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VIRGINIA POPESCU-MARINESCU

(15 July 1930, Calopăr, Dolj county – 16 April 2008, Bucharest)

Our distinguished colleague VIRGINIA POPESCU-MARINESCU passed away after a last spine surgery in "*Bagdasar Arseni*" *Hospital* in Bucharest. We lost a well-known European specialist in the limnology of the Danube and inland waters (zoobenthos). We have known Virginia Marinescu for over 50 years and respected her for her tireless work, for her spirit of collaboration and organization of the research team, for the good advice and guidance she generously gave to the young ones. Our close friend Vingi left us forever, after ceaselessly dedicating her life, until the very last moment, to researches on the living organisms of Romanian waters.

Virginia Marinescu was born in the village of Calopăr, Dolj county, on the right bank of the Jiu River, an ancient settlement, which has maintained and cultivated archaic habits of real beauty and wisdom to these days. Near this village, there was discovered the fortified Getic settlement at Bâzdâna, belonging to the second stage of the Iron Age, chronologically followed by an early Bronze Age settlement (Cotzofeni Culture). The first document of the village of Calopăr dates back to 1804.

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Virginia Marinescu graduated from the University of Bucharest, the Faculty of Biology, Department of Biology-Zoology. Beginning with 1952 she was fully involved in her work:

- 1952-1953: The Ministry of Agriculture-Department of Higher Education – speciality technical adviser;
- 1953-1957: The Agricultural Institute-Bucharest, the Faculty of Veterinary Medicine-Anatomy and Zoology-assistant professor;
- 1958-2002: The Biological Research Center Bucharest, the Traian Săvulescu Institute, the Institute of Biology, the Institute of Development Biology (IDB), the National Institute of Research and Development for Biological Sciences (NIRDBS) Bucharest – director of research programs; coordinator of research teams; head of department (1991-2002) at IDB and NIRDBS; scientific secretary at the Institute of Biology (1971-1979), IDB and NIRDBS (1991-2002).

In 1966, Virginia Marinescu publicly defended at the Faculty of Biology, Bucharest University, the PhD thesis with the title "*Comparative Anatomy of the Gobiidae fishes from Romania*", and obtained the diploma and the scientific title of PhD in Biology in March 1967.

As a remarkable specialist in the study of zoobenthic organisms from the Romanian waters, as well as from the entire Danube River, she collaborated with valuable specialists in many research projects (the late famous Romanian ichthyologist Th. Buşniţă, Gh. Brezeanu, M. Olteanu, Elena Prunescu-Arion, Professor S. Godeanu, C. Măzăreanu, K. Battes, F. Pricope, I. Cărăuş, Rodica Rujinschi, etc.), guided young biologists, some of them among the best specialists in aquatic ecology later.

She collaborated with outstanding personalities of the Danube River watershed limnology, among them representatives of the riparian countries (Reinchard Liepold – first president and then honorary president of the International Arbeitsgemeinschaft Donauforschung), Edmund Weber – Austria, Peter Koth, Thomas Tittizer, Bodo Wachs – Germany, Imrich Daubner, Vladimir Sladecek – Slovenia, Arpad Berczik – Hungary, Lidia Sirenko, Viktor Romanenko – Ukraine, etc.).

The results of the researches performed by Virginia Marinescu along the years have been inscribed in more than 130 scientific papers published in prestigious journals in Romania and abroad or presented at international manifestations, the personal bibliography including also four books, among which we mention: Buşniţă Th., Brezeanu Gh., Olteanu M., Popescu-Marinescu Virginia, Prunescu-Arion Elena, 1970 – ***The Monograph of the Iron Gates Area – The hydrobiologic study of the Danube and its tributaries***, the Publishing House of the Romanian Academy, Bucharest, 266 pp; Battes K., Măzăreanu C., Pricope F., Cărăuş I., Marinescu Virginia, Rujinschi Rodica, 2003 – ***Production and***

Productivity of aquatic ecosystems, "Ion Borcea" Publishing House, Bacău, 339 pp. and ***The results of the Romanian researches carried out in the framework of the International Biological Program***, 1979, the Publishing House of the Romanian Academy, Bucharest, p. 115–119.

Virginia Marinescu's scientific activity carried out for more than 55 years was framed in three major programmes of limnological research:

1. The International Biological Programme-knowledge of Romanian aquatic ecosystems;
2. The international programme for the limnological study of the Danube River;
3. The priority research programme on the protection and capitalization of the Romanian water resources (some of the topics were also included in the International Programme for the Limnological Study of the Danube River).

Virginia Marinescu participated directly or was involved as coordinator in research cases, among which we mention:

- The hydrobiological study of the Danube River – Romanian sector between Baziaş and Sulina or on certain sectors (Turnu Severin – Tulcea – 1972, Pristol (Gruia) – Tulcea – 1973, Brăila – Tulcea – 1976, the Danube entrance into the Delta area – 1981-1982) – 1971 – 1982;
- Hydrobiological researches on some Romanian mountain rivers – 1972;
- The hydrobiological study of the dam lakes Goleşti – Argeş, Iezerul (Mostiştea), Tămădău, Cotorca, etc. – 1978-1979;
- The assessment of the productive biopotential of the Danube Delta – Meleaua Sacalin (Bay) – 1979-1980;
- Study of the development biology of some aquatic animals in different environmental conditions – 1992-1996;
- Researches on the development of some Ponto-Caspian relict organisms – 1993-1996;
- Study of the cell level effects of some harmful factors in the development of certain aquatic invertebrates – 1994-1997.
- Study of the organisms modifications induced by the harmful action of certain water dissolved substances;
- Experimental study of the effects of wastewaters and some chemical compounds (copper sulphate, natrium diclordon, hungazine, omnidel, ifliquat, paraquat, heavy metals: copper, zinc, lead, ammonia, etc.);
- Researches on the effects of geo-thermal waters on some aquatic organisms;
- Study of chemical control of excessive aquatic vegetation;
- Survey of the state and evolution trends of the aquatic biocoenoses from the Romanian hydrographical network, in a series of rivers and streams: the Cerna

and its tributaries, the Jiu and tributaries, the Timiş and tributaries, the Olt, the Sadu, the Mureş, the Prahova etc.;

- Study of the evolution of planktonic and phytophile biocoenoses from certain areas of the deltaic biome;
- The assessment of the bioproductive potential of the Danube Delta and elaboration of technologies for its superior capitalization and conservation – 1978;
- Benthic Zoocoenoses from the Danube River;
- Study of the benthic zoocoenoses at the Iron-Gates (Porţile-de-Fier) Danubian sector, performed both before and after the river damming and extended until 2002;
- Study of the development and evolution of the Danube arms biocenoses – Sulina and St. George – and the shallow water stretches area in front of the Danube Delta;
- Reproduction, growth and development of certain invertebrates, aquatic fauna components, as well as development of cells and organs in aquatic vertebrates (reproduction and development of Ponto-Caspian relicts polychaeta *Hypaniola kowalewskii* (Grimm) and *Manayunkia caspia* Ann., development of Caryophylleidae Cestoda of *Caryophyllaeus* genus, parasites that infest oligochaeta with their larval stages (the mouth of the Danube branches – Sacalin Bay, then the interior lakes of the country, particularly the dam lake of the River Argeş);
- Study of the fish brain development, mainly at Gobiidae, linked with the species way of life and phylogeny; development of brain vesicles at 15 species of Gobiidae (*Gobius melanostomus*, *G. niger*, *G. fluviatilis*, *G. ophiocephalus*, *G. syrman*, *G. cephalarges*, *G. ratan*, *G. kessleri*, *G. gymnotrachelus*, *G. batrachocephalus*, *Pomaloschistus microps leopardinus*, *P. minutus*, *Proterorhinus marmoralus*, *Benthophiius stellatus* and *Aphya minuta*) and the Chondrostei fishes *Acipenser stellatus* and *Polyodon spathula*.

The acknowledgement of Virginia Marinescu's scientific merits is also expressed by the awards she won for her successful work:

- The "Emanoil Teodorescu" award of the Romanian Academy;
- Two gold and two silver medals, as well as the accompanying diplomas obtained at different editions of the International Showroom of Inventics Eureka.

Virginia Popescu-Marinescu was a member of national and international scientific organizations, fulfilling all her duties:

– Romanian Society of Ecology;

– Commission of Hydrobiology of the Romanian Academy; Association of the Scientists in Romania;

– International Society for the Study of the Danube IAD [International Die Arbeitsgemeinschaft Donauforschung (IAD) – Vereinigung for Theoretische und Angewandte Limnology (IVL – SIL – Societas Internationalis Limnology)];

– Romanian Association for Life Sciences PROBIOS – Founding Member;

– Editor of the journal “Hidrobiologia” published under the aegis of the Publishing House of the Romanian Academy.

At Virginia Popescu-Marinescu’s great departure we share her family’s profound feelings of grief and, together with them, we will keep a bright memory of our distinguished colleague and friend, for her whole life given to water research, for her efforts to be useful to people until her last breath.

Sleep in peace, Vingi!

Professor MARIAN-TRAIAN GOMOIU

Corresponding Member of the Romanian Academy
Editor-in-chief of the *Romanian Journal of Biology-Zoology*

BUTTERFLIES OF THE NATURAL RESERVES OF THE GEOPARK OF DINOSAURS–HAȚEG COUNTRY (HUNEDOARA COUNTY, ROMANIA)

SILVIA BURNAZ*, DOREL RUȘTI**

86 species of butterflies (S. ord. Rhopalocera, Ord. Lepidoptera) have been recorded from the natural reserves situated in the natural park known as The Geopark of Dinosaurs-Hațeg Country. Besides the well-known sites with reptilian palaeofauna (Upper Cretacic, Maastrichtian) very important natural reserves are included. The lawns of Narcissus from Sălaşu de Sus, The stones of Ohaba de Sub Piatră, The Peat bog of Peşteana and The Forest of Slivuț (Hațeg) are the most known natural protected areas. If the first third protected areas are known for their floristical interest, The Forest of Slivuț (Hațeg) is known because of its reserve of European bison (*Bison bonasus*). Sample and observation on butterflies were accomplished in 2004-2008, each year in April-May and June-September. A checklist of the recorded species is presented. This systematic list is accompanied by data concerning the studied sites and the categories of endangerment according to IUCN criteria. Data about the fly period of the adults, larval and adult food are also presented. *Euphydryas aurinia*, *Maculinea alcon*, *Maculinea arion*, *Maculinea teleius*, *Hyponephele lycaon* and *Arethusana arethusa* are some rare species identified in the area of these natural reserves. These species are listed in the Red List of Butterflies of Romania as vulnerable or endangered species.

Key words: butterflies, natural reserves, Geopark of Dinosaurs-Hațeg Country, Romania.

INTRODUCTION

One of the most important natural parks of Romania, The Geopark of Dinosaurs-Hațeg Country, was found in 2004. The aim of this park is especially to protect the sites of reptilian palaeofauna (Upper Cretacic, Maastrichtian) situated on the territory of the Hațeg Basin (Sântămărie Orlea and General Berthelot Communes). Historical, archaeological and natural sites are protected in the area of Hațeg Country. Another strategy of administration of this natural park is to support a durable economic and social development of the localities and to promote the originality of the traditional customs.

The aim of this study is to present butterflies fauna of the principal natural reserves situated in the Geopark of Dinosaurs-Hațeg Country. Other data concerning the Macrolepidoptera fauna of Hațeg Depression (the sector of Tuştea-Sarmizegetusa-Pui-Subcetate) were published by Burnaz (1994, 2002).

In 2003-2004, specialists of Bucharest University and of the "Grigore Antipa" National Museum of Natural History (Bucharest) studied butterflies of Haţeg Depression and also realised an interesting exhibition and an "Exploratorium" (a booklet and series of CD created to promote the diversity of the species of butterflies of the natural habitats of the Geopark). On the basis of their observation, 145 butterflies species were recorded from various natural habitats of Geopark of Dinosaurs-Haţeg Country (Ruşti *et al.*, 2004). The checklist of the species presented by the authors also includes the subalpine and alpine species of the Retezat Mountains that border the protected area of the Geopark.

This natural park, covering an area of 102.392 ha, includes the whole surface of Haţeg Depression (southwestern part of Hunedoara County) (The Resolution of the Romanian Government no. 2151/2004). The Haţeg Depression is situated in a zone of contact between Southern Carpathians and Western Carpathians, being bordered by the Şureanu Mountains (E), Retezat Mountains (S), Ţarcu Mountains (SW) and Poiana Ruscă Mountains (W and NW) (Grumăzescu, 1975; Popa, 1999). In the western part of the depression a piemontane plain with 300 m-350 m altitude is prevailing. In the eastern part of the depression, near Pui locality, the high piemontane zone, bordered by mountains, is crossed by the Strei River.

Two other natural and national parks are in the neighbourhood: The Natural Park of Grădiştea Muncelului-Cioclovina (Şureanu Mountains) and The National Park of the Retezat Mountains.

The Geopark of Dinosaurs-Haţeg Country has some protected areas known for their floristical and faunistical importance. We have especially studied the following natural reserves:

1. The natural reserve The Forest of Slivuţ is situated near Haţeg town and it was created especially to protect, in a small fold some specimens of European bisons (*Bison bonasus*). But the importance of this protected area is due to its oak coenoses that represent a rest of a large area of oak forests in Haţeg Depression. It has a total area of 40 ha.

2. The lawns of Sălaşu de Sus are situated on the territory of Sălaşu de Sus Commune (between Sălaşu de Sus and Nucşoara localities) and represent the only area with *Narcissus stellaris* that has survived in the Haţeg Depression. These coenoses are bordered by the Retezat Mountains and cover an area of 20 ha.

3. The stones of Ohaba de Sub Piatră are situated on the territory of Ohaba de Sub Piatră locality (Sălaşu de Sus Commune) and represent a floristical reserve. It has a total area of 0.8 ha.

4. The Peat bog of Peşteana is situated on the territory of Densuş Commune, in a plateau (480 m alt.) of Poiana Ruscă Mountains. This mesotrophic peat bog is especially known because of the important palynological studies carried out here by various botanists.

The Haţeg Depression, as part of the natural park, has a complex geological structure represented by crystalline schists in the mountainous area and sedimentary rocks (limestones, gneises, gritstones, micro conglomerates) in the area of the low depression.

The natural park is crossed by the Strei River and its affluents Râu Bărbat and Râu Mare. The most part of Strei Basin, and especially Râu Mare Valley, was arranged from the hydroenergetical point of view and some anthropical lakes were created.

A temperate continental climate characterizes the entire area of the Geopark. According to Grumăzescu (1975), the annual average of the temperature is of 6-8 ^{o}C (in the depressionary zone) and the annual average of precipitations is of 600-800 mm.

In the area of the natural park, the hills and mountains that border the Depression of Haţeg are covered by deciduous forests (oak and beech forests) alternating with pastures and lawns.

Some very important associations characterize the vegetation of the natural reserves. Boşcaiu (1965) has described *Peucedanum (rocheliani)-Molinietum coeruleae* association from the natural reserve of Sălaşu de Sus. The coenoses of this association are situated in the southern part of Sălaşu de Sus village. *Narcissus stellaris*, *Peucedanum rochelianum*, *Molinia coerulea*, *Gladiolus imbricatus*, *Gentiana pneumonanthe*, *Iris sibirica*, *Orchis morio*, *Anthoxanthum odoratum*, *Briza media*, *Poa pratensis*, *Festuca rubra*, *Agrostis tenuis*, *Luzula campestris*, *Myosotis palustris*, *Senecio jacobaea*, *Achillea ptarmica*, *Carex flava*, *Carex hirta*, *Lythrum salicaria*, *Salix cinerea*, *Galium verum*, *Potentilla erecta*, *Thymus montanus* and other species have been identified in these mesohygrophilous lawns.

The stones of Ohaba de Sub Piatră are protected because of their rare plants like: *Plantago holosteum*, *Anthemis montana*, *Alyssum murale*, *Astragalus onobrychis* var. *linearifolius*, *Minuartio-Festucetum pseudodalmaticae* (Mikyska 33) Klika 38 *Plantaginetosum holostei* Boşcaiu, Peterfi & Cernelea 1974 sub association was described for this natural reserve.

The Forest of Slivuţ is formed especially by *Quercus petraea*, *Quercus robur* but also by *Fagus sylvatica* and *Carpinus betulus*. *Hepatica transsylvanica*, an endemic species in Romania, was also reported for this protected area.

The vegetation of the peat bog of Peşteana is represented by *Carici rostratae-Sphagnetum recurvi* Zoly 31 association. *Polytrichum strictum*, *Menyanthes trifoliata*, *Sphagnum magellanicum*, *Drosera rotundifolia*, *Eriophorum vaginatum*, *Frangula alnus*, *Betula pendula*, *Corylus avellana*, *Salix cinerea*, *Potentilla erecta*, *Polytrichum strictum*, *Carex rostrata* and other species were recorded from this protected area (Lazăr *et al*., 1974; Fărcaş *et al*., 2006).

Shrubs are present in all these areas at the edge of the forests and road sides. The most important associations of shrubs are *Pruno spinosae-Crataegetum* (Soó 1927) Hueck 1931, *Coryletum avellanae* Soó 1927, *Sambucetum nigrae* Oberd. *et al*. 1967. Coenoses of *Alnetum glutinosae-incanae* Br.-Bl. 1915, 1930 association border the Sălaşu de Sus River.

MATERIAL AND METHODS

The study of butterflies was carried out during 2004-2008. Using an entomological net we sampled in the protected areas, every year, in April-May and June-September. Lawns, shrubs, forests, alder associations, rocks and peat bog vegetation were the principal habitats we have studied.

The lepidopterological material was identified after Niculescu (1961, 1963, 1965), Contarini & Fiumi (1982), Still (1996), Feltwell (2001), Tolman & Lewington (2007). For the checklist of Lepidoptera species we have utilized the scientifical nomenclature and the classification of butterflies published by Rákosy (2002).

The status of the species, according to IUCN 2001 categories of endangerment, is also presented (Rákosy, 2002).

RESULTS AND DISCUSSION

On the basis of the samples and field observations a total of 86 species of butterflies were identified. It means that 40.56% of the total Rhopalocera species recorded in Romania were found in the protected areas of the Geopark. The greatest number of species has been recorded from the protected area of Sălaşu de Sus lawns (Table 1).

Table 1

The number of species recorded from the protected areas
of the Geopark of Dinosaurs-Haţeg Country

SITES	NUMBER OF SPECIES
Ohaba de Sub Piatră Stones	70
Sălaşu de Sus lawns	75
Slivuţ Forest (Haţeg)	71
The Peat bog of Peşteana	43

Concerning the structure of the families of Rhopalocera we emphasize the dominance of the species of Nymphalidae (41 species) and Lycaenidae (22 species) (Table 2).

Table 2

The families of S.ord. Rhopalocera and the number of species recorded
from the protected areas of the Geopark of Dinosaurs-Haţeg Country

FAMILIES	NUMBER OF SPECIES
HESPERIIDAE	9
PAPILIONIDAE	3
PIERIDAE	10
LYCAENIDAE	22
NYMPHALIDAE	41
TOTAL	**86**

The checklist of the species and data about the sites of sampling and IUCN categories of endangerment are presented (Table 3). The classification of butterflies used in the checklist is that published by Rákosy (2002).

Table 3

The checklist of the butterflies species (S. ord. Rhopalocera, Ord. Lepidoptera) recorded from the natural protected areas of the Geopark of Dinosaurs-Haţeg Country

TAXA	**P**	**SO**	**LS**	**SF**	**CE**
HESPERIIDAE					
Erynnis tages tages (Linnaeus, 1758)	+	+	+	+	LC
Carcharodus alceae (Esper, 1780)	-	+	-	-	LC
Pyrgus malvae malvae (Linnaeus, 1758)	+	+	+	+	LC
Pyrgus carthami (Hübner, 1813)	-	+	+	+	LC
Carterocephalus palaemon (Pallas, 1771)	-	+	+	+	LC
Thymelicus lineola (Ochsenheimer, 1808)	-	+	+	+	LC
Thymelicus sylvestris (Poda, 1761)	-	-	-	+	LC
Hesperia comma (Linnaeus, 1758)	+	+	+	+	LC
Ochlodes venatus faunus (Turati, 1905)	+	+	+	+	LC
PAPILIONIDAE					
Papilio machaon machaon (Linnaeus, 1758)	+	+	+	+	NT
Parnassius mnemosyne distincta Bryk & Eisner, 1930	-	-	-	+	VU
Iphiclides podalirius (Linnaeus, 1758)	+	+	+	+	NT
PIERIDAE					
Leptidea sinapis sinapis (Linnaeus, 1758)	+	+	+	+	LC
Anthocharis cardamines (Linnaeus, 1758)	-	+	+	+	LC
Aporia crataegi crataegi (Linnaeus 1758)	-	+	+	+	LC
Pieris brassicae brassicae (Linnaeus, 1758)	-	+	-	+	LC
Pieris rapae (Linnaeus, 1758)	+	+	+	+	LC
Pieris napi napi (Linnaeus, 1758)	+	+	+	+	LC
Pontia edusa (Fabricius, 1777)	+	+	+	+	LC
Colias croceus (Fourcroy, 1785)	+	+	+	+	LC
Colias hyale (Linnaeus, 1758)	+	+	+	+	LC
Gonepteryx rhamni rhamni (Linnaeus, 1758)	+	+	+	+	LC
LYCAENIDAE					
Hamearis lucina (Linnaeus, 1758)	+	+	+	+	LC
Lycaena phlaeas phlaeas (Linnaeus, 1761)	-	+	+	+	LC
Lycaena dispar rutila (Werneburg, 1864)	+	+	+	-	VU
Lycaena virgaureae virgaureae (Linnaeus, 1758)	+	+	+	-	NT
Lycaena alciphron (Rottemburg, 1775)	-	+	+	-	VU
Thecla betulae (Linnaeus, 1758)	-	+	+	+	LC
Neozephyrus quercus (Linnaeus, 1758)	-	-	-	+	VU
Callophrys rubi (Linnaeus, 1758)	-	+	+	+	LC
Satyrium w-album (Knoch, 1782)	-	-	+	+	LC

Table 3 (continued)

Satyrium pruni (Linnaeus, 1758)	-	-	-	+	NT
Cupido minimus minimus (Fuessly, 1775)	+	+	+	+	NT
Everes argiades (Pallas, 1771)	-	+	+	+	LC
Celastrina argiolus (Linnaeus, 1758)	-	+	+	+	LC
Scoliantides orion lariana Fruhstorfer, 1910	-	+	-	-	NT
Glaucopsyche alexis (Poda, 1761)	-	+	+	+	LC
Maculinea arion (Linnaeus, 1758)	-	-	+	-	NT
Maculinea teleius (Bergsträsser, 1779)	-	-	+	-	EN
Maculinea alcon (Denis & Schiffermüller, 1775)	-	-	+	-	EN
Plebeius argus argus (Linnaeus, 1758)	+	+	+	+	LC
Plebeius argyrognomon (Bergsträsser, 1779)	+	+	+	+	LC
Aricia agestis (Denis & Schiffermüller, 1775)	-	+	-	-	LC
Polyommatus semiargus semiargus (Rottemburg, 1775)	-	-	+	+	LC
Polyommatus icarus (Rottemburg, 1775)	+	+	+	+	LC
NYMPHALIDAE					
Argynnis paphia paphia (Linnaeus 1758)	+	+	+	+	LC
Argynnis aglaja (Linnaeus, 1758)	+	+	+	+	LC
Argynnis adippe (Denis & Schiffermüller, 1775)	+	+	+	+	LC
Argynnis niobe niobe (Linnaeus, 1758)	-	+	+	+	LC
Issoria lathonia (Linnaeus, 1758)	-	-	+	+	LC
Brenthis daphne (Denis & Schiffermüller, 1775)	-	+	+	+	VU
Brenthis hecate (Denis & Schiffermüller, 1775)	-	+	+	-	VU
Boloria euphrosyne (Linnaeus, 1758)	+	+	+	+	LC
Boloria selene (Denis & Schiffermüller, 1775)	+	+	+	+	LC
Boloria dia dia (Linnaeus, 1767)	+	+	+	+	LC
Vanessa atalanta (Linnaeus, 1758)	+	+	+	+	LC
Vanessa cardui (Linnaeus, 1758)	+	+	+	+	LC
Inachis io (Linnaeus, 1758)	+	+	+	+	LC
Aglais urticae (Linnaeus, 1758)	+	-	+	+	LC
Polygonia c-album (Linnaeus, 1758)	+	+	+	+	LC
Araschnia levana (Linnaeus, 1758)	+	+	+	+	LC
Nymphalis antiopa (Linnaeus, 1758)	-	+	+	+	LC
Euphydryas aurinia aurinia (Rottemburg, 1775)	-	-	+	-	EN
Melitaea cinxia cinxia (Linnaeus, 1758)	+	+	+	+	LC
Melitaea britomartis Assmann, 1847	-	+	+	+	LC
Melitaea athalia athalia (Rottemburg, 1775)	+	+	+	+	LC
Neptis hylas (Linnaeus, 1758)	-	+	+	+	VU

Table 3 (continued)

Neptis rivularis (Scopoli, 1763)	-	+	+	+	LC
Apatura ilia ilia (Denis & Schiffermüller, 1775)	-	-	+	+	VU
Apatura iris (Linnaeus, 1758)	-	-	+	+	VU
Pararge aegeria tircis Butler, 1867	+	+	+	+	LC
Lasiommata megera megera (Linnaeus, 1767)	+	+	+	+	LC
Lasiommata maera (Linnaeus, 1758)	+	+	+	+	LC
Coenonympha arcania arcania (Linnaeus, 1761)	+	+	+	+	LC
Coenonympha glycerion glycerion (Borkhausen, 1788)	+	+	+	+	LC
Coenonympha pamphilus (Linnaeus, 1758)	+	+	+	+	LC
Pyronia tithonus tithonus (Linnaeus, 1767)	-	+	+	-	EN
Aphantopus hyperantus (Linnaeus, 1758)	+	+	+	+	LC
Erebia aethiops aethiops (Esper, 1777)	-	-	-	+	LC
Maniola jurtina jurtina (Linnaeus, 1758)	+	+	+	+	LC
Hyponephele lycaon (Rottemburg, 1775)	-	+	-	-	VU
Melanargia galathea (Linnaeus, 1758)	+	+	+	+	LC
Minois dryas (Scopoli, 1763)	-	+	+	+	LC
Hipparchia fagi (Scopoli, 1763)	-	+	+	+	LC
Brinthesia circe pannonica (Fruhstorfer, 1919)	-	+	+	+	LC
Arethusana arethusa (Denis & Schiffermüller, 1775)	-	+	-	-	EN

Abbreviations: SO: Stones of Ohaba de Sub Piatră; LS: Lawns of Sălaşu de Sus; SF: Slivuţ Forest (Haţeg); P: The Peat bog of Peşteana; Categories of endangerment according to IUCN 2001 (Rákosy (2002): CE-Categories of Endangerment; EN- Endangered taxa; VU-Vulnerable taxa; NT-Near threatened taxa; LC–Least concern taxa (according to IUCN classification; Rákosy 2002).

Some of the identified species in these protected areas are included in the *Red List of Romanian butterflies* (Rákosy, 2002) as vulnerable or endangered taxa:

Maculinea alcon alcon (Denis & Schiffermüller, 1775) – 3♂♂, 8.08.2008 at Sălaşu de Sus lawns. These specimens were collected in a damp habitat near Sălaş Valley with *Gentiana pneumonanthe*. The adults fly in June-July and often visit *Teucrium chamaedrys*, *Thymus serpyllum*, *Aster amellus*, *Centaurea scabiosa*, *Cardamine pratensis*, *Arabis hirsuta* and especially *Achillea ptarmica*. Female lays down her eggs on the flowers of *Gentiana pneumonanthe*. Larvae breed on *Gentiana pneumonanthe* and finish their stage in ant nests.

Maculinea arion (Linnaeus, 1758) – 3♂♂, 22.06.2006, 1♂, 18.06.2007 at Sălaşu de Sus lawns. This species prefers dry habitats of Sălaşu de Sus natural reserve. Females lay their eggs on flowers of *Thymus serpyllum*. Younger larvae eat pollen and seeds of *Thymus* and then drop to the ground. They are attractive to *Myrmica sabuleti*. Pupation takes place in the nest of ants. Adults emerge the following summer and live about three or four weeks. The adults fly in June-

August and visit *Achillea ptarmica*, *Scabiosa columbaria*, *Filipendula vulgaris* and *Dianthus carthusianorum*.

Maculinea teleius (Bergsträsser, 1779) – 2♂♂, 22.06.2008 collected Sălaşu de Sus lawns. Adults fly from July to the beginning of August, especially in wet meadows. In their early stages larvae breed on *Sanguisorba officinalis.* In their last, fourth instars', they are adopted by a species of *Myrmica*. *Maculinea teleius* is listed in the *Red List of Butterflies of Romania* as an endangered species (Rákosy, 2002). It is also a protected species listed in the Annexes of the Emergency Ordinance of the Romanian Government no. 57/2007.

Hyponephele lycaon lycaon (Rottemburg, 1775) – 1♂, 6.07.2006 at Ohaba de Sub Piatră Stones. Butterflies prefer rocky habitats and fly in June-August. Larvae feed on various grasses (Poaceae).

Euphydryas aurinia aurinia (Rottemburg, 1775) – 3♂♂, 20.05.2006; 2♂♂, 27.05.2007; 4♂♂, 23.05.2008 at Sălaşu de Sus natural reserve. Euro-siberian element. It is widespread in the northern part of Africa, Europe and Asia. The adults prefer open spaces in both damp and dry conditions (Still, 1996). In Romania it is a frequent species in Banat (Arad, Timiş) and Transylvania (Mureş, Braşov, Hunedoara, Alba) (König, 1979; Moldoveanu, 1995). In Hunedoara County the adults especially prefer the dump habitats of the limestone areas (Burnaz, 2005). It is the first time we found this species in a low plain, near the Retezat Mountains. Here, in the natural reserve of Narcissus, we have seen many individuals (over 15 individuals/day) in the second decade of May and in the first decade of June. The adults rest on *Carex hirta* and other Cyperaceae and Poaceae. The larvae feed on *Succisa pratensis*, *Scabiosa columbaria* and *Plantago* sp. (Still, 1996; Tolman & Lewington, 2007).

Arethusana arethusa (Denis & Schiffermüller, 1775) – 1♂, 26.06.2006, at Ohaba de Sub Piatră. The adults fly in June-August and prefer dry grassy habitats. We have also seen them flying at the edge of a deciduous forest situated on the left part of Strei Valley in the neighbourhood of the natural reserve. Larvae feed on various Poaceae such as *Bromus*, *Festuca*, *Dactylis* and *Poa*. This species is listed as an endangered species in the *Red List of butterflies of Romania* (Rákosy, 2002).

Other taxa listed as vulnerable are: *Apatura iris*, *Apatura ilia ilia*, *Lycaena alciphron*, *Lycaena dispar rutila*, *Neozephyrus quercus*, *Neptis hylas*, *Brenthis daphne*, *Brenthis hecate*, *Hyponephele lycaon* and *Parnassius mnemosyne distincta* recorded from Slivuț Forest and Sălaşu de Sus natural reserves.

The taxa *Parnassius mnemosyne distincta*, *Lycaena dispar rutila*, *Maculinea arion* and *Euphydryas aurinia* are listed in the 4A Annexe of the Emergency Ordinance of the Romanian Government no. 57/2007 as species of European community interest that need a strict protection.

Maculinea alcon, *Maculinea teleius* and *Neptis hylas* are listed in the 4B Annexe of the same law as species of national interest that need a strict protection.

CONCLUSIONS

Even if the identified taxa represent only 40.56% of the total species of butterflies of Romania, we consider that the natural reserves we have studied have a great diversity.

Maculinea arion and *Maculinea alcon* have a relative high frequency in the area of Sălaşu de Sus natural reserve but *Maculinea teleius* is a rare species.

Some of species such as *Euphydryas aurinia*, *Maculinea teleius*, *Maculinea alcon*, *Lycaena dispar rutila*, *Apatura iris*, *Apatura ilia*, *Arethusana arethusa* and *Hyponephele lycaon* are listed in the *Red List of Romanian butterflies* as endangered or vulnerable species and need protection in their characteristic habitats.

Some of these species such as *Lycaena dispar rutila*, *Maculinea alcon* and *Euphydryas aurinia aurinia* are listed in the annexes of the Government Urgency Ruling no. 57/2007 as species of community interest and national interest.

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EUROPEAN AND EXOTIC INSECT PEST SPECIES IN BRUKENTHAL MUSEUM (SIBIU COUNTY, ROMANIA)

IULIANA ANTONIE*, IRINA TEODORESCU**

Investigations on books, woods and textiles pieces in the storage areas of Brukenthal Museum allow the identification of 20 insect pest species, belonging to five orders, ten families and three trophic categories. A total of 13 species were detected on old books, 12 species on ethnographic textile pieces and five species in wood sculpture exhibits. The attacks were detected by alive or dead adults, larvae feeding tubes, nymphal cocoons, exuviae, characteristics of attacked pieces, larvae galleries, adult's exit holes, faeces, and sawdust. To test the trophic preference (with *Lepisma sacharina*, *Tineolla biselliella* and Dermestidae adults) some experiments were made to establish the superior thermic threshold (with T. *biselliella*). The most noxious pests (*Tineolla biselliella*, *Anobium punctatum* and *Stegobium paniceum*) and the species with the highest attack intensity (*Anobium punctatum*) were established.

Key words: museum pests, wood pests, clothing moths, carpet beetles, booklice, cryptogenic species.

INTRODUCTION

Museums are very susceptible to pest damages, many biological agents (insects, rodents, bats, birds and molds) that can deteriorate collections. In correlation with the types of food sources, insect pests to museum collections belong to four groups: textile or fabrics pests; wood pests; paper pests and general pests. Insect destroying activity can be detected by the presence of adults or larvae (alive or dead), cast skins (exuviae) or different body parts, by its resultant damages (chewing sign or grazed surfaces, exit holes of adults produced in wood surfaces or book covers, loss of fur, hair or feather, debris, fecal pellets, stains or fecal spots).

Textile pests (protein feeders; fabric pests) include necrophagous insects: Dermestidae (Coleoptera) and Tineidae (Lepidoptera). Their larvae can digest keratin (a protein present in vertebrate hair) and chitin, from insect tegument. Tineidae adults do not eat, but larvae feed on skin, leather, hair, wool, silk, feathers, baleen, and even cotton, linen and paper (Kronkright, 1991), occasionally insects or other dry dead animals. Dermestidae adults are polynivorous and larvae feed on skin, hair, fur and feathers (Kronkright, 1991), leather book bindings, horns, carpets, woolen and silk goods and carrions.

Wood pests are fungi, insects, bacteria, and marine borers (Highley, 1999). Insects include Isoptera, hymenopterans Formicidae (*Camponotus* species) and coleopterans Lyctidae, Bostrichidae, Anobiidae, Cerambycidae (*Hylotrupes bajulus*); Ptinidae and Dermestidae species superficially and occasionally damage wood. "Many more wood-destroying insects attack trees that are weakened by disease, fire, or old age, or are blown down or felled for lumber" (Ebeling, 2002). Anobiidae and Lyctidae are named "powder post beetle" because their larvae transform wood to a mass of very fine, powder-like frass (excrements and bits of wood) produced by the feeding process. This powder covered wood surface, which was penetrated by numerous "exit, flight, or emergence holes" (the hole where the adult beetle has left the timber). The adults do not eat wood, but their larvae make unseen galleries within wood. *Hylotrupes bajulus* is a major cause of damage to softwood building timbers, and attack pine (*Pinus*) and fir (*Abies*).

Book pests were signaled "with over 2200 years ago, from Aristotle" (Parker, 1988). "In libraries and archives where there are stored, consulted and exposed books, imprints, manuscripts, maps, stamps, photos and other documents, the main agents of biodeterioration are silverfish and thermobies, coleopterans bibliophages (such as *Lasioderma serricorne*, *Stegobium paniceum*, *Ptinus fur*, Dermestidae), *Blatta orientalis*, *Phyllodromia germanica*, booklice, Tineidae and termites" (Magaudda, 2004). **Booklice or psocid species** (*Liposcelis divinatorius*, *Trogium pulsatorium*) feed on microscopic molds and, thus, any manufactured material of plant origin that would support the growth of these molds is susceptible to be their food. In museum settings, they can commonly be found in books and book bindings, storage boxes, paper goods, herbaria and insectaria collections. Psocids can stain paper documents and book pages. *S. paniceum* can cause serious damage to books and preserved plant materials, and larval galleries pass through pages or spine books. *Ptinus fur*, mentioned in 1776 by Linné as an important pest in libraries (Parker, 1988), in museums eat cotton and woolen clothes, and larvae galleries pass through books. Silverfish *L. saccharina* feed on cellulosic material, sizing on paper, book bindings, glues, pastes, rayon, grains, skins and leather, particularly when they are soiled (Kronkright, 1991), therefore "different material used to paper manufacture, who include starchy, dextrin, casein, the glue and paste in older book bindings" (Parker, 1988).

As **omnivorous species** in museums are mentioned cockroaches that feed on leather, paper, glues, animal skins, hair and wool fabrics, especially if they are stained with food and sweat. "Cockroaches attack paper lacking other organic food sources" (Magaudda, 2004).

Brukenthal Museum is located in Sibiu, a city in the center of Romania, where in 1544 the first Romanian Book was printed. The Brukenthal Museum, founded in 1790 by Baron Samuel von Brukenthal, houses the European painting collection belonging to the main European painting schools of the 15^{th} up to the 18^{th} century as well as the Transylvanian Painting Collection and the Collection of

Modern and Contemporary Art. The museum possesses paintings (by Rubens, Titian, Van Dyck, Poussin, Hals, Grigorescu, Andreescu, Luchian, Tonitza, Aman, Petraşcu, Pallady, Ciucurencu, Baba and many others), graphics, sculptures, furniture, silverware, porcelain, glassware, etc. Its library has more than 280,000 volumes, including manuscripts and rare books (442 valuable incunabula, grouped in 382 volumes), printings dating from the 15th and 16th centuries.

In three storage spaces of this museum we have performed investigations (1990-1996 and 2007-2008) to detect insect pests. In Romania, similar investigations were registered (Mustaţă, 1998; Bucşa & Bucşa, 2005, 2009; Bucşa *et al.*, 2005; Gămălie & Mustaţă, 2005; Moşneagu & Gămălie, 2006; Gămălie, 2007).

MATERIAL AND METHODS

Many exhibits, drawers, ceilings, floors, walls from three storage spaces with old books, ethnographic textile and wood sculpture were examined. Alive or dead insects, chewing marks, exit holes in the surface of wood, cover books, furs, cloths, fur or feather loss, frass, fecal pellets, dried stains or fecal spots have been detected. To identify the presence, monitor and control some insects there have been used traps (with boric acid for cockroaches, pieces of woolen material for *Tineolla biselliella*, sticky paper cards for *Lepisma saccharina*, *Stegobium paniceum*, Psocidae, Dermestidae and card covered with sweet flour paste, for *L. saccharina*).

Three experiments were also performed:

- *L. saccharina* was reared three months nourishing only with paper;
- *T. biselliella* larvae were reared on different types of food to determine their preference and were exposed to different temperature values to establish their superior biologic threshold;
- Flowers of *Spiraea*, *Prunus* and Umbelliferae from the museum proximity were controlled in May and June months, to capture Dermestidae adults in their food (with pollen) and mating period.

RESULTS AND DISCUSSION

A number of 20 insect species, belonging to five orders (Thysanura, Blattaria, Psocoptera, Lepidoptera and Coleoptera), ten families (Lepismatidae, Blattidae, Phyllodromidae, Liposcelidae, Tineidae, Dermestidae, Anobiidae, Lyctidae, Ptinidae and Cerambycidae) (Table 1), three trophic categories (phytophagous, necrophagous and omnivorous) and four pest groups (textile or fabrics pests, wood pests, paper pests, general pests) were identified (Figs. 1-8). Alive or dead adults and larvae, feeding tubes, nymphal cocoons, exuviae, characteristic attack, larvae galleries, adult's exit holes, faeces, and sawdust have been detected (Table 2).

As **textile pests**, 12 species were detected: *Anthrenus* and *Attagenus* species, *T. biselliella*, *D. lardarius*, *L. saccharina*, *Ph. germanica*, *B. orientalis* and *P. fur*.

From **carpet beetles** there were detected adults, larvae, results in feeding activity and larval exuviae of *Attagenus piceus* and *A. pellio*, *Anthrenus scrophulariae*, *A. verbasci*, *A. pimpinellae* and *A. museorum*. Larvae burrow into, or graze the surface of the food source.

From **cloths moths** we have identified *T. biselliella*, which damaged woolen clothes, feathers and weavings. In the storage space only males were observed. The larvae live and feed in dark sites, chew fibers and make trails of damaged fibers, building a feeding tube used as protection. Mature larvae make a silk nymphal cocoon. Attacks were detected as larvae excreta, feeding tubes, nymphal cocoons, exuviae, dead adults, or as objects covered with a mixture of silk and faeces. The nymphal cocoons were detected on attacked pieces and on drawers, ceilings, walls.

As **paper pests** we have encountered 13 species: *L. saccharina*, *L. divinatorius*, *T. pulsatorium*, *Ph. germanica*, *B. orientalis*, *Anthrenus museorum*, *A. scrophulariae*, *A. pimpinellae*, *Attagenus pellio*, *X. rufovillosum*, *A. punctatum*, *S. paniceum* and *P. fur*. *L. saccharina* prefer glue and paste used to old books manufacture, fabrics from vegetable silk, cotton. *X. rufovillosum*, *A. punctatum* and *S. paniceum*, detected in old book storage space, attacked the wood support of book leather covers.

As wood pests (Table 3), 5 species were detected: *Lyctus linearis*, *X. rufovillosum*, *Ernobius mollis*, *A. punctatum* and *Hylotrupes bajulus*. The *Lyctus* attack was detected by their frass and by adult's exit holes. In Lyctidae, frass was fine, flour-like, inside tunnels, and in Anobiidae it was a fine powder with elongated pellets conspicuous; sticks together in clumps. The adult's exit holes were perfectly circular, but they differ in size (0.8 to 1.6 mm diameter of Lyctidae and 1.6 to 3 mm of Anobiidae).

General pests were *P. germanica* and *B. orientalis*, omnivorous, household pests. Adults and larvae of *B. orientalis* caused large, irregular perforations and depressions in book covers. Higher species richness registered in Dermestidae and Anobiidae (Fig. 9).

The most dangerous pests were *T. biselliella* (on ethnographic wool, fur, and silk pieces), *A. punctatum* (on wood pieces and old books with leather cover on wood support) and *S. paniceum* (on book covers and zones rich in starch).



Fig. 1. *Stegobium paniceum* attack on paper.

Fig. 2. *Anobium punctatum* attack on paper.

Fig. 3. *Anobium punctatum* and *Attagenus pellio* attack on book cover.



Fig. 4. *Stegobium paniceum* attack on book cover.

Fig. 5. *Anobium punctatum* attack on wood pieces.

Fig. 6. *Attagenus pellio* attack on wool coat (detail).

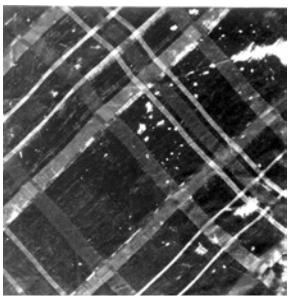
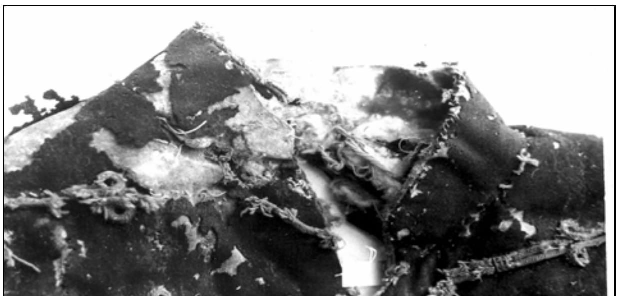

Fig. 7. *Tineolla biselliella* attack on silk kerchief (detail).

Fig. 8. *Tineolla biselliella* attack on wool coat (detail, collar area).

Table 1

Insect pest species in the Brukenthal Museum storage spaces

Order/ Family	Species	Common name	Old books in storage space	Ethnographic textile in quarantine storage space	Wood sculptures in storage space
Thysanura Lepismatidae	*Lepisma saccharina*	silverfish	+	+	
Blattaria Phyllodromidae	*Phyllodromia germanica*	German cockroaches	+	+	
Blattidae	*Blatta orientalis*	oriental cockroaches	+	+	
Psocoptera Liposcelidae	*Liposcelis divinatorius*	Booklice	+		
	Trogium pulsatorium	Booklice	+		
Lepidoptera Tineidae	*Tineolla bisselliella*	webbing clothes moth		+	
Coleoptera Dermestidae	*Anthrenus museorum*	museum beetle	+	+	
	Anthrenus scrophulariae	buffalo carpet beetle	+	+	
	Anthrenus verbasci	varied carpet beetle		+	
	Anthrenus pimpinellae	carpet beetle	+	+	
	Attagenus piceus	black carpet beetle		+	
	Attagenus pellio	black carpet beetle	+	+	
	Dermestes lardarius	larder beetle		+	
Anobiidae	*Xestobium rufovillosum*	deathwatch beetle	+		+
	Ernobius mollis	deathwatch beetle			+
	Anobium punctatum	common furniture beetle or death watch beetle	+		+
	Stegobium paniceum	drugstore beetle, bread beetle or biscuit beetle	+		
Lyctidae	*Lyctus linearis*	true powder post beetle			+
Ptinidae	*Ptinus fur*	white marked spider beetle or spider beetle	+	+	
Cerambycidae	*Hylotrupes bajulus*	old house borer, house longhorn beetle, European house borer			+
	Total		13	12	5

Table 2

Materials damaged of insect pests and type of damages in the Brukenthal Museum

Pest species	Materials damaged	Type of damage
Lepisma saccharina	Damp old paper items and some fabrics from vegetable silk and cotton	Irregular scratched and eroded material surface (glue and paste used to old paper manufacture and vegetable fabrics) and faeces. Some of feeding damage was 20 cm^2 large.
Phyllodromia germanica	Book leather covers, papers, hair and wool fabrics	Adults, larvae, chewing marks and faeces
Blatta orientalis	Book leather covers, papers, hair and wool fabrics	Adults, larvae, large chewing marks and faeces
Liposcelis divinatorius	Books, particularly in warm and humid sites	Eating animal glue used to solder leather book covers; scratched and eroded books surface
Trogium pulsatorium	Books, particularly in warm and humid sites	Eating animal glue used to solder leather book covers; scratched and eroded book surface
Tineolla biselliella	Waistcoats, shirts, silk handkerchiefs, wool carpets	Many alive and dead adults, large irregular adults exit holes, larvae silk webbing and feeding tubes, faeces, nymphal cocoons, exuviae
Anthrenus museorum	Leather covers of 8 old books, leather, furs, carpets, woolen and silk textiles	Larvae galleries in leather book covers of old book and irregular holes in carpets, woolen and silk textiles
Anthrenus scrophulariae	Leather book covers and hat feathers from Năsăud zone	Circular holes (2 mm in diameter) in hat feathers
Anthrenus verbasci	Leather, furs, carpets, woolen and silk textiles	Larvae gallery and irregular holes in carpets, furs, woolen and silk textiles
Anthrenus pimpinellae	Leather book covers	Only adult insects
Attagenus piceus	Ethnographic textiles	Only adult insects
Attagenus pellio	Books, ethnographic textiles	Larvae attack on leather book covers, woolen clothes and carpets and irregular adults exit holes in textiles
Dermestes lardarius	Ram horns	Larvae sinuous galleries
Xestobium rufovillosum	Wood support of book leather covers and 7 sculptures of lime, in a damp site	Sinuous larvae galleries (3-4 mm in diameter) with frass, 3 mm rounded adult's exit holes, in one case, on entire sculpture
Ernobius mollis	Two church shrines of fir wood	Dead adults and larvae galleries (2-3 mm in diameter) with sawdust
Anobium punctatum	Wood support of leather covers of 16 old books and 28 sculptures of lime	Wood support of books and sculptures of lime penetrated by 2 mm round adults exit holes, covered by fine powder frass and inside with sinuous gallery (1-2 mm in diameter), with frass
Stegobium paniceum	Book leather covers, 10-30 adjacent pages	Thousand horizontal and vertical larvae galleries, round adults exit holes, dust
Lyctus linearis	One beech sculpture	Sculpture penetrated by round adults exit holes, covered by powder-like frass, and inside with very fine galleries (1 mm diameter), with frass
Ptinus fur	Books, woolen,cotton clothes	Only alive adults, in book and textile
Hylotrupes bajulus	Two church shrines of fir wood	Few oval galleries (4-5 mm in diameter) in church wooden shrines

The highest attack intensity was registered in the storage space with wood sculptures, where 31 of 36 wood pieces (86.11%) were attacked, especially by *Anobium punctatum* which prefers alburn zone of old, dry softwood. From 57 books with wood support of leather covers, 29 (16.53 %) presented xylophagous insects attack, and from these 16 (46.40 %) were attacked by *A. punctatum*.

Table 3

Insect pests in storage space with wood sculptures

Species	Exit holes diameter	Number of attacked pieces	Alive insects	Wood essence
Anobium punctatum	1-2 mm	28	2	*Tilia* (lime)
Xestobium rufovillosum	3-4 mm	7	–	*Tilia* (lime)
Ernobius mollis	2-3 mm	2	–	*Abies* (fir)
Lyctus linearis	1 mm	1	–	*Fagus* (beech)
Hylotrupes bajulus	4-5 mm	1	–	*Abies* (fir)

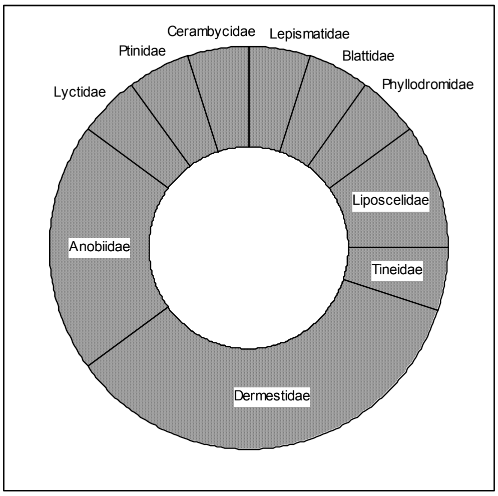

Fig. 9. Comparison between species richness of insect pest families in Brukenthal Museum.

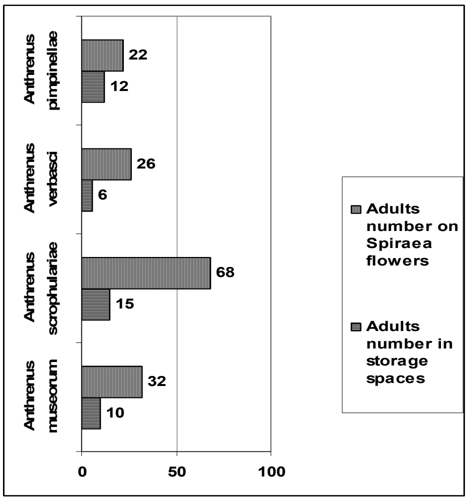

Fig. 10. Comparison between number of Dermestidae adults, captured on *Spiraea* flowers and in the museum.

Experiments were unsophisticated. One of these was demonstrating that *L. saccharina*, which survive three months nourishing only with paper, can be a noxious books pest. *T. biselliella* larvae reared on different types of food (wool, fur, silk, linen, and cotton) manifest a preference for cashmere and fine wool materials, especially dark colored, and color of their excreta and nymphal cocoon was correlated to feeding substratum. Exposed to different temperature values, *T. biselliella* larvae dry and die above 35 ^{o}C (a good method to destroy them).

Comparative analyses of the number of Dermestidae adults captured in museum and from flowers demonstrate both an evident preference for *Spiraea* flowers (Fig. 10) and the necessity to avoid flower plants in the proximity of museum, because after nourishing and copulation they come back in museum.

THE ORIGIN ZONE OF INSECT PESTS IDENTIFYING IN BRUKENTHAL MUSEUM

Lepisma saccharina, *Blatella germanica*, *Stegobium paniceum* are considered **archaeozoan** species (introduced in historical times, with uncertain origin). As cosmopolitan species, with origin difficult to be ascertained (**cryptogenic**) were *Anthrenus museorum*, *A. scrophulariae*, *A. pimpinellae*, *A. verbasci*, *Attagenus piceus*, *Dermestes lardarius*, *Tineolla biselliella*, *Liposcelis divinatorius*, *Trogium pulsatorium*, *Ernobius mollis*, *Ptinus fur* and *Blatta orientalis*. Some cosmopolitan species of *Anthrenus*, *Attagenus*, *Dermestes*, *Ptinus*, *S. paniceum* were discovered in Egypt, found in the corpses as well as the food offerings given to the deceased, which have been buried in predynastic (~4500–2900 B.C.) and dynastic tombs (~2900 B.C.–395 A.D.) (Levinson & Levinson, 1994). *Anobium punctatum*, *Xestobium rufovillosum*, *Hylotrupes bajulus* and *Attagenus pellio* are native to Europe.

MEASURES OF INSECT PEST CONTROL IN THE BRUKENTHAL MUSEUM

To eliminate the insect pests in the Brukenthal Museum it has been developed and implemented an "Integrated Pest Management Program" (IPM) accomplishing a successful control. This IPM approach includes: assessment of insect problems, infestation prevention by inspection of materials brought into the museum and careful control of entry points, eradication of detected pests (Parker, 1988; Odegaard, 1991; Pinniger & Winsor, 2004). The exhibits suspected or established to be infested were isolated and treated, to prevent spread of infestation to other pieces. Cleaning infested zones and insects alive destroying, dead insects eliminating, and application of adequate chemical treatments, correlated with attacked materials and type of attack were the most used methods of pest control. To prevent the re-infestation process, we monitor periodically the insect's activity, to make sure that all stages have been killed. A special attention was given to storage areas, especially to quarantine ones, which are important sources for introducing insect species with infested materials. Cool, dry and warm storage areas are maintained to prevent insect's development. A great importance had some simple methods: closing windows or installing screens to prevent the entrance of *Blatta*, *Dermestes*, *Anthrenus*, *Tineola*, eliminating of moisture that might favor certain fungi and insect species, maintaining low humidity and temperature (in storage sites), eliminating the access of Dermestidae to flowering plants from the museum proximity, eliminating supplementary food sources to cockroaches. Good results were obtained by traps used to detect, monitor and control certain pests. In the case of *T. biselliella*, traps were represented by some pieces of textiles placed on the floor, in the rooms where woolen, silk fabrics, furs, or items with feathers were exposed or stored. The traps were periodically controlled and insects have been destroyed. Against *T. biselliella* there were also used pyrethroid pesticides and some small attacked pieces were maintained at – 27^{o}C, for seven days. Traps for *Blatta* and *Phyllodromia* consist in small pieces of bread soaked with boric acid and sugar solution, or other food soaked with pesticides, placed along the edges of the floor and at corners. Traps for silverfish were made by cards covered with sweet flour paste. In some cases, to kill psocids, attacked books were exposed at 50 ^{o}C. To destroy xylophagous species, pesticides were introduced in holes with a syringe, and then all holes were closed with wax or paraffin. For small wood pieces and books with Dermestidae and xylophagous species, vacuum method was used. Safely in control of wood and book pests were ventilation, use of some dehumidifier substances, temperature controls. As a result of all these methods, in 2007-2008 only few individuals of *Tineola* and Dermestidae were detected and in 2009 no insect attack was registered in the Brukenthal Museum.

CONCLUSIONS

From investigations on books, woods and textile pieces in the storage areas of the Brukenthal Museum 20 insect pest species were identified, belonging to 5 orders, 10 families and 3 trophic categories.

A total of 13 species were detected on old books (*Lepisma saccharina*, *Phyllodromia germanica*, *Blatta orientalis*, *Liposcelis divinatorius*, *Trogium pulsatorium*, *Anthrenus museorum*, *A. scrophulariae*, *A. pimpinellae*, *Attagenus pellio*, *Xestobium rufovillosum*, *Anobium punctatum*, *Stegobium paniceum*, *Ptinus fur*), 12 species on ethnographic textile pieces (*Lepisma saccharina*, *Phyllodromia germanica*, *Blatta orientalis*, *Tineolla biselliella*, *Anthrenus museorum*, *A. verbasci*, *A. scrophulariae*, *A. pimpinellae*, *Attagenus piceus*, *A. pellio*, *Dermestes lardarius*, *Ptinus fur*) and 5 species in wood sculpture exhibits (*Xestobium rufovillosum*, *Ernobius mollis*, *Anobium punctatum*, *Lyctus linearis* and *Hylotrupes bajulus*). The attacks were detected by alive or death adults, larvae feeding tubes, nymphal cocoons, exuviae, characteristics of attacked pieces, larvae galleries, adult's exit holes, faeces, and sawdust. Species richness was higher within Dermestidae and Anobiidae families and the highest attack intensity was registered on wood sculptures and books with wood support of leather covers. The most noxious pests were: *Tineola biselliella*, *Anobium punctatum* and *Stegobium paniceum*.

As a result of an "Integrated Pest Management Program" application a successful control of insect pests was accomplished.

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FIRST INVESTIGATIONS OF THE WATER QUALITY OF THE LAKE SREBRNO IN SERBIA BASED ON SAPROBIOLOGICAL ANALYSIS OF BENTHIC FAUNA

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MAJA RAKOVIC, VLADIMIR KALAFATIC

First limnological investigations of the Lake Srebrno water quality were performed in March 2007. Investigations included qualitative, quantitative and saprobiological analysis of bottom fauna communities, physical chemical analysis of sediments and determination of chlorophyll *a* concentration, as well as trophic status analysis. Samples were collected at eighteen localities distributed along shoreline and profundal of the lake. Twenty taxa from nine macroinvertebrate groups were recorded. The classification of the Lake Srebrno based on trophic and saprobic levels was assessed. The Lake Srebrno as a whole had eutrophic status with the gradation to hypertrophy. Calculated values of Pantle-Buck's Saprobic Index (S), based on bioindicator organisms of macrozoobenthos, ranged from S = 2.81 to S = 3.60. The water quality was estimated to be within limits proposed to III and IV-III class of the Serbian (Yugoslav) watercourses.

Key words: Lake Srebrno, Serbia, bottom fauna, physical chemical sediment analysis, trophy, saprobity, water quality.

INTRODUCTION

The Lake Srebrno (Silver Lake) is an artificial lake which has been poorly investigated in the hydrobiological aspect until now. First limnological investigations were performed during March 2007, with a focus on determining the composition of benthocenoses and water quality of the lake.

Bottom fauna is a very important component of aquatic ecosystems. Organisms of the bottom fauna are vulnerable to environmental changes, so composition and structure of macrozoobenthic communities are used as indicators of aquatic ecosystem status and in evaluating water quality (Rosenberg & Resh, 1993).

The presence of specific bottom fauna species, their life cycle and relations between other members of the ecosystem have been the subject of previous investigations of stagnant waters in Serbia: Obedska Bara and the Sava Lake (Jankovic, 1967, 1974, 1982; Jakovcev, 1989; Martinovic-Vitanovic, 1996). These aquatic ecosystems are lowland lakes formed in large river valleys (Martinovic-Vitanovic, 1996). The difference between them refers to their origin; Obedska Bara is a natural system originating by flooding, while the Sava Lake and Lake Srebrno are artificial lakes formed by dams partitioning them from the main river flow.

Larvae of Chironomidae species have a special position in the bottom fauna of Lake Srebrno because of their great diversity and abundance in macrophyte vegetation and in the substrate. This group is dominant in bottom fauna of the Lake Srebrno, and is also characteristic of the Obedska Bara ecosystem (Jankovic, 1967).

Representatives of the groups Chironomidae, Chaoboridae and Oligochaeta are important indicators for pollution level and trophy of continental waters (Kerovec *et al*., 1989; Timm, 1999; Moog, 2002), and they are characteristic for bottom fauna of Lake Srebrno.

This study demonstrates qualitative and quantitative bottom fauna composition, results of saprobiological analysis based on bioindicator concept. The goal of this study was to estimate water quality of the Lake Srebrno in March 2007 with application of saprobic system and calculated Saprobic Index. This study is the first limnological result for an investigated ecosystem, which represents an important tourist centre.

STUDY AREA

The Lake Srebrno (Fig. 1) is located in the east part of Serbia, 3 km from town of Veliko Gradiste, at the Serbian-Romanian border formed by the river Danube close to the Lake, and in subjacent of Lipovaca hill (362 m sea-level altitude). This district is characterized by a moderate continental climate with expressed annual seasons. Winters are sharp with frequent and intense eastern wind (Kosava), and summers are very hot with high air and water temperatures.

Lake Srebrno is an armlet at the right-hand side of the river Danube, separated from the Danube by upstream and downstream barriers constructed in 1971. The island Ostrovo was located between the Lake and the main river bed of the Danube. Three villages are located on the banks of the lake: Ostrovo (eastern part), Zatonje (western part) and Kisiljevo (on the most southern part of the meander).

The lake is “oxbow” shaped, 14 km long, with an average width of 300 m, and a total area of 4 km^2. Its elevation is 70 m above mean sea level, with a maximum depth of 8 m. The lake is supplied with the Danube water by underground natural filtration throughout the length of the sand drifts, and also receives water directly from the stream Kisiljevo and canal near Ostrovo village. A hotel, a few restaurants, an auto camp and weekend retreats are situated on the lake banks.

MATERIAL AND METHODS

Samples were collected on the 15^{th} and 16^{th} March 2007 from 18 sites, arranged in four sectors (Fig. 1):

Sector I – Tourist centre (sites 1-6);
Sector II – village Kisiljevo (sites 7-11);
Sector III – village Ostrovo (sites 12-16);
Sector IV – village Zatonje (sites 17 and 18).

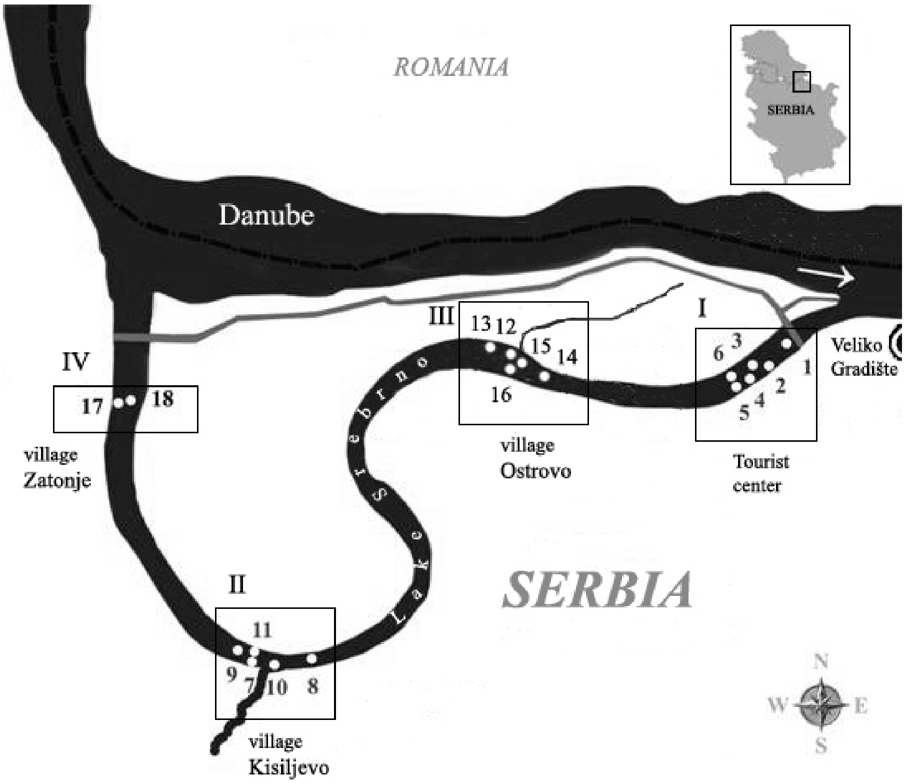

Fig. 1. Map of the Lake Srebrno with sampling sites:

Sector I
N 44^0 45′ 47.98″ E 21^0 28 ′ 35.97″

Sector II
N 44^0 44′ 16.78″ E 21^0 24 ′ 56.66″

Sector III
N 44^0 46′ 02.38″ E 21^0 26 ′ 22.35″

Sector IV
N 44^0 45′ 52.95″ E 21^0 23 ′ 55.58″

Partition of the Lake into four sectors is based on the hypothesis of different types of pollution occurring as a repercussion of tourist activities and the residence of a large number of tourists in the tourist centre (Sector I), compared with input of polluted materials from the three villages – Zatonje with its auto camp (IV), Ostrovo with the canal (III) and Kisiljevo with Kisiljevo brook (II), where pollution would also come from agricultural production (crop and stock farming).

At all sampling sites, a Van Veen type of grab (270 cm^2 grab area) was used for quantitative analysis of bottom fauna, except at site 12, where a qualitative sample was taken. Substrate classification was performed, by subjective evaluation, *in situ* and in the laboratory, based on the diameter of mineral particles (Wentworth, 1922).

Aquatic invertebrates were sorted according to sediments by washing through a sieve (200 µm). All samples were fixed *in situ* with 4% formaldehyde and then transported to a laboratory. A stereo zoom microscope with binocular magnifier (magnification 5-50×), Krüss, Germany, and microscope (10x10, and 10x40), Opton, Germany were used for assortment and determination of organisms. Identification of organisms was carried out to the species level, or to the lowest possible taxonomic level, using keys: Brinkhurst & Jamieson (1971), Elliot & Mann (1979), Timm (1999), Lellak (1980), Wiederholm (1983) and Croft (1986). Density of the bottom fauna populations at sampling sites was defined by counting individuals in quantitative samples and was calculated per unit area of the bottom surface (APHA-AWWA-WEF, 1995).

Absolute abundance of organisms is given as the number of individuals per square meter – no. ind. m^{-2}, and the participation of every benthos group in the total abundance of benthocenosis at sampling sites is given as a percentage.

Physical and chemical sediment analyses were performed using standard methods and techniques, APHA-AWWA-WEF (1995), in the Institute of Public Health, Belgrade. The following parameters were analyzed: pH, total nitrogen, total phosphorus, total organic carbon (TOC), cyanides, heavy metals (As, Cu, Zn, Cr, Cd, Ni, Pb and Hg) and pollutants: pesticides, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and phenols. Canadian and American Standards (CCME and USEPA) – Sediment Quality Guidelines (CCME, 2002; USEPA, 2002) are used to present results of silt analyses.

The trophical status of the lake was determined according to bottom fauna production (absolute abundance given as no. ind. m^{-2}), algal production by analysis of chlorophyll *a* concentration in the lake water and by measuring water transparency with a Secchi disc. Relative algal biomass in samples was estimated as concentration of Chl *a* (maximum concentration of Chl *a* as a criterion), measured spectrophotometrically from a hot 90% ethanol extract (APHA-AWWA-WEF, 1995).

The Saprobic index S, according to Pantle & Buck (1955) and classification of saprobity levels, according to Moog (2002), were used to estimate the water quality at each site.

The index employs the formula:

$$\mathbf{S = \Sigma sh / \Sigma h}$$

where **s** stands for saprobic valency, *i.e.* species degree of saprobity (according to Moog, 1995), and **h** for abundance (rare = 1, frequent = 3, and abundant = 5).

Water quality was also estimated on the basis of criteria set out in official legislation (Official gazette of the SRS, 1968; Official gazette of the SFRY, 1978), according to this – accumulation should have the same water quality as the main watercourse.

The following scheme shows the classification of the Saprobic index S with the water quality classes and the saprobity *versus* trophy levels:

Saprobic index	Water quality class	Saprobity level	*vs.*	Trophy level
0.50 to 1.50	I	oligosaprobic		Oligotrophy
1.51 to 1.75	II to I	beta- to oligosaprobic		
1.76 to 2.50	II	beta-mesosaprobic		Mesotrophy
2.51 to 2.75	III to II	alpha- to beta-mesosaprobic		
2.76 to 3.50	III	alpha-mesosaprobic		Eutrophy
3.51 to 3.75	IV to III	poly- to alpha-mesosaprobic		
3.76 to 4.50	IV	polysaprobic		Hypertrophy

RESULTS AND DISCUSSION

PHYSICAL AND CHEMICAL CHARACTERISTICS OF SAMPLING SITES

Morphometric characteristics of habitats, physical parameters of sediments and water, and concentration of Chl *a* of Lake Srebrno are shown in Table 1.

The 18 samples of bottom fauna communities collected at sites distributed along the shoreline and at the bottom of the lake came mainly from soft substrates – fine silt and loess. The silt was black with a smell of hydrogen sulphide (H_2S). Habitat heterogeneity was detected at sector II: sites 9 and 11 where the presence of sand was recorded, while at site 7 coarse detritus was also detected (Table 1).

The average depth of the lake in each sector was around 5 m. The minimum depth of the Lake was at locality 7 (2.5 m), while the maximum depth was at localities 8 and 16 (7 m). The average temperature was around 10 ^{o}C. The minimum temperature was at sites 15 and 16 (9.2 ^{o}C), and the maximum temperature was at site 8 (12 ^{o}C). Water transparency was between 0.80 m (site 1) and 1.40 m (site 13), and average water transparency was around 1 m (Table 1). Average sector Chl *a* concentrations were between 19.98 μg/L (Sector III) and 42.92 μg/L (Sector IV) (Table 1).

Table 1

Physical characteristics of sediment and water and Chlorophyll *a* concentration (mean values per sector) in the Lake Srebrno in March 2007

Sampling site / Sector	Depth (m)	Transparency (m)	Substrate	Water Temperature (ºC)	Chlorophyll *a* concentration (μg/l)
SECTOR I / 1-6	5.28	1.12	m, l	10.17	24.05
SECTOR II / 7-11	5.00	1.02	m, l, p, d	11.24	27.38
SECTOR III / 12-16	5.00	1.16	m	9.72	19.98
SECTOR IV / 17-18	5.50	1.10	m, l	10.90	42.92

Legend: l – loess; m – silt; p – sand; d – detritus.

Sediment samples for chemical analysis were taken from every site at the same time as samples of bottom fauna. Results of chemical sediment analysis are presented in Table 2.

Silt pH varied between localities from 8.06 to 8.61, showing the medium to be weakly alkaline. Silt nitrogen concentrations varied amongst localities from 0.23% (site 11) to 0.64% (site 16), while total phosphorus concentrations were between 429.4 mg/kg (site 14) and 1172.5 mg/kg (site 9). The lowest percent of total organic carbon (TOC) was at site 12 (1.53%), and the highest percent was 4.37% (site 8). Cyanide concentrations were under the detection limit (< 1.0 mg/kg), as were mercury concentrations (< 0.6 mg/kg). Other heavy metals (As, Cu, Zn, Cr, Cd, Ni, Pb) showed little variation amongst sampling sites (Table 2).

Concentrations of some heavy metals, at some sites, were above minimum safe concentration limits, indicating possible harmful effects on aquatic organisms, according to Canadian and American Standards (CCME, 2002; USEPA, 2002):

Sector I – Cu, Cr, Zn, Cd, Pb, As, Ni; Sectors II and III – Cr, Pb, As, Ni; Sector IV – Pb, As, Ni.

Heavy metals: As – at Sectors I and II, and Ni – at Sectors I, II and III were above limits, therefore a harmful effect on aquatic organisms should be expected, according to Canadian and American Standards (CCME, 2002, USEPA, 2002). The enhanced concentrations of these two heavy metals in all Sectors of Lake Srebrno are likely to have harmful effects on the benthic community (Laliberte & Tremblay, 2002). Pesticides were not detected in the lake (< 10.0 μg/kg) and neither was the presence of phenols recorded (< 10.0 μg/kg).

The fact that no samples contained measurable quantities of mercury, cyanides, phenols and pesticides (HCH – α, β, δ; Lindane; Heptachlor; Heptachlor epoxide; Alachlor; Aldrin; Dieldrin; Endrin; DDT – DDE, DDD; Hexachlorbenzol; Atrazin; Simazin and Propazin) illustrate the very favorable conditions of the lake for supporting organisms.

Polycyclic aromatic hydrocarbons (PAHs) were present at all sampling sites with concentrations between 36.4 μg/kg (site 12) and 524.8 μg/kg (site 17). Polychlorinated biphenyls (PCBs) were recorded at only two sampling sites of Sector I: 500.7 μg/kg (site 2) and 95.1 μg/kg (site 3), which indicates limited local pollution, probably as a result of removing a transformer station from tourist centre.

The following polycyclic aromatic hydrocarbons were above safe concentration limits, according to Canadian Standards (CCME, 2002) (Table 2 – shown cumulative): benzo(a)pyrene – in sectors I, II and IV, pyrene, anthracene and chrysene in site 11 (sector II) and naphthalene in sector IV. Polycyclic aromatic hydrocarbons usually come from waste water and arise as intermediate degradation products of some organic (phyto) materials, also petroleum is a source for this (Martinovic-Vitanovic, 1996). A possible reason for the presence and high concentrations of PAHs is accelerated urbanization in the investigated area.

BOTTOM FAUNA

The macrozoobenthos community of Lake Srebrno was made up of representatives of nine faunistic groups totalling 20 taxa: Chironomidae (9), Oligochaeta (4), Trichoptera (1), Hirudinea (1), Chaoboridae (1), while representatives of Nematoda, Diptera (Ceratopogonidae), Hydracarina and Bryozoa were not determined to the lower taxonomic levels (Table 3).

The density of macrozoobenthos communities of Lake Srebrno fluctuated from 481 ind. m^{-2} (site 13, Sector III) to 8,510 ind. m^{-2} (site 7, Sector II). The lowest diversity of the bottom fauna community was at site 13 (one group only), while the highest number of faunistic groups was at site 7 (six groups). The number of taxa per site fluctuated between two (site 13) and 11 (site 7) (Table 3).

Benthocenoses of Lake Srebrno showed little diversity and had a composition and structure similar to those of other artificial lakes (Jankovic, 1967, 1974, 1982; Jakovcev, 1989; Martinovic-Vitanovic, 1996). Unusually, at the time of sampling, there was a complete absence of the Mollusca group, an important component of the bottom fauna. In the Sava Lake (Jakovcev, 1989), on the silt substrate without detritus, a big reduction of macrozoobenthic groups was also recorded.

A soft medium of loess and silt was characteristic for most sampling sites of Lake Srebrno (Table 1). Only in Sector II a heterogeneous substrate was recorded (silt, loess and sand) and at site 7 coarse detritus was also detected. This site, at the mouth of Kisiljevo stream, was different from other sites by composition, diversity and abundance of bottom fauna, having the greatest taxa diversity – 6 groups with 11 taxa, and maximum abundance –8,510 ind. m^{-2}. Site 7 was also the shallowest site (2.5 m), where coarse detritus and erosion materials were being imported by the Kisiljevo stream, which implies back filling. All of sector II was under the influence of Kisiljevo stream, which passes through the village bringing increased organic pollution.

Table 2

Chemical sediment characteristics of the Lake Srebrno (Serbia) in March 2007

Site	pH	Total N (%)	Total P (mg/kg)	TOC (%)	Cyanides (mg/kg)	Heavy metals								Pesticides (µg/kg)	PAHs (µg/kg)	Phenols (µg/kg)	PCBs (µg/kg)
						As (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Cr (mg/kg)	Cd (mg/kg)	Ni (mg/kg)	Pb (mg/kg)	Hg (mg/kg)				
1	8.34	0.26	584.8	3.30	< 1.0	12.9	47.8	106.9	49.0	0.6	73.2	65.8	< 0.6	< 10.0	237.5	< 10.0	< 10.0
2	8.38	0.27	519.2	1.85	< 1.0	10.8	37.0	90.0	41.4	0.5	61.9	55.1	< 0.6	< 10.0	182.2	< 10.0	500.7
3	8.35	0.46	743.5	2.25	< 1.0	19.4	42.3	104.6	48.6	0.7	72.2	64.5	< 0.6	< 10.0	86.0	< 10.0	95.1
4	8.45	0.35	735.2	1.96	< 1.0	12.9	41.3	120.4	57.4	0.9	85.8	68.5	< 0.6	< 10.0	214.1	< 10.0	< 10.0
5	8.36	0.49	1023.7	3.55	< 1.0	26.9	49.8	127.3	59.7	0.8	88.1	64.8	< 0.6	< 10.0	284.6	< 10.0	< 10.0
6	8.31	0.45	608.4	1.85	< 1.0	15.7	37.5	112.8	51.7	0.6	72.1	61.7	< 0.6	< 10.0	301.8	< 10.0	< 10.0
7	8.18	0.36	655.8	2.12	< 1.0	6.6	18.0	53.8	25.3	0.2	32.3	22.6	< 0.6	< 10.0	80.0	< 10.0	< 10.0
8	8.32	0.50	922.3	4.37	< 1.0	32.1	31.4	72.7	39.0	0.4	53.6	34.8	< 0.6	< 10.0	422.8	< 10.0	< 10.0
9	8.49	0.43	1172.5	3.11	< 1.0	14.7	33.6	83.7	47.6	0.3	62.9	40.6	< 0.6	< 10.0	190.4	< 10.0	< 10.0
10	8.29	0.31	745.4	2.79	< 1.0	12.1	26.9	72.3	37.5	0.3	49.6	33.4	< 0.6	< 10.0	126.1	< 10.0	< 10.0
11	8.40	0.23	715.7	2.00	< 1.0	8.1	21.6	60.4	28.3	0.2	38.5	21.0	< 0.6	< 10.0	398.8	< 10.0	< 10.0
12	8.28	0.35	730.8	1.53	< 1.0	11.2	34.4	60.3	32.4	0.3	50.4	34.6	< 0.6	< 10.0	36.4	< 10.0	< 10.0
13	8.23	0.38	775.5	1.81	< 1.0	8.5	27.1	42.5	25.6	0.2	43.0	24.9	< 0.6	< 10.0	43.6	< 10.0	< 10.0
14	8.61	0.28	429.4	2.47	< 1.0	10.0	31.3	82.6	40.4	0.5	62.3	47.6	< 0.6	< 10.0	172.2	< 10.0	< 10.0
15	8.37	0.39	536.9	2.04	< 1.0	8.0	30.9	57.3	29.4	0.2	45.7	33.5	< 0.6	< 10.0	131.7	< 10.0	< 10.0
16	8.06	0.64	658.9	2.96	< 1.0	15.9	30.5	47.9	25.3	0.3	36.6	27.1	< 0.6	< 10.0	182.2	< 10.0	< 10.0
17	8.17	0.41	650.1	1.84	< 1.0	12.6	22.3	67.0	36.5	0.6	49.7	40.5	< 0.6	< 10.0	524.8	< 10.0	< 10.0
18	8.40	0.32	739.2	3.28	< 1.0	10.3	23.8	63.1	33.6	0.2	49.6	33.1	< 0.6	< 10.0	372.9	< 10.0	< 10.0

Table 3

Number of groups and taxa in macrozoobenthos and their relative abundance (%) in benthic communities at sampling sites (1-18) and sectors (I-IV) of the Lake Srebrno in March 2007

Sector	I						II					III					IV	
Sampling sites	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
NEMATODA	16.31	26.92	7.84	18.18	12.9	2.22	2.17		6.25	7.89	2.38	21.21		27.91	29.27	3.45	23.07	3.03
OLIGOCHAETA		15.38				13.33	3.04					3.03					3.85	
HIRUDINEA									2.08									
HYDRACARINA		3.85								5.26	2.38							
BRYOZOA							+		+	+								
CHIRONOMIDAE	64.52	53.85	60.78	77.27	83.87	80	92.61	53.73	89.58	86.84	88.09	72.72	100	69.77	65.85	62.07	63.46	90.9
CERATOPOGONIDAE			1.96				1.74		2.08		2.38	3.03		2.33		3.45		
CHAOBORIDAE	19.35		29.41	4.54	3.23	4.44		46.27			9.52				4.88	31.03	9.61	6.06
TRICHOPTERA							0.43											
Relative abundance-Total (%)	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Number of groups per site	**3**	**4**	**4**	**3**	**3**	**4**	**6**	**2**	**5**	**4**	**5**	**4**	**1**	**3**	**3**	**4**	**4**	**3**
Number of groups per sector	**6**						**9**					**5**					**4**	
Number of taxa per site	**6**	**6**	**5**	**4**	**5**	**7**	**11**	**5**	**6**	**5**	**7**	**8**	**2**	**6**	**5**	**6**	**5**	**4**
Number of taxa per sector	**11**						**16**					**11**					**5**	

Legend: + – finding of Bryozoan's statoblasts

Mainly pelophylic organisms were present at sampling sites having a silt medium. Along with substrate type previously discussed, the absence of vegetation, especially of submerged vegetation, at the time of sampling, was a factor influencing the potential diversity of bottom fauna (by structuring it) that was not high, being generally a uniform one, therefore characteristic for stagnant water (Jankovic, 1974, 1982; Martinovic-Vitanovic, 1996) such as Lake Srebrno.

The Chironomidae group was dominant in the benthocenosis of Lake Srebrno. In relation to other faunistic groups, the great diversity of this insect group was due to the presence of 9 taxa belonging to 2 subfamilies: Chironominae (8 taxa) and Tanypodinae (one taxon). *Chironomus plumosus* Linnaeus was the dominant species, and *Chironomus riparius* Meigen was subdominant according to their population frequencies (0.94 and 0.89, respectively) and abundances (relative abundances being in the range 54.5-84.6 and 9.1-38.7, respectively).

Qualitative and quantitative analyses of benthocenoses, and especially of the Chironomidae group, were used to assess the trophic levels in aquatic ecosystems (Jonasson, 1972; Johnson *et al*., 1993; Armitage *et al*., 1995; Lindegaard, 1995).

Species of the genus *Chironomus* are bioindicators for the presence of organic pollutants, and were used to help define the level of eutrophication of the lake. *Chironomus plumosus* occurs in lakes with high eutrophic levels (Resh & Rosenberg, 1984; Dudley & Feltmate, 1992). *Chironomus riparius* has a widespread distribution in the northern hemisphere, mostly in the temperate zone, and is a common resident of polluted waters (Lindegaard, 1995). Larvae of those species are tolerant to a wide range of variation of pH, oxygen concentration and diameter of sediment particles (Ristola, 2002).

Because of the dominance of species of the genus *Chironomus* in the bottom fauna, Lake Srebrno could be classified as an eutrophic lake of *Chironomus* type (Lindegaard, 1995).

The Nematoda group was recorded at 16 of the 18 sites, as the subdominant group of macrozoobenthic organisms of Lake Srebrno.

The Oligochaeta was represented with widespread pelophylic species of the Tubificidae family: *Limnodrilus hoffmeisteri* Claparede, *L. claparedeanus* Ratzel and *Potamothrix hammoniensis* Michaelsen. They were recorded in all sectors of the lake, at 5 sampling sites in total (sites 2 and 6 – Sector I; site 7 – Sector II; site 12 – Sector III; site 17 – Sector IV), while only fragments were recorded at sites 12 and 17, and their determination to the species level was not possible. Besides a low presence, in regard to the fact that all annotated taxa originated from only one family, Oligochaeta of the Srebrno Lake had shown a little diversity and abundance. The identified species of Oligochaeta indicate organic pollution, as they are known to be tolerant to oxygen deficiency in the substrate and in the contact layer. The low abundance of Oligochaeta and their proportionately small contribution to macrozoobenthic abundance could be due to seasonal dynamics. Samples were collected in March 2007, and Oligochaeta have a tendency to increase their abundance from spring to summer, with a decreased abundance in the winter (Jankovic, 1974).

The uniform bottom fauna community of Lake Srebrno was probably due to substrate homogeneity. The high recorded faunistic similarity between localities was the result of abundant taxa that typify soft sediments, which were detected at every sampling site of the lake. The minimum degree of similarity was detected between site 7 and 13 – 15.4% and maximum – 100% was found for sites 5 and 15.

Recorded faunistic similarity (values of Quotient of Similarity – QS accorded to Sorensen, 1948; authors' unpublished results) was mainly in the range of medium (21-60%) to high (61-100%) degrees of similarity, 56% and 42% of pair-wise comparisons between sites, respectively.

The lower values of faunistic similarity between Srebrno Lake localities resulted from the presence of members of the Oligochaeta, Hydracarina, and Bryozoa groups that were detected at a small number of sites, and the sporadic presence of species of Hirudinea, Trichoptera – *Philopotamus montanus* Donovan, and Chironomidae – *Polypedilum nubeculosum* Meigen, *Cryptochironomus defectus* Kieffer, *Dicrotendipes nervosus* Staeger and *Glyptotendipes pallens* Meigen.

The presence of the genus *Chaoborus* (Chaoboridae), which is usual in stagnant water with unfavorable oxygen conditions at the lowest water layers, indicates high levels of trophy and saprobity. Representatives of the groups Chaoboridae, Chironomidae and Oligochaeta that were found are faunistic elements of eutrophic and polluted waters (Jankovic, 1974).

The saprobic status of the lake (Table 4) was determined by species characteristic for low oxygen conditions (and species with high saprobic valences) that were very abundant in this lake (*Chironomus plumosus*, SI = 3.50 and *Chironomus riparius*, SI = 3.60), and the presence of less abundant species with high saprobic valences (*L. hoffmeisteri*, SI = 3.50, *L. claparedeanus*, SI = 2.90 and *Potamothrix hammoniensis*, SI = 2.70). Values of Saprobic Index (S) were in the range from S = 2.81 (site 12) to S = 3.60 (site 13), which indicated alpha-meso- and poly-alpha-mesosaprobity.

WATER QUALITY

Water transparencies and chlorophyll *a* concentrations (mean values per sectors) showed that Lake Srebrno was at a high trophy level According to the classification schemes for lake water trophy (OECD, 1982), Lake Srebrno in March 2007 had an eutrophic status: Chl *a* concentrations in 11 of the 18 samples were above 25 µg/L (the standard is a maximum Chl *a* concentration for eutrophic waters of 25-75 µg/L) and water transparency was never greater than 1.40 m (the standard is a minimum water transparency for eutrophic waters of 1.5-0.7 m).

According to mean Chl *a* concentrations, sectors II and IV had an eutrophic status, and the waters of sectors I and III (Sector I – sites 1, 2, 3, 4 and Sector III –

Table 4

Water quality of the Lake Srebrno in Serbia based on saprobiological analysis of macrozoobenthic communities at the sampling sites (1-18) and sectors (I-IV) in March 2007

Sector	**I**						**II**					**III**					**IV**	
Sampling sites	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Saprobity index S	3.54	3.27	3.56	3.21	3.56	3.41	3.24	3.36	3.43	3.55	3.56	2.81	3.60	3.56	3.56	3.54	3.56	3.58
Saprobity level	p-α	α-p	p-α	α	p-α	α-p	α	α-p	α-p	p-α	p-α	α	p-α	p-α	p-α	p-α	p-α	p-α
Classes	IV-III	III-IV	IV-III	III	IV-III	III-IV	III	III-IV	III-IV	IV-III	IV-III	III	IV-III	IV-III	IV-III	IV-III	IV-III	IV-III

sites 13 and 15) were varying from meso to eutrophic (8-25 μg/L). The only exception was the Chl *a* concentration at sampling site 12, which was only 4.44 μg/L.

The major sources of nutrients that get into the Lake, as a consequence of anthropogenic activities (increasing the trophic level from eutrophy gradually to hypertrophy), are artificial fertilizer for agriculture and stock farming, and communal waste water from the tourist centre, villages and weekend retreats around the lake, all of which discharge their waste untreated directly into the Lake. Canadian and American (CCME and USEPA) Guidelines for assessment of contaminated sediments in freshwater ecosystems did not provide standards for total nitrogen, total phosphorus and total carbon as water eutrophication factors (CCME, 2002; USEPA, 2002).

Table 4 presents results of saprobiological bottom fauna analysis. Water of Lake Srebrno at three sampling sites is in the range of III water quality class (sites 4, 7 and 12), at four sampling sites it is persisting in IV to III class (sites 2, 6, 8 and 9) while at all other sampling sites water quality was in IV-III class limits. Evaluated water quality was in the range of high saprobic level, based on Moog's saprobic system (2002), and Saprobity Index (S), according to Pantle-Buck method (1955), and that align water of the Lake Srebrno in III class and persisting in IV to III water quality class (Official gazette of the SFRY, 1978).

CONCLUSIONS

The results presented in this study are based on analysis of benthocenosis structure and on saprobiological analysis, which indicate that Lake Srebrno is an eutrophic ecosystem. Physical and chemical analyses of the water and silt, as well as concentrations of Chl *a*, confirmed this classification. Eutrophication is normal for this type of water basin, but in this case it is increased by anthropogenic factors.

Lake Srebrno in March 2007 belonged to the alpha-mesosaprobic zone, with gradation from poly- to alpha-mesosaprobity. Estimated water quality was in III and with gradation from IV to III class.

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PECULIARITIES OF ECOLOGICAL EVOLUTION OF MUSURA BAY (THE DANUBE DELTA) BETWEEN 2005-2007

ALINA COMAN, CRISTINA SANDU

The ecological evolution of Musura Bay (the Danube Delta) was significantly affected by the hydromorphological changes occurred in the catchment and by the climate change effects. The formation of a sandbank at its mouth, the reduced inflow of marine water and the increasing inflow of the Danube freshwater, lead to a decreasing salinity and a shift of abiotic and biotic parameters from marine to freshwater type. The active siltation together with the increasing water temperatures lead to a marked decreasing trend of water depth, up to an average of 1.4 m recorded between 2005-2007. The annual averages of nutrient and chlorophyll *a* content were moderate, the assessment of trophic status based on OECD and national criteria indicating a mesotrophic ecosystem. The correlation of chlorophyll *a*, as a measure of algal biomass, and the abiotic parameters have shown linear correlations with the temperature ($p > 0.05$, $r = 0.291$, $n = 45$) and total phosphorus ($p > 0.05$, $r = 0.284$, $n = 45$). The low amount of organic matter adversely impacted the structural and functional parameters of the benthic community. Based on climate models predictions, severe droughts are expected in the southern part of Romania especially during summer, which will impact even more this aquatic ecosystem, leading to a decrease of the ecosystem services provided to the local community or even to its extinction. Therefore, the local and regional management plans should include potential mitigation measures.

Key words: the Danube Delta, anthropogenic impact, physico-chemical parameters, wetlands.

INTRODUCTION

The coastal systems (coastal lands, areas where freshwater and salt water mix, and nearshore marine areas) are among the most productive yet highly threatened wetlands in the world due to the increasing exploitation pressure: nearly 40% of the people in the world live within 100 kilometers of the coast. Besides fisheries and game, timber, fuel, construction materials, genetic resources, demand for shipping and navigation, waste disposal, recreation, aquaculture and habitation are increasing (MEA, 2005).

Located at the confluence of Sulina and Chilia arms of the Danube River with the Black Sea (Fig. 1), Musura Bay is part of the Danube Delta Biosphere Reserve.

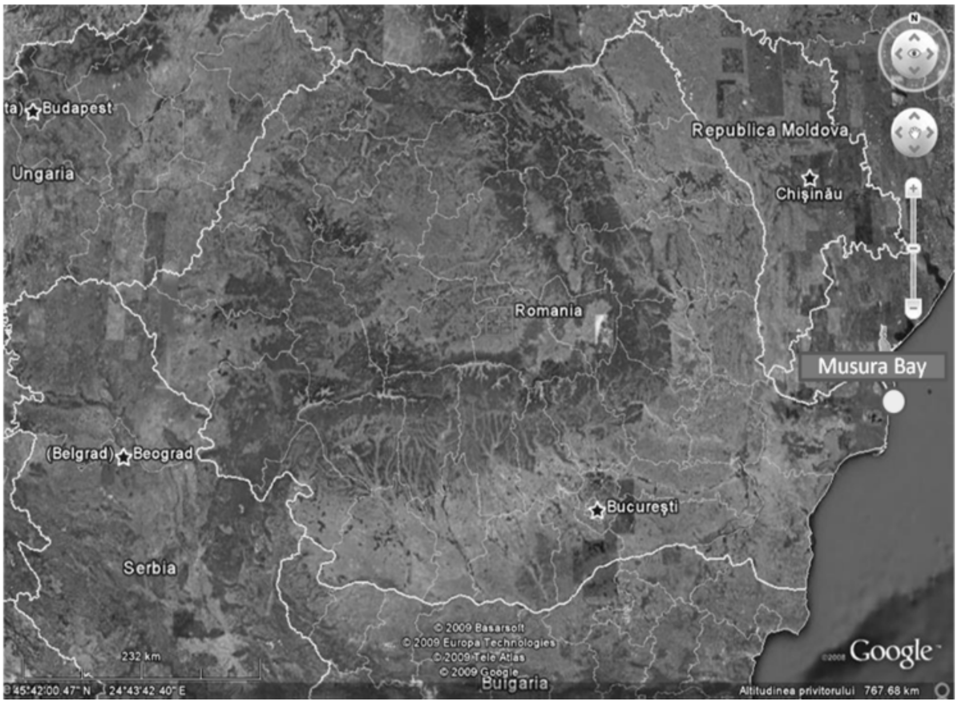
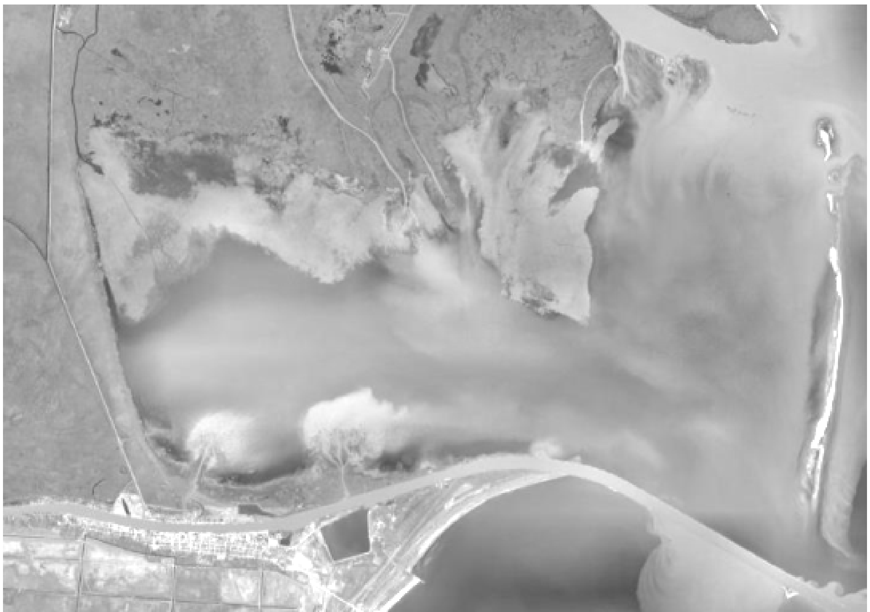


Fig. 1. Location of Musura Bay (www.earth.google.com).

The hydromorphological changes occurred in the Danube catchment, the works carried out for navigation maintenance on Sulina channel and the shift of the marine currents at the bay's mouth, lead to a rapid evolution of the bay towards transformation in a freshwater lagoon. In the middle of the XIXth century, the bay had a wide opening towards the sea (13 km) and depths over 12 m, offering to the aquatic biocenoses the same marine conditions as the sea (Burghele 1946, quoted by Zinevici *et al*., 2006). However, in the last decades, the alluvial deposition and the rapid advancement of Chilia secondary delta in the northern part of the bay, together with the construction of a new channel (9 km) at the mouth of Sulina arm, led to an accelerated narrowing of bay's mouth; consequently, in 2005, the opening towards the sea recorded 5 km, while the depth decreased to 2 m (Zinevici *et al*., 2006).

The further changes, which followed the extreme hydrological events occurred between 2005-2007 (floods and high alluvial deposition in 2005-2006, severe droughts and high temperatures in 2007), contributed even more to the narrowing of the bay's mouth and led to an accelerated siltation; also, the former submerged sand bank located at the bay's mouth, became emerged, limiting the inflow of marine waters (Fig. 2).

(a)



(b)

Fig. 2. Musura Bay in 2005 (a) and 2009 (b) (modified from www.earth.google.com).

The habitat alteration impacted also the water quality: a decreasing salinity and a gradual shift from marine to freshwater characteristics occurred, influencing also the aquatic communities.

This paper presents the water quality of Musura Bay between 2005-2007, emphasizing the impact of some abiotic parameters on the aquatic biocenosis; based on the current predictions for the area, several management measures which might contribute to the conservation of this ecosystem even under the impact of global changes are underlined.

MATERIAL AND METHODS

The water and sediment samples have been taken between 2005-2007 in May, July and October, from five stations. The water samples were collected on column with a Patalas-Schindler device, while for sediment, a Corer device was used. The location of sampling sites and the sampling design are presented in Ionică *et al*. (2008).

The transparency was determined with a Secchi disk; the temperature, pH, conductivity, salinity, dissolved oxygen content were measured in the field with a multiparameter WTW 340 i (Germany). Samples for chemical analyses were frozen for further analyses in the lab. Nutrients were determined spectrophotometrically (CECIL 1100, UK): NH_4^+ – as yellow compound with Nessler reagent, NO_2^- – as red compound with sulphanilic acid and α-naphthylamine, NO_3^- – as yellow compound with sodium salicylate (Tartari & Mosello, 1997), total reactive phosphorus (TRP) – as blue phosphomolybdate, reduced by ascorbic acid, total phosphorus (TP) – by oxidation with potassium peroxodisulphate (Tartari & Mosello, 1997); the organic matter content was estimated from the chemical oxygen demand determined by oxidation with $K_2Cr_2O_7$ (COD-Cr), while the content of organic matter in the sediment was determined by loss on ignition (Golterman, 1969).

Chlorophyll-*a* was measured spectrophotometrically according to ISO 10260-1992.

RESULTS

The progressive transformation of Musura Bay in a lagoon with a limited connection with the sea and the increased freshwater input of the Danube River determined the shift of the abiotic conditions from marine to freshwater characteristics.

Under the active siltation occurred as a consequence of the alluvial deposition, the bay's depth decreased from the initial values of over 12 m (Burghele, 1946, quoted by Zinevici *et al.*, 2006) to an average of 1.4 m recorded during the investigated period (Fig. 3); the submerged sand bank, created by the marine currents, limited even more the marine water inflow in the bay area. The banks and the north-western part of the bay were invaded by emerged, submerged and floating vegetation, the bay resembling nowadays with a shallow lake, characteristic for the Danube Delta region.

The transparency index (T/D), defined as the ratio between the Secchi depth (transparency, T) and the total depth (D), shows an increasing trend between 2005-2007 (Fig. 3), as a consequence of the differences recorded in the hydrological regime of the Danube: high floods in 2005 and 2006, droughts in 2007. The floods brought a high amount of allluvia; in this shallow ecosystem, exposed to winds and storms, the sediment resuspension occurs frequently, reducing the transparency, which has a negative impact on the development of the primary producers.

The pH varied in the usual range for the Danube water, with a slightly alkaline character: 7.5-9.1; higher values were recorded in summer as a consequence of the intense photosynthesis processes, when the CO_2 is absorbed from the environment, increasing the pH.

During the investigated period, the conductivity recorded low levels, fluctuating around 400 µS/cm, a value specific to freshwater ecosystems; the only exception was recorded in Oct. 2007, when due to the droughts and the lower freshwater inflows of the Danube, a higher value was recorded (725 µS/cm).

The oxygen saturation fluctuated around 100%, the lowest values being recorded in 2006 as a consequence of the long floods and the high alluvial inflows, the continuous resuspension of fine particles leading to an increased oxygen consumption in decomposition processes.

The chemical oxygen demand (used to estimate the amount of organic matter in the water column) recorded an ascending trend between 2005-2007, the maximum values being reached in 2007, in the absence of floods and the dilution effect triggered by the inflows; another possible cause might be the frequent sediment resuspension as water shallowness peaked also in 2007 as a consequence of the severe droughts.

The dynamics of dissolved inorganic nitrogen recorded a wide range of fluctuations due to the increased run-offs from the agricultural fields triggered by the floods; although the general trend is decreasing, the maximum values were recorded in 2006 (Fig. 3), in a direct correlation with the longer floods recorded that year. The total phosphorus fluctuated during the investigated period, but in a narrower range.

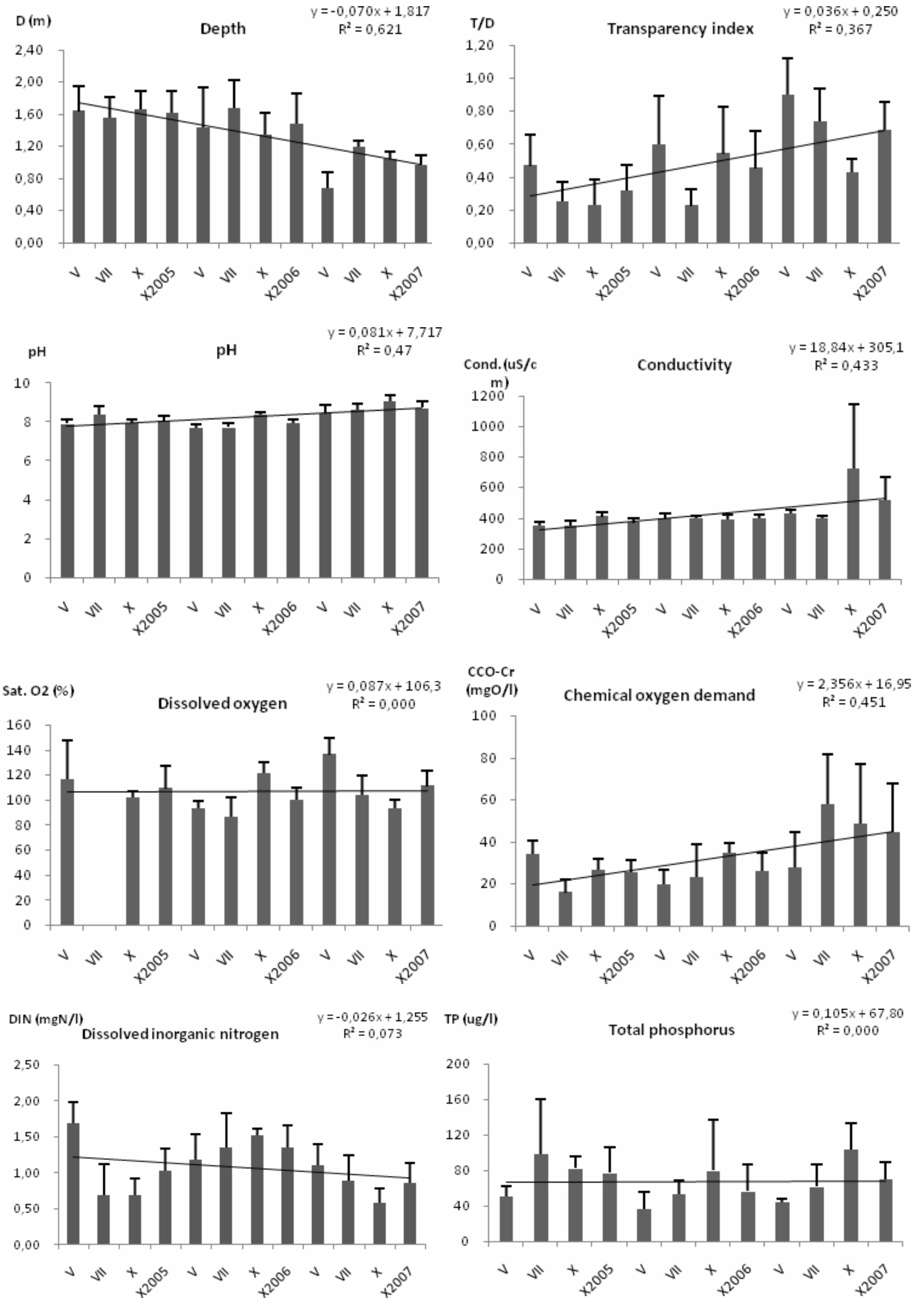


Fig. 3. Physico-chemical characterization of Musura Bay between 2005-2007.

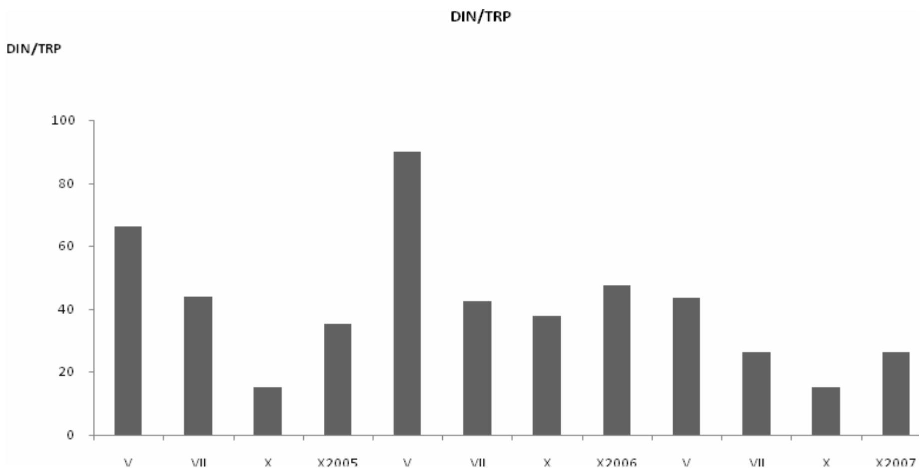


Fig. 4. Dynamics of DIN/TRP ratio in Musura Bay between 2005-2007.

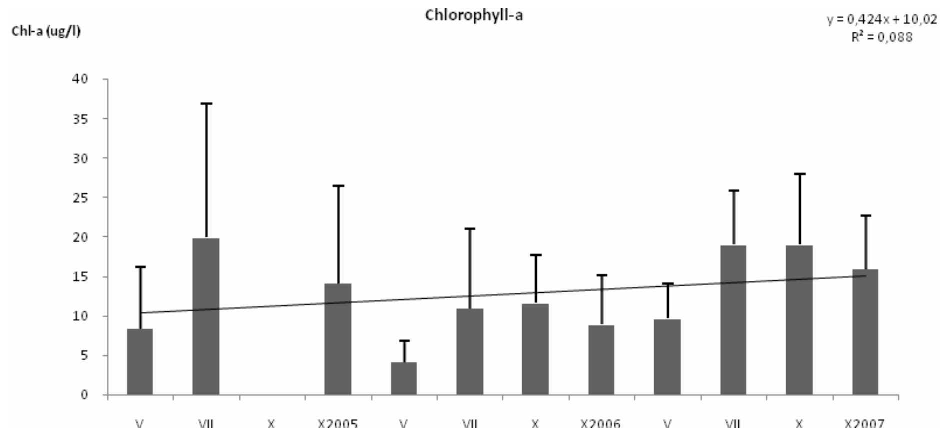


Fig. 5. Dynamics of chlorophyll-a in Musura Bay (2005-2007).

The ratio between dissolved inorganic nitrogen and total reactive phosphorus (DIN/TRP) was higher than 10, indicating P as the potential limiting factor (Fig. 4).

The chlorophyll *a* recorded an increasing trend, with lower values between 2005-2006 due to the dilution effect induced by floods and maximum values in 2007; however, in comparison with the lakes of the Danube Delta, the values were low (Sandu, 2006), the average being 15 µg/L (Fig. 5).

The content of organic matter in the sediment recorded a decreasing trend between 2005-2007 (Fig. 6); the higher values recorded in 2005-2006 are probably a consequence of the alluvia and the allochthonous organic inflow brought by the floods. Due to the frequent sediment resuspension and the sandy substrate, the amount of organic matter in the sediment is far below the values usually recorded in the Danube Delta lakes.

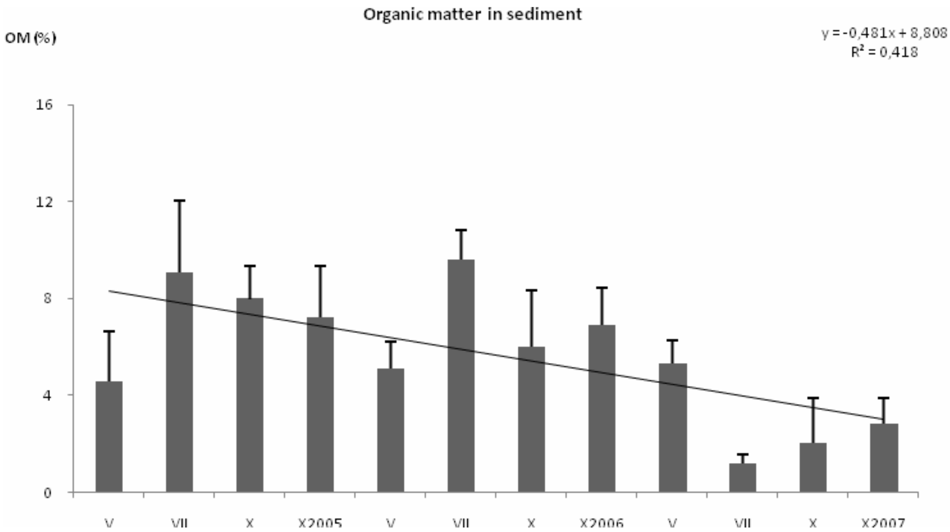


Fig. 6. Dynamics of organic matter content in sediment, Musura Bay (2005-2007).

DISCUSSION

Considered for centuries as low-use and nuisant areas, wetlands were drained, filled, embanked and converted to agricultural or construction land until their disappearance and the consequent loss of the ecosystem services they have provided (such as fish and game, water supply, climate regulation, flood mitigation, recreation and tourism) triggered highly negative consequences for human well-being (Leschine *et al.*, 1997; Voora & Venema, 2008).

Their degradation was determined by the increasing anthropogenic pressure: besides hydromorphological alterations (consisting in dams, embankments, channelization, hydropower plants, navigation), wetlands are subject to water withdrawal, pollution (with nutrients or xenobiotics), global warming (increased evaporation rate, shift of precipitation regime, droughts), overexploitation, introduction of alien invasive species, etc.

Wetlands deliver a wide range of ecosystem services that contribute to human well-being, such as food provisioning, water supply, water purification, climate regulation, flood regulation, coastal protection, recreational opportunities, and, increasingly, tourism (MEA, 2005). However, due to an inappropriate management, many wetlands disappeared or lost their functions; *e.g.* in the Danube River Basin, over 80% of the former floodplains were affected or lost (www.icpdr.org).

Located in the lower part of the Danube catchment, at the confluence of the Danube River with the Black Sea, the Danube Delta was impacted, directly or indirectly, by many anthropogenic drivers (Vădineanu *et al.*, 2001, 2003); among the most important were: hydromorphological changes (parts of the delta being dried for agricultural purposes before 1990, channelization, hydrotechnical works in the catchment), exploitation of resources (fish, game, fruits, construction materials, etc.), pollution (with different xenobiotics like heavy metals, oil products, detergents, persistent organic pollutants, etc.), eutrophication (as a consequence of the increased nutrient content), introduction of invasive species and, recently, the impact of global climate changes.

Musura Bay, situated in the eastern part of the delta, was subject to a combined action of anthropogenic and natural drivers: on the one side, the influence of the Danube catchment, and, on the other side, the changes occurred in the Black Sea; under this double action, the bay was transformed in less than two centuries from a marine gulf to a freshwater lagoon threatened by a rapid siltation.

The nutrient loading has emerged as one of the most important drivers of ecosystem change in freshwater and coastal ecosystems, projected to increase in the future (MEA, 2005).

In Musura Bay, the nutrient concentrations show moderate values; according to the international (OECD, 1982) and national (OM 161/2006) criteria, the assessment of trophic status based on the analysis of dissolved inorganic nitrogen, total phosphorus, oxygen saturation and chlorophyll *a* content shows a mesotrophic status, while most of the Danube Delta lakes are eutrophic (Sandu, 2006).

The linear correlation found between the chlorophyll *a* and the concentration of total phosphorus (Fig. 7) confirms the fact that in this aquatic ecosystem phosphorus is the potential limiting factor, indicated also by the average value of DIN/TRP ratio above 10 (Fig. 4). A similar correlation was identified also in other lakes of the Danube Delta (Sandu, 2006) emphasizing the limiting role of P for the development of algal community in this area.

At benthic level, the low amount of organic matter (Fig. 6) was one of the main causes contributing to the low structural and functional values recorded by the zoobenthic community; similar as for the lakes of the Danube Delta, the dominant groups were chironomids and oligochaets (Radu *et al.*, 2008).

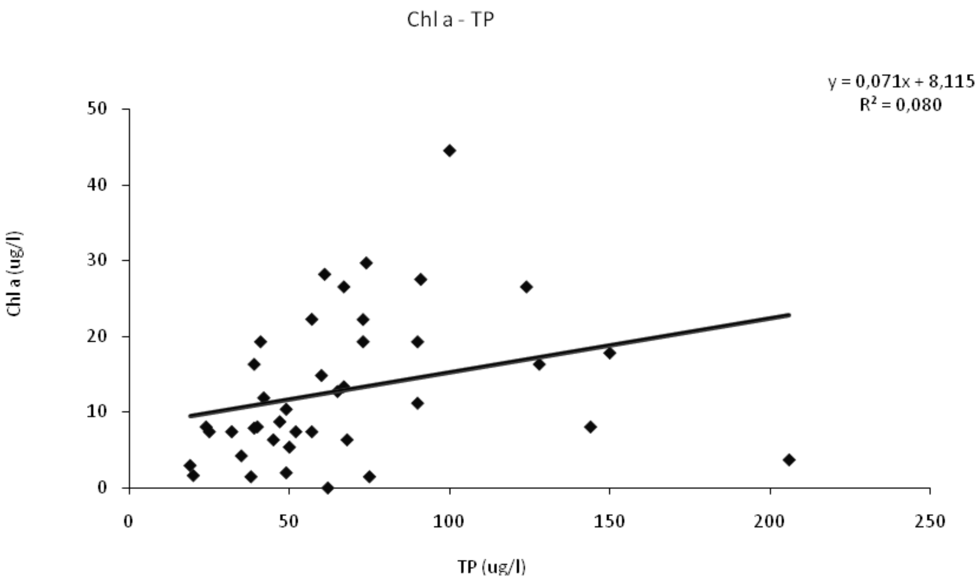


Fig. 7. Linear correlation between the content of chlorophyll-a and total phosphorus ($p > 0.05$, $r = 0.284$, $n = 45$).

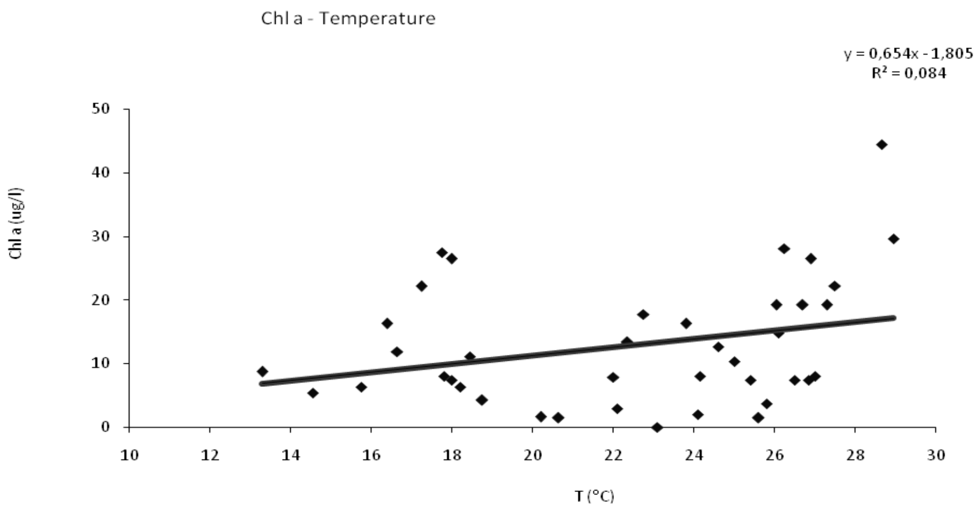


Fig. 8. Linear correlation between the content of chlorophyll-a and temperature ($p > 0.05$, $r = 0.291$, $n = 45$).

The submerged and floating macrophytes in the northern part of the bay offer ideal conditions for the development of a rich weedbed fauna, the diversity being twice higher than of the zoobenthic community; the preferred substrate was *Potamogeton perfoliatus*, while *Typha angustifolia* was the least colonized (Radu *et al*., 2008).

Besides eutrophication, another important driver, emerged in the latest decades mainly as a consequence of the increasing amount of green house gases (GHG), is the global climate change, which is expected to exacerbate the loss and degradation of many wetlands, increasing the incidence of vector-borne and waterborne diseases (IPCC, 2008).

One of the main impacts is the increasing air and water temperature. How could this influence the aquatic biocenosis of the bay?

The linear correlation found between the chlorophyll *a* content and water temperature (Fig. 8) shows that an increasing temperature of the water will determine a growing development of the algae; the cyanobacteria, more thermophile, will be favored by the new environmental conditions, while diatoms, more cryophile (Wetzel, 2001), will record a regression. Unfortunately, not all the phytoplankton groups have the same nutritional value for the food web: while diatoms are a preferred food for primary consumers and phytophagous fish, many cyanobacteria release toxins in the environment and are avoided by the consumers, impacting negatively the trophic chain.

The increasing temperature will also have a negative impact on the dissolved oxygen content (the solubility decreasing with the temperature), lowering the self-purification capacity of water bodies and increasing the risk of oxygen depletion, especially at the water-sediment interface (Sandu *et al*., 2009); on long-term, a general shift towards species tolerant of high temperatures is expected (EEA, 2004).

Another major effect of the climate change is the increased occurrence of extreme hydrological events (droughts, floods), which might impact severely the local community by increasing the risk of waterborne diseases (due to the higher risk of microbiological contamination) (IPCC, 2008). Droughts have also a negative impact on the aquatic ecosystem – the increased evaporation rate due to the higher temperatures, together with the decreasing amount of precipitation, will reduce the water depth, increasing also the risk of pollution with substances that might be remobilized from the anoxic sediments.

Based on climate models predictions, on medium term (2020-2050), frequent droughts are expected in the southern part of Romania especially in summer (Bălteanu *et al*., 2009; Boroneanț *et al*., 2009), which will have a negative impact on the Danube Delta and Musura Bay, and consequently on the local community that relies on the ecosystem services provided by this area. As the siltation process is very active, if the actual trends will continue, in few decades the bay may turn into a terrestrial ecosystem.

The gradual decrease of water level and the increase of navigation, as a consequence of tourism development, will determine an increase of pollutants content, which will adversely impact both the biodiversity and human health as part of these pollutants can bioaccumulate along the food web. Also, the increase of water temperature will lead to cyanobacterial blooms; during these blooms, some species release toxins affecting water quality, cattle and human health.

Growing pressures from multiple direct drivers increase the likelihood of potentially abrupt changes in wetland ecosystems, which can be large in magnitude and difficult, expensive, or impossible to reverse (MEA, 2005). Therefore, in order to limit the anthropogenic impact, the management measures should prevent the further deterioration of the aquatic environment, taking into consideration the actual predictions and developing, *e.g.* further measures to support sustainable fisheries, improving water circulation between the bay and the inner part of the delta, limiting further hydromorphological changes, designing a sustainable tourism in the area which should consider both human and environmental needs.

CONCLUSIONS

The hydromorphological and climate changes occurred in the Danube catchment affected the ecological evolution of Musura Bay, leading to an accelerated shift towards a freshwater lagoon which impacted also the aquatic communities.

The impact of climate change at local level, consisting in increased frequency of floods and droughts and increasing water temperature, accelerates the changes in the bay: the active siltation due to the increased amounts of alluvia brought by the recent floods (2005-2006) leads to a marked decrease of water depth, while the water temperature increased especially in 2007, as a consequence of the drought. The linear correlation between the chlorophyll *a* and water temperature shows that further temperature increases will determine increasing algal biomass.

The nutrient content is relatively low as compared with the lakes of the Danube Delta, indicating a mesotrophic ecosystem, with phosphorus as potential limiting factor of the algal growth.

Without appropriate management measures, due to the active siltation this aquatic ecosystem may disappear in the following decades, with negative consequences on the local community which relies on its ecosystem services.

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