p_i = perimeter (m) of unit *i*	SHDI ≥ 0
Interspersion and juxtaposition index (IJI)	$IJI = \frac{-\sum_{i=1}^{m'} \sum_{k=i+1}^{m'} \left[\left(\frac{e_{ik}}{E} \right) \bullet \ln \left(\frac{e_{ik}}{E} \right) \right]}{\ln \left(1/2 \left[m' \left(m'-1 \right) \right] \right)}$ The index equals 0 when the distribution of adjacent classes between unique classes increases unbalance and equals 100 when all classes are equally adjacent to the other classes. m' = number of class types present in the landscape without the limit; i = 1, …, m, class types; k = 1, …, m, landscape class types; e_{ik} = total length (m) of landscape edges between *i* and *k* units; E = total length (m) of landscape edges (including landscape limit)	% 0 < IJI ≤ 100

RESULTS AND DISCUSSION

The analysis of **landscape fragmentation and landscape pattern** revealed decreases for three landscape metrics (MPS, ED, SDI) and increases for the other two (NumP and IJI) (Tab. 4). The number of patches (NumP) recorded insignificant increases, with approximately 1.8% for the analysed timeframe, from 428 units in 1990 to 436 units in 2006. The values demonstrate a small increase in landscape fragmentation. Edge density (ED) decreased with 1.24%, reaching a value of 20.67 in 2006, while the mean patch size (MPS) decreased with 1.84%, arguments for landscape fragmentation and an increased complexity of shapes.

Table 4: Landscape metrics values for 1990 and 2006; *NumP-Number of patches; ED – Edge density; MPS – Mean patch size; SHDI – Shannon diversity index; IJI – Interspersion and juxtaposition index.

	NUMP*	ED	MPS	SHDI	IJI
1990	428.00	20.93	299.53	1.24	63.19
2006	436.00	20.67	294.03	1.23	65.33

The Shannon Diversity Index (SDI) presents a small decrease of 0.81%, from 1.24 to 1.23 in 2006. The index is used for quantifying landscape diversity (Pătru-Stupariu et al., 2009; Pătru-Stupariu et al., 2011; Schreiber et al., 2003) based on the composition (number of classes) and structure (distributions and proportions covered in the landscape) (Eiden et al., 2000; Niculae, 2012; Schreiber et al., 2003).

The value of the index increases as the number of land use classes amplifies and their distribution in the landscape balances (Schreiber et al., 2003). In the case of the "Iron Gates" Natural Park, the insignificant decreases in the Shannon Diversity Index (from 1.24 to 1.23) would imply a reduced diversity of the landscape. However, since the number of classes remained constant for the analysed timeframe this reduction can be justified by a decrease in the proportion of several land uses and covers.

Values of the Interspersion and Juxtaposition Index (IJI) increased by approximately 3.4% in 2006 compared to 1990 (2.14 units). The high values for both years indicated an increased adjacency between landscape units from the same class in relation to the others, their distribution becoming regular in a progressive manner.

The five landscape metrics we analyzed for the years 1990 and 2006 reveal an insignificant increase of landscape fragmentation and a reduced decrease of landscape diversity. One of the reasons that generated these results was the establishment of the protected area status in 2005; land use and land cover changes recording a low manifestation in the protected area. Landscape fragmentation was determined also by the densification of built-up surfaces in settlements from the "Iron Gates" Natural Park.

Works on the European road E70 lead to the fragmentation of forest landscapes, affecting the structure of habitats consisting of calcareous and siliceous rocky slopes with chasmophytic vegetation. Constructions along the Danube banks (Fig. 2) destructed the habitats of alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior*.

An important habitat for orchids, semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco-Brometalia) was affected by the fragmentation for obtaining agricultural lands in the proximity of settlements as Berzasca or Dubova.

Figure 2: Constructions along the Danube banks at Dubova.

Based on field researches and literature reviews we identified and classified a series of anthropic **threats** to landscapes in the "Iron Gates" Natural Park, with major negative effects on the habitats of community interest.

We also prioritized the areas in which a series of **environmental conflicts** can be found.

Human activities that determine pressure on the habitats of community interest belong to three categories: densification of human settlements (the number and density of permanent and temporary settlements, their shape and size), densification of transportation infrastructure (at national, county and local level) and land-uses (agricultural lands, animal growth, forestry, industrial activities) (CCMESI, 1999; CCMESI, 2014; Niculae, 2012). We prioritized the following human activities that influence habitats of community interest (CCMESI, 2014):

– Densification of built-up and commercial surfaces. The main threat is represented by the construction of vacation housings along the Danube, with direct effects on the ripicol and riparian habitats, as well as protected species (such as *Testudo hermanni*). The new insertions represent direct threats through the destruction of habitats (CCMESI, 2014);

– Transport activities on the roads and the Danube, especially along the E70 affecting habitats (Fig. 3) with rupicolous calcareous or basophilic grasslands of the Alysso-Sedion albi;

– Intensification of agricultural activities, especially in the area of depression basins or mountainous plateaus, affecting habitats with rupicolous calcareous or basophilic grasslands of the Alysso-Sedion albi or the semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco-Brometalia);

– Mining and energy production (at Cozla, Eibenthal, Baia Nouă) with direct impact especially on forest landscapes (Fig. 4). A threat is represented by the tailing dumps situated in the proximity of habitats. The existence of the "Iron Gates" hydro energy system has effects on the habitats, mainly through water level oscillation. Lately numerous wind turbines have been builded in the study area with direct effects especially on bird species and their habitats.

Settlements have an unbalanced distribution in the "Iron Gates" Natural Park, with higher densities along river valleys and the main roads, and in areas where slopes and fragmentation are reduced. Relief factors of restrictiveness determined a reduced density of population in the Caraș-Severin and Mehedinți counties.

A large proportion of the constructed surfaces and industrial activities are located in the proximity of protected areas and habitats of community interest (Fig. 5) increasing the probability of environmental conflicts emerging.

Numerous conflict areas from the "Iron Gates" Natural Park are concentrated around industry, many of them being residual activities from the communist period. The exploitation of different resources determined a high impact on environment, respectively on habitats and species of community interest. Conflict areas can be found around exploitation quarries, tailing dumps, mines or abandoned constructions (Moldova Noua, Cozla, Baia Nouă, etc.).

The city of Moldova Nouă is confronted with the largest number of conflict areas due to industrial activities (Chincea et al., 2014). The main conflict area induced by industrial activities is located at the tailing dump of Moldova Nouă, situated near the Ostrovul Moldova Veche wetland (Fig. 6) – part of ROSPA0026 Cursul Dunării – Baziaş-Porţile de Fier. It has a surface of about 270 ha and represents a cross-border environmental degradation sources.

These environmental conflicts are generated by the densification of built-up surfaces in the adjacent settlements and agricultural land uses. Such areas are found around the settlements of Eșelnița, Dubova, and Berzasca, in which the construction of vacation residences and their endowments determined the emergence of new environmental conflicts.

Figure 3: Landscape fragmentation by E70.

Figure 4: Mining exploitation in the proximity of Ciucarul Mare.

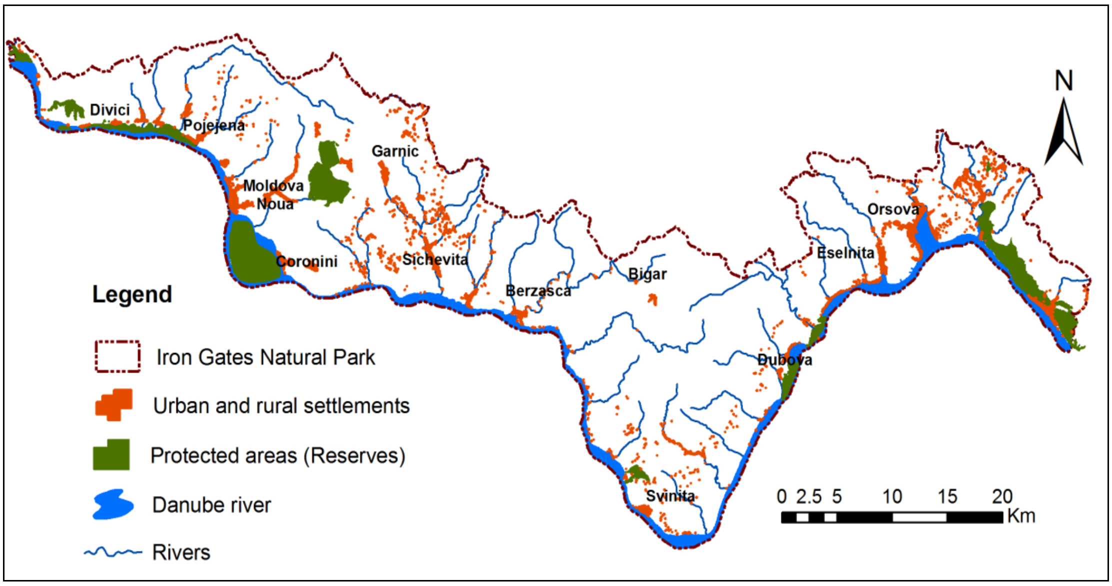

Figure 5: Densification of built-up surfaces in relation with reserves in the "Iron Gates" Park.

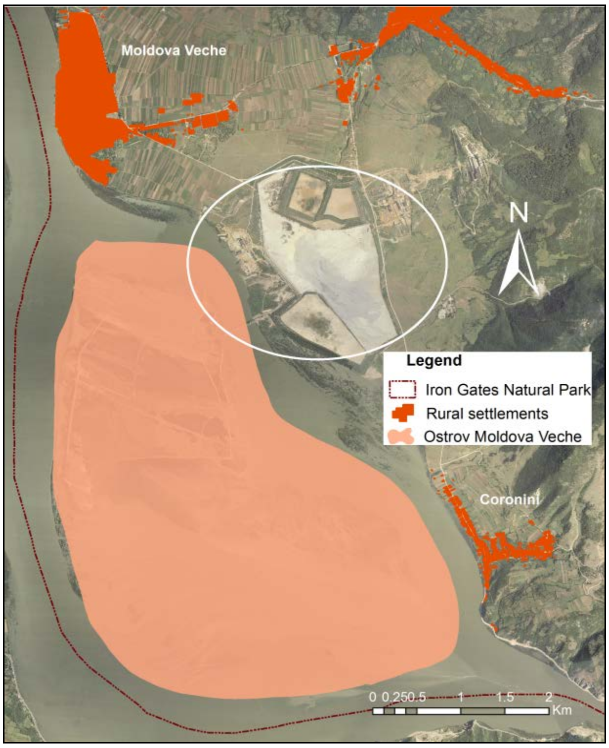

Figure 6: Conflict area determined by the presence of the tailing dump in the proximity of the Ostrovul Moldova Veche wetland.

Another area in which environmental conflicts are manifesting is represented by the area of the Calinovăț Island and the Divici – Pojejena wetlands (Figs. 7 and 8).

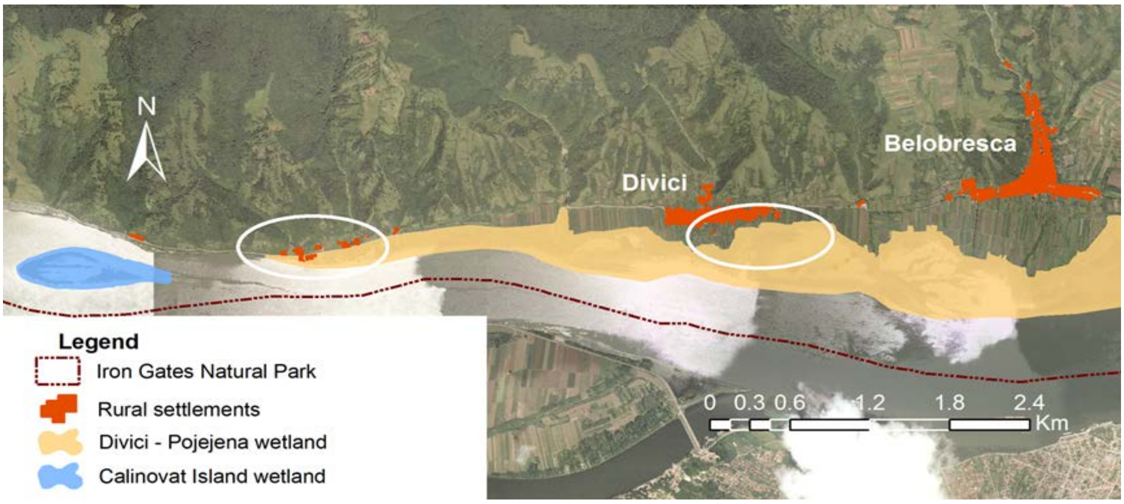

Figure 7: Conflicts generated by the densification of built-up surfaces.

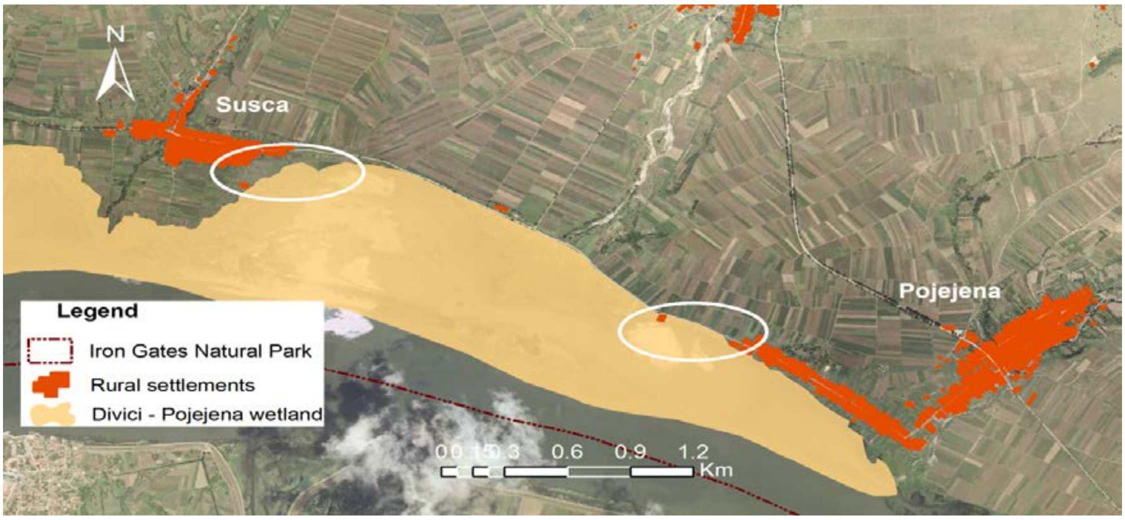

Figure 8: Densification of built-up surfaces and intensification of agriculture.

CONCLUSIONS

The "Iron Gates" Natural Park represents an area in which landscapes have suffered reduced modifications after its establishment as a protected area (2000) in comparison with territories in the proximity that lack a conservation status (CCMESI, 2014). The ecological integrity of the environment in the "Iron Gates" Natural Park was in a low proportion influenced by landscape fragmentation.

Recent changes in the structure of landscapes have not yet induced significant changes in spatial relations established in time between landscape elements. The connectivity and permeability of habitats is of significant importance in the framework of a protected area where the development of human activities (transportation, energy, agriculture) tends to determine fragmentation and represent barriers in the dispersion of species.

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REFERENCES

1. Antrop M., 2004 – Landscape change and the urbanization process in Europe, *Landscape and Urban Planning*, 67, 9-26.
2. Bossard M., Feranec J. and Otahel J., 2000 – Technical report no. 40. CORINE land cover technical guide – Addendum 2000, European Environment Agency, Copenhagen, 105.
3. Burel F. and Baudry J., 1999 – Ecologie du paysage, Editions TEC and DOC, Paris, 359. (in French)
4. CCMESI, 1999 – Dinamica peisajelor rurale din România, Studiu de caz: Câmpia Română, Contract 17/1998, Cod CNCSU 56A, Tema 2, Bucureşti. (in Romanian)
5. CCMESI, 2014 – Integrated Management Of Biological And Landscape Diversity For Sustainable Regional Development And Ecological Connectivity In The Carpathians.
6. Chincea I., Niculae M. I., Pătroescu M. and Nita M. R., 2014 – Spatial-temporal forms of Human pressure and their environmental impacts in the Caraş-Severin County, Romania, *World Journal of Environmental Research*, 4, 2, 53-60.
7. Cucu L. A., Niculae M. I. and Pătroescu M., 2013a – Hierarchical analysis of the threats for species of Community Interest in the "Iron Gates" Natural Park, Romania, Forum Geografic, *Studii și cercetări de geografie și protecția mediului*, 12, 1, 52-58.
8. Cucu L. A., Niculae M. I. and Pătroescu M., 2013b – Species management in the "Iron Gates" Natural Park, *Present Environment and Sustainable Development*, 7, 2, 145-155.
9. Eiden G., Kayadjanian M. and Vidal C., 2000 – Quantifing Landscape Structures: spatial and temporal dimensions, in From land cover to landscape diversity in the European Union, EU, http://ec.europa.eu/agriculture/publi/landscape/ch2.htm#2, Accessed at 27.04.2015.
10. Evans D., 2012 – Building the EU's Natura 2000 network, *Nature Conservation*, 1, 11-26.
11. Farina A., 1998 – Principles and methods in landscape ecology, Chapman and Hall, London, 412.
12. Feranec J., Jaffrain G., Soukup T. and Hazeu G., 2010 – Determining changes and flows in European landscapes 1990-2000 using CORINE land cover data, *Applied Geography*, 30, 19-35.
13. Fischer J. and Lindenmayer D. B., 2007 – Landscape modification and habitat fragmentation. A synthesis, *Global Ecology and Biogeography*, 16, 265-280.
14. Forman R. T. T., 1995 – Land mosaics: the ecology of Landscapes and Regions, Cambridge University Press, Cambridge, 656.
15. Forman R. T. T. and Gordon M., 1986 – Landscape Ecology, John Wiley and Sons, New York, 618.
16. Guvernul României, 2011 – HG nr. 971/2011 pentru modificarea şi completarea Hotărârii Guvernului nr. 1.284/2007, *Monitorul Oficial al României*, I, 715/2011. (in Romanian)
17. Guvernul României, 2013 – Hotărârea nr. 1048/2013, *Monitorul Oficial al României*, I, 119/2014. (in Romanian)
18. Heymann Y., Steenmans C., Croisille G. and Bossard M., 1994 – CORINE Land Cover. Technical guide, Office for Official Publication of the EC, Luxembourg, 136.
19. Ioja C., Pătroescu M., Rozylowicz L., Popescu V., Vergheleț M., Zotta M. and Felciuc M., 2010 – The efficacy of Romania's protected areas, *Biological Conservation*, 143, 11, 2468-2476.
20. Ioja C., 2013 – Metode de evaluare a stării mediului, Edit. Etnologică, București, 183. (in Romanian)
21. IUCN, 2014 – IUCN Protected Areas Categories System, available at http://www.iucn.org/about/work/programmes/gpap_home/gpap_quality/gpap_pacategories.
22. Lindenmayer D. B. and Fischer J., 2006 – Habitat fragmentation and landscape change, An ecological and conservation synthesis, Island Press, Washington, DC, 88-106.
23. Matacă S. S., 2005 – Parcul Natural Porțile de Fier. Floră, Edit. Universitaria, Craiova. (in Romanian)
24. McGarigal K. and Marks B. J., 1994 – FRAGSTATS, Spatial pattern analysis program for quantifying landscape structure, Version 2.0, Oregon State University, Corvallis, OR, 134.

25. McGarigal K., Cushman S. A., Neel M. C. and Ene E., 2002 – FRAGSTATS: Spatial Pattern Analysis Program for Categorical Maps, Amherst, MA, University of Massachusetts, available at http://www.umass.edu/landeco/research/fragstats/fragstats.html, accessed at 22.04.2015.
26. Ministerul Mediului şi Pădurilor, 2011 – Ordinul nr. 2387/2011 pentru modificarea Ordinului ministrului mediului şi dezvoltării durabile nr. 1.964/2007 privind instituirea regimului de arie naturală protejată a siturilor de importanţă comunitară, ca parte integrantă a reţelei ecologice europene Natura 2000, *Monitorul Oficial al României*, I, 846/2011. (in Romanian)
27. Niculae M. I. and Pătroescu M., 2011 – Quantifying forest ecosystems fragmentation in the Subcarpathians between the Râmnicu Sărat and the Buzău valleys, Romania, using landscape metrics, Forum Geografic, *Studii şi cercetări de geografie şi protecţia mediului*, 10, 1, 187-194.
28. Niculae M. A. I., 2012 – Evoluţia spaţială şi temporală a peisajelor din Subcarpaţii cuprinşi între Buzău şi Râmnicu Sărat, Edit. Universităţii din Bucureşti, Bucureşti. (in Romanian)
29. Pătroescu M. and Rozylowicz L., 2000 – Natural Transborder Parks: the direction of Biodiversity preservation in Romania, in Crabbe P. et al. (ed.) Implementing ecological integrity, Kluwer Academic Press, 101-113.
30. Pătroescu M., Chincea I., Pascovici N., Ioja C., Matacă S. S., Popa M. E., Florescu V., Vâlceanu C., Odorescu I., Popescu V., Dumitraşcu D., Rozylowicz L., Necsuliu R. and Sbîrcea S., 2004 – Planul de management al Parcului Natural Porțile de Fier în perspectiva dezvoltării durabile, *Drobeta, Seria Ştiinţele naturii,* XIV, Edit. Craiova, Drobeta Turnu-Severin, 64-92. (in Romanian)
31. Pătru-Stupariu I., Stupariu M. S. and Cuculici R., 2009 – Landscape metrics for assessment of mountain landscape using GIS applications, *Revista de Geomorfologie*, 11, 59-62.
32. Pătru-Stupariu I., Stupariu M. S., Cuculici R. and Huzui A., 2011 – Application of the global indicators to landscape change modeling on Prahova Valley (Romanian Carpathians and Subcarpathians), *International Journal of the Physical Sciences*, 6, 3, 534-539.
33. Pe’er G., Dicks L. V., Visconti P., Arlettaz R., Báldi A., Benton T. G., Collins S., Dietrich M., Gregory R. D., Hartig F., Henle K., Hobson P. R., Kleijn D., Neumann R. K., Robijns T., Schmidt J., Shwartz A., Sutherland W. J., Turbé A., Wulf F. and Scott A. V., 2014 – EU agricultural reform fails on biodiversity, *Science*, 344, 1090-1092.
34. Popescu V. D., Rozylowicz L., Niculae I. M., Cucu A. L. and Hartel T., 2014 – Species, Habitats, Society: An Evaluation of Research Supporting EU’s Natura 2000 Network, *PLoS ONE*, 9, 11, e113648.
35. Primack R. B., Pătroescu M., Rozylowicz L. and Ioja C., 2008 – Fundamentele conservării diversității biologice, Edit. AGIR, Bucureşti, 668 (in Romanian)
36. Pullin A. S., Baldi A., Can O. E., Dieterich M., Kati V., Livoreil B., Lövei G., Mihók B., Nevin O., Selva N. and Sousa-Pinto I., 2009 – Conservation Focus on Europe: Major Conservation Policy Issues, *Conservation Biology*, 23, 818-824.
37. Rempel R. S., Kaukinen D. and Carr A. P., 2012 – Patch Analyst and Patch Grid, Ontario Ministry of Natural Resources, Centre for Northern Forest Ecosystem Research, Thunder Bay, Ontario. Available at http://www.cnfer.on.ca/SEP/patchanalyst/, accessed at 26.04.2015.
38. Rozylowicz L., 2008 – Metode de analiză a distribuţiei areal-geografice a ţestoasei lui Hermann (Testudo hermanni Gmelin, 1789) în România, Studiu de caz: Parcul Natural Porţile de Fier, Edit. Universității din București. (in Romanian)
39. Schreiber W. E., Drăguţ L. and Man T. C. (eds), 2003 – Analiza peisajelor geografice din partea de vest a Câmpiei Transilvaniei, Presa Universitară Clujeană, Cluj-Napoca. (in Romanian)
40. Turner I. B. L. and Meyer W. B., 1994 – Global Land-Use and Land Cover Change: An Overview, in Changes in Land Use and Land Cover: A global Perspective, Mezer B. I. and Turner B. L., (eds), Cambridge University Press.
41. Turner M. G., Gardner R. H. and O’Neill R. V., 2001 – Landscape ecology in theory and practice, Pattern and process, Springer-Verlag, New York, USA, 406.

SPATIAL AND TEMPORAL DYNAMIC OF RURAL AND URBAN LANDSCAPES IDENTIFIED IN THE "IRON GATES" NATURAL PARK

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KEYWORDS: Rural and urban landscape, land use, land cover, landscape change, "Iron Gates" Natural Park, Romania.

ABSTRACT

In the present paper, we identified landscape typologies in the "Iron Gates" Natural Park from Romania and assessed their dynamic starting with 1990 to 2006. We evaluated the dynamic of landscapes based on land use and land covers changes as extracted from the Corine Land Cover databases. We found no major modifications in the distribution of landscapes, only 4.4% of the study area recording changes. Forestry landscapes have the highest ratio of change (on 1.5% from the total surface of the park), with significant decreases also recorded in landscapes of shrub and rare vegetation, as well as mixed agricultural landscapes. Among the active transformation processes, forestation (on 45% of the modified surface) and agricultural activities (20%) recorded the highest distribution.

RÉSUMÉ: La dynamique spatiale et temporelle des paysages ruraux et urbains dans le Parc Naturel des "Portes de Fer".

L'article fait un inventaire des catégories de paysages qui se trouvent dans le Parc Naturel des "Portes de Fer" des Roumanie et analyse la dynamique de ces paysages de 1990 à 2006. L'analyse de la dymamique a été réalisée en prenant en considération les changements des modes d'utilisation des terrains quantifiés avec les données de CORINE Land Cover. Les changements n'ont pas été majeurs, la surface modifiée étant de 4.4% du total du territoire. La croissance la plus importante de la superficie a été enregistrée pour les paysages forestiers (1.5% du total du parc). Des réductions plus importantes ont été enregistrées pour les broussailles et les paysages avec moins de végétation naturelle, en incluant ici les terrains agricoles mixtes. Comme processus de transformation, la régénération des forêts a représenté (45% du total de la superficie modifiée) et l'agriculture de type intensive (a représenté 20%).

REZUMAT: Dinamica spaţială şi temporală a peisajelor rurale şi urbane identificate în arealul Parcului Natural Porţile de Fier.

Lucrarea îşi propune să identifice categoriile de peisaje din cadrul Parcului Natural „Porţile de Fier" din România, şi să evalueze dinamica acestora în intervalul 1990 la 2006. Evaluarea dinamicii s-a realizat pe baza analizei schimbării modului de utilizare al terenurilor, utilizând datele CORINE LandCover. În intervalul analizat nu s-au înregistrat schimbări majore, suprafaţa modificată fiind de 4.4% din totalul arealului. Cele mai mari creşteri ale suprafeţelor s-au înregistrat în cazul peisajelor forestiere (1.5% din suprafaţa parcului). Diminuări însemnate s-au înregistrat în cazul suprafeţelor cu tufărişuri şi cele cu vegetaţie rară, coroborate cu cele agricole mixte. În ceea ce priveşte procesele de transformare identificate, împăduririle au ocupat cea mai mare suprafaţă (45% din suprafaţa modificată), completate de intensificarea agriculturii (20% din suprafaţa modificată).

INTRODUCTION

According to the European Landscape Convention (Council of Europe, 2000), the landscape designates parts of a territory perceived by the population; its characteristics being a result of actions and interactions between natural and human factors. Landscapes contribute to sustainable development and human well-being, with its recognized functions as the social, cultural, economic or ecological ones (Prieur, 2006). Landscapes spatial and temporal dynamic represents subjects of interest for researchers at different spatial scales (Niculae, 2012).

In protected areas, landscapes are considered a component of the natural material heritage (Grigorovschi et al., 2007), with its complexity and characteristics determined by the interaction of three main components: abiotic potential (as a support for the other two), biodiversity and cultural diversity (Pătroescu et al., 2000; Pătru-Stupariu, 2011; Toma, 2008). The landscape is seen as a materialization of the natural capital and present land use (Feranec et al., 2002), representing a symbolic element of social dialogue between communities through its connections at diverse spatial and temporal scales (Faburel et al., 2012).

In analysing landscape dynamic the CLC database, aerial images and existing maps represent important data sources as the land use is one of the most used indicators (Feranec et al., 2002). Monitoring the changes in land uses and land covers of a certain territory represents an important instrument in assessing the manner to which policies and public measures influence the use of natural resources by the population (Thiha and Honda, 2007). Changes in land uses are determined by the intensification of certain land-use forms, whilst changes in land cover relate both to their conversion (changing into another class) and modification of the characteristic conditions (Coppin et al., 2004).

In Romanian protected areas with large surfaces (national and natural parks, Natura 2000 sites), landscapes represent an important component as they integrate patrimonial values of natural or cultural elements. Landscapes represent elements conferring identity, individuality, and often uniqueness to protected areas of national interest which contribute to the protection and conservation of landscape structures and functionality. The identification of defining elements of landscapes and their typologies represents an essential instrument in analysing their spatial and temporal dynamic. In addition – in the case of protected areas – it represents a tool for developing an adequate landscape management, useful both to protected areas managers and spatial planners at local or regional scales.

The aim of our study is to analyze, landscape dynamic in the “Iron Gates” Natural Park from 1990 onwards. The objectives of our paper are: a) identifying landscape typologies in the “Iron Gates” Natural Park, and b) evaluating the spatial and temporal dynamic of landscape typologies in the study area in the period of significant social and economic changes, and to return to a private properties regime and establishment of the protected area.

MATERIAL AND METHODS

The “Iron Gates” Natural Park was established through Law 5/2000 regarding the National Planning Framework, Section III – protected areas (Guvernul României, 2013). According to the IUCN classification, the “Iron Gates” Natural Park corresponds to category V, being a protected area managed especially for landscape conservation and recreation (IUCN, 2014). Located in the south-western part of Romania (Pătroescu and Rozylowicz, 2000), the “Iron Gates” Natural Park is circumscribed by the Caraş-Severin and Mehedinţi counties (Cucu et al., 2012), overlapping for the most parts the Locvei, Almăj and Mehedinţi mountains, and the Mehedinţi Plateau (CCMESI, 2002).

The area is characterized by a high biodiversity and geologic complexity, and by the presence of numerous cultural vestiges, all revealing the existence of a scientific and landscape heritage of international importance (Matacă, 2005).

The "Iron Gates" Natural Park is placed in the temperate continental climate area with Mediterranean influences (Bazac and Moldoveanu, 1996; Pătroescu et al., 2005). Annual temperatures are 11.5°C in Moldova Nouă and Șvinița, and 11.6°C in Drobeta Turnu Severin, while precipitations are between 559 mm in Orșova and 800-1,000 mm in Moldova Veche (Bazac and Moldoveanu, 1996; Matacă, 2005).

The diversity of soils present in the study area plays an important role in the structure and functions of both ecosystems and landscapes.

The vegetation is represented especially by forest ecosystems together with associations of shrubs, pastures, and ruderal elements. A specific element of the "Iron Gates" Natural Park is the presence of Sub Mediterranean vegetation (Călinescu and Iana, 1964; CCMESI, 2002; Pătroescu and Rozylowicz, 2000) which projects in the physiognomy of landscapes present in the area. Of special interest are the formations known as "şibleac" – association of thermophile shrubs specific to the Danube Gorge (Călinescu and Iana, 1964; Pătroescu and Rozylowicz, 2000; Matacă, 2005).

The "Iron Gates" area is characterized by the presence of a high number of vascular plants (with 1,749 species and 120 different subspecies present in the park, they spread over 570 genus and 131 families, accounting for approximately 50% of the total species in Romania), of which Mediterranean and Sub Mediterranean species are represented by 217 taxon (Matacă, 2005).

Methods used in identifying landscape typologies in the "Iron Gates" Natural Park

We realized the identification of landscape typologies based on aerial images, existing maps and field researches. The first stage was represented by the identification of elements characterizing the composition of landscapes. The identification and classification of landscapes from the "Iron Gates" Natural Park is a complex process, with diverse criteria of functional, structural, spatial, temporal, and aesthetic nature used in delineating landscape types and subtypes (Ciocănea, 2013).

For the structural characteristics we used the morphological criteria expressed by the form, type and texture, but also included elements, either of natural or anthropic origin (Ciocănea, 2013; Drăguţ, 2000). We delineated the functional characteristics based on the functions identified in the field, while for the spatial-temporal characteristics of anthropic landscapes we considered the form, geographic position, and territorial expansion (Ciocănea, 2013; Jucu, 2010).

We constructed the landscape typologies based mainly on the land use and land cover, which we considered to directly project on categories of natural landscapes, especially agricultural and forest landscapes (Niculae, 2012). In delineating anthropic landscapes we used two main aspects: economic criteria (agricultural and industrial activities) and social-demographic criteria (based on the number of inhabitants and the type of settlement – urban or rural) (Niculae, 2012; Perşu and Nancu, 2009; Vert, 2001).

Analysis of landscape dynamic in the “Iron Gates” Natural Park

We evaluated landscape dynamic in the “Iron Gates” Natural Park based on the spatial database established by the European Environmental Agency (EEA) in the framework of the CORINE LandCover (CLC) project. We selected spatial data in a raster format and a 100*100 meters resolution for the years 1990 and 2006 (data available at the links http://www.eea.europa.eu/data-and-maps/data/corine-land-cover-1990-raster-3 and http://www.eea.europa.eu/data-and-maps/data/corine-land-cover-2006-raster-3). Using Arcgis 9.3 we projected the initial data in the Stereo 70 system keeping the 100*100 resolution. Based on the data we obtained land use and land cover maps (Figs. 1 and 2) specific to the study area.

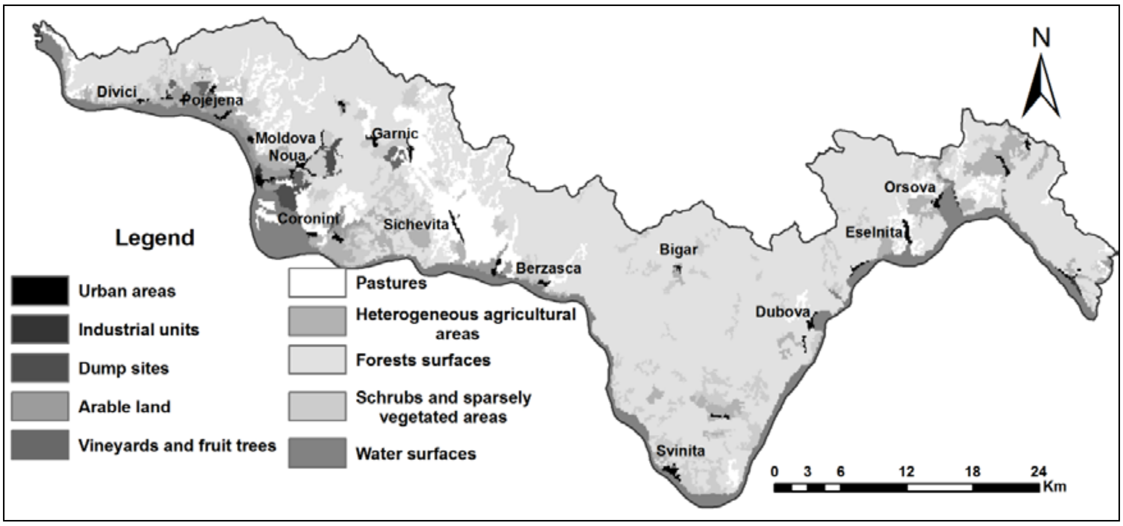


Figure 1: Land use and land cover classes in the “Iron Gates” Natural Park
for the year 1990 (CLC 1990).

Based on the situations identified in the field and the objectives of our study, we reclassified the 19 classes resulting from CLC data level III (both for 1990 and 2006) into 10 classes (Tab. 1), each with a corresponding code from one to 10. The resulting land use and land cover classes are corresponding to the main categories of landscapes identified in the “Iron Gates” Natural Park.

To evaluate the similitudes between the reference map and the compared one (Geri et al., 2010), we calculated the kappa coefficient of Cohen (KIA) (Cohen, 1960, 1968) for the main land uses and land cover in the “Iron Gates” Natural Park, as well as for the entire study area (Rosenfield and Fitzpatrick-Lins, 1986).

Based on the CLC databases, we identified and prioritized the main processes of transformation in the study area (Niculae, 2012; Feranec et al., 2000; Haines-Young and Weber, 2006; Perdigao and Christensen, 2000).

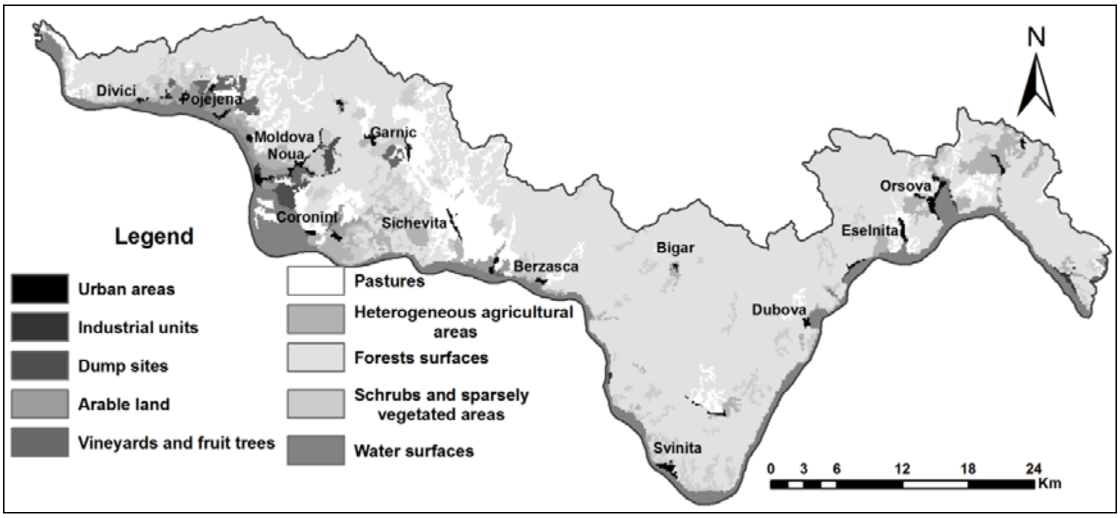


Figure 2: Land use and land cover classes in the “Iron Gates” Natural Park for the year 2006 (CLC 2006).

Table 1: Reclassified land use and land cover classes in the “Iron Gates” Natural Park (Bossard et al., 2000).

CLC Level I code	CLC Level II code	CLC Level III code	Reclassified code	Name of reclassified classes
1.	11	112	1	Urban areas
	12	121; 123	2	Industrial units
	13	131; 132	3	Mineral extraction and dump sites
2.	21	211	4	Arable land
	22	221; 222	5	Vineyards and fruit trees
	23	231	6	Pastures
	24	242; 243	7	Heterogeneous agricultural areas
3.	31	311; 313	8	Forests
	32	321; 324	9	Shrubs and sparsely vegetated areas
	33	332; 333		
5.	51	511; 512	10	Water surfaces

In order to analyze land use dynamic that influence the dynamic of landscapes in the “Iron Gates” Natural Park, we delineated six transformation processes (Feranec et al., 2000; Feranec et al., 2010) which play important roles in landscape dynamic (Tab. 2).

Based on the transition matrix above, we quantified the surface for each process of transformation and their proportion (both to the total area of the “Iron Gates” Natural Park and to the total surface that has been modified).

Table 2: Main transformation processes identified in the “Iron Gates” Natural Park (Feranec et al., 2010).

Process of transformation	Description
Urbanisation (including industrial development) (PT1)	Transformation of agricultural lands (classes 21, 22, 23), forests and semi natural surfaces (31, 32, 33) and water bodies (51) in surfaces dominated by built up areas
Intensification of agriculture (PT2)	Transformation of land uses of low intensity (semi natural surfaces – classes 3.2, 3.3) in agricultural intensive fields, and transformations between the agricultural classes of level II and III
Reduction of agriculture (PT3)	Transformation of intensive used fields (classes 2.1, 2.2) in land uses of low intensity
Forestation (PT4)	Natural forest regeneration and consequence of man-made plantations for the fixation of degraded lands and increasing the naturalness degree (converting classes 2.1, 2.2, 2.3, 2.4, 3.3 into class 3.1)
Deforestation (PT5)	Lands occupied by forests (class 3.1) converted in other land use classes
Management of water bodies (wetlands) (PT6)	Transformation of agricultural lands (classes 2.1, 2.2, 2.3 and 2.4) in wetlands, including lands covered by waters during floods
Other changes (PT7)	Other transformations: cultivation, extraction sites, unclassified transformations, etc.

RESULTS AND DISCUSSION

Categories of landscapes identified in the “Iron Gates” Natural Park

In the “Iron Gates” Natural Park we identified two main landscape types (Fig. 3).

A. Natural landscapes determined by physical and geographical characteristics

Based on the differences regarding qualitative and quantitative aspects of elements included in the natural landscapes, we were able to differentiate two subcategories (CCMESI, 2014; Niculae, 2012): a) natural landscapes induced by the structural and petrographic relief, and b) landscapes imposed by the physiognomy and distribution of vegetation.

Landscapes determined by the structural and petrographic relief represent real elements of the natural heritage and include the following subcategories: mountain peak landscapes, tectonic and sedimentary basin landscapes, meadow landscapes, terraces landscapes, and the Danube Gorge landscape (Fig. 4A).

Landscapes dominated by vegetation elements include forest landscapes distributed in the mountainous units, the forested grasslands (on small surfaces and with increase fragmentation), and the specific landscape of the “Iron Gates” Natural Park of the vegetation formation known as “șibleac” (Fig. 4B) – secondary association resulted from the deforestation of the highest layers from the thermophile forests and containing now only elements of the lower layers such as downy oak, manna, wig, lilac, etc. (Matacă, 2005; Călinescu and Iana, 1964).

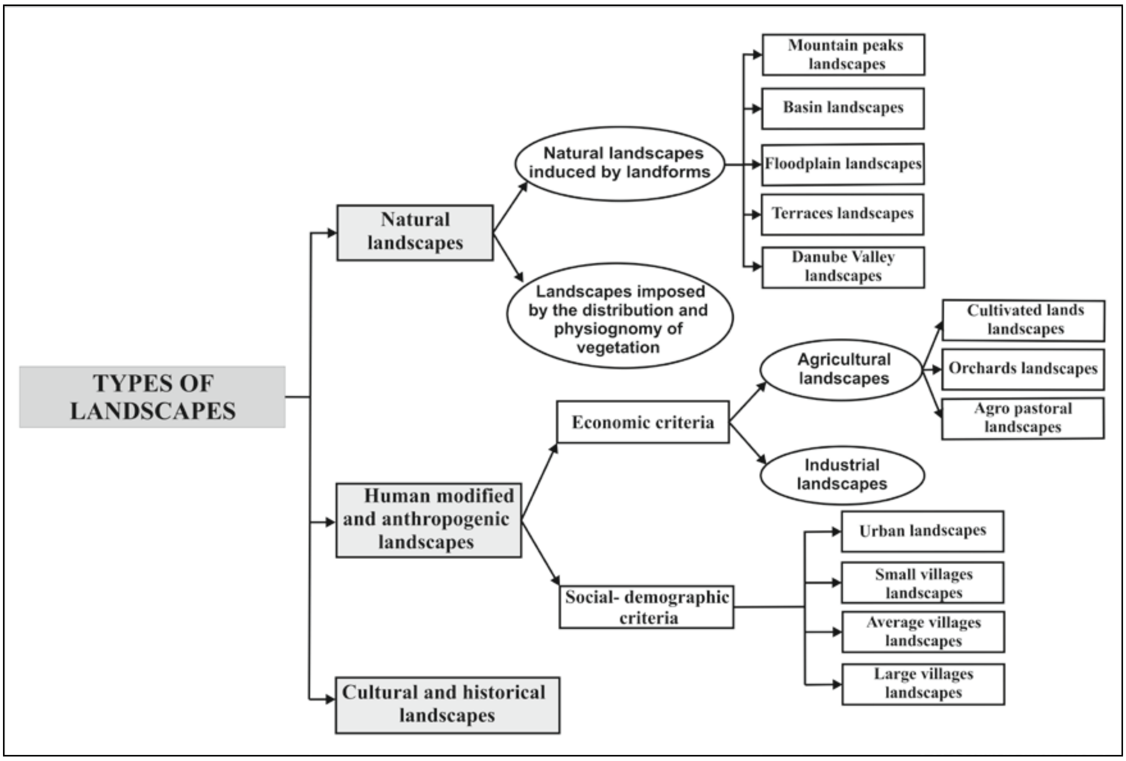
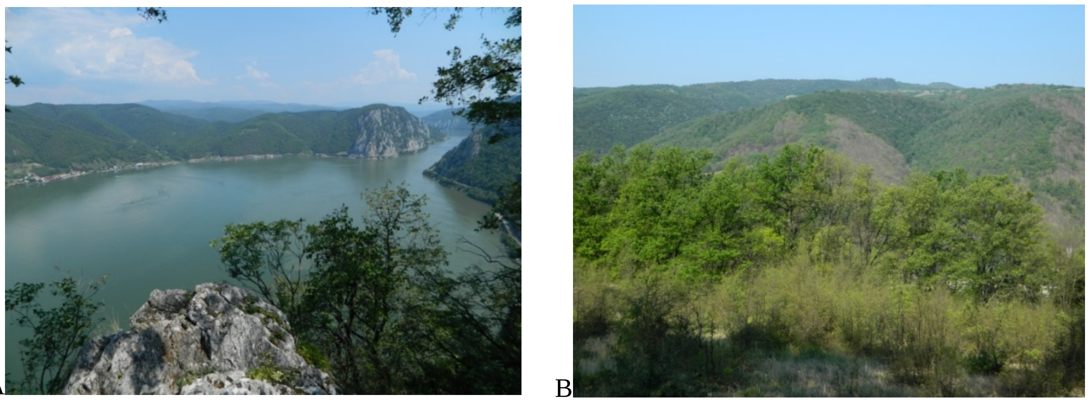


Figure 3: Landscape typologies in the "Iron Gates" Natural Park.



A B

Figure 4: Landscape of the Danube Gorge and the Dubova Bay (A);
"şibleac" association on the Ciucaru Mare Peak (B).

B. Anthropic landscapes

Using the economic and social-demographic criteria, we identified in the "Iron Gates" Natural Park the following subtypes of anthropic landscapes (CCMESI, 2014): a) agricultural landscapes, b) industrial landscapes, and c) landscape of rural and urban settlements.

Agricultural landscapes determined by the main land uses are represented by subtypes as the landscape of closed cultivated lands (Figs. 5A and 5B), orchard landscapes, agro-pastoral landscapes specific to mountainous and basin areas, and mixed agricultural landscapes.

Considering the social-demographic criteria, we identified the following subtypes: urban landscapes (Orșova, Moldova Nouă), landscape of small villages (Cârșie, Zăsloane, Eibenthal, etc.), landscape of medium villages (Gornea, Pojejena, etc.) and the landscape of large villages (Eșelnița, Berzasca, Coronini, etc.).

A  B 

Figure 5: Agricultural landscapes identified on the Sfânta Elena (A) and Gârnic (B) plateaus.

A special category is represented by the cultural and historical landscapes determined by the elements of material and immaterial heritage (Schreiber et al., 2008). The constructed heritage is represented by buildings considered historical monuments or with architectural value, archaeological sites (Gornea, Schela Cladovei – where evidences of the oldest permanent settlement in Europe have been identified) (CCMESI, 2004), ruins of citadels and fortresses (Drencova, Divici, Trikule, Ladislau, etc.), traditional households, monasteries and churches (Vodița Monastery, Sfânta Ana Monastery, Baziaș Monastery, Eșelnița Church, Eibenthal Church, Berzasca Church, etc.). All these elements are harmoniously integrated with the elements of the small heritage: defence systems, crosses and trinities, water mills on the Camenița Valley, statues, etc.

Landscape dynamic in the “Iron Gates” Natural Park

Following the cross-tabulation analysis using ArcGis 9.3, we obtained a transition matrix (Tab. 3) which presents the value for each process of transformation, therefore representing a strong measurement of the spatial and temporal dynamic of landscapes in the “Iron Gates” Natural Park.

The quantification of changes in land use and land cover classes allowed us to record areas where the surfaces increased or reduced for each of the 10 landscape categories, and to establish the modification rates of their total surface (Tab. 4).

A number of six classes recorded surface increases in the 1990-2006 periods, while the total surface in the case of three classes reduced. Only the surface of mineral extraction and dump sites remained constant for the analyzed period.

Orchards and vineyards recorded the most significant increases (+687 ha, ~93%), followed by the lands occupied by industrial activities (+86 ha, ~69%), built up surfaces (+87 ha, ~6%), and forest surfaces (+1884 ha, ~2.3%).

Significant decreases were recorded by the class of shrubs, rare vegetation and natural grasslands (–2254 ha, ~22%), and the class of mixt agricultural lands (–760 ha, ~11.5%).

The surface that suffered no modifications in the analyzed period is of 122,502 ha, representing ~95.6%, while the modified surfaces represent 5,696 ha (~4.4%).

Table 3: Transition matrix resulted from the comparison of the two datasets; * Land use and land cover classes according to table 1.

Classes	2006										
1990	1*	2	3	4	5	6	7	8	9	10	Total
1*	1,282	47	0	0	0	2	35	8	0	0	1,374
2	0	125	0	0	0	0	0	0	0	0	125
3	0	0	698	0	0	0	0	0	0	0	698
4	0	0	0	2,074	34	0	1	0	0	4	2,113
5	0	0	0	0	738	0	0	0	0	0	738
6	0	0	0	0	0	12,653	0	92	119	0	12,864
7	148	15	0	8	16	204	5,408	259	486	101	6,645
8	15	0	0	0	0	60	235	82,128	424	6	82,868
9	0	24	0	0	637	257	151	2220	6,784	0	10,073
10	16	0	0	6	0	0	55	5	6	10,612	10,700
Total	1,461	211	698	2,088	1,425	13,176	5,885	84,712	7,819	10,723	128,198

Table 4: Changes recorded in land use and land covers classes between 1990-2006; * Values represent differences between increases and reductions for the surface of each class.

Land use and land cover classes	Area 1990 (ha)	Area 2006 (ha)	Areas with increases (ha) (1990-006)	Areas with reduction (ha) (1990-2006)	Difference (ha) (1990-2006)*
1	1,374	1,461	179	92	+87
2	125	211	86	0	+86
3	698	698	0	0	0
4	2,113	2,088	14	39	–25
5	738	1,425	687	0	+687
6	12,864	13,176	523	211	+312
7	6,645	5,885	477	1,237	–760
8	82,868	84,712	2,584	740	+1,844
9	10,073	7,819	1,035	3,289	–2,254
10	10,700	10,723	111	88	+23

These results are confirmed by the value of the Kappa concordance index calculated for the two time periods regarding the land use and land cover. The value of 0.93 indicates a reduced spatial modification of surfaces (Cohen, 1960; Cohen, 1968) and a high concordance (0.80 < KIA < 1.00) (Altman, 1991).

The existing relationships between the six processes of transformation (PT1-PT6) and the classes derived from the CLC level II database allowed us to establish the matrix of transformations (Tab. 5) recorded for each land use and land cover class in 1990-2006.

Based on the correlation between the values from the transition matrix (resulted from the comparison of the two data sets) and the matrix of transformation processes among the land use and land cover classes, we calculated the percent of surfaces affected by the main processes of transformation (PT1-PT6) in relation to the total surface of the "Iron Gates" Natural Park and the total modified surface (Feranec et al., 2010) (Tab. 4).

Table 5: Matrix of transformation processes among the land uses and land cover classes. * The numbers 1 to 10 in the first column and row correspond to the reclassified codes from table 1, and those in brackets to the CLC level II codes; ** 1 – urbanisation; 2 – intensification of agriculture; 3 – reduction of agriculture; 4 – forestation; 5 – deforestation; 6 – management of water bodies (wetlands); 7 – other changes.

Classes	1990									
2006	1* (11)	2 (12)	3 (13)	4 (21)	5 (22)	6 (23)	7 (24)	8 (31)	9 (32; 33)	10 (51)
1(11)	0	7	7	1**	1	1	1	1	1	1
2 (12)	7	0	7	1	1	1	1	1	1	1
3 (13)	7	7	0	1	1	1	1	1	1	1
4 (21)	7	7	7	0	3	2	2	5	2	7
5 (22)	7	7	7	2	0	2	2	5	2	7
6 (23)	7	7	7	3	3	0	3	5	2	7
7 (24)	7	7	7	3	3	2	0	5	2	7
8 (31)	7	7	7	4	4	4	4	0	4	4
9 (32, 33)	7	7	7	7	7	7	7	5	0	7
10 (51)	7	7	6	6	6	6	6	6	6	0

Table 6: The main processes of transformation identified in the “Iron Gates” Natural Park; * Percent calculated from the total modified surface; ** Percent calculated from the total surface of the “Iron Gates” Natural Park.

Processes of transformation	Surface (ha)	Percent (%)*	Percent (%)**
Urbanisation (including industrial development) (PT1)	218	3.83	0.17
Intensification of agriculture (PT2)	1,103	19.36	0.86
Reduction of agriculture (PT3)	205	3.60	0.16
Forestation (PT4)	2,576	45.22	2.01
Deforestation (PT5)	719	12.62	0.56
Management of water bodies (wetlands) (PT6)	111	1.95	0.09
Other changes (PT7)	764	13.41	0.6
Unmodified surface	122,502	–	95.56
Total modified surface	5,696	100	4.44

Changes in land use and land cover represent an important indicator in evaluating the dynamic of landscapes (Feranec et al., 2002) we identified in the “Iron Gates” Natural Park. The main categories of landscapes represent elements of the natural and cultural heritage that increase the value of this protected area of national, regional and worldwide interest. Natural landscapes determined by the physical and geographical characteristics, together with the anthropic landscapes generated by social and economic factors, represent an important element that was considered in the establishment of the protected area regime.

The characteristics of the relief and land cover generate a high proportion of surfaces covered by forests; therefore, forest landscapes are dominant in the "Iron Gates" Natural Park, being accompanied by the agricultural and agro-pastoral landscapes.

Landscapes of urban and rural settlements are present along the Danube and on its tributary valleys, but also on the mountainous plateaus where the morphometric characteristics of the relief represented a favourability factor in the historical evolution of settlements.

Elements of the material and immaterial heritage (Schreiber et al., 2008) supplement the typologies of identified landscapes increasing the personality of local communities from the "Iron Gates" Natural Park.

The dynamic of landscapes determined by the land use and land cover did not record significant changes in the analyzed interval (with modification on only ~ 4.4% of the total surfaces), sustained also by the value of the KIA index (0.93) representing reduced spatial modification of landscapes in 2006 compared to 1990.

The highest surface increases were recorded for forest landscapes, orchards, and agro-pastoral landscapes with pastures. Having a protected area status, the "Iron Gates" region benefits from a high degree of protection and conservation, measures that directly target forest landscapes. In the "Iron Gates" Natural Park forest surfaces have increased either through natural regeneration, or anthropic plantations for increasing the naturalness or fixating degraded lands.

Surfaces occupied by shrubs and rare vegetation, corroborated with mixed agricultural uses (heterogeneous), recorded significant decreases in surfaces, in the favour of forest surfaces for the expansion of pastures, or by the development of residential and industrial areas required for satisfying the human needs (Niculae and Pătroescu, 2011). Previous studies (Cucu et al., 2013) have revealed that the most aggressive threats to the protected areas at "Iron Gates" Natural Park are represented by industrial activities, different pollution, and human impact.

Values extracted from the Corine Land Cover model are different than those obtained from statistical data existing at county and national level. These differences are generated mainly due to data interpretation and the methodology of classification for different land uses and land covers established the European Environmental Agency (Feranec et al., 2000).

According to the management plan of the "Iron Gates" Natural Park – approved by the Romanian Government in December 2013 (Guvernul Romaniei, 2013) – residential, industrial, and resource exploitation spaces have expanded especially in the sustainable development zone as established by the present legislation.

Our research on the processes of transformation in the "Iron Gates" Natural Park showed that forestations (either by human actions or natural causes) have the highest proportion (~ 2% of the total area and ~ 45% of the surface modified between 1990 and 2006). In addition, the increase of agricultural activities was present on ~ 0.9% of the park area (~ 20% of the surface modified between 1990 and 2006). These values have been generated particularly by the dominance of rural communities in the park and by the relief conditions favouring these types of economic activities.

CONCLUSIONS

In the framework of present environmental, social, and economic changes, landscapes are generally confronted to an accelerated dynamic. This is not the case in the "Iron Gates" Natural Park, where the protected area regime and the characteristics of social and economic elements determined changes in fewer than 5% of the total surface of landscapes.

The typologies of landscapes identified in the “Iron Gates” Natural Park can serve as support for both future studies and public administration. Our analysis represent a model for the dynamic of landscapes which can be improved by adding data of a better special resolution or integrating the view of residents as an important element in landscape evaluation.

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REFERENCES

1. Altman D. G., 1991 – Practical statistics for medical research, Chapman and Hall, London, 624.
2. Bazac G. and Moldoveanu M., 1996 – Unele caracteristici ale influențelor mediteraneene asupra climei din Sud-Vestul României, *Terra*, XXVIII, 86-97. (in Romanian)
3. Călinescu R. and Iana S., 1964 – Considerațiuni biogeografice asupra Defileului Dunării, *Analele Universității București, Seria Geologie-Geografie*, XIII, 1, 151-167. (in Romanian)
4. CCMESI, 2002 – Metodologie de inventariere a habitatelor populate de țestoasa lui Hermann în arealul Parcului Natural Porțile de Fier, in Pătroescu M., (ed.), LIFE00NAT/RO/7171, Rapoarte de acțiune, Universitatea din București, CCMESI. (in Romanian)
5. CCMESI, 2004 – “Iron Gates” Natural Park, LIFE Nature project LIFE/NAT/RO/7171, University of Bucharest, CCMESI.
6. CCMESI, 2014 – Studiu privind întocmirea metodologiei de identificare, caracterizare şi clasificare a peisajelor în zona transfrontalieră Parcul Natural Porţile de Fier şi Parcul Naţional Djerdap, Raport final realizat în cadrul proiectului Integrated Management Of Biological And Landscape Diversity For Sustainable Regional Development And Ecological Connectivity In The Carpathians (Bioregio Carpathians), 75. (in Romanian)
7. Ciocănea C. M., 2013 – Modificări structurale şi funcţionale ale peisajelor urbane determinate de modelele de consum ale societăţii, Studiu de caz – Sectorul 3 al Municipiului Bucureşti, Teză de doctorat, Facultatea de Geografie, Universitatea din Bucureşti, 239. (in Romanian)
8. Cohen J., 1960 – A coefficient of agreement for nominal scales, *Educational and Psychological Measurement*, 20, 1, 37-46.
9. Cohen J., 1968 – Weighted kappa: Nominal scale agreement provision for scaled disagreement or partial credit, *Psychological Bulletin*, 70, 213-220.
10. Coppin P., Jonckheere J., Nackaerts K., Muys B. and Lambin E., 2004 – Digital change detection methods in ecosystem monitoring: a review, *International Journal of Remote Sensing*, 25, 9, 1565-1596.
11. Council of Europe, 2000 – European Landscape Convention. Available at: http://conventions.coe.int/Treaty/Commun/QueVoulezVous.asp?NT=176&CM=8&CL=ENG, accessed on 6.11.1982.
12. Cucu L. A., Niculae M. I. and Pătroescu M., 2012 – Hierarchical analysis of the threats for species of Community Interest in the “Iron Gates” Natural Park, Romania, *Forum Geografic, Studii și cercetări de geografie și protecţia mediului*, 12, 1, 52-58.
13. Cucu L. A., Niculae M. I. and Pătroescu M., 2013 – Species management in the “Iron Gates” Natural Park: an overview of zonation effectiveness, *Present Environment & Sustainable Development*, 7, 2, 145-155.
14. Drăguţ L., 2000 – Geografia peisajului, Edit. Presa Universitară Clujeană, Cluj, 119. (in Romanian)

15. Faburel G. (coord.), Altaber C., Chevallier K., Meyer L. and Gageonnet C., 2012 – Le bien-être et ses paysages comme territoires des infrastructures de transport terrestre, Conflits d'acteurs, enjeux de valeurs et savoirs paysagers, du Bureau de recherches Aménités pour le Ministère de l'Ecologie, du Développement Durable et de l'Energie, Programme scientifique Infrastructures de Transport Terrestre Ecologie Paysages (ITTECOP), 1-19.
16. Feranec J., Suri M., Otahel J., Cebecauer T., Kolar J., Soukup T., Zdenkova D., Waszmuth J., Vajdea V., Vajdea A. M. and Niţică C., 2000 – Inventory of major landscape changes in the Czech Republic, Hungary, Romania and Slovak Republic 1970s-1990s, *International Journal of Applied Earth Observation and Geoinformation*, 2, 2, 129-139. (in French)
17. Feranec J., Šúri M., Cebecauer T. and Oťaheľ J., 2002 – Methodological aspects of landscape changes detection and analysis in Slovakia applying the CORINE land cover databases, *Geografický časopis*, 53, 3, 271-288.
18. Feranec J., Jaffrain G., Soukup T. and Hazeu G., 2010 – Determining changes and flows in European landscapes 1990-2000 using CORINE land cover data, *Applied Geography*, 30, 19-35.
19. Geri F., Amici V. and Rocchini D., 2010 – Human activity impact on the heterogeneity of a Mediterranean landscape, *Applied Geography*, 30, 370-379.
20. Grigorovschi M., Dida M., Gafar M., Erca C., Retegan E. and Suler T., 2007 – Ghid de valorificare a patrimoniului rural, Casa de Presă şi Edit. Tribuna, Sibiu, 172. (in Romanian)
21. Gruia L. and Glăvan V., 1979 – Posibilități de îmbunătățire a potențialului agro și silvocultural al unor soluri din Defileul Dunării, *Analele Universității din București*, XXVIII, 2, 89-93. (in Romanian)
22. Guvernul României, 2013 – Hotărârea nr. 1048/2013 pentru aprobarea Planului de management și a Regulamentului Parcului Natural Porțile de Fier, Monitorul Oficial al României, nr. 119/2014, I. (in Romanian)
23. Haines-Young R. and Weber J. L., 2006 – Land accounts for Europe 1990-2000, Towards integrated land and ecosystem accounting, EEA Report, 11, European Environment Agency, Copenhagen, 108.
24. IUCN, 2014 – IUCN Protected Areas Categories System, available at http://www.iucn.org/about/work/programmes/gpap_home/gpap_quality/gpap_pacategories/ accessed on 7.02.2014.
25. Jucu I. S., 2010 – Cadrul teoretic şi metodologic de analiză al procesului de restructurare urbană specific oraşului românesc post-socialist, *Analele Asociaţiei Profesionale a Geografilor din România*, 1, 1, 67-84. (in Romanian)
26. Matacă S. S., 2005 – Parcul Natural Porţile de Fier, Floră, vegetaţie şi protecţia naturii, Edit. Universitaria, Craiova, 550. (in Romanian)
27. Niculae M. I., 2012 – Evoluția spațială și temporală a peisajelor rurale din Subcarpații cuprinși între Buzău și Râmnicu Sărat, Edit. Universității din București, București, 282. (in Romanian)
28. Niculae M. I. and Pătroescu M., 2011 – Quantifying forest ecosystems fragmentation in the Subcarpathians between the Râmnicu Sărat and the Buzău valleys, Romania, using landscape metrics, *Forum Geografic, Studii şi cercetări de geografie şi protecţia mediului*, 10, 1, 187-194.
29. Pătroescu M. and Rozylowicz L., 2000 – Natural Transborder Parks: the direction of Biodiversity preservation in Romania, in Crabbe et al. (eds), Implementing ecological integrity, Kluwer Academic Press, 101-113.
30. Pătroescu M., Toma S., Sasaki L. and Apostol G., 2000 – Priorities in the re-habilitation and re-naturation of rural landscape of the Romanian Plaine, Southern Romania, *Analele Universității București, Seria Geografie*, 95-102.
31. Pătroescu M., Iojă C., Rozylowicz L., Popescu V., Tetelea C., Dumitrașcu D. and Necșuliu R., 2005 – Planul de management al Parcului Natural Porţile de Fier – Partea I, caracterizare complexă a arealului studiat, in Pătroescu M. (ed.), Raport de cercetare, proiectul LIFE00/NAT/RO/7171. (in Romanian)

32. Pătru-Stupariu I., 2011 – Peisaj şi gestiunea durabilă a peisajului, Aplicaţii la Culoarul transcarpatic Bran-Rucăr-Dragoslavele, Edit. Universităţii din Bucureşti, Bucureşti, 214. (in Romanian)
33. Perdigao V. and Christensen S., 2000 – The Lacoast Atlas: Land cover changes in European coastal zone, S.P.I.00.39 EN, European Commission, DJ-Joint Research Centre, Ispra.
34. Perșu M. and Nancu D., 2009 – Types of rural landscapes in the Oltenian Subcarpathian depressions, Forum geographic, *Studii şi cercetări de geografie şi protecţia mediului*, 8, 124-130.
35. Prieur M., 2006 – Paysage et approches sociale, économique, culturelle et écologique, in Conseil de l'Europe (2006) Paysage et développement durable, Les enjeux de la Convention européenne du paysage, 9-29. (in French)
36. Rosenfield G. H. and Fitzpatrick-Lins K., 1986 – A coefficient of agreement as a measure of thematic classification accuracy, *Photogrammetric Engineering and Remote Sensing*, 52, 2, 223-227.
37. Rozylowicz L., 2008 – Metode de analiză a distribuției areal – geografice a țestoasei lui Hermann (Testudo hermanni Gmelin, 1789) în România, Studiu de caz Parcul Natural Porțile de Fier, Edit. Universității din București, București, 169. (in Romanian)
38. Schreiber W., Cocean P., Ciangă N. and Benedek J., 2008 – Protection and valorization of cultural landscapes in Transylvania, in Infrastructure and Ecology of Rural Area 12, Monograph, Cultural landscape, Protecting histroical cultural landscape to strengthen regional identities and local economies, Polish Academy of Science, Crakow Branch Commission of Technical Infrastructure, Crakow, Polish, 155-161.
39. Thiha Weeb E. L. and Honda K., 2007 – Biophysical and policy drivers of landscape change in a central Vietnamese district, *Environmental Conservation*, 34, 164-172.
40. Toma S., 2008 – Dinamica structurilor agrare și proiecția lor în ecologia peisajelor rurale din Câmpia Română, Teză de doctorat, Universitatea din București, București, 362. (in Romanian)
41. Vert C., 2001 –Tipuri de peisaje rurale în Banat, MIRTON, Timișoara, 331. (in Romanian)