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6

The Wetlands Diversity

Editors

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IN MEMORIAM

Grigore Antipa

(1867 - 1944)

One of the greatest Romanian naturalists, *Grigore Antipa*, was born on the 7th of December 1867, in Moldavia, in Botoşani.

Broadly, his academic training was the result of education at Ion Mărgineanu Primary school between 1874 - 1878; Academic Institute of Iaşi (Secondary school and high school) between 1878 - 1885; Faculty of Sciences and Medicine, University of Iaşi - Natural Sciences Department 1885; University of Jena 1885.

Identified as a person with a high, intuitive and demonstrative intellectual potential, the famous morphologist, evolutionist and father of ecology, Ernst Hekael accepted to be his scientific adviser, and on the 9th of March 1891 *Grigore Antipa* became doctor in biology (PhD) with suma cum laude. His gifts were also recognized later, through his acceptance in the Romanian Academy (1910), and his nomination as Doctor honoris causa of the Faculty of Agronomy from Berlin.

His experience as a naturalist grew in his many expeditions along the Danube, in Helgoland Island (1890), Black Sea (1893) and in many fisheries from Northern Europe (1912), through which his understanding of nature, and how to manage it, flourished.

As a result of these achievements he held a lot of important public positions: General director of the State Fisheries (1893 - 1914), Administrator of the State Fisheries (1895), Director of the Zoological Collections, Museum of Natural History and Antiquities (1893 - 1908), Director of the National Museum of Natural History (1908 - 1944), Secretary of the Science Department of the Romanian Academy (1913 - 1939), Vice president of the Science Department of the Romanian Academy (1921 - 1923), President of the Science Department of the Romanian Academy (1938 - 1941).

Internationally his stature was frequently recognized by the members of Zoological Society of London, Oceanographic Institute of Paris, Geographical Society of Vienna, Geographical Society of Berlin, Agricultural Society of France, Agricultural Society of USA.

In addition to these achievements, his strong pioneering character is underlined by his significant original work: the first Romanian oceanographical research (1893); the first Romanian fishing law (1895); the first Romanian national museum of natural history which today is called with his name (1906); the first dioramas in the world (1906); the first sustainable development projects for the reconstruction of the wetlands of the Danube river (1893 - 1914); the first Romanian national cadastral survey of the lakes and wetlands (1893 - 1914); the first data base concerning the aquatic fauna of Romania (1893 - 1914); proposals for the international convention for Danube fishing regulations (1899); the first publication regarding the entire fish fauna of Romania ”Fauna Ihtiologică a României” (1909); the first publication regarding fishing in Romania ”Pescăria şi pescuitul în România” (1916), the first Romanian publication regarding the Black Sea ”Marea Neagră”, vol. 1. Oceanografia, bionomia şi biologia generală a Mării Negre” (1941); etc.

Beyond a long list of major achievements which prove him to have been a relentless scientist, economist and organiser, *Grigore Antipa* will forever be seen, from a national point of view, as the first major promoter of natural sciences, the first genuine ecologist and hydrobiologist, and more than that a living example of professional success and morality for all of us.

The hard times of the World War II, at time he passed through with success in scientific, organizational and patriotic activities, demonstrate the fact that special characters can also overcome bad historical periods, through their results which last way into the future ...

The Editors

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Preface

In a global environment in which the climate changes are observed from few decades no more only through scientific studies but also through day by day life experiences of average people which feel and understand allready the presence of the medium and long-term significant change in the "average weather" all over the world, the most comon key words which reflect the general concern are: heating, desertification, rationalisation and surviwing.

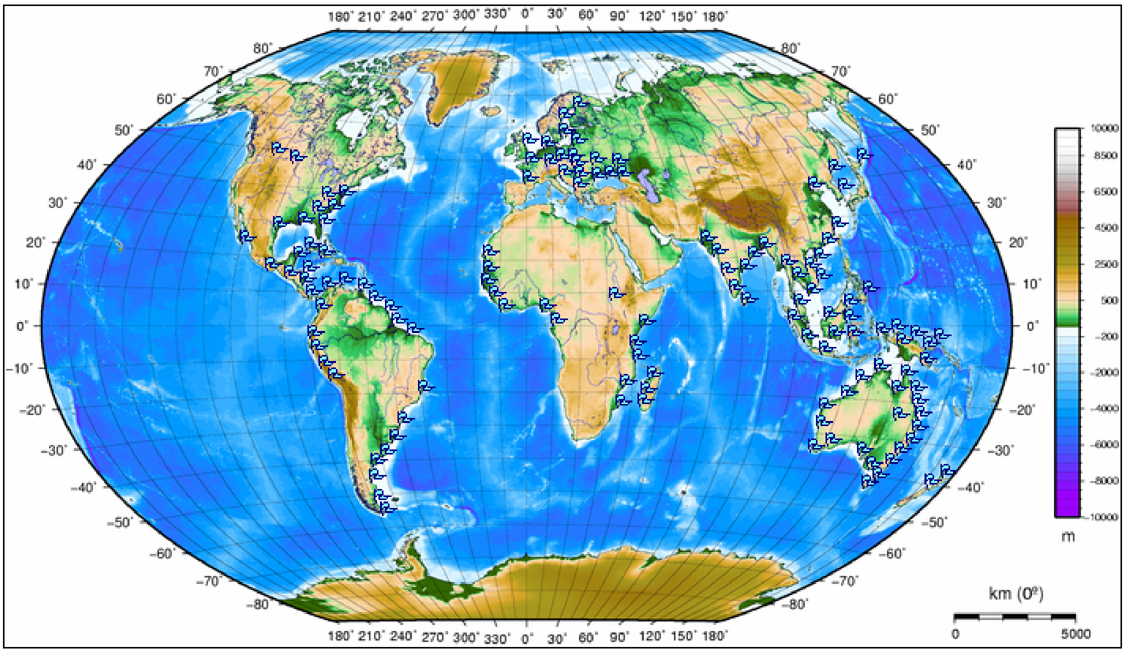
The causes, effects, trends and possibilities of human society to positively intervene to slow down this process or to adapt to it involve a huge variety of aproacess and efforts.

With the fact in mind that these aproaces and efforts shuld be based on genuine scientific understanding, the editors of the Transylvanian Review of Systematical and Ecological Research series launch a second annual volume dedicated to the wetlands, volume resulted mainly as a result of the Aquatic Biodiversity International Conference, Sibiu/Romania, 2007.

The therm wetland is used here in the acceptance of the Convention on Wetlands, signed in Ramsar, in 1971, for the conservation and wise use of wetlands and their resources. **Marine/Coastal Wetlands -** Permanent shallow marine waters in most cases less than six metres deep at low tide, includes sea bays and straits; Marine subtidal aquatic beds, includes kelp beds, sea-grass beds, tropical marine meadows; Coral reefs; Rocky marine shores, includes rocky offshore islands, sea cliffs; Sand, shingle or pebble shores, includes sand bars, spits and sandy islets, includes dune systems and humid dune slacks; Estuarine waters, permanent water of estuaries and estuarine systems of deltas; Intertidal mud, sand or salt flats; Intertidal marshes, includes salt marshes, salt meadows, saltings, raised salt marshes, includes tidal brackish and freshwater marshes; Intertidal forested wetlands, includes mangrove swamps, nipah swamps and tidal freshwater swamp forests; Coastal brackish/saline lagoons, brackish to saline lagoons with at least one relatively narrow connection to the sea; Coastal freshwater lagoons, includes freshwater delta lagoons; Karst and other subterranean hydrological systems, marine/coastal. **Inland Wetlands -** Permanent inland deltas; Permanent rivers/streams/creeks, includes waterfalls; Seasonal/intermittent/irregular rivers/streams/creeks; Permanent freshwater lakes (over eight ha), includes large oxbow lakes; Seasonal/intermittent freshwater lakes (over eight ha), includes floodplain lakes; Permanent saline/brackish/alkaline lakes; Seasonal/intermittent saline/brackish/alkaline lakes and flats; Permanent saline/brackish/alkaline marshes/pools; Seasonal/intermittent saline/brackish/alkaline marshes/pools; Permanent freshwater marshes/pools, ponds (below eight ha), marshes and swamps on inorganic soils, with emergent vegetation water-logged for at least most of the growing season; Seasonal/intermittent freshwater marshes/pools on inorganic soils, includes sloughs, potholes, seasonally flooded meadows, sedge marshes; Non-forested peatlands, includes shrub or open bogs, swamps, fens; Alpine wetlands, includes alpine meadows, temporary waters from snowmelt; Tundra wetlands, includes tundra pools, temporary waters from snowmelt; Shrub-dominated wetlands, shrub swamps, shrub-dominated freshwater marshes, shrub carr, alder thicket on inorganic soils; Freshwater, tree-dominated wetlands; includes freshwater swamp forests, seasonally flooded forests, wooded swamps on inorganic soils; Forested peatlands; peatswamp forests; Freshwater springs, oases; Geothermal wetlands; Karst and other subterranean hydrological systems, inland. **Human-made wetlands -** Aquaculture (e. g., fish/shrimp) ponds; Ponds; includes farm ponds, stock ponds, small tanks; (generally below eight ha); Irrigated land, includes irrigation channels and rice fields; Seasonally flooded agricultural land (including intensively managed or grazed wet meadow or pasture); Salt exploitation sites, salt pans, salines, etc.; Water storage areas, reservoirs/barrages/dams/impoundments (generally over eight ha); Excavations; gravel/brick/clay pits; borrow pits, mining pools; Wastewater treatment areas, sewage farms, settling ponds, oxidation basins, etc.; Canals and drainage channels, ditches; Karst and other subterranean hydrological systems, human-made.

The Editors of the ***Transylvanian Review of Systematical and Ecological Research*** start this new annual sub-series (***Wetlands Diversity***) as an international scientific debate platform for the wetlands conservation, and not to take in the last moment, some last heavenly "images" of a perishing world …

This first volume of this new sub-series (Wetlands Divesity) include researches from diverse wetlands around the world.



The subject areas (⚑) for the published studies in this volume.

No doubt that this new data will develop knowledge and understanding of the ecological status of the wetlands and will continue to evolve.

Acknowledgements

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

The Editors

THE EXPLANATION OF WORLDWIDE SPREAD OF ACID SULPHATE SOILS

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KEYWORDS: wetlands, acid sulphate soils, genesis, behaviour, world distribution, landscapes, environmental risks.

ABSTRACT

Sulphate acid soils (SSA) are very acidic soils formed as a result of the oxidation of pyrite (FeS_2) and the formation of sulphuric acid, (H_2SO_4) and are characterized by a low pH of 3.5 (1:1 in water). They appear when pyrite-rich marine sediments are drained or when pyrite-rich rocks are exposed to the air. The sulphate acid soils are categorised as being potential sulphate acid soils (SPSA) or sulphate acid soils (SSA).

SPSA appear in brackish and salt environments (swamps with common reeds, mangroves; figure 1 ecological scheme). In the upper sediment layers, with the help of organic vegetative matter, the sulphate (SO_4^{2-}) is reduced to sulphite (S^{2-}) (Sulphitisation) and combines with iron hydroxide ($Fe(OH)_3$) from the mineral layers. Soils rich in pyrite can be formed in this way through slow sedimentation or rising sea levels.

Sulphuric acid is formed through the oxidation of pyrite and yellow spots of jarosit ($KFe_3(SO_4)_2(OH)_6$) appear. These are characteristics of sulphate acids soils, whose acidity is fatal for plants and animas, even in flowing water. This acidity can, however, be neutralised if sufficient calcium carbonate is present at the same time as the pyrite.

A post-sulphitisation phase can be distinguished from pre-sulphitisation and active sulphitisation. During post-sulphitisation the formation of sulphuric acid determines the breakdown of alumino-silicates, thereby influencing long-term pedogenetic processes.

Ten ecotops have been identified in which the SPSA and SSA appear in conjunction with different environment factors, for example climate (tropical or temperate), vegetation, geological era, sedimentation and human influence.

Most of the SPSA and SSA appear in the deltas, estuaries and coastal zones of tropical regions. In the deltas and coastal zones, where sedimentation occurs quickly, the pyrite is diluted and often mixed with calcium carbonate which neutralises the acidity.

ZUSAMMENFASSUNG: Erläuterung des weltweiten Vorkommens von sulfatsauren Böden.

Sulfatsaure Böden, SSB (ASS), sind sehr saure Böden und bilden sich durch die Oxydation von Pyrit (FeS_2) und durch die Bildung von Schwefelsäure (H_2SO_4). Sie entstehen durch das Trockenlegen oder durch Luftkontakt maritimer pyrithaltiger Sedimente. Man unterscheidet zwischen potentiellen Sulfatsauren Böden, als PSSB bezeichnet und Sulfatsauren Böden, SSB. Die Entstehung der PSSB's (Sulfidisation) findet in brackiger und salziger Umgebung statt (Rohrmarschen, Mangroven, usw.; figur 1 Ökologisches Schema). In den oberen Sedimentschichten wird mit Hilfe der organischen Substanz der Vegetation Sulfat zu

Sulfit reduziert (Sulphitisation), welches sich mit dem Eisenhydroxid der Mineralschichten bindet. Unter gewissen Umständen (langsame Sedimentationsgeschwindigkeit, steigender Meeresspiegel, usw.), können sich so Sedimentböden mit grossen Mengen Pyrit bilden.

Bei der Oxydation des Pyrites (Sulfuricisation) werden Sulfatsäuren und hochsaures gelbfarbiges Jarosit ($KFe_3(SO_4)_2(OH)_6$) gebildet. Dies ist charakteristisch für Sulfatsaure Böden, deren Säuregrad eine ernste Bedrohung für Pflanzen und Tiere darstellt, selbst in fliessendem Wasser. Wenn aber gleichzeitig mit dem Pyrit genügend Calciumcarbonat vorkommt, können die Säuren neutralisiert werden.

Neben Pre-sulfuricisation (oder Sulfidisation) und aktiver Sulfuricisation unterscheidet man noch die Post-Sulfuricisation, wobei die bodengenetischen Prozesse über lange Zeit durch ehemalige Schwefelsäurebildung und damit einher gehender Zerstörung von Aluminium-Silikatmineralen beeinflusst werden.

Es wurden 10 physiografische Ökotope und Umweltgebiete in Verbindung mit dem Grossklima, der Vegtation, der Ablagerungsgeschichte und menschlichem Eingriff ausgewiesen, in welchen SSB, PSSB und Post-SSB vorkommen. Diese Gebietstypen sind auf Kontinentkarten zur Darstellung des weltweiten Vorkommens abgebildet. Die meisten der PSSB und SSB kommen in tropischen Deltas, Ästuaren und Küstenregionen tropischer Gebiete vor. Doch in Deltas und entlang Küsten mit grosser Ablagerungsgeschwindigkeit wird das Pyrit stark verdünnt und meist mit Calciumcarbonat gemischt, wobei eventuell gebildete Säuren neutralisiert werden.

REZUMAT: Explicația răspândirii globale a solurilor sulfatat acide.

Solurile sulfatat acide (SSA) sunt soluri foarte acide, formate ca urmare a oxidării piritei (FeS_2) şi formării acidului sulfuric (H_2SO_4) şi sunt caracterizate printr-un pH inferior valorii de 3,5 (1:1 în apă). Ele apar ca urmare a drenării sedimentelor marine reduse, nematurate, bogate în pirită sau a expunerii la zi a unor sedimente vechi (roci) cu conținut ridicat în pirită. Solurile sulfatat acide se împart în: soluri potențial sulfatat acide (SPSA) şi soluri sulfatat acide (SSA).

Cele dintâi apar în medii sălcii sau sărate (mlaştini cu stuf, mangrove). În stratele superficiale ale sedimentelor, sulfatul (SO_4^{2-}) este redus până la sulfit (S^{2-}) (sulfitizare) cu ajutorul materiei organice din vegetație şi se uneşte cu hidroxidul de fier ($Fe(OH)_3$) din sedimentele minerale. Prin sedimentare lentă sau creşterea nivelului mării se pot forma astfel, sedimente-sol bogate în pirită.

Prin oxidarea piritei (sulfurizare) se formează acidul sulfuric şi apar petele galbene de jarosit ($KFe_3(SO_4)_2(OH)_6$) caracteristice solurilor sulfatat acide a căror aciditate este fatală, atât pentru plante, cât şi pentru animale, chiar şi prin apa de drenaj. Dacă, însă, în acelaşi timp cu pirita apare destul carbonat de calciu, aciditatea este neutralizată.

În afară de pre-sulfurizare (sulfitizare) şi sulfurizare activă, se distinge şi o post-sulfurizare, în care procesele pedogenetice sunt influențate pe lungă durată de vechea formare de acid sulfuric, care determină distrugerea minerarelor alumino-silicate.

Au fost distinşi zece ecotopi fiziografici şi medii în care solurile potențial sulfatat acide şi solurile sulfatat acide apar legate de diferiți factori de mediu, ca de exemplu climat (tropical sau temperat), vegetație, ere geologice, sedimentație şi influența omului.

În deltele, estuarele şi regiunile costiere din regiunile tropicale, apar cele mai multe soluri potențial sulfatat acide şi sulfatat acide. În deltele şi regiunile costiere cu sedimentare rapidă, pirita este diluată şi de cele mai multe ori amestecată cu carbonat de calciu, care neutralizează formarea acidității.

INTRODUCTION

Acid Sulphate Soils (ASS's) are very acid soils in which the acidity is based on sulphuric acid, an oxidation product of Sulphur (Van Breemen, 1973; Dent, 1986). ASS's develop at drainage of sulphide- (mostly pyrite-) containing sediments. The sediments vary from young and unconsolidated to old consolidated sediments, and from soft to hard sedimentary rocks. Pyrite contents may vary also largely, but when the sediments or rocks contain not enough neutralising material to counterbalance the acids produced by the pyrite, very acid ASS's are formed. The soils are unfavourable or even poisonous for plant growth, unsuitable for agricultural purposes and their drainage water cause loss of biological functions and habitats, killing nearly all life.

Reduced and non-oxidized pyritic materials without enough neutralizing materials are called Potential Acid Sulphate Soils (PASS's) (Brinkman and Pons, 1973). They generally are situated below ground water table and, either may occur as subsoils below the developed horizons of the ASS's, or lay below all kinds of waterlogged wetland soil materials, such as peat and various non-pyritic alluvial sediments (NAAS). Pyritic sedimentary rocks are occurring at greater depths, accompanying layers of coal, lignite, pyrite and other mine materials (Fanning and Fanning, 1989; Carson, et al., 1982).

The world distribution of ASS's and the related PASS parent materials are indicated on the Soil map of the World (FAO - Unesco, 1974). The map shows the main occurrences along coasts, in estuaries and in delta's. More detailed soil maps together with numerous publications and the publicised results of the International Symposia on Acid Sulphate Soils (Dost and Van Breemen, 1982 - Bangkok; Bush, 1993 - Coolangatta) are giving additional data about their genesis and behaviour, their distribution and the hazards in agriculture, and the risks for the environments. The exact distribution of PASS's, however, is much lesser known, because of their 'hidden' occurrences. They are disclosed in mine galleries and mine waste as well as outcropping rocks, which, when exposed tot the air, develop ASS's.

In some tropical areas, very old ASS's are described. (Veen, 1970 - Suriname; Marius 1982 - Sénégal; Sadio, 1989 - Sénégal; Carson at all., 1982 - Canada/USA; Fitzpatric at all., 1993 - Australia). They are considerable deep soils, which can be recognized by their deep-laying (> 4 m), non-oxidized PASS parent materials (Brinkman and Pons, 1968). When these parent materials are lacking, their identification as ASS's becomes difficult. The weathering processes under influence of the extreme sulphuric-acid conditions, especially the hydrolysis of silicates promoting an increase of Al+++ activity, produce soils, which strongly resemble old, weathered, tropical soils. Carson at al., (1982) believe that some tropical soils, deep-weathered profiles (eg. silcretes) and rotten rocks in inland areas were long ago derived from ASS's.

The distribution of Acid Sulphate Soils along the continental coasts on earth is very irregular in every aspect. On some continents, e.g. Europe, only few ASS's are present, whereas in others, e. g. Australia, they are very common. Also its distribution along the coasts, in the coastal plains, estuaries and deltas is varying. Within areas of ASS's, they may alternate with all kinds of non-acid alluvial soils on every possible scale.

The aim of the present study is to give an idea of the variety in geomorphological sedimentary landscapes in which PASS's may occur, the conditions in each of these landscapes, and their properties, which are responsible for the accumulation of the potential acidity. As well the study will consider where these characteristics once were, and are present or lacking along the continental coasts.

THE PROCESSES OF FORMING AND ACCUMULATION OF PYRITES (SULFIDIZATION)

With the knowledge of the conditions under which pyrite is formed and accumulated, the occurrences of PASS's on a certain locality may be understood. The chemical process of the formation of pyrite (*sulfidization*, Carson at al., 1982) is given by the overall equation:

$$Fe_2O_3(s) + 4\ SO_4^{2-}\ (aq) + 8HCl + \tfrac{1}{2}O_2 \rightarrow 2\ FeS_2(s) + 8HCO_3\ (aq) + 4H_2O$$

sediment sea water organic partial pyrite alkaline
matter oxidation (pot. Acidity)

It may be concluded that pyrite is formed in 1, a water-logged, practically oxygen-free environments with 2, easy weatherable Fe-oxides (present in Fe-containing sediments) and 3, at presence or continual addition of easy decomposable organic matter, when 4, constantly S is added to the system in the form of SO_4^{2-} - ions of brackish or saline sea water and 5, sulphate-reducing bacteria (*Desulfovibrio desulfuricans*) are present.

In the figure 1 (Pons at all., 1982; Pons, 1989), the sites in which pyrites are accumulated are sketched. They are reduced profile horizons of soils in areas with certain telmatophytic wetland vegetations (mangroves, reed and rush marshes, herbaceous vegetations, etc.) in tidal regions. Mean High (MHW) and Mean Low Water tables (MLW) show sub-tidal, inter-tidal and super-tidal zones (Pons, 1989), which induce the profile horizons position of maximal pyrite accumulation. Only where sulphates are circulating, in saline and brackish areas in the tropics, and in brackish ones in the temperate climate zone, where respectively mangroves and vegetation communities of reed and rushes are growing, pyrite formation on a considerably scale is possible. The organic matter for the sulphidization is mainly derived from their roots.

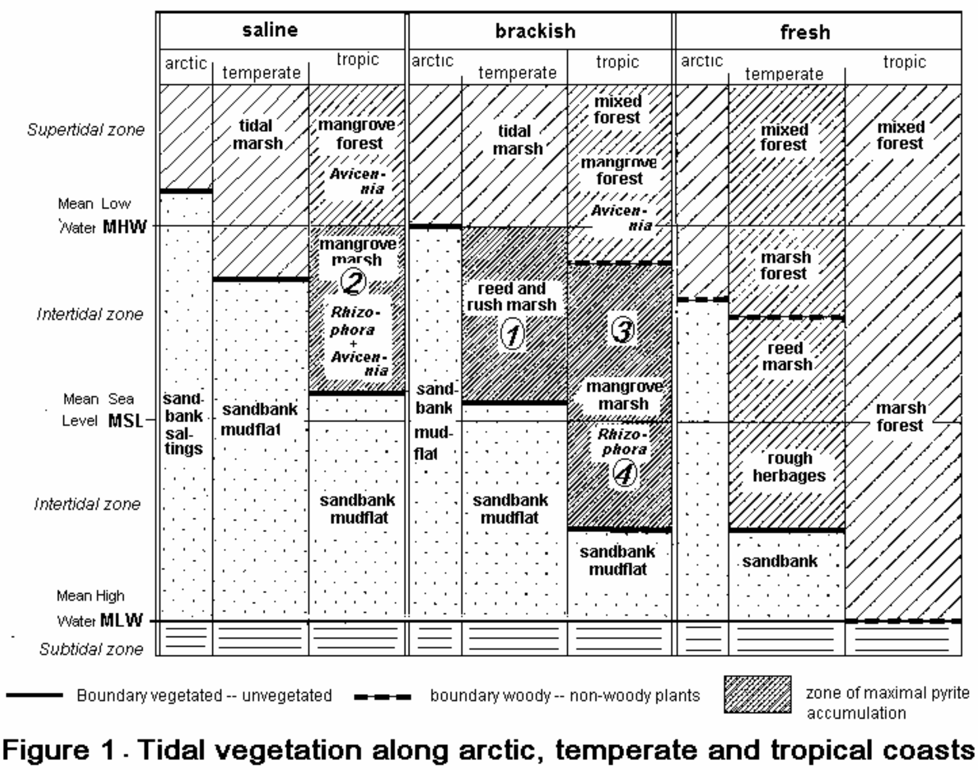

Figure 1 . Tidal vegetation along arctic, temperate and tropical coasts

The pyrite accumulation is a rather slow process, in the order of 10 kg per cubic meter in 100 years (Dent, 1986), or about 1% dry mass per 100 years. This is comparably with bulk densities of PASS's in Australia, where Melville, based on a lot of measurements, reasonable bulk densities of PSS's of 0.7 to 0.8 t/m^3 found (Melville, personal communication). This restricts the origin of dangerous PASS's to areas of slow sediment accretion; otherwise the pyrites will be too much diluted.

Other bodies of PASS's are formed on bottoms of slowly accreting, saline to brackish seas and lagoons. The formation of pyrite in these oxygen-poor deposits is promoted by simultaneous sedimentation of mineral and organic particles, both derived from the debouching rivers. The present Black Sea forms a typical example of such a sea bottom PASS body. In Australia the origin of under-water PASS sediment bodies in estuaries is much discussed (Melville at al. 1993). Now it seems reasonable that the main source of the Holocene in filling of the estuary embayment was from sediment stored on the continental shelf, probably mainly deposited there during the last interglacial (Melville, personal communication).

Changes in sea level, and the degree of tidal movement, as well as land surface movements play an important role in the extend of PASS's, horizontally as well as vertically and especially in respect to depth. A rise of sea level, causing prolonged, constantly favourable conditions on one place, results in deep PASS's with large pyrite contents. A very probable sea level fall after about 6000 yBC as well as isostatic or other uplifts, caused drainage and development of ASS. Recent subsidence as in southeastern USA and around the southern North Sea may cause new formation of PASS or burying PASS and ASS.

The presence or forming of $CaCO_3$ in the sediment during the formation of PASS's (sulfidization*)* does not restrict pyrite formation and high pyrite contents. Certain conditions in marine and brackish shallow-water environments cause a low $CaCO_3$ content of deposits, especially of the clayey ones and in the tropics. A restriction for the creation of ASS's (sulfuricization) is a large amount of neutralising matter in the pyrite containing sediments, especially of $CaCO_3$**,** and in a lesser way also of absorbed cations on the clay complex. In the long run amounts of Iron-Manganese Aluminium silicate minerals may also neutralize acids, but only to pH's 4 - 5. When $CaCO_3$ exceeds the pyrites three times in weight and is sufficiently distributed, no acidity will develop and upon oxidation gypsum and other reaction products are formed. When no ASS's will form, the sediment will not be considered as PASS's and is called Non-Acid Alluvial Soil material (NAAS).

The occurrence of PASS's is illustrated by the presence of ASS's. Upon oxidation, pyrite forms acids and the PASS's are transformed into ASS's, if the acids are not neutralised by $CaCO_3$ or other neutralising minerals. The process is called sulfuricization (Carson at al., 1982) and includes also weathering of minerals by the sulphuric acid produced, as well as the formation of new mineral phases from the dissolution products. The chemical equation for the pyrite oxidation is:

$$FeS_2 + 3\tfrac{3}{4}H_2O + \tfrac{1}{3}K+ \rightarrow \tfrac{1}{3}KFe_3(SO_4)_2(OH)_6 + 1\tfrac{1}{3}SO_4^{++} + 3H^+$$

(yellow jarosite)

The pH reaches very low values and in most cases straw-yellow coloured jarosite is formed. In such environments breakdown of clay- and other Aluminium silicate minerals is common.

Carson at al. (1982) divides the process of sulfuricization into three sub processes: A. Pre-sulfuricization, B. Active sulfuricization and C. Post-sulfuricization. Phase A, Pre-sulfuricization includes all processes of origin of PASS's. Phase B, Active sulfuricization describes the oxidation processes, leading to ASS's and the third phase, the Post-sulfuricization, deals with the soil formation following the leaching of sulphuric acids and the neutralisation of the extreme acidity by Aluminium silicates to pH levels of 4 to 5.

We will treat the occurrences of PASS's on three different levels: a. on the largest level or on a continental scale; b. on the middle level or on the scale of the sediment bodies (coastal plains, delta's, estuaries, lagoon bottoms, pyrite containing sedimentary rocks, etc.) and; c. in some cases on the lowest level of the regional soil patterns (Pons at al., 1982) of the sediment bodies (back swamps, filled-up channels, depths of the dangerous pyrite horizons below surface, micro pyrite distribution, etc.).

Based on the processes of pyrite forming and accumulation, on the conditions of origin of PASS's and ASS's, and on the process of Post-sulfuridicization, a limited series of the overall physiographic areas of PASS's and ASS's forming are distinguished:

1. Areas of shallow PASS's, eventually with ASS's, in coastal plains, estuaries and deltas, developed in brackish reed and rush marshes in the temperate zone;
2. Areas developed in saline and brackish mangroves, in the tropics;
3. Areas with deeply to very deeply developed PASS's, eventually with ASS's, formed in equilibrium with a rising sea level, mostly tropical;
4. Areas of 1, 2 and 3 on slightly lifted, Middle Holocene coastal terraces, with well developed ASS's, rather deep and red-mottled;
5. Deeply to very deeply developed PASS's on Middle Pleistocene coastal terraces with very old, deep, red-mottled and strongly weathered ASS's;
6. Very old, strongly weathered inland soils with traces of Post-sulfuridicization;
7. Areas 1, 2, 3 and 4 of PASS's, partly covered by recent non-acid sediments, and partly or completely eroded and replaced by rapidly developing deposits with diluted pyrite of coastal plains, estuaries and deltas;
8. Sea, estuary and lagoon bottoms with underwater PASS's bodies, sometimes with ASS's and eventually with a cover of shallow, non-acid NAAS sediments;
9. ASS's on outcropping PASS rocks;
10. Human induced ASS's on PASS of mine wastes, dredged or excavated materi-als, etc;

The numbers 1 to 10 on the maps of the figures 2, 4, 5, 6 and 7 are referring to these physiographic regions.

OCCURRENCES OF PASS's IN TEMPERATE CLIMATES

The occurrences of PASS's on a continental scale is related to the broad climatic zones of the earth, as well as with the recent Earth history, the Young Pleistocene period with its glaciations and loess deposits and the Holocene with its post-glacial sea level movements. Also the impact of men had and has influence on the ASS occurrences. In Europe, North America (Fig. 2) and Asia (Fig. 6), glaciers advanced far to the south, leaving behind thick, mostly calcareous, fresh deposits after they retreated. Calcareous loess in all three continents is bordering the moraines to the south and covered extensive older land surfaces with fresh, calcareous material. The large rivers (Danube, Rhine, Rhone, Po, Mississippi, Colorado, Rio Grande, Hoangho, Jang Tse Kiang, etc.), transported large amounts of these sediments to their deltas (7). Probably PASS's were formed in these deltas, but mostly the pyrites were diluted. When eventually PASS's oxidised, the acids were counterbalanced. Only locally, on places were, in small catchments, no $CaCO_3$ was available, so non-calcareous PASS bodies could develop with insufficient neutralizing materials, e. g. in East Anglia (Dent, 1986), in northwest Germany, in Denmark, in south-western France and north-western Spain (1).

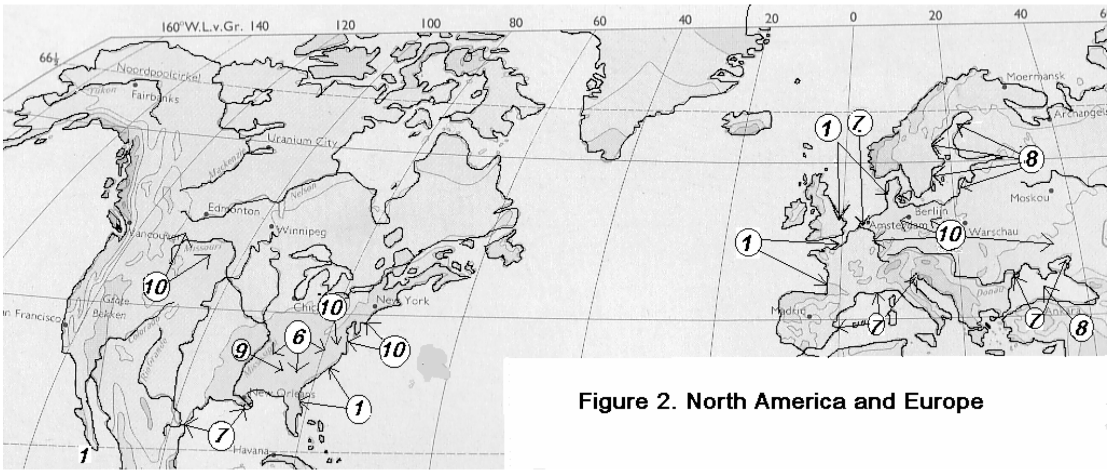

Figure 2. North America and Europe

In the Netherlands limited areas of PASS's are present in Middle Holocene clay deposits in the old estuary of the Rhine and Meuse. The clay, rich in reed and rush root remnants (Fig. 1, zone 1), is now situated on a depth of 4 - 6 m below sea level as a result of post-glacial land subsidence. Since > 4000 years ago, they were overgrown by peat, which is now locally removed, partly by storm wave erosion and partly by peat digging for fuel, giving way to lakes. ASS's developed when the lakes were pumped dry and the older clay deposits on the bottom were drained for agricultural purposes. The first serious investigations on such ASS's were carried out in relation to the problems of the reclamation of the Haarlemmermeer, in which Schiphol is now situated, by Van Bemmelen (1866). Later, Zuur (1936) discovered PASS's on the bottom of one of the Jsselmeer polders, preceding the drainage, during the underwater survey. Spreading calcareous mud by under load vessels over the PASS's solved the problem, before the pumping dry.

Edelman (1950) published a detailed soil map of a part of the Eendrachtspolder near Rotterdam (Fig. 3). The bottom of this polder is also composed of the old Middle Holocene clay deposits. He explained the presence of ASS's (katteklei) from PASS's with pyrites, formed in low $CaCO_3$ containing clay sediments in brackish reed and rush marshes. In the figure 1 the ecological site is indicated as area α, in the pyrite accumulation zone of temperate climates.

Especially in Europe and China with their long agricultural tradition, long-time erosion of cultivated soils increased the sedimentation rate of the large rivers and accelerated the build-up of deltas and costal plains. Non-acid deposits (NAAS) now cover many PASS's. In China (Fig. 6), whereas the rivers Jang Tse Kiang and Hoangho developed PASS's in their deltas during Old Holocene Times, they are now completely eroded away or covered by the massive young and calcareous deposits. This also happened to a lesser degree in North America after the cultivation of the central plains, resulting in an accelerated erosion in the catchments, as e.g. in that of the Mississippi/Missouri, and to the fast growing Mississippi delta which now has covered all older delta deposits (7).

In the Mediterranean and Black Sea without tides, PASS's are lacking because there is only week flushing of the salt marshes with saline or brackish water along their coasts (one of the requirements of a strong pyrite accumulation) is too week. Moreover, in the deltas and coastal plains of the rivers Rhone, Po and Danube, all PASS's are now covered with extensive, human induced, young and calcareous sediments (7).

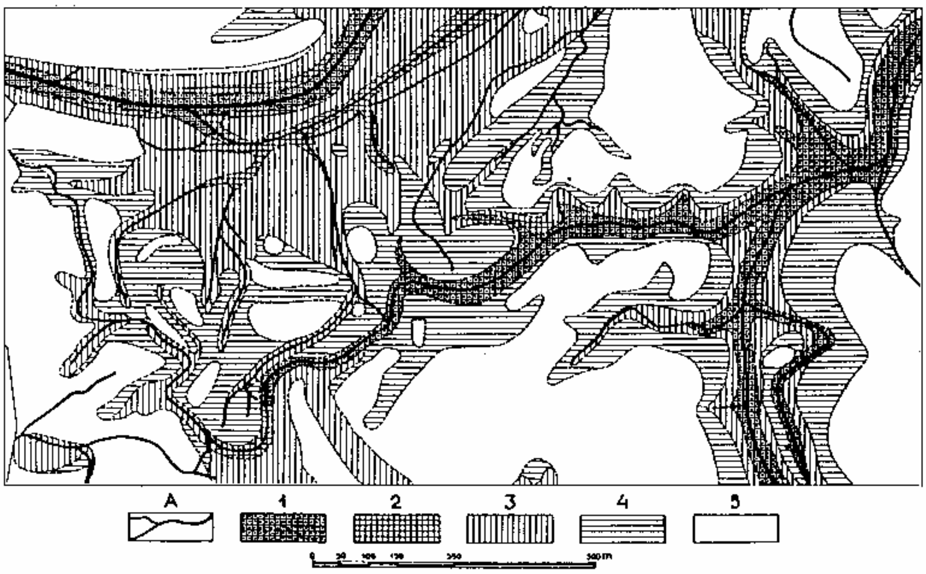

Figure 3 Simplified soil map of a part of the Eendrachtspolder near Rotterdam. After Edelman and unpublished survey of Scheepers. A) creek bed 1) calcareous sandy clay 2) calcareous clay 3) non-calcareous clay on a calcareous clay 4) deep non-calcareous clay 5) "katteklei"

Europe's main occurrences of PASS's are situated in the East Sea and the Bothnic Gulf (8). Here, as a result of the complicated combined history of sea level rise and post-glacial uplift, about 4000 years ago, a brackish sea (*Littorina* Sea) developed, on the bottom of which an extensive PASS body formed. The debouching rivers provided mineral as well as organic materials. At the continuing post-glacial uplift, peats overgrew the gradually outcropping PASS's. Other PASS's came directly to the surface and were oxidized to ASS's. On some places, younger, NAAS river deposits have partly covered these PASS's in thinner and thicker layers (8).

In temperate Asia, along the coasts of Hokkaido (Japan), northeast China and North Korea, some ASS's (1) are present in small valleys, originating from brackish vegetations, comparable to reed and rushes in Europe, etc.

With mining of lignite in Europe and lignite and coal in North America in open-cut mines, large amounts of coal and lignite-related layers and waste rocks with large pyrite contents are exposed to the air, giving very poisonous ASS's (10). Especially in the eastern part of Germany (around Leipzig), piles of PASS have caused large acidification problems. Also in western Germany (left bank of the Rhine), in Denmark, in the Don basin in Ukraine, and in Montana and North Dakota and the Appalachians in the USA with their open lignite and coalmines, pyritic materials are giving large problems (10). Only with carefully planning and knowledge of the problems of PASS's and ASS's, will they be overcome.

Along the east coast of North America, waterways are dredged in recent times for deepening shipping canals. The sulphide-bearing, dredged materials, deposited in diked-up basins, developed ASS's upon oxidation (Fanning and Fanning, 1989). Obviously, in these estuaries extensive bottom PASS bodies are present, comparable to the *Littorina* sea deposits. They also described some outcropping, pyrite-bearing rocks forming ASS's (9).

Fanning and Fanning, (1989), in their chapter on sulphidization and sulfuricization indicated the possibility of these processes in the genesis of a number of soils, in the USA is more generally, e.g. clay pan development and the formation of certain saline-alkaline soils could have been influenced by post-sulfuricization (6).

OCCURRENCES OF PASS's AND ASS's IN THE TROPICS

Between 30° North and 30° South Latitude, along the tropical coasts, mangroves are occupying the tidal marshes. Under brackish conditions, as in the figure 1 shows, mangroves not only grow in the upper part of the inter-tidal zone (zone **γ**), as reed and rushes do in the temperate climatic zone (zone 1), but can settle also in the lower parts of this zone (Fig. 1, zone 4). Moreover, also in the upper part of the intertidal zone, mangroves can grow under saline conditions (zone 2). In the highly reduced layers of all these horizons (2, 3 and 4**),** large quantities of organic matter of mangrove roots are accumulating. They form the basis of a strong pyrite composition. This is the main reason that the greater part of the PASS's is concentrated in tropical deltas, estuaries and coastal plains. Secondary reasons is the presence of dense tropical forests in the catchments, preventing soil erosion and causing 'clean' rivers and slow sedimentation rates in deltas, etc. An other important factor is that the old and strongly leached soils of the catchments do not contribute sediments with high neutralizing capacities. Modern, intensive agriculture in most parts of the tropics is only young, which means that erosion of the catchments has accelerated only recently and that only some of the ASS's have been covered by fresh deposits, and only with shallow layers.

Along important parts of both coasts of Middle America and some Caribbean islands (Fig. 4), narrow bands of mangroves occur (2). In parts of them, PASS's are present, in other parts enough base-rich Aluminium silicates from volcanic origin are able to neutralize sulphuric acids. The south-eastern coast of South America, south of Natal up to Buenos Aires (2), has also small estuaries with narrower to broader mangrove bands with PASS's, due to slow sedimentation rates.

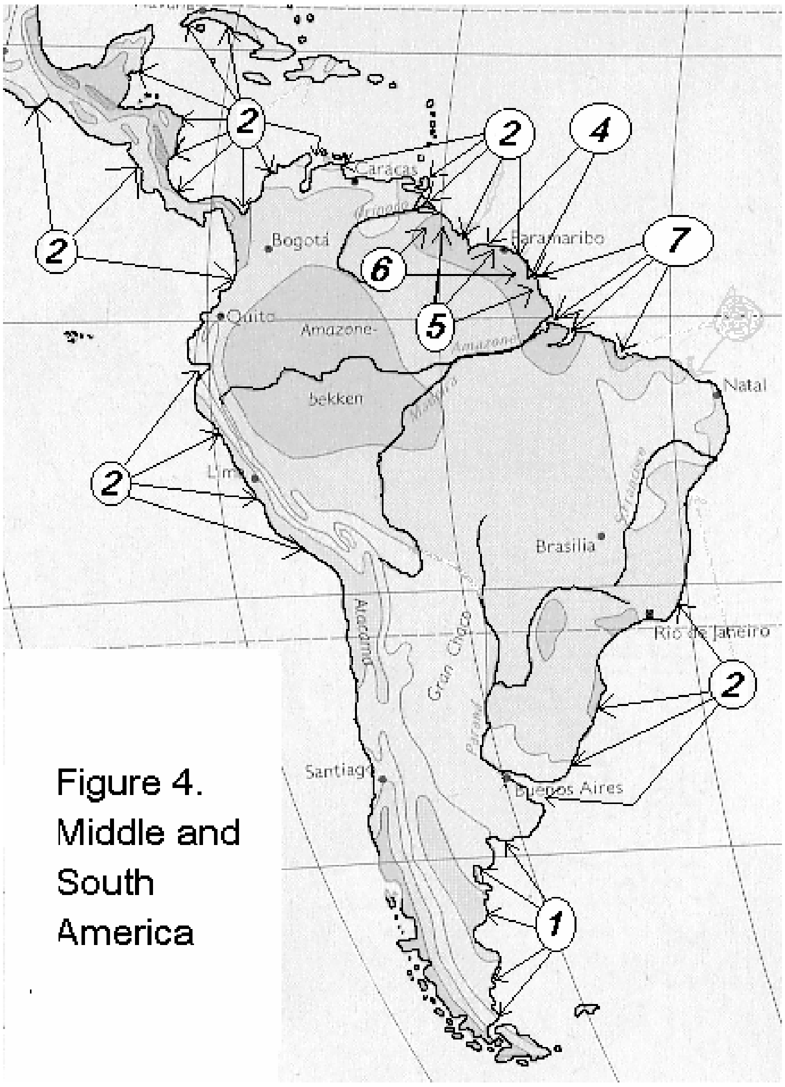

Figure 4. Middle and South America

In the estuary complex of the Amazone-Xingu-Tocantins rivers, especially the branches of the proper Amazone itself, the Purús and the Madeira rivers, draining the Andes Mountains, transport much fresh silt. PASS's are lacking (7) as a result of dilution of the formed pyrites and by neutralization of eventually formed ASS's by certain fresh minerals from the Andes. Rivers, sediment-free, draining parts of the tropical inland forests, as the Rio Negro and the Tapajós, are not able to change this pattern into a low-sedimentation rate. Moreover, the constant, tremendous water transport of the Amazone prevents saline and brackish water to enter the river mouth.

The South Equatorial Ocean Current in northwestern direction along the Guyana coast transports a big part of the Amazone sediments. Although dense mangrove vegetations produce pyrites, the sedimentation is fast enough to prevent bad concentrations of pyrites in the clays by dilution (7) (Augustinus, 1978). Behind this band of NAAS, an old, dissected Middle Pleistocene marine terrace occurs (Veen 1970). In its narrow valleys, peaty PASS's (2) are present, which are drained and not yet developed into ASS's (Brinkman and Pons 1968).

The old coastal terrace of Middle Pleistocene age, situated between the NAAS's (7) and the PASS's filled valleys (2), at a level of about 3 - 4 m above mean sea level, consists of deep PASS's (5). During the last glaciations (Würm), the terrace dissected and very deep (> 4 m) ASS's (5) developed, with heavily weathered and red mottled soils. They are not easy recognizable from other red mottled topical soils. Probably also in older Pleistocene Times, comparable situations have existed and in the inland coastal zone, some strongly weathered, red mottled soils exist, perhaps also from ASS's origin (6) (Veen, 1970). Along other stabile parts of the east coast of South America comparable situations may occur.

Deltas along the north-eastern coast of South America, the greater Orinoco (Dost and Pons, 1971) and San Fransisco deltas and several smaller ones, all contain PASS's (2), as a result of their former low sedimentation rates and extensive mangrove vegetation. Along the Argentinean east coast, south of the mangroves, in small estuaries and deltas PASS's are present, formed in brackish reed and rush vegetations (1).

Africa (Fig. 5) is mainly situated in the tropical climatic zone, with exception of the Mediterranean and the Cape. In the first area, no ASS's have been formed because of lack of tides (Fig. 1). Along the Atlantic coast to some distance north of Dakar, along the Red Sea coast and in South Africa, mangroves are lacking and no ASS's are probably present.

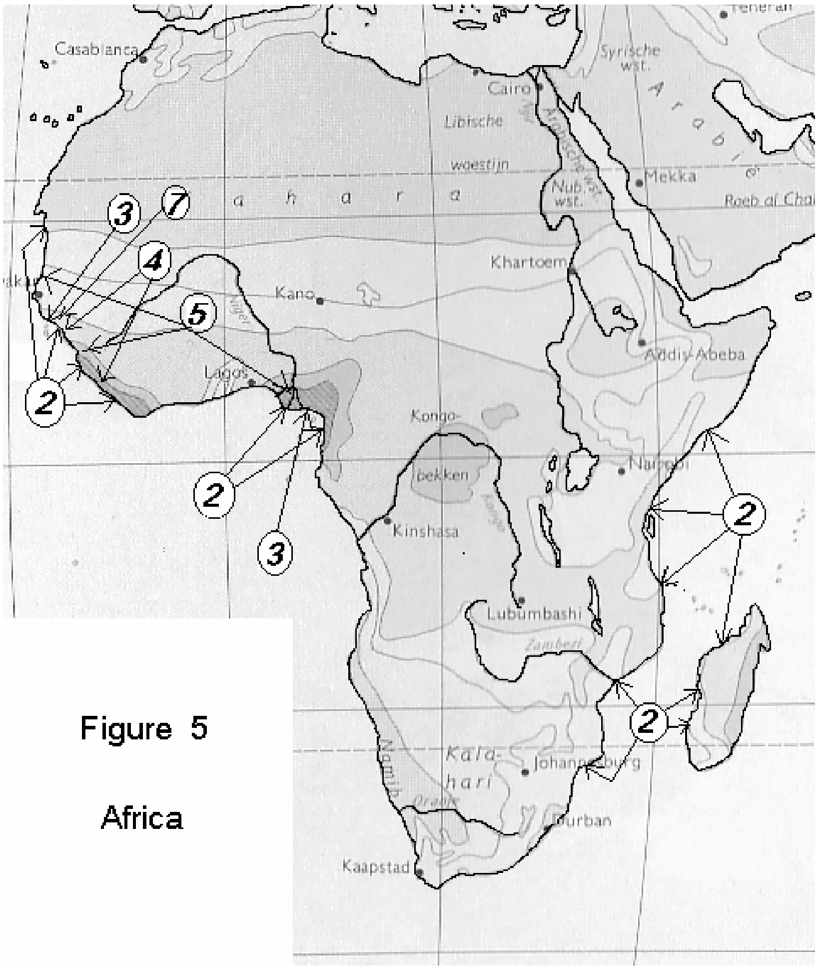

Figure 5

Africa

Along the western coasts, between the northern and southern desert zones and also along the east coast, extensive surfaces of PASS's and ASS's occur, especially in the large deltas, e. g. of the Niger (2) in well-understood patterns with estuary levees and back swamps. Numerous small deltas and estuaries in Sénégal (Marius, 1982), Gambia (Dent, 1986), Guinée Bissau (Pons-Ghițulescu, 1986), Sierra Leone (Hart et al., 1963) and Nigeria (Euroconult, 1971) are known to contain large surfaces of very acid ASS's (2). In Liberia, Cameroon, Gabon and Congo-Brazzaville we suppose the same. Also along the east coast of Africa, in Kenya, Tanzania and Mozambique, and on the west coast of Madagascar, ASS's (2) in small estuaries and coastal plains are common. In Guinée, was mapped a broad estuarine coastal plain, nearly totally covered with ASS's. Recently Guinée soil scientists informed me that nearly all these ASS's are now covered by 0,5 to 1,00 m thick modern deposits of NAAS sediments (7), eroded after the de-forestation in the hinterland.

The west coast seems to be stable and on many places, e.g. in Sénégal, Guinée-Bissau and Guinée, remnants of the Middle Holocene marine terrace are present. Remarkably are the deep, highly pyritic PASS's, in the whole area (Dent, 1968; Dent and Pons, 1995) and the deep, heavy leached and red-mottled ASS's (4) in Guinée-Bissau (Pons-Ghițulescu, 1986) and Sénégal (Marius, 1982; Sadio, 1989).

In all these countries, certain weathered, red mottled soils in the inland coastal zone resemble post-sulfuridicization soils (6), but little information is available about them.

The tropical part of Asia (Fig. 6) includes a number of deltas, estuaries and coastal plains, in which ASS's occur. In the larger deltas, e.g. the Irrawaddy and Salween in Myanmar (former Burma), the Chao Phrya in Thailand and the Mekong in South Vietnam, the conditions for composition of pyrites and the formation of PASS's in Old Holocene Times were favourable. In these deltas, which are situated on more or less stable coasts, extensive areas of dangerous PASS's have been formed (4). At a limited fall of sea level, or maybe a slight uplift of the land, these PASS's were drained and extensive areas of ASS's developed (4).

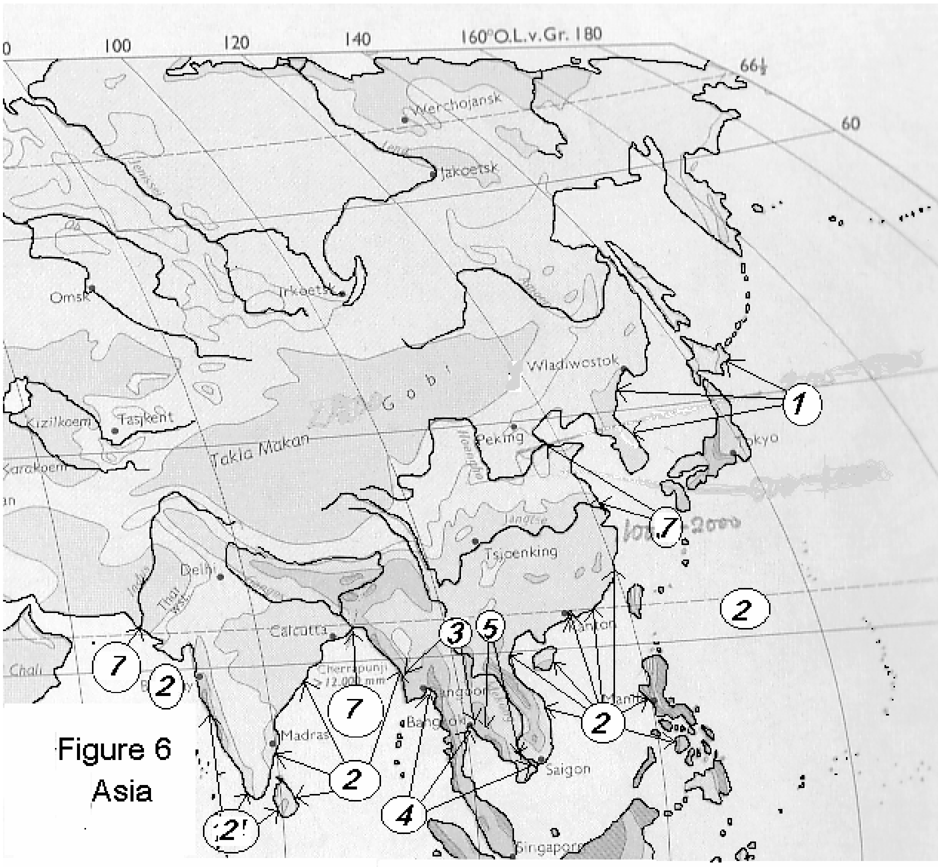

Figure 6
Asia

We believe that the same happened in other deltas.

In the last 3 to 2 000 years, with the increase of the population and the starting of large scale land reclamations for agriculture, a much greater sedimentation rate caused a rapid extension of many deltas. The old ASS's are partly not covered, still lying on the surface (4), or they are covered by river levees and only shallow back swamp deposits (7) (Dent and Pons 1995). Other parts are covered by deep river levee soils or/and are eroded (7). The older parts of these deltas (4) are bordered at their seasides by young coastal plains with NAAS (7)

In other deltas, the older PASS deltas may have completely eroded and been replaced by NAAS deposits of younger deltas. It is very probable that in the largest of those deltas, e. g. of the Ganges and Brahmaputra in India, the Red River in North Vietnam and the Sikyang or Pearl River in China (7), the PASS's and ASS's have completely disappeared and replaced by NAAS estuarine deposits (7). Maybe also deltas as those of the Indus, the Jang Tse Kiang and Hoangho (7) are also belonging to this group. Chinese soil scientists, on a 1993 excursion could show us only limited areas of ASS's in the delta of the Pearl River

It is in most of the smaller deltas and estuaries along the coasts of India, Ceylon and Bangladesh, Myanmar (Burma), Thailand, Vietnam and southern China, as well as of the Philippines and Formosa, that ASS's are present at the surface and not covered by young NAAS deposits (2). Those are giving the large problems with agriculture, fisheries and ecology.

Along all these coasts, also traces of old, heavy weathered ASS's on Middle Pleistocene terraces (5) are found, and probably in Thailand and South Vietnam as well on yet older land surfaces (6). Information about that, however, is far from complete, also about pre-sulfuricidation phenomena.

One of the main reasons of the large extension of the ASS's in Myanmar (Burma), Thailand and Vietnam, is the lack of fresh weatherable basic minerals in the catchments. In contrast to that, the presence of neutralizing minerals of volcanic origin restricts the occurrence of ASS's in the Philippines and also in Japan, although they locally exist in small estuaries.

In Indonesia, including Malaysia (Fig. 7) originally completely covered with humid, tropical forests, PASS's and ASS's are widespread (Driessen and Supraptohardjo, 1974). On the non-volcanic islands, Borneo, Celebes, New Guinea, some small Sunda islands and other islands, some non-volcanic parts of Sumatra and in Malaysia (2), PAAS's and ASS's occupy large surfaces in the greater and smaller deltas and estuaries. Before reclamation, peat layers, variably covered undeveloped PASS's. Their exact genesis and physiographical situation is not very clear. Recent tectonic uplifts and subsidence of land in combination with sea level movements in the unstable archipelago, has caused very different physiographic conditions in the different catchments and deltas. In some deltas, very deep PASS's are present (3), but soil patterns of PASS's as well as of ASS's are unknown.

On Java and some other volcanic parts of other islands, a high volcanic activity continuously increases sedimentation rates of the rivers to the north coast. Besides that, large amounts of basic, dark coloured, Iron-Manganese Aluminium-silicate minerals neutralize any eventually produced acids. In 1999, we discovered in some small estuaries on the south coast of Java, where no volcanic material is added to the sediments, well developed PASS's, locally developed to ASS's (2).

Both New Guineas are for the greater part not volcanic and show along their coasts extensive areas of PASS', mostly not developed into ASS's (2). However, the large mountain-fed rainfall and fluvial discharge in rivers such as the Tepic, together with small tides precludes deposition of PASS.

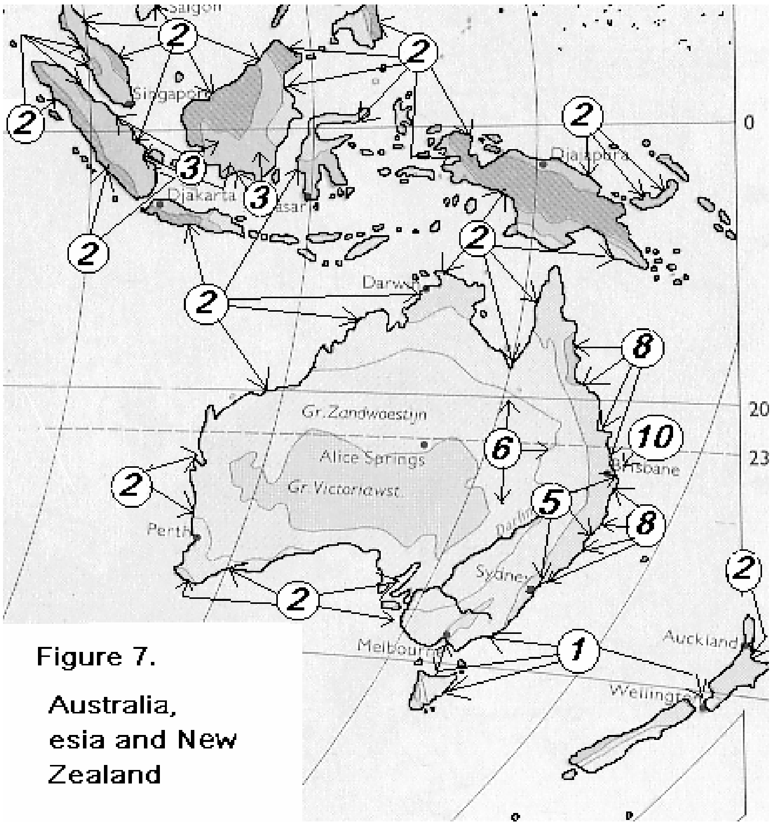

Figure 7.
Australia,
esia and New
Zealand

Australia, nearly all tropical to temperate, is practical completely surrounded by saline and brackish mangrove marshes, including the east coast of Tasmania. Was reported that on many places quite large surfaces op PASS's are present on which locally ASS's have formed (2). Along the western and southern coasts, bordering large deserts, sedimentation is minimal, so the surfaces of PASS's in these coastal plains (2) are small. Along the northern and eastern coasts with their humid climates, large deltas and estuaries with PASS's occur (2).

Very deep (> 40 m) and sometime very large PASS's bodies (8) in estuaries and lagoons along the east coast of Australia, have the character of under water deposits (8), resembling Littorina PASS. They have grown up to sea level, and are covered by shallow, recent ASS's (2). The PASS bodies (8) are formed in drowned river valleys and embayments behind Holocene sand barriers through the inlets of which, the rivers reach the ocean. Although locally, on top of them, river levees have developed, the bulk of the sediments of the PASS bodies must have been derived from the ocean bottom before the coast (Melville at all., 1993). Recent investigations in the Tweed valley seem to confirm this (personal communication Melville). The relative shallow levee-basin system is probably a recent sediment veneer on top of these PASS bodies, also originating from the ocean bottom and laid down under slightly changed tidal movements during the last centuries

Along this stable coast, also remnants of the PASS's of the Middle Pleistocene marine terrace (5) at levels of about 3 m above present sea level are present. On similar large PASS bodies developed, during the low interglacial sea levels, deep, heavy-weathered and leached, red-mottled ASS's, which are completely comparable with the same Middle Pleistocene ones in Africa.

Inland Australia includes strong and deep weathered soils, developed on weathered rocks, particularly the Cretaceous marine sediments. Fitzpatrick at al. (1993) describe ASS's from inland Australia, related with saline-alcaline soils (6). Some soil scientists (Fitzpatrick and Melville, personal communication) believe that the inland silcretes and laterites of Tertiary and pre-Tertiary age are post-sulfuridicizated and have passed through a stage of ASS weathering (6). It is difficult to distinguish them from 'normal' topical weathered soils.

Along the northern and eastern coasts of Tasmania (1), and in northern New Zealand (Dent, 1986) PASS's and ASS's are present, near Hokianga Harbour (2) under dwarf mangroves.

Dredging the entrances to the Brisbane River and harbour, and depositing the materials into diked-in reservoirs, has allowed oxidation of these PASS materials to ASS's (10), and caused tremendous problems in the environment by their drainage water.

GENERAL CONCLUSIONS

The occurrence of PASS's and related SSS's is limited to coastal or former coastal areas. They are more common in the tropics than in temperate areas, because mangroves are able to grow on lower levels below mean sea level (MSL) as compared with reed marshes (Fig. 1). Their distribution is broader in slowly accreting deltas and estuaries, because at fast sedimentation rates, pyrite is diluted by the high amounts of sediment grains. Consequently PAAS's only form in relation to rivers with densely wooded catchments or along coasts bordering deserts without sediment transport from rivers. ASS's are easier formed in deltas and estuaries, which are related to non-volcanic catchments with deeply weathered soils. In temperate areas with fresh, calcareous materials (loess, glacial moraines) in their catchments or in volcanic catchments, producing sediments with high neutralising capacities, ASS's are nearly lacking. Special categories of PAAS's are those, which are formed on the bottoms of seas and lagoons, with high supplies of organic matter.

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RIPARIAN VEGETATION AND MACROZOOBENTHOS OF THE BAČKOVSKÝ POTOK BROOK IN THE SLÁNSKE VRCHY MOUNTAINS (SLOVAKIA)

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KEYWORDS: Slovakia, Slánske Vrchy Mountains, river banks, vegetation, macroinvertebrates.

ABSTRACT

Riparian vegetation and water macroinvertebrates in the upper part of Bačkovský Potok brook in the Slánske vrchy Mountains were investigated during 2005 - 2006 period. In riparian vegetation 106 taxa were found. Seven sections were assigned in the studied area according to riparian vegetation character and taxonomic composition. The number of identified species varied among 11 and 40. Species richness decreased initially from spring area to the sector bellow. Least species richness was found in the central part of the investigated area, in canyon like rock gap (the brook flows here down the bedrock and among rare boulders). Species richness increased again in the lower part and reached a maximum in the lowest woody area. Cluster analysis (according to Jaccard similarity index) shows small similarity between sections. The macrozoobenthos is composed of 99 taxa. Species richness was lowest in spring area (5 taxa) and in the canyon (14). We found out the highest species richness in lower woody section (max. 64 taxa). Generally, Ephemeroptera, Plecoptera, Trichoptera, Coleoptera and Malacostraca were the most abundant groups, and they (except Coleoptera) composed the major part of macroinvertebrates biomass. Also, the frequency of these taxonomical groups was markedly higher than frequency of the other taxa. According to clustering, the most similar were the low section assemblages. The upper section and the part of stream in the canyon were most different. The taxon richness continuances of riparian vegetation and macrozoobenthos showed that there is a marked tendency to increase downstream. Marked differences were detected in similarity of sections/localities according to taxonomic composition of riparian vegetation and macrozoobenthos.

ZUSAMMENFASSUNG: Ufervegetation und Makroevertebraten im Bačkovský Potok- Bach im Gebirge Slánske Vrchy (Slowakei).

Ufervegetation und Makroevertebraten im Oberlauf des Bačkovský Potok-Bachs im Slànske Vrchy Gebirge wurden während der Jahre 2005 - 2006 untersucht. Für die Ufervegetation wurden 106 Taxa vorgefunden. Sieben Abschnitte wurden am Standort nach dem Charakter und taxonomischer Struktur der Ufervegetation abgegrenzt. Die Anzahl der definiereten Arten in diesen Abschnitten variierte zwischen 11 und 40. Die Vielfalt der Gattungen nahm zunächst vom Quellbereich zum darunter liegenden Abschnitt hin ab. Die wenigsten Gattungen wurden im zentralen Abschnitt des Untersuchungsgebietes in canyonähnlichen Felsspalten gezählt (hier fliesst der Bach direkt auf dem anstehenden Fels durch eng liegende Felsblöcke). Die Artenzahl nahm im unteren Abschnitt wieder zu und erreichte das Maximum im niedrigsten waldigen Gewässerabschnitt (mit max. 64 Taxa). Die Clusteranalyse (nach dem Jaccardindex) zeigt nur geringe Ähnlichkeiten zwischen den Sektionen. Allgemein waren Ephemeroptera, Plecoptera, Trichoptera, Coleoptera und Malacostraca die am meisten vorhandenen taxonomischen Gruppen und sie stellten (ausser Coleoptera) den Hauptbestandteil der makrowirbellosen Biomasse dar. Die Häufigkeit dieser taxonomischen Gruppen war ebenfalls bedeutend grösser als die Häufigkeit der anderen Taxa.. In Bezug auf das Clustering waren die unten gelegenen Abschnitte am ähnlichsten. Der oberste Gewässerabschnitt und der Abschnitt in der Felsschlucht waren am unterschiedlichsten. Die Artenzahl hängt von der Ufervegetation ab und es besteht eine deutliche Tendenz, dass die Reichhaltigkeit des Taxonbestandes an Makrovertebraren stromabwärts zunimmt. Deutliche Unterschiede wurden zwischen den Gewässerabschnitten/Probenstellen in Bezug auf die taxonomische Struktur im Uferbestand und Makrozoobenthos festgestellt.

REZUMAT: Vegetația ripariană și macrozoobentosul pârâului Bačkovský Potok din Munții Slánske Vrchy (Slovacia).

Vegetația ripariană şi macronevertebratele acvatice din partea superioară a pârâului Bačkovský Potok din Munții Slánske Vrchy au fost investigate între 2005 - 2006. În cazul vegetației ripariene, au fost găsiți 106 taxoni. Şapte secțiuni au fost considerate ca fiind de interes, în funcție de caracterul vegetației ripariene și a compoziției taxonomice. În aceste secțiuni, numărul speciilor variază de la 11 la 40. Bogăția de specii descreşte din aria izvorului către aval. Bogăția în specii descreşte în partea centrală a ariei investigate, într-o formă de relief negativă de tip canion în rocă (pârâul curge pe patul de rocă şi printre bolovani rari). Bogăția în specii creşte din nou înspre aval şi atinge maximul în zona joasă împădurită. Analiza de tip cluster (în conformitate cu indicele de similaritate Jaccard) relevă o similaritate redusă între secțiuni. Macrozoobentosul este compus din 99 de taxoni. Bogăția în specii a fost cea mai scăzută în aria izvorului (5 taxoni) şi în canion (14). Am găsit cea mai ridicată bogăție în specii, în zona joasă împădurită (cu un maxim de 64 de taxoni). În general, Ephemeroptera, Plecoptera, Trichoptera, Coleoptera şi Malacostraca au fost cele mai abundente grupe, şi acestea (exceptând Coleoptera) compun majoritatea biomasei macronevertebratelor. De asemenea, frecvența acestor grupe a fost în mod accentuat mai mare decât frecvența altor taxoni. În conformitate cu analiza de tip cluster, cele mai similare au fost asociațiile secțiunii joase. Secțiunea superioară şi cea de canion au fost cele mai diferite. Bogăția în taxoni a vegetației ripariene şi a macrozoobentosului arată că există o tendință ridicată de creştere spre aval. S-au observat diferențe mari în ceea ce priveşte similaritatea secțiunilor în conformitate cu structura taxonomică a vegetației ripariene şi a macrozoobentosului.

INTRODUCTION

Terrestrial and aquatic ecosystems are directly connected (energy and nutrient flow) through the riparian ecotones (Gregory et al., 1991). Riparian vegetation is very important for the stream processes. The diversity of plants in riparian ecosystems provides inputs of organic matter, energy and nutrient to aquatic ecosystems (Winterbourn et al., 1985; Rowe and Taylor, 1994; Bunn et al., 1999; Clausen et al., 2000). Riparian zones may buffer streams from contaminants. Riparian vegetation also serves to create shade. It is necessary for natural temperature regimes (Bunn et al., 1999). The riparian zones are the boundary of terrestrial and aquatic ecosystems. They are good indicators of the drainage basin quality (Richards et al., 1993). Differences in riparian vegetation and forestation reflect differences in species diversity and abundance of benthic communities (Petersen et al., 2004; Ormerod et al., 1993; Gee and Smith, 1997).

The riparian ecotones are often degraded by urban development, industrial activity, agriculture, grazing, and wood-cutting (Stevens and Cummins, 1999). These activities often result in stream bank erosion, increased sedimentation, alteration of geomorphology of riparian habitats, loss of species diversity and assemblage composition of macroinvertebrates, and other effects (Osborne and Kovacic, 1993; Lenat and Crawford, 1994; Barton and Farmer, 1997; Stevens and Cummins, 1999; Weigel et al., 2000). This study investigated the relationship between the riparian vegetation and macroinvertebrate communities in Bačkovský potok stream in eastern Slovakia (Fig. 1).

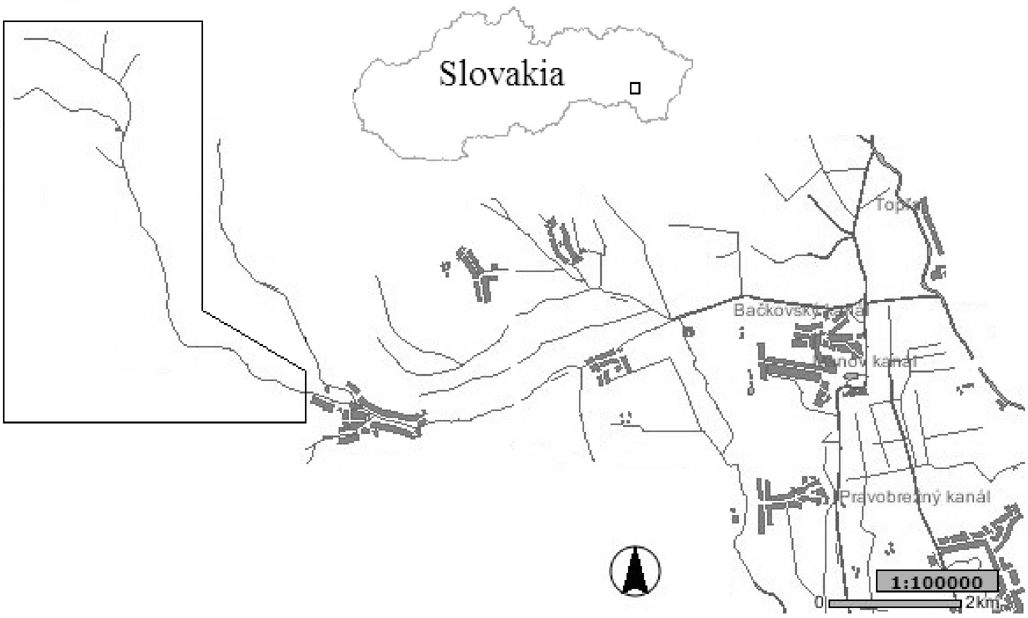

Figure 1: Map of the studied area (boxed)
and general hydrographical situation.

MATERIALS AND METHODS

The riparian vegetation was determined on-site, in 2 terms in vegetative periods in years 2005 and 2006 using Simon (2002). We established qualitative results (species composition) only. According to riparian vegetation character and taxonomic composition, seven sections were assigned in investigated area.

Macroinvertebrates were sampled seasonally in years 2006 and 2007 using the 350 μm mesh-size net (frame 25 x 25 cm) with a kicking technique sample in defined sections (with a total 14 sample sites). Multireplicate samples were taken based on "multihabitat design" method, from each of present microhabitats. Each sample was preserved in 4% formaldehyde. All specimens were identified to the lowest possible taxonomical level (excepting Oligochaeta, Hirudinea and Heteroptera).

Data analysis

We estimated the alfa diversity indices (species richness) of riparian vegetation and macroinvertebrate communities in selected sectors. Using Cluster analysis (paired group, Jaccard similarity index), we compared the similarity between sites/sections. We analysed our data with the PAST software (PAlaeontological STatistics, ver. 1.53, Hammer et al., 2001).

Study area

Bačkovský potok stream springs are located in the Slanské vrchy mountais, at an altitude of 765 m and it is a right tributary of Topla river. The mouth is at an altitude of 105 m. It runs south-easterly first, passing the Nature reserve of Bačkovská dolina valley, and then runs to the east through the East Slovak upland. The upper part is steep and the riverbed is relatively undisrupted. The lowest part of this brook flows crossways the East Slovak lowland. The topography in this section is flat and the river-basin is canalized and markedly disrupted. The area of our interest is in the top part of this stream, from spring to the Bačkov village. This sector is the least affected by human activities. The geological background is volcanic in this part. The mean January temperature is here about minus 6 to minus 7 °C, the mean July temperature is from 14 up to 16 °C and the annual rainfall is around 700 - 800 mm (Mazúr, 1980).

RESULTS AND DISCUSSIONS

Riparian vegetation

We found 106 taxa of vascular plants in the riparian vegetation. According to the riparian vegetation character and taxonomic composition, we specified seven sectors in investigated area. The numbers of species varied from a low of 11 up to 40 in selected sectors. The species richness decreased initially from the spring area, and the lowest number of species occurred in the central sectors, round the canyon-like rock gap. The spring area and the highest part of the watershed were deforested (by catastrophic occurrence and then salvage cutting). The α-diversity increased again in the lower part and the maximum achieved in the lowest woody area (Tab. 1, Fig. 2). The final decline is connected with the change of the woodland to the combined tree/bush-like stream bank vegetation and variation in the land use (from forestry to pasture management). According the cluster analysis (Fig. 3), it is visible, that the sectors are very different. The most similar are the sectors five and six. The others are ordered out of accord to their location in the river continuum.

Macroinvertebrates

We found 99 benthic macroinvertebrates taxa in this stream. This number is relatively low, in comparison with some other Slovak streams and rivers (Krno, 1996; Novikmec et al., 2007) but it is probably caused by the shortness of investigated area and its streams. Results from some other Slovak streams with comparable length/area (e. g. Derka et al., 2001; Koščo and Manko, 2006; Žiak, 2007) are lower yet. The one and only other previous research investigation in this mountain, in the Hermanovský potok stream, confirmed only 18 taxa (Terek et al., 1988). The most commonly found benthic macroinvertebrate taxa were mayflies (Ephemeroptera), stoneflies (Plecoptera), cadisflies (Trichoptera), beatles (Coleoptera), amphipods (Amphipoda) and dipterans (Diptera). These taxonomical groups were significant regarding abundance and species richness. Total taxa richness ranged from 5 to 64 taxa. The taxa richness was lowest in the spring area and in the canyon (Tab. 2, Fig. 3). The highest numbers of taxa occurred in the lower woody section. It is in accordance with Naiman et al. (1993) and Tate and Heinly (1995), who state that forest shade and coverage appeared to increase EPT, total richness and diversity taxa. In the canyon, the species richness is limited by substratum conditions. The species richness in the spring area is probably a result of deforestation and devastation of the riverbed. Krno (1999, 2000) found that the species richness and composition of stonefly communities were strongly influenced by deforestation and erosion in the top parts of river basins. It is possible, that in this stream the whole macrozoobenthos assemblages are similarly affected.

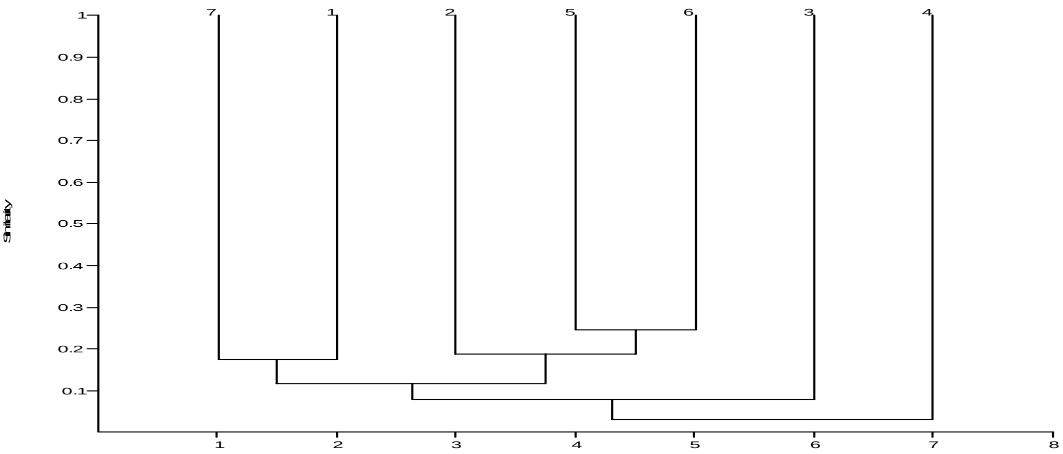

Figure 2: Classification of the 7 sectors based on the presence/absence of riparian vegetation species (paired group clustering method, Jaccard´s index of similarity; vertical axis = similarity level).

Table 1: Riparian vegetation presence, frequency and species richness in the seven sectors.

	Sector							Frequency
Species	1	2	3	4	5	6	7	
Acer campestre L.	0	0	1	0	0	1	1	43%
Acer negundo L.	0	0	0	0	0	0	1	14%
Acer platanoides L.	0	1	0	0	1	1	0	43%
Acer pseudoplatanus L.	0	1	0	0	0	1	0	29%
Aegopodium podagraria L.	0	0	0	1	1	1	1	57%
Achillea millefolium L.	0	0	0	0	0	0	1	14%
Alnus glutinosa (L.) Gaetn.	0	0	0	0	1	1	1	43%
Anthriscus sylvestris (L.) Hoffm.	0	0	0	1	0	0	0	14%
Arctium lappa L.	0	0	1	0	0	0	0	14%
Aruncus sylvestris Kostel.	0	0	0	0	0	1	0	14%
Arctium tomentosum Mill.	0	0	0	0	0	0	1	14%
Asarum europaeum L.	0	0	0	0	0	1	0	14%
Astrantia major L.	0	0	1	0	0	0	0	14%
Asperula odorata L.	1	0	0	0	0	0	0	14%
Asplenium septentrionale (L.) Hoffm.	0	0	0	1	0	0	0	14%
Asplenium trichomanes L. emend. Huds.	0	0	0	1	0	0	0	14%
Athyrium filix-femina (L.) Roth.	0	1	0	0	0	0	0	14%
Bidens cernua L.	1	0	0	0	0	0	0	14%
Brachypodium sylvaticum (Huds.) Beauv.	0	0	0	0	0	1	0	14%
Cardamine amara L.	0	1	0	0	0	0	0	14%
Calamagrostis arundinacea (L.) Roth.	0	0	1	0	0	0	0	14%
Carpinus betulus L.	0	0	0	0	0	1	0	14%
Cardamine bulbifera (L.) Crantz.	0	1	0	0	0	1	0	29%
Cardamine glandulifera O. Schwartz.	0	1	0	0	0	0	0	14%
Campanula patula L.	0	0	0	0	0	0	1	14%
Cardamine pratensis L.	0	0	0	0	1	0	0	14%
Carex sylvatica Huds.	1	0	0	0	1	0	0	29%
Campanula trachelium L.	0	0	0	0	0	1	0	14%
Circaea lutetiana L.	0	0	0	0	1	0	1	29%
Corylus avellana L.	0	1	0	0	0	1	1	43%
Cornus sanguinea L.	0	0	0	0	1	1	0	29%
Crataegus laevigata (Poir.) DC.	0	0	0	0	0	1	0	14%
Crataegus monogyna Jacq.	0	0	0	0	0	0	1	14%
Daucus carota L.	0	0	0	0	0	0	1	14%
Dactylis glomerata L.	1	0	0	0	0	0	1	29%
Dryopteris filix-mas (L.) Schott.	1	1	0	0	0	1	0	43%
Epilobium roseum Schreb.	1	0	0	0	0	0	0	14%
Equisetum sylvaticum L.	0	0	0	1	0	0	0	14%
Erigeron annuus (L.) Pers.	0	0	0	0	0	0	1	14%
Euphorbia amygdaloides L.	1	0	0	0	0	1	0	29%
Eupatorium cannabinum L.	1	0	0	0	0	0	0	14%
Fagus sylvatica L.	0	1	0	0	1	1	0	43%
Fraxinus excelsior L.	0	0	1	0	0	1	0	29%
Fragaria vesca L.	0	0	0	0	0	0	1	14%
Galium aparine L.	0	0	1	0	0	0	0	14%

Species	Sector							Frequency
	1	2	3	4	5	6	7	
Galium odoratum (L.) Scop.	0	0	0	0	0	1	0	14%
Galium schultesii Vest.	0	1	0	0	0	0	0	14%
Geranium robertianum L.	1	1	0	0	1	0	0	43%
Geum urbanum L.	0	0	1	0	0	1	1	43%
Glechoma hederacea L.	1	0	0	0	0	0	1	29%
Glechoma hirsute Waldst. and Kit.	0	0	0	0	1	1	0	29%
Gymnocarpium dryopteris (L.) Newman.	0	1	0	0	0	0	0	14%
Hesperis matronalis L.	1	0	0	0	0	0	0	14%
Hypericum montanum L.	1	0	0	0	0	0	0	14%
Hyoscyamus niger L.	1	0	0	0	0	0	0	14%
Chrysosplenium alternifolium L.	0	1	1	0	0	0	0	29%
Impatiens noli-tangere L.	1	1	1	0	1	0	0	57%
Impatiens parviflora DC.	0	0	0	0	0	1	0	14%
Lapsana communis L.	0	1	0	0	1	0	1	43%
Lamium maculatum L.	0	1	0	0	0	1	0	29%
Leersia oryzoides (L.) SW.	1	0	0	0	0	0	0	14%
Lilium martagon L.	0	0	0	0	0	1	0	14%
Lunaria rediviva L.	0	1	0	0	0	1	0	29%
Lycopus europaeus L.	0	0	0	0	1	0	1	29%
Lysimachia nummularia L.	0	0	0	0	0	0	1	14%
Lysimachia vulgaris L.	0	0	0	0	0	0	1	14%
Mentha longifolia (L.) L.	1	0	0	0	0	0	1	29%
Mercurialis perennis L.	0	1	0	0	1	0	0	29%
Mycelis muralis L. (Dumrt.)	1	1	0	0	1	1	1	71%
Myosotis sylvatica Ehrn. ex. Hoffm.	0	0	0	1	0	0	0	14%
Neottia nidus-avis (L.) Rich.	0	0	0	1	0	0	0	14%
Oxalis acetosella L.	0	1	0	0	0	1	0	29%
Persicaria hydropiper (L.) Delabre	1	0	0	0	0	0	0	14%
Petasites sp. Mill.	1	0	0	0	0	0	0	14%
Plantago media L.	1	0	0	0	0	0	0	14%
Polystichum aculeatum (L.) Rothm.	0	0	0	1	0	0	0	14%
Polygonatum multiflorum (L.) All.	0	0	0	0	0	1	0	14%
Poa pratensis L.	1	0	0	0	0	0	1	29%
Polypodium vulgare L.	0	0	0	1	0	0	0	14%
Prenanthes purpurea L.	0	0	0	0	1	0	0	14%
Prunella vulgaris L.	0	0	0	0	1	0	1	29%
Pulmonaria mollis Wulf. ex Hornem.	0	0	0	0	1	1	0	29%
Quercus petraea (Matt.) Liebl.	0	0	0	0	0	1	0	14%
Pulmonaria obscura Dumort.	1	0	0	0	0	0	0	14%
Ranunculus repens L.	1	0	0	0	0	0	1	29%
Ribes uva-crispa L.	0	0	0	0	0	1	0	14%
Rosa canina L.	0	0	0	0	0	0	1	14%
Rorippa sylvestris (L.) Bessr.	0	1	0	0	0	0	0	14%
Rubus idaeus L.	1	0	0	0	0	1	0	29%
Rubus sp. L.	0	0	0	0	1	1	0	29%

	Sector							Frequency
Species	1	2	3	4	5	6	7	
Rumex sanguineus L.	1	0	0	0	0	0	0	14%
Salix fragilis L.	0	0	0	1	0	1	1	43%
Sambucus nigra L.	0	0	1	0	1	1	0	43%
Sambucus racemosa L.	0	0	0	0	0	1	0	14%
Scirpus sylvaticus L.	0	0	0	1	0	0	1	29%
Senecio sarracenius L.	0	0	0	0	1	0	0	14%
Senecio sylvaticus L.	1	0	0	0	0	0	0	14%
Solanum dulcamara L.	0	0	0	1	0	0	0	14%
Stellaria holostea L.	0	0	0	0	0	1	0	14%
Stachys sylvatica L.	1	0	0	0	1	1	1	57%
Symphytum officinale L.	0	0	0	1	1	0	0	29%
Torilis japonica (Hout.) DC.	0	0	0	1	0	0	1	29%
Tussilago farfara L.	1	0	0	0	0	0	1	29%
Urtica dioica L.	1	0	1	0	1	1	1	71%
Viola reichenbachiana Jor. ex. Boreau.	0	0	0	0	0	1	0	14%
Species richness	29	21	11	14	24	40	32	

The cluster analysis of the sections similarity (Fig. 4) showed, that the most similar are the sectors five and six. There are three clusters generally. The first sections, one and two, the second (four, five, six, seven) and very different the site three. The clusters/sectors similarity is in accordance with the river continuum (sites location) and with disturbances in several parts of the watershed. The sectors one and two are in the spring area and the adjacent territory. This part is deforested and the riverbed is visible disrupted through the tractor driving (the riverbed is occasionally used as a forest road) and erosion. The site three is the canyon like rock gap with rare boulders. The riverbed creates most often bedrock. The sites four, five, six and seven are relatively undisrupted, with natural riverbed and forested catchment area, which in the lowest part of the investigated area (seven) continuously shifts in to the fastigiated, mixed tree/bush-like riverbank vegetation and pastural managed land.

Table 2: Presence, frequency and species richness of the collected macroinvertebrates.

	Sector							Frequency
Species	1	2	3	4	5	6	7	
Turbellaria								
Dugesia gonocephala (Dugés, 1830)	0	0	0	1	1	0	1	43%
Oligochaeta								
Lumbricidae sp.	0	0	0	1	1	0	1	43%
Tubificidae sp.	0	1	1	1	1	1	1	86%
Hirudinea								
Erpobdella sp.	0	1	0	0	1	0	1	43%
Amphipoda								
Gammarus balcanicus Schäferna, 1922	1	1	1	1	1	1	1	100%
Ephemeroptera								
Baetis (*Alainites*) *muticus* (Linnaeus, 1758)	0	0	0	0	1	1	1	43%
Baetis alpinus Pictet, 1843-1845	0	0	0	0	1	1	1	43%
Baetis melanonyx Pictet, 1843-1845	0	0	1	0	1	0	1	43%
Baetis rhodani Pictet, 1843-1845	0	0	1	0	1	1	1	57%

Species	Sector							Frequency
	1	2	3	4	5	6	7	
Baetis vernus gr. juv	0	0	0	1	0	0	0	14%
Ecdyonurus picteti (Meyer-Dür, 1864)	0	1	0	1	1	0	0	43%
Ecdyonurus macani Thomas and Sowa, 1970	0	0	1	0	0	0	1	29%
Ecdyonurus starmachi Sowa, 1971	0	0	0	0	1	1	1	43%
Epeorus assimilis Eaton, 1885	0	0	0	0	1	0	1	29%
Ephemera danica Müller, 1764	0	0	0	0	0	0	1	14%
*Ephemerella mucronat*a (Bengtsson, 1909)	0	0	0	0	1	0	1	29%
Habroleptoides confusa Sartori and Jacob, 1986	0	0	0	0	1	1	1	43%
Habrophlebia lauta Eaton, 1884	0	0	0	0	1	1	1	43%
Rhithrogena iridina (Kolenati, 1859)	0	0	0	0	1	0	0	14%
Rhithrogena picteti Sowa, 1971	0	1	0	0	1	1	1	57%
Rhithrogena semicolorata (Curtis, 1834)	0	0	0	0	1	1	0	29%
Serratella (*Ephemerella*) *ignita* (Pda, 1761)	0	0	0	0	0	0	1	14%
Plecoptera								
Brachyptera risi (Morton, 1896)	0	0	0	0	1	1	1	43%
Brachyptera seticornis (Klapálek, 1902)	0	0	0	1	1	0	1	43%
Diura bicaudata (Linnaeus, 1758)	0	0	0	0	0	0	0	0%
Isoperla grammatica (Poda, 1761)	0	0	0	0	0	0	0	0%
Isoperla oxylepis (Despax, 1936)	0	0	0	0	0	1	1	29%
Leuctra aurita Navas, 1919	0	0	1	0	1	0	0	29%
Leuctra hippopus Kempny, 1899	0	0	0	0	0	1	1	29%
Leuctra inermis Kempny, 1899	0	0	0	0	1	0	0	14%
Leuctra rauscheri Aubert, 1957	0	0	0	0	1	0	0	14%
Nemoura cambrica Stephens, 1836	0	0	0	1	1	0	0	29%
Nemoura cinerea (Retzius,1783)	1	1	0	1	1	0	1	71%
Nemoura marginata Pictet, 1835	0	1	0	0	0	0	0	14%
Nemoura cf. *sciurus* Aubert, 1949	0	0	0	0	1	0	0	14%
Nemoura uncinata Despax, 1934	0	0	0	0	1	0	0	14%
Perla marginata (Panzer, 1799)	0	1	0	1	1	0	1	57%
Perla pallida Guerin, 1838	0	0	0	0	1	0	1	29%
Perlodes intricatus (Pictet, 1841)	0	0	0	0	0	0	0	0%
Perlodes sp. juv.	0	0	0	0	0	0	1	14%
Protonemura auberti Illieş, 1954	0	0	1	0	0	0	0	14%
Protonemura intricata (Ris, 1902)	1	1	0	1	1	1	1	86%
Protonemura sp.juv.	0	0	0	0	0	0	1	14%
Heteroptera								
Gerris sp.	0	0	0	0	1	0	0	14%
Coleoptera								
Elmis maugetii Latreille, 1798	0	0	0	0	1	1	1	43%
Elodes sp. - larvae	1	1	0	0	1	1	0	57%
Esolus angustatus (Müller, 1821)	0	1	0	0	1	0	0	29%
Esolus parallelepipedus (Müller, 1806)	0	0	0	0	0	0	1	14%

Species	Species							Frequency
	1	2	3	4	5	6	7	
Gyrinus sp.	0	0	0	0	1	0	0	14%
Hydraena excisa Kiesenwetter, 1849	0	0	0	0	0	0	1	14%
Hydraena gracilis Germar, 1824	0	1	0	0	1	1	1	57%
Hydraena pygmaea Waterhouse, 1833	0	0	0	0	1	0	1	29%
Hydraena riparia Kugelann, 1794	0	0	0	0	0	0	1	14%
Hydraena saga d'Orchynt, 1930	0	0	0	0	1	0	1	29%
Hydraena sp.	0	0	0	0	1	1	1	43%
Hydrocyphon deflexicollis (Müller, 1821) - larv.	0	0	0	0	0	0	1	14%
Hydroporus sp.	0	1	0	0	0	0	0	14%
Hygrotus impressopunctatus (Schaller, 1783)	0	0	0	0	1	0	0	14%
*Limnius perrisi (*Dufour*, 1843)*	0	1	0	0	1	0	0	29%
Limnius sp. - larv.	0	0	0	0	1	1	1	43%
Limnius volckmari (Panzer, 1793)	0	0	0	0	1	1	1	43%
Platambus maculatus (Linnaeus, 1758) - larv.	0	0	0	0	0	1	0	14%
Trichoptera								
Agapetus sp.	0	0	0	0	1	0	0	14%
Ecclisopteryx madida (McLachlan, 1867)	0	0	0	1	1	0	1	43%
Glossosoma conformis Neboiss, 1963	0	0	0	0	0	1	0	14%
Hydropsyche sp.	0	0	0	1	1	1	1	57%
Odontocerum albicorne (Scopoli, 1763)	0	0	0	0	1	0	0	14%
Philopotamus sp.	0	0	0	1	1	0	1	43%
Polycentropodidae sp.	0	1	0	0	1	0	0	29%
Psychomyiidae sp.	0	0	1	1	1	0	1	57%
Rhyacophila s. str.	0	0	0	1	1	1	1	57%
Rhyacophila sp.	0	0	0	0	1	1	1	43%
Rhyacophila tristis Pictet, 1835	0	0	0	1	1	1	1	57%
Sericostoma sp.	0	0	0	0	1	1	1	43%
sF. Drusinae	0	0	1	1	1	0	0	43%
sF. Limnophilinae Tr. Stenophylacini	1	1	1	1	1	1	1	100%
Trichoptera sp.	0	0	0	0	1	1	0	29%
Wormaldia sp.	0	0	0	0	1	0	0	14%
Diptera								
Chironomus gr. *plumosus* (Linnaeus, 1758)	0	1	0	1	1	1	0	57%
Eusimulium angustatum (Rbtsov, 1956)	0	0	1	0	0	1	0	29%
Simulium morsitans Edwards, 1915	0	0	1	0	0	0	1	29%
Simulium reptans (Linnaeus, 1758)	0	0	0	1	1	0	1	43%
Dicranota bimaculata (Schummel, 1829)	0	0	0	1	1	0	1	43%
Pedicia rivosa (Linnaeus, 1758)	0	0	0	0	1	0	1	29%
Tipula saginata Bergroth, 1891	0	0	0	0	0	1	1	29%
Dixa nubilipennis Curtis, 1832	0	0	1	0	0	0	0	14%
Dixa puberula Loew, 1849	0	0	1	1	0	0	0	29%
Ibisia marginata (Fabricus, 1781)	0	0	0	0	1	0	0	14%
Ablabesmyia sp.	0	0	0	0	1	0	0	14%
Species richness	5	17	14	23	64	32	53	

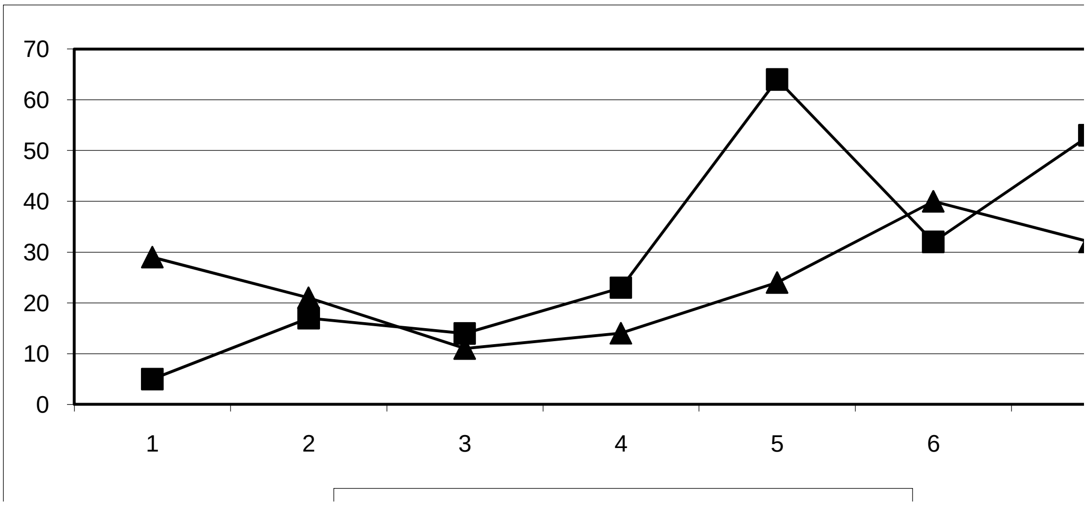

Figure 3: Species richness of riparian vegetation and macroinvertebrate asssemblages in the seven sectors.

Riparian vegetation - macrozoobenthos comparison

The taxon richness of the riparian vegetation and macroinvertebrates, according to the river continuum, increased downstream (Fig. 3), even though they are unequal. In contrast, the similarity of the sections according to the riparian vegetation was very different from the similarity according to macrozoobenthos (Figs. 2, 4). The reasons may be:

1. The macroinvertebrates are strongly affected by the disruptions in the riverbed and in the catchment area.
2. The macroinvertebrate assemblages vary more continuously than the riparian vegetation, because in the streams already are registered buffered impacts and the plant communities reflect on immediate impacts (e.g. deforestation).
3. Plants are more influenced through the route-building and induced changes than macroinvertebrates, because the riverbed was not so markedly changed, or it restored rapidly its primal functions and conditions.
4. The plant community composition depends on the distance from the route situated in the valley, and also on the direct and adjacent antropic impacts (e.g. displaced taxa).
5. It is important, whether the riverbed vegetation serves to create shade and buffer zone, provides the organic matter input and its other functions. The species composition of riparian vegetation appears to be not essential for the macrozoobenthos in this case.

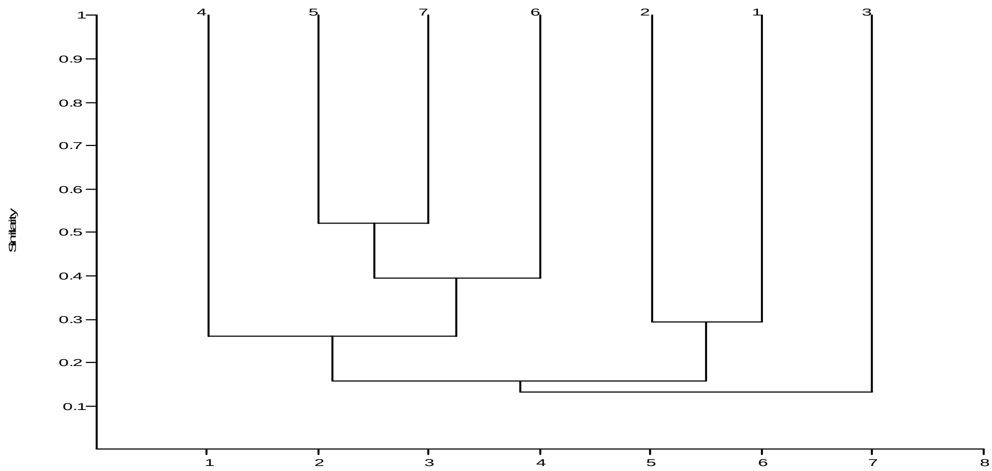

Figure 4: Sectors classification based on the presence/absence of macroinvertebrate species (paired group clustering method, Jaccard´s index of similarity; vertical axis = similarity level).

Rios and Bailey (2006) sustain that the macroinvertebrate communities are influenced more by local scale riparian variables rather than land use-catchments variables, analogous to Stewart et al. (2000) and Sponseller et al. (2001).

Our results showed that the local riparian vegetation together with micro scale land use-catchments and disturbances are very important factors influencing local macroinvertebrate assemblages. However, it is not possible to determine the contribution of these features separately in this case.

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THE STATE OF MUSSEL SETTLEMENTS FROM AGIGEA, ON THE ROMANIAN COAST OF THE BLACK SEA

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KEYWORDS: Black Sea, Romania, Agigea, Ukraine, Odessa, coastal reinforcement, mussel settlements, age structure, mortality rate, annual survival, life span.

ABSTRACT

The present state of the mussel settlements from coastal reinforcement of Agigea (Romania) at the depths of 0 - 16 m was analysed. Density, biomass, mortality, annual survival rate, life span of mussels and age structure of mussel settlements were revealed. The mortality coefficient of mussels was minimal at the depth of 12 m. The highest mussel mortality level was noted in the wave breaking area (depth 0 m). The annual survival rate of mussels at depths of 2 - 12 m is related (negatively) to mollusks average density and biomass. In comparison with other areas of the north-western Black Sea the mussel settlements from Agigea have higher values of density, biomass, survival rate and life span (8 years).

RÉSUMÉ: Etat des populations de moules à Agigea (côte roumaine de la Mer Noire).

L'état actuel des populations de moules sur les constructions du port d'Agigea à des profondeurs entre 0 et 16 m a été analysé. Ont été étudiés: les effectifs, la biomasse, la mortalité, le taux annuel de survie, la durée de vie et la structure des âges des populations de moules. Le coefficient de mortalité atteint un minimum à la profondeur de 12 m. Celui le plus élévé a été enregistré dans la zone de ressac (niveau de la mer). Le taux annuel de survie des mollusques aux profondeurs entre 2 et 12 m est inversement proportionel à la densité et à la biomasse des moules. Par comparaison avec d'autres régions du nord-ouest de la Mer Noire, les populations de moules d'Agigea présentent des valeurs plus élevées de densité, de biomasse, ainsi que de taux de survie et de durée de vie (8 ans).

REZUMAT: Starea coloniilor de midii de la Agigea la ţărmul românesc al Mării Negre.

A fost analizată starea actuală a coloniilor de midii de pe elementele de construcţie pentru armarea ţărmului de la Agigea la adâncimi de 0 - 16 m. Au fost evidenţiate densitatea, biomasa, mortalitatea, rata de supravieţuire anuală, durata de viaţă şi structura pe vârste a coloniilor de midii. Coeficientul de mortalitate a midiilor a fost minim la adâncimea de 12 m. Cel mai ridicat coeficient de mortalitate a midiilor a fost înregistrat în zona de spargere a valurilor (adâncimea de 0 m). Rata de supravieţuire anuală a midiilor la adâncimea de 2 - 12 m este relaţionată (negativ) cu densitatea şi biomasa medie a moluştelor. În comparaţie cu alte zone din nord-vestul Mării Negre, coloniile de midii de la Agigea au valori mai mari ale densităţii, biomasei, ratei supravieţuirii şi duratei de viaţă (8 ani).

INTRODUCTION

At the beginning of the 1960s mussel *Mytilus galloprovincialis* Linnaeus, 1758 formed numerous, dense settlements, known as “the mussel fields”, on a relatively large area of the North-Western Black Sea. In 1970 - 1990 a lengthy hypoxia was noted almost annually in this region in the waters in the vicinity of the bottom, which usually resulted in the death of benthic organisms. Hypoxia had a negative influence on the mussel population structure. The highest mortality of adult individuals during the period of anoxia was the cause of the radical change in terms of age class structure of the mussel, with the dominance of young individuals (Shurova, 2000; quoted by Shurova, 2005). As a result, for instance, in the period 1984 - 1992 the average age of mussel from the Ukrainian Black Sea shelf was reduced two times. The maximum age of mollusc individuals identified by the author was of 10 years, as opposed to 28 years in the reference period.

The considerable decrease in the number of molluscs belonging to adult age groups, with a higher reproduction level than in the case of young molluscs, led to a decreased coefficient of reproduction (Ro). Compared to 1985 its values decreased almost 10 times (Shurova, 2005). The analysis of the state of bottom mussel settlements at the Romanian shelf also has shown (Shurova and Gomoiu, 2006) a high level of mortality rate of mollusks at depth 26 - 46 m.

The purpose of this research was to study the present state of the mussel settlements from coastal reinforcement of the Agigea.

In order to analyse the age structure of the mussel settlements from this area, studies were made on mussels collected vertically every two meters in October 2004, starting from the surface and down to a depth of 16 m. After separating the mussels from the other zoobenthic components, the inner organs were extracted and the valves were separated. The valve length (L) of each individual (a total of 2986) was subsequently measured.

Individual age of the mussels was revealed by the method of sclerochronology on the basis of counting annual bands in the inner nacreous shell layer (Shurova and Zolotarev, 1988). These data were used to generate size-age structure for each site. The mortality coefficient (Z) was estimated from the gradient of the age-frequency curve, which is expressed in the following equation:

$$N_t = N_0 * e^{-Zt}$$

where N_t - the number of mussels at given time t, N_0 - initial number of the mussels.

Percentage survival rate per annum was calculated for each site as $e^{-Z} * 100$.

Life-span of the mussels was estimated as maximum age of the mollusk in sample. Mean age of mussels was calculated using data of numbers of mollusks of all age classes.

RESULTS AND DISCUSIONS

The maximum length of the mussel from coastal reinforcement of the Agigea, as well as others population characteristics of the Black Sea mussel, varies considerably according to depth (Tab. 1).

Table 1: The population characteristics of *Mytilus galloprovincialis* populations in the Agigea dyke area.

Depth (m)	No. of anlysed ind.	Maximum length (l_{max} mm)	Average age (years)	Life span (years)	Mortality coefficient (z, year^{-1})	Annual survival (%)	Density (ind./m^2)	Biomass (g/m^2)
0	1859	50.1	0.69	4	1.1790	30.76	46475	27072.5
2	150	72.5	2.39	6	0.2544	77.54	3750	28772.6
4	236	80.3	3.12	8	0.3387	71.27	5900	45193.2
6	164	81.8	3.02	8	0.2886	74.93	4100	36076.9
8	172	78.0	2.51	7	0.2542	77.55	4300	35975.2
10	111	79.9	2.43	6	0.1954	82.25	2775	22705.9
12	88	66.8	3.74	7	0.0650	93.71	2200	16069.2
14	97	59.7	2.81	6	0.2112	80.96	2425	16219.2
16	109	54.3	2.88	5	0.2584	77.23	2750	13368.9
Total	2986							
Average total		69.27	2.62	6.33	0.3315	74.02	8297	26828.2

The largest mussels, with lengths of up to 81.8 mm, were found at 6 m depth. The mortality coefficient of mussels was minimal (0.0650 year^{-1}) at 12 m depth. About 94 % of the initial number of mollusks survive there every year. The highest mussel mortality level in coastal reinforcement of the Agigea (a mortality coefficient is 1.179 year^{-1}) was noted in the wave breaking area (depth 0). Here the annual survival rate of mussels represents only 30.76% of the initial number of mollusks, though at other depths of their values were two times more (Fig. 1).

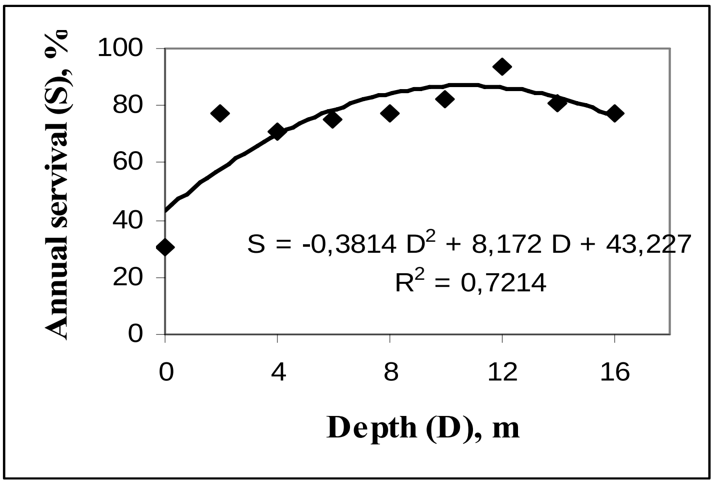


Figure 1: Variations of annual survival (%) of the mussel at different depths in coastal reinforcement of Agigea.

The curve of interrelation of annual survival of mussels from coastal reinforcement of the Agigea and depths is polynomial. However at depth of 4 - 12 m linear dependence of survival rate of the mussel to depth are observed (Fig. 2). So with increase in depth from 4 m to 12 m, the mortality rate of mussels gradually decreases, and the annual survival of this mollusk increases. Probably, the reason for changes of annual survival of the mussel is increase of salinity of waters at a larger depth.

The average mortality coefficient for all mussel settlements from this area was 0.3315 year^{-1}, and the annual survival rate -74.02%.

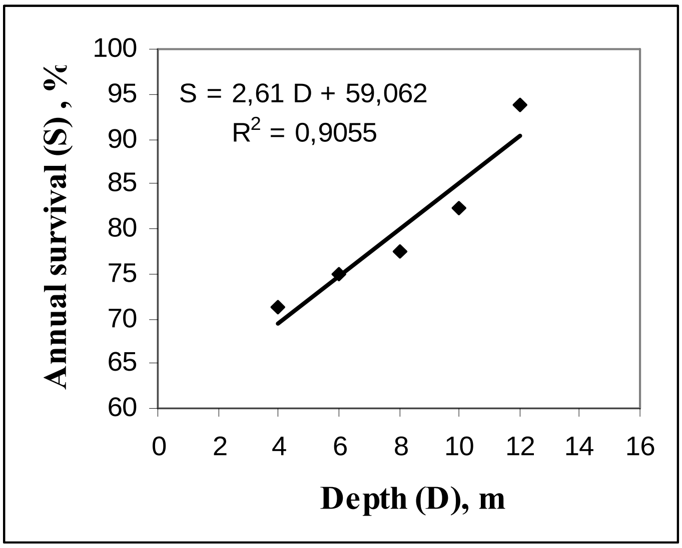


Figure 2: The differences of annual survival rate of the mussel at the depths of 4 - 12 m of coastal reinforcement of the Agigea.

The annual survival rate of mussels at depths of 2 - 12 m is related (negatively) also to average density (Fig. 3) and biomass of mollusk (Fig. 4). The negative interrelation of average density and average biomass of mussels with a level (%) of annual survival rate of this mollusk testify that high mortality of the mussel from coastal reinforcement of the Agigea can be due to very high density and biomass of this mollusk. Another reason can be enormous size of falling off of mussels from a substratum, where annual survival rate of this mollusk is very high.

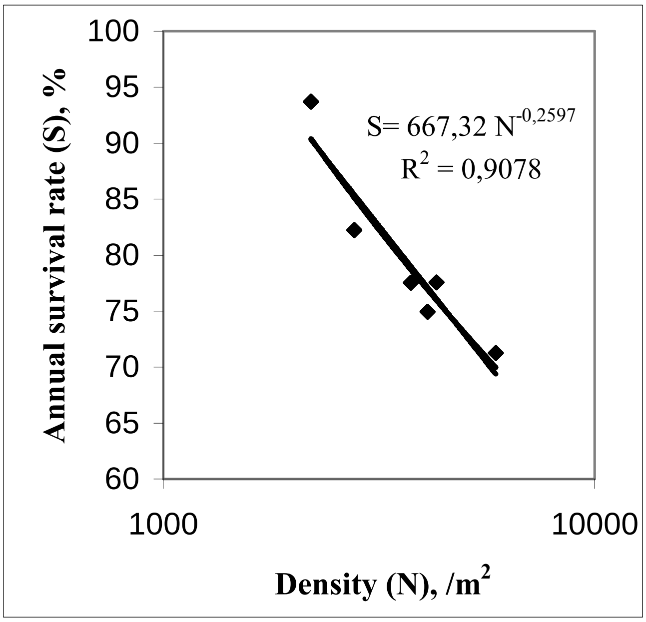


Figure 3: Relationship of the average density of the mussel and annual survival rate of this mollusk at depths of 2 - 12 m of coastal reinforcement of the Agigea.

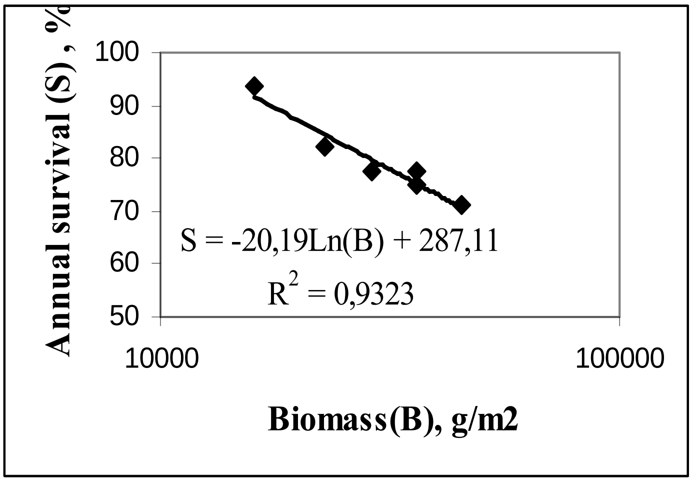


Figure 4: Relationship of mussel biomass and annual survival rate of this mollusk at depths of 2 - 12 m of coastal reinforcement of the Agigea.

Mussel mortality and the mussel survival level in some environmental conditions are determined by life span. According to our research, the maximum age of *Mytilus galloprovincialis* in mussel settlements from coastal reinforcement of the Agigea is eight years (Tab. 1). The maximum life span varies according to depth. Thus, the mussels with maximum age were encountered at depths of four and six metres. The highest average age of *Mytilus galloprovincialis* individuals from coastal reinforcement of Agigea was determined at the depth of 12 m (3.74 years). The lowest average age (Fig. 5) was recorded in the wave breaking area (0 m), due to the high proportion of juvenile individuals (> 80 %).

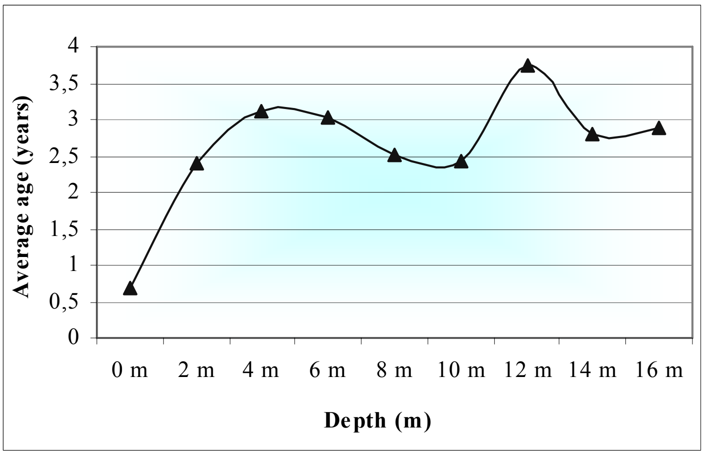


Figure 5: The average age variation of the mussels *Mytilus galloprovincialis* from coastal reinforcement of the Agigea.

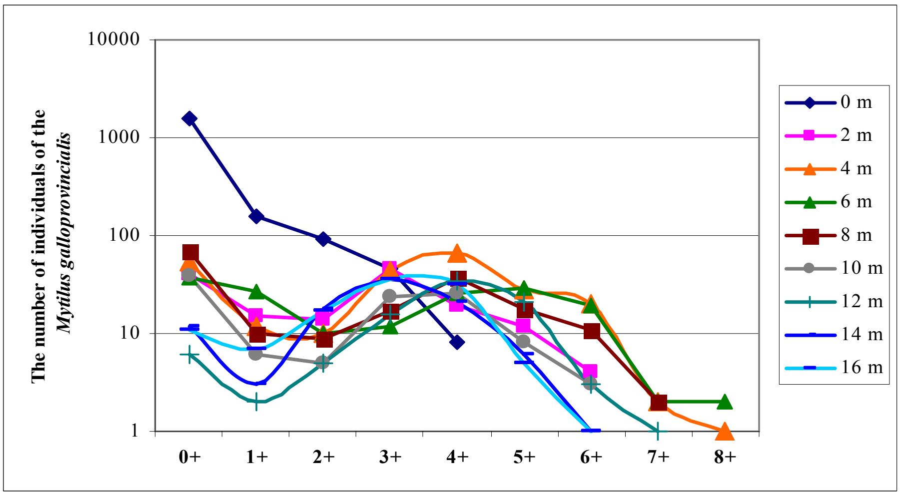


Figure 6: The age structure of the mussel settlements
from coastal reinforcement of the Agigea.

Most individuals in the wave breaking area are unable to survive the winter storms that occur each year, being practically scraped from the concrete blocks (stabilopods). The value of the exponential correlation quotient age of mussel and number of mollusks of every age class in this settlement was highest (0.9424). Only the settlement of the mussel from this depth was stationary, where levels of birth rate and mortality rate are practically equal.

With depth, values of the exponential correlation quotients decrease considerably and settlements of this mollusk are not stationary due to the fact that in these settlements there is a low number of young mollusks (age 1 - 3 years) that testifies to a very low of level of new generations in 2001 - 2003 in comparison with the past years (Fig. 6). Another reason for this phenomenon can be non-uniform distribution of young individuals at different depths.

We generally consider that the method of determining age by classifying *Mytilus galloprovincialis* individuals in size classes alone is not sufficiently adequate, since some 4-year-old individuals can reach over 65 mm, having the same length as 6-year-old individuals (Fig. 7).

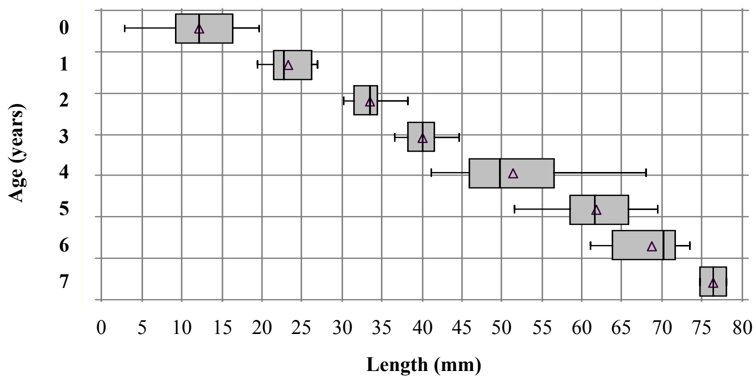
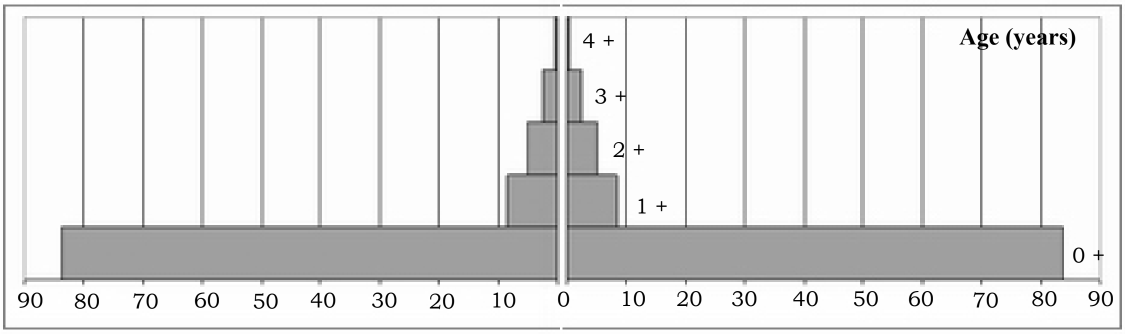


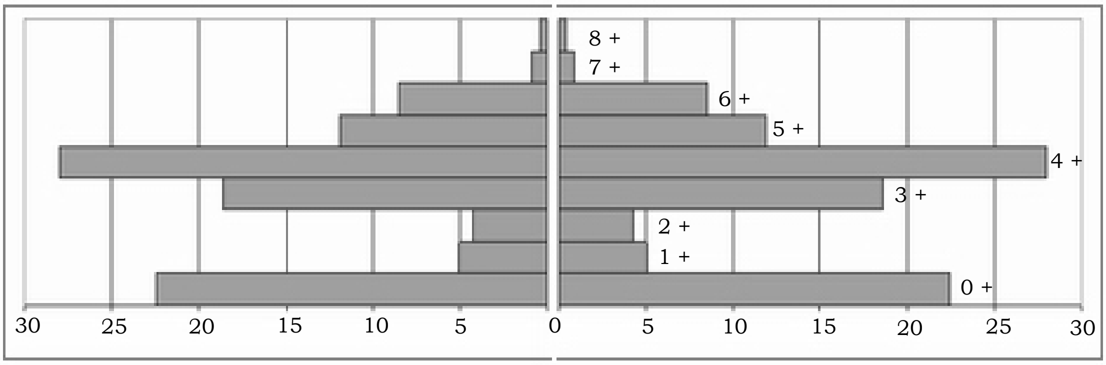
Figure 7: Size-age ratio of mussels
from coastal reinforcement of the Agigea at the depth of 8 m.



% number of individuals of the *Mytilus galloprovincialis* at the each age

Figure 8: The age pyramid of the mussel settlements
from coastal reinforcement of the Agigea at the depth of 0 m.

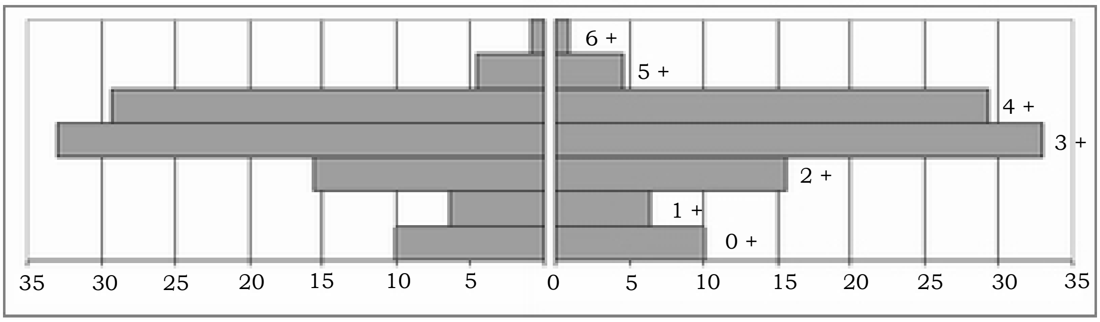
Age (years)



% number of individuals of the *Mytilus galloprovincialis* of the each age

Figure 9: The age pyramid of the mussel settlements
from coastal reinforcement of the Agigea at the depth of 4 m.

Age (years)



% number of individuals of the *Mytilus galloprovincialis* of the each age

Figure 10: The age pyramid of a mussel settlements
from coastal reinforcement of the Agigea at the depth of 16 m.

Distribution according to age classes will remain not always constant in time, because birth rate is seasonally integrated in biocoenosis functioning. The graphic representation of age class proportions generally assumes the shape of an age pyramid, because there are usually more juvenile individuals than adults. The base of the pyramid can be wide, regular or narrow. The shape of the pyramid emphasises significant aspects of its structure and population size perspectives. Thus, a wide base pyramid emphasises the predominance of juvenile individuals and adults, the population undergoing numeric growth. A regular base pyramid shows the balance of juvenile individuals and adults, the population being stationary. The narrow base pyramid expresses the predominance of mature groups, the population undergoing a decline (Varvara et al., 2001).

For our study we have constructed age pyramids for the mussel populations collected vertically from coastal reinforcement of the Agigea (Figs. 8, 9, 10). In the case of the mussel population collected from the wave breaking area we note the shape of the very wide base pyramid, with the highest proportion of individuals aged < 1 year, only a few 4-year-old individuals being recorded (this being the lowest maximum age recorded at this depth).

At greater depths, the shape of the pyramid changes considerably, because of the low proportion of juvenile individuals (< 15 %) and the predominance of mature individuals with ages up to 6 years. An interesting shape was noted in the case of most pyramids (with the exception of the one at the surface) - a drastic reduction in the number of individuals with average ages between two and three years. The pyramids thus double in terms of shape. The small number of individuals of these ages can be probably explained by the fact that during the period (2000 - 2001) in the Agigea area mass mortality was recorded, because of unfavourable weather conditions and changes in the structure of the Constanța Sud - Agigea harbour dyke through stabilopod addition.

It is necessary to note that settlements of mussels at the coastal reinforcement are frequently non-uniform and temporary. Most mussels in the wave breaking area are unable to survive the winter storms that occur each year, because density and biomass of this mollusk varies considerably (Tab. 2).

Table 2: Density (N, ind./м^2) and biomass (B, g/м^2) of the mussels from coastal reinforcement of the Odessa port (Ukraine) in July 2006.

Station	Depth, m	N	B
1	0.0	240	0.4
1	1.5	3030	2213.0
1	1.5	2820	2762.1
1	1.5	2550	2475.0
1	2.2	990	2.9
1	2.2	570	5.8
1	2.2	3480	17100.0
1	3.0	4785	8040.2
1	3.0	11340	8805.4
2	0.0	195	0.5
2	1.5	1845	165.3
2	1.5	2160	3211.0
2	1.5	555	3270.0
2	3.0	18600	18741.2
2	3.0	15435	29951.1
2	4.2	18600	11959.0

Station	Depth, m	N	B
2	4.2	26550	21574.0
2	4.2	3375	26400.2
3	0.0	525	11.0
3	0.0	525	77.3
3	1.5	5280	3314.5
3	1.5	1470	1945.3
3	1.5	555	1455.1
3	3.0	11985	20095.2
3	3.0	41025	34537.4
3	3.0	6780	21960.1
3	8.0	1425	7095.4
3	8.0	0	0
4	0.0	540	3.2
4	0.0	315	8.3
4	1.5	4650	3422.2
4	1.5	4080	2383.1
4	1.5	1050	2370.9
4	3.0	106305	10560.0
4	3.0	30945	14508.5
4	3.0	25485	7815.4
4	7.0	2550	23400.2
4	7.0	4470	25080.1
4	7.0	1635	17700.1

A comparison of mussel population parameters of the data obtained by Shurova (2005) for bottom settlements of this mollusk from the north-western part of the Black Sea and Romanian shelf has shown lower values of the mortality coefficient mussels from the coastal reinforcement of the Agigea and a higher annual survival rate of mollusk.

The mussel settlements from Agigea (in comparison with other areas of the north-western Black Sea) have very high values of density and biomass (Tab. 3). So, the density of mussels from coastal reinforcement of the Odessa port at the depths of 0 - 8 m is almost 4 times, the average biomass - 23 times lower, than in mussel settlements from coastal reinforcement of the Agigea. Especially significant distinctions in density and biomass were observed at the depth of 0 m.

The mortality coefficients of the mussel from coastal reinforcement of the Agigea are lower too, and in this settlements there are higher annual survival rates of mussels (Tab. 4), though parameters of growth of the mollusk were practically identical (Fig. 4).

Table 3: Average density and biomass of the mussel from coastal reinforcement of the Odessa port (Ukraine, July 2006) and Agigea (October 2004).

Depth, m		Density, ind./m^2		Biomass, g/m^2	
Odessa	Agigea	Odessa	Agigea	Odessa	Agigea
0	0	390	46475	16.8	27072.5
1.5-2.2	2	1826	3750	1022.5	28772.6
3.0-4.2	4	16482	5900	16155.2	45193.2
7.0-8.0	8	2276	4300	16481.0	35975.2
Average total		2273±2.16	8152±1.80	1462,6±5.08	33557±1.12

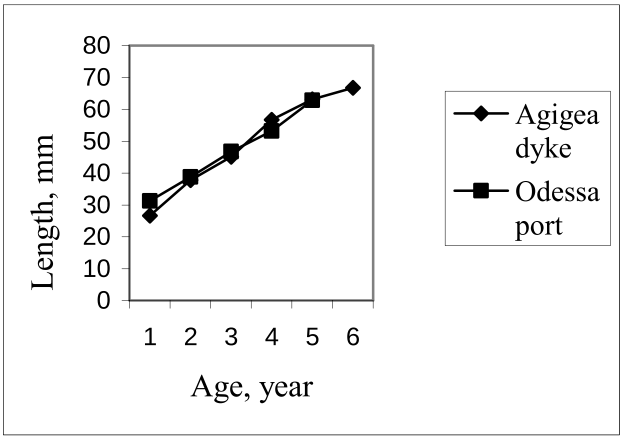


Figure 11: Curves of mussel growth at a depth of 4 m (reinforcement of Agigea and Odessa).

Table 4: Population characteristics of the mussel from coastal reinforcement of the Odessa port (Ukraine, July 2006) and Agigea (October 2004).

Depth, Manual, m		Mortality coeficient (Z, year $^{-1}$)		Annual survival of mussels %		Life span (years)	
Odessa	Agigea	Odessa	Agigea	Odessa	Agigea	Odessa	Agige
1.5	2	0.47	0.25	62.63	77.54	5	6
3	4	0.75	0.33	47.24	71.27	5	8
7	8	0.41	0.25	66.10	77.55	8	7

CONCLUSIONS

The maximum life span of the mussel from coastal reinforcement of the Agigea is eight years.

The lowest average age (0.69 years) was found in the wave breaking area, the highest average age was at 12 m (3.74 years), with maximum age mussels being determined at 4 and 6 m depths.

The mussel has a minimum mortality coefficient (0.0650 year^{-1}) at a depth of 12 m, an area in which 93.71% of the initial number of molluscs survive every year. The highest mussel mortality level (mortality coefficient 1.179 year^{-1}) was emphasised in the wave breaking area, where only 30.76% of the initial number of molluscs survive every year. The average mortality coefficient of the mussel for the sector under study is of 0.3315 year^{-1}, and the annual survival rate is high - 74.02 %.

Comparison of the data obtained for bottom settlements of mussels of the north-western part of the Black Sea show that mussels from coastal reinforcement of the Agigea are characterized by lower values of the mortality coefficient. Average biomass, density, annual survival rate of mussels at Agigea is higher than those, obtained for similar settlements of mussels from coastal reinforcement of the Odessa.

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AQUATIC MACROINVERTEBRATE COMMUNITIES IN RIVER TORYSA ACROSS THE JAVORINA MILITARY TRAINING AREA IN THE LEVOČSKÉ VRCHY MOUNTAINS (SLOVAKIA)

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KEYWORDS: Slovak Carpathians, Hornád River basin, Torysa River, macrozoobenthos.

ABSTRACT

The upper part of Torysa river (Levočské vrchy Mountains, Slovakia) flows alternately across a military training area (MTA) Javorina and a civil area. It is planned to build new water reservoir in this area in the future. The structure and quantitative features of macrozoobenthos were investigated by samples taken from five localities during year 2005. From the viewpoint of the qualitative composition, about ten groups have been found in the river Torysa. The highest species richness achieved were from the orders Plecoptera (22 species) and Ephemeroptera (11 species). The abundance of macrozoobenthos varied from 1532 to 3027 ex. m^{-2}, the values of biomass ranged between 5416 mg. m^{-2}, and 8260 mg. m^{-2}. The abundance and biomass of water insect larval stages (from the orders Ephemeroptera, Plecoptera and Trichoptera) was noted as well as that of crustaceans (Amphipoda). Mayflies (Ephemeroptera) were most abundant at all sites (with 56.5 - 70.7 % proportion of gross abundance). Stoneflies (Plecoptera) and Malacostraca (Crustacea) composed the major part of biomass in the upper area (stoneflies 30.6 - 34.2 % and Malacostraca 27.7 - 33.6 %). The importance of mayflies within the biomass increased downstream and they made up 41.4 % and 49.4 % ratio, respectively, at the two lowest sites. Caddisflies (Trichoptera) were important within macrozoobenthos abundance and biomass too. According to Albrecht (1959), these rates correspond to median values of the macrozoobenthos in four sites, and to low values in one site. Also of interest, were the saprobity index values. They ranged between 0.67 and 1.43. The maximum was observed at a site in the MTA below a woodcutting area (with wood-transported through the riverbed), and the minimum at nearest site down the river with modified riverbed (mega- and macrolithal) and high stoneflies abundance. Single groups of macroinvertebrates (e. g. mayflies vs. stoneflies) responded differently to human impacts (organic pollution, and land use in catchment area, riverbed and bank modifications and disturbantions). Generally, human impacts on macroinvertebrates communities were less observable than in settled civil areas. The most important intervention in MTA was woodcutting near the river and wood transport through the riverbed. In areas without woodcutting activities, the conditions and macrozoobenthos communities' performanced markedly better.

RÉSUMÉ: Communautés de macro-invertebrés aquatiques dans les cours d'eau de la zone d'entraînement militaire de Javorina (Montagnes Levočské Vrchy, Slovakie).

La partie supérieure de la rivière Torysa (Montagnes Levočské Vrchy, Slovakie) coule en alternance à travers la zone d'entraînement militaire (MTA) Javorina et une zone civile. Dans cette zone il est prévu de construire dans le futur un nouveau réservoir d'eau. La structure et les paramètres quantitatifs du macrozoobenthos ont été étudiés à travers des échantillons prélevés dans five localités pendant l'année 2005. Du point de vue de la composition qualitative, ten groupes ont été identifiés dans la rivière Torysa. La plus grande abondance spécifique a été obtenue pour les ordres Plecoptera (22 espèces) et Ephemeroptera (11 espèces). L'abondance du macrozoobenthos a varié entre 1532 et 3027 ex. m^{-2}, les valeurs de la biomasse se sont situées entre 5416mg.m^{-2} et 8260 mg.m^{-2}. L'abondance et la biomasse des états larvaires des insectes aquatiques (appartenant aux ordres Ephemeroptera, Plecoptera et Trichoptera) ont été notées ainsi que celles des crustacés (Amphipoda). Les éphémères (Ephemeroptera) ont été les plus abondants dans tous les sites (avec 56.5 à 70.7 % de l'abondance totale). Les Perles (Plecoptera) et les Malacostracés (Crustacea) ont formé la plus grande partie de la biomasse dans la zone supérieure (Perles 30.6 - 34.2 %, Malacostracés 27.7 - 33.6 %). L'importance des éphémères dans la biomasse a augmenté en aval, atteignant des proportions de 41.4 % et 49.4 %, dans les deux sites les plus bas. Les trichoptères (Trichoptera) ont aussi eu une part signaficative dans l'abondance et la biomasse du macrozoobenthos. Selon Albrecht (1959), ces proportions correspondent aux valeurs moyennes du macrozoobenthos dans 4 sites, et aux valeurs basses dans 1 site. Un autre point d'intérêt a été constitué par les valeurs de l'indice de saprobie. Celles-ci ont atteint des valeurs comprises entre 0.67 et 1.43. Le maximum a été observé dans un site à l'intérieur de la MTA sous une zone d'exploitation forestière (avec un transport des troncs via la rivière), et le minimum dans le site proximal en aval où le lit de la rivière était modifié (méga- et macrolithique) et où les Perles sont abondantes. Les populations monospecifiques de macro-invertebrés (i. e. éphémères vs. perles) répondent différemment à l'impact anthropique (pollution organique, utilisation du terrain dans le bassin de drainage, modifications et dérangements du lit de la rivière et des berges). Généralement, l'impact anthropique sur les communautés de macro-invertebrés a été moins visible que dans les zones non militaires peuplées. La plus grande intervention dans la MTA a été l'exploitation forestière près de la rivière et le transport du bois via le cours de l'eau. Dans les zones sans exploitation forestière, les conditions et les indices des communautés macrozoobenthiques ont été nettement meilleurs.

REZUMAT: Comunități de macronevertebrate acvatice în râul Torysa de-a lungul poligonului militar Javorina (Munții Levočské Vrchy, Slovacia).

Partea superioară a râului Torysa (Munții Levočské vrchy, Slovacia) curge alternativ peste poligonul militar Javorina (MTA) şi o zonă civilă. Aici, în viitor, se va construi un nou rezervor de apă. Structura şi caracteristicile cantitative ale macrozoobentosului au fost investigate prin intermediul probelor, prelevate din cinci localități în 2005. Din punctul de vedere al compoziției calitative, au fost găsite zece grupe. Cea mai mare bogăție de specii a fost înregistrată pentru Plecoptera (22) şi Ephemeroptera (11). Abundența macrozoobentosului variază între 1532 şi 3027 ex. m^{-2}, valorile biomasei acoperă intervalul dintre 5416 mg. m^{-2} şi 8260 mg. m^{-2}. Au fost notate abundența şi biomasa stadiilor larvale ale insectelor (Ephemeroptera, Plecoptera şi Trichoptera) ca şi cele ale crustceelor (Amphipoda). Efemeropterele au fost cele mai abundente în toate siturile (56,5 - 70,0 %). Plecopterele şi crustaceele (Malacostraca) au alcătuit partea cea mai mare a biomasei în aria superioară

(Plecoptera 39,6 - 34,2 % şi Malacostraca 27,7 - 33,6 %). Importanța ca biomasă a efemeropterelor creşte în aval şi ajunge la 41,4 % respectiv 49,4 %, în cazul celor mai joase secțiuni. Trichopterele sunt importante în ceea ce priveşte abundența macrozoobentosului şi a biomasei acestuia. În conformitate cu Albrecht (1959), aceste valori corespund cu valorile medii ale macrozoobentosului în patru secțiuni, şi cele mai joase valori în o secțiune. De asemenea de interes, au fost valorile indicelui saprob. Acestea au variat între 0,67 şi 1,43. Maximul a fost observat înt-un sit în MTA, în aval de zona cu exploatări forestiere (cu buştenii transportați prin albia râului), şi minimul într-o secțiune limitrofă din aval cu albia râului puternic modificată şi abundență ridicată a plecopterelor. Grupele de macronevertebrate (ex. efemeroptere vs. plecoptere) au răspuns în mod diferit la impactul antropic (poluare organică, utilizarea terenurilor în bazinul de retenție, modificări ale albiei şi malurilor). În general, impactul antropic asupra macronevertebratelor a fost mai puțin observabil în zona militară decât în cea locuită. Cea mai importantă intervenție umană în MTA a fost tăierea copacilor de lângă râu şi transportul acestora prin albie. În zonele fără exploatarea lemnului, condițiile şi comunitățile de macronvertebrate sunt semnificativ mai bune.

INTRODUCTION

The upper part of Torysa river (Fig. 1) flows alternately across MTA (Military Training Area) Javorina and civil areas. We anticipated, that this MTA is well protected and that it is like a „Nature reserve“, and the civil area more anthropogenically affected by for e. g. organic pollution, riverbed and riverbanks alterations/modifications/regulations. The results of our investigation in this part of Torysa river can be usable for comparison of the expected changes of the effect of water reservoir building (in the actual MTA, a water reservoir for drinking water is planed to be built) the effect of changes in exploitation of MTA (this territory will be likely returned to the primary owner). Some faunistic data about macrozoobenthos in the Torysa river was published already (Hradil, 1965; Landa, 1969; Kokorďák, 1973; Kirka et al., 1981; Koščo et al., 1988; Landa and Soldána, 1989).

The macrozoobenthos of catchments, rivers and streams in military areas (Army Training Areas, Military Installations) and the effects of military training and army activities have been evaluated by few American researchers by now. Williams et al. (2005) evaluated the interactive effect of environmental variability and military training on stream biota, Risch (2004) examined the short-term and long-term quality of surface water in Army Training Area (including macrozoobenthos features). Robinson (2004) made an inventory of aquatic macroinvertebrates and calculated selected biotic indices in Army Training Area, and Quist et al. (2003) estimated the military training effect on terrestrial and aquatic communities on a military installation. The results of these few surveys show that water macroinvertebrates in military area streams are influenced in an analogous way to macroinvertebrates in civil areas streams (different activities result in similar effects). Endangered species do not occur more often in these territories than in civil areas in spite of some kind of preservation and control of many human activity.

MTA Javorina is not used for intensive army trainings/exercises nowadays. The freshwater communities are then affected only by civil activities. The strict military preservations results in many restrictions in land using. These restrictions make this area different from the others. We anticipated that it results in smaller disturbation and clear lower negative effect of human activities on the macrozoobenthos communities.

STUDY AREA

The Torysa river spring is located in the Levočské vrchy Mountains, at an altitude of 1100 m. It flows through the Spišsko-šarišské medzihorie (intermountain territory/area) and it is a left tributary of Hornád river. The mouth is situated in the so-called Košická kotlina area (Košice basin) at an altitude 179 m. This river is 128 km long and the drainage area is 1349 km^2. The drainage is situated in a flysh region with typical high rate of erosion and unstable flow volume (frequent floods after rains and minimal water discharges in dry seasons/years). The most important tributaries are right-side tributary Slavkovský potok brook and left-side tributaries Ľutinka and Delňa brooks. The drain-mode is snow-rainy with accumulation of snowfall in winter months (November, December and January) with maximum discharges in March and April (snow-melt). The mean yearly discharge is in the range 5 - 8 $m^3. s^{-1}$, minimal 0.5 $m^3. s^{-1}$ maximum 110 $m^3. s^{-1}$. The forest coverage is about 50 % in the upper zone and about 30 % in the lower zone (Mazúr, 1980).

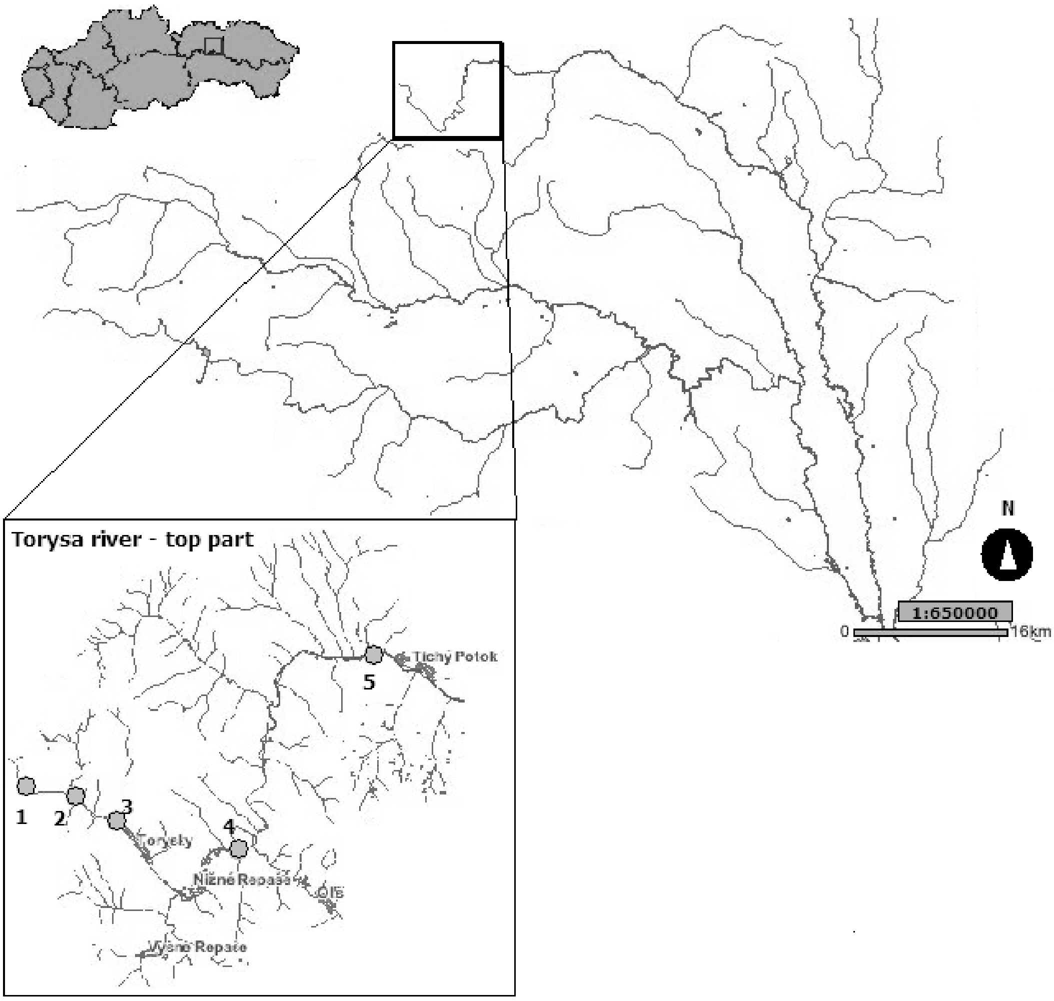

Figure 1: Map of the Torysa river and the studied area (boxed) with study sites (**O**).

Our research area runs from Tichý Potok village. The spring-area lies in MTA Javorina. The anthropogenic influences are minimized here (restrictions are enforced on wood-cutting) and the riverbanks are covered with wood. The next part of the river flows out of MTA, through Torysky and Nižné Repáše Villages. The anthropogenic influences occur here (mainly riverbed and riverbanks regulation/stabilisation, organic pollution). The surroundings environment is exploited as grassland and meadows, riverbanks are mostly not covered with woody plants. Under the meeting with Olšava brook the river flows through the MTA again. In this part has the landscape woodland-character like the highest part of drainage. Second rich left-side tributary is the Škapová brook meet Torysa in this section. Above the Tichý Potok Village the Torysa river definitely leaves the MTA.

According to Kux and Weisz (1964) Torysa is above the Tichý Potok village a sub mountain brook. The spring occurs in a territory with mean yearly temperature about 4 ºC. The mean yearly temperature increases up to 7 °C in the direction to the mouth. Mean yearly rainfall does 600 - 850 mm (Mazúr, 1980). The sample sites are situated in the upper part of the river (Tab. 1).

Excepting the site three the substratum was natural, according to flysh background and slope. The site three was different because of the riverbed (macro - and megalithal) and riverbanks (concrete „semi vegetation" panels) (Tab. 2).

Table 1: The sample sites characteristics.

Site	Location and specifications	Altitude	Coordinates	Shadowing	Mean width	Mean depth
No.		(m)	(WGS 84)	(%)	(m)	(m)
1	MTA	1050	49°06´27N	75	1.5	0.2
	under the spring		020°39´02E			
2	MTA	950	49°07´04N	90	3.5	0.25
	(wood-cutting)		020°38´58E			
3	above the Torysky Village	830	49°06´03N	70	3.5	0.4
	(fixed river -bed and -banks)		029°40´00E			
4	under the Nižné Repaše Village	730	49°06´01N	5	7	0.35
			020°43´22E			
5	MTA	530	49°09´03N	0	9	0.4

Table 2: The substratum characteristics: + present, ++ abundant, +++ very abundant, CPOM - coarse particulate organic matter.

Substratum	Site no.				
	1	2	3	4	5
megalithal	5%	5%	40%	0%	5%
macrolithal	40%	35%	20%	30%	30%
mesolithal	35%	35%	5%	25%	25%
microlithal	10%	15%	15%	20%	20%
akal	5%	5%	10%	15%	15%
psamal	5%	5%	10%	10%	5%
xylal	+++	++	+	+	+
CPOM	+	+	+	+	+

MATERIAL AND METHODS

Quantitative samples were taken in 2005 in monthly intervals; in this paper we operate only with the February, March, April, June and September samples. We took multireplicate samples from all presented microhabitats. The „Euro-net“ (frame 25 x 25 cm, mesh size 350 µm) was used and the partially sorted samples from 25 x 25 large squares were fixed used formalin. The determination and next processing were carried out in laboratory. We established the formalin body mass (weight) to compare our results with historical folders. We present only mean abundance and biomass in this paper. The autecological features we undertook from Šporka (2003) and the structural and quantitative features of communities are estimated according to Losos et al. (1985). We used mayflies and stoneflies species composition to calculation the saprobity indices.

Table 3: Abundance and biomass of macrozoobenthos.

Site no.	1		2		3		4		5	
Abundance / **B**iomass	A	B	A	B	A	B	A	B	A	B
Parameter	$ex.m^{-2}$	$mg.m^{-2}$	$ex.m^{-2}$	$mg.m^{-2}$	$ex.m^{-2}$	$mg.m^{-2}$	$ex.m^{-2}$	$mg.m^{-2}$	$ex.m^{-2}$	$mg.m^{-2}$
	%	%	%	%	%	%	%	%	%	%
Malacostraca	436	2289	271	1502	367	2778	186	911	124	651
	23.4	31.4	17.7	27.7	20.3	33.6	8.4	12.3	4.1	8.7
Ephemeroptera	1122	1861	882	1086	1023	2267	1502	3078	2139	3702
	60.1	25.5	57.6	20.1	56.5	27.4	68.2	41.4	70.7	49.4
Plecoptera	225	2233	258	1854	203	2594	261	1305	418	685
	12.1	30.6	16.8	34.2	11.2	31.4	11.8	17.5	13.8	9.1
Trichoptera	54	891	97	971	184	614	143	2119	224	2428
	2.9	12.2	6.3	17.9	10.2	7.4	6.5	28.5	7.4	32.4
Others	29	16	24	3	33	7	111	23	122	33
	1.5	0.3	1.6	0.1	1.8	0.2	5.1	0.3	4.1	0.4
Total	1866	7290	1532	5461	1810	8260	2203	7436	3027	7499

RESULTS

Ephemeroptera. The mayfly communities belong to four families (Baetidae, Heptageniidae, Leptophlebiidae and Ephemerellidae) and 14 species. The α-diversity (species richness) was equal on first two sites (five), decreased (three) on site three and at sites four and five were the highest values (eight on site four and seven on site five; Tab. 4). The mayfly larvae were significant on all sites (with 56.5 - 70.7 % proportion on gross abundance). Their contribution to biomass was generally lower and increased downstream. At sites one, two and three the values goes from 20.1 up to 27.4 % of the total biomass but at site four and five it was nearly double (41.4 and 49.4 %; Tab. 3). The mean values of the abundance varied between 882 ex. m^{-2} and 2139 ex. m^{-2} and the biomass varied in range from 1086 up to 3702 ex. m^{-2}. The tendency of growth downstream was higher by the biomass than by the abundance (Tab. 3). The representatives fall into the feeding types of grazers-scrapers and gatherers-collectors. There were only r-selection types in mayflies. The species composition indicated oligosaprobity.

Table 4: Mayfly species presence and frequency.

Site no.	1	2	3	4	5	
Species	Presence/Absence					Frequency
Baetis alpinus Pictet, 1843-1845	+	+	+	+	+	100
Baetis buceratus Eaton, 1870	0	0	0	+	0	20
Baetis melanonyx Pictet, 1843-1845	0	0	0	+	0	20
Baetis rhodani Pictet, 1843-1845	+	+	+	+	+	100
Baetis vernus Curtis, 1843	0	0	0	+	0	20
Ecdyonurus macani Thomas and Sowa, 1970	0	+	0	0	+	40
Ecdyonurus torrentis Kimmins, 1942	+	0	0	0	0	20
Epeorus assimilis Eaton, 1885	0	0	0	0	+	20
Heptagenia sp. juv	0	0	0	+	0	20
Rhitrogena iridina (Kolenati, 1859)	0	0	+	0	0	20
Rhitrogena semicolorata (Curtis, 1843)	0	0	0	0	+	20
Seratella ignita (Poda, 1761)	0	+	0	+	+	60
*Ephemerella mucronata (*Bengtsson, 1909)	+	+	0	+	+	80
Habroleptoides confusa Sartori and Jacob, 1986	+	0	0	0	0	20

Plecoptera. We found five families of stoneflies (Taeniopterygidae, Nemouridae, Leuctridae, Perlodidae and Perlidae) and 22 species in Torysa river. The species richness was almost equal (7 - 8 species) except site three with double (16) species (Tab. 5). Also the stoneflies were eudominant at all sites (11 % - 17 %). In contrast to the mayflies the ratio of the gross biomass decreased downstream (from 30 % to 9 %). The mean abundance fluctuated between 203 and 418 ex. m^{-2} and the values of biomass ranged from 685 up to 2594 mg. m^{-2}. The percentage of their biomass was always greater than the abundance-percentage except the site five (the lowest site; Tab. 5). The stoneflies represented (except a few species) r-selection types. They fall into the feeding types of the grazer-scrapers, collector-gatherers and predators. The observed species indicated xeno- or oligo-saprobity.

Malacostraca. The crustaceans (Malacostraca, Amphipoda) were relatively most abundant on site one (with 23 %) and the lowest relative abundance on site five (4 %). Their contribution to the total biomass was similar to the stoneflies (about 30 % on site 1 - 3, 12 % on site four and 9 % on site five). The frequency was (like the former orders) 100 % (Tab. 3). There were found two species of Amphipods: *Gammarus balcanicus* and *Gammarus fossarum*.

Trichoptera. Caddisflies composed from 3 % (site one) up to 10 % (site three) of total abundance and 7 % (site three) respectively 18 % (site two) of total biomass in the upper part and 30 % in the lower part. The occurrence-frequency was 100 % (Tab. 3). The major part of the Caddisflies belong to the families Rhyacophilidae, Hydropsychidae, Limnephilidae and Leptoceridae.

Other taxa. In the macroinvertebrate communities of Torysa river are present some other taxa too. Turbellaria, Nematomorpha, Mollusca, Oligochaeta, Hirudinea, Coleoptera, Chironomidae, Simuliidae and some others Diptera were found in the river. They were recendent or subrecendent mostly. The beetles (*Elmis, Limnius*) and Dipterans (Chironomidae and Simuliidae) had the highest frequency of the occurrence. The more infrequent taxonomical groups (Turbellaria - *Dugesia gonocephala*, Nematomorpha - *Gordius* sp., Mollusca - *Ancylus fluviatilis*) have frequency 40 %.

Table 5: Stonefly species presence and frequency.

Site No.	1	2	3	4	5	
Species	Presence/Absence					Frequency
Amphinemura standfussi (Ris, 1902)	0	0	+	0	0	20
Protonemura praecox (Morton, 1894)	+	0	+	0	0	40
Protonemura aestiva Kis, 1965	0	0	+	0	+	40
Protonemura intricata (Ris, 1902)	0	0	+	0	0	20
Nemoura cinerea (Retzius, 1783)	0	+	+	0	0	40
Nemoura marginata Pictet, 1835	0	0	+	0	0	20
Nemoura flexuosa Aubert, 1949	+	0	+	+	0	60
Brachyptera seticornis (Klapálek, 1902)	+	0	0	0	0	20
Brachyptera risi (Morton, 1896)	+	+	+	0	+	80
Perlodes intricatus (Pictet, 1841)	0	0	+	0	0	20
Perlodes microcephalus (Pictet, 1833)	0	+	+	+	0	60
Isoperla oxylepis (Despax, 1963)	+	+	0	0	+	60
Isoperla grammatica (Poda, 1761)	0	0	+	0	0	20
Isoperla sudetica (Kolenati, 1859)	0	0	+	0	+	40
Perla marginata (Panzer, 1799)	0	0	0	+	+	40
Leuctra armata Kempny, 1899	0	0	0	0	+	20
Leuctra inermis Kempny, 1899	+	+	+	0	+	80
Leuctra hippopus Kempny, 1899	+	+	+	+	0	80
Leuctra nigra (Olivier, 1811)	0	0	0	+	+	40
Leuctra rauscheri Aubert, 1957	0	0	+	+	0	40
Leuctra prima Kempny, 1899	0	+	+	+	0	60

DISCUSSIONS

We compare the biomass and abundance values with Kirka´s et al. (1981) historical data on the sites four and five (joint sites). The total macroinvertebrates abundance is on site four lower (2203 opposite to 2980 ex. m^{-2} by Kirka et al., 1981) and at site five higher (3027 to 1815 ex. m^{-2}) than before 24 years. The biomass values were at both sites lower (about 7500, Kirka et al. (1981) found 12500, resp. 11500 mg. m^{-2}). The differences may be due to data interpretation. We state the average abundance and biomass and Kirka et al. (1981) only values from May and July. In agreement with them, we established the sites one, three, four and five into category of middle-values biomass, only the site two into category of low-values biomass accordance to Albrecht (1959). This site (two) was disrupted through the wood-cutting and manipulation close to the streambed. At this site, decreased abundance and biomass was noted and increased number of unassuming species (more resistant to erosion and fine particulate organic matter and sediments e.g. Nemouridae).

The mayflies predominate over the others taxa in abundance, the same as to Kirka et al. (1981). Their abundance increased downstream similar to the results of Novikmec et al. (2007) from the East Carpathians streams. Different results showed the contribution of stoneflies. We found out that they were more abundant than the cadisflies and Gammaridae, which is different to the results of Kirka et al. (1981) on the same sites. They present also higher biomass and abundance values of Oligochaete and different results in the other subrecendent taxa. The biomass of single taxa-groups was also different from Kirka et al. (1981). We observed e.g. lower mayfly's biomass. The reason is the date of sampling. They sampled in May and July when are the mayfly nymphs most often biggest, short from the emergence. In opposite, the stoneflies biomass was in our results higher, because the prevailing early spring stonefly species completely emerged by the May sampling dates. The seasonality of temporal benthic fauna plays a very important role. However, our results show growth/fall abundance tendency for separate taxa groups. It is not visible in results from some other rivers (Curtean-Bănăduc and Bănăduc, 2007).

The frequency of the taxa groups was highest (100%) by Gammarids, mayflies, stoneflies, beatles, cadisflies and dipterans. This finding is similar to results of Manko and Koščo (2004) in the lower parts of Torysa river. The differences were marked by stoneflies (they found out the 50% frequency; the major part of stonefly species occurs in the top parts of streams) and by cadisflies and beatles (75 %). The differences between top- and lower part documents the presence of the others taxa (Hirudinea, Odonata and Heteroptera). Kirka et al. (1981) and Koščo et al. (1988) present similar results from the top part of Torysa river in frequency and taxonomic composition of the assembladges on the family and order levels.

The water quality is very good in this part of the river. The saprobic indices indicate oligosaprobity at all sites. The short section of regulated riverbed (site three) has no strong negative effect on the benthic communities. More significant is wood-cutting, manipulation and transport of the wood through the riverbed. On this locality, the value of saprobity index was three, a value determined in part by the effect of megalithal, riverbed-width reduction, oxygenation due to turbulences and high density of reophilous stonefly species with low individual saprobity index probably.

This MTA is not a „nature reserve" despite our expectations, it is not used as MTA, but wood-cutting (commercial exploatation and economically interests) a little devastate the land (and river bottom fauna). In accordance with the results of Williams et al. (2005), Risch (2004), Robinson (2004) and Quist et al. (2003) we found out, that in the military areas is the effect of human activities on aquatic communities analogous to macroinvertebrates occurred in civil areas streams. These authors explain it with similar effect of different activities. In MTA Javorina, the activities and disturbances are very similar to civil areas. Our results confirm also the deduction that endangered species don't occur more often in these territories than in civil areas.

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THE DYNAMICS OF METALS IN FISH FROM NISTRU AND PRUT RIVERS (MOLDOVA)

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KEYWORDS: Moldova, fish, Cyprinidae, Percidae, metal accumulation, pollution.

ABSTRACT

The patterns of the dynamics of trace element uptake for skeletal muscle, liver, gonads, skin and gills was evaluated in different species of *Cyprinidae* and *Percidae* fish from Nistru and Prut rivers and Dubăsari, Cuciurgan, Costeşti-Stânca reservoirs in accordance to different parameters. The investigated parameters were: species, age patterns, sex and the status of environmental conditions. The mechanism of self-regulation of the processes of accumulation and redistribution of trace elements among different organs in fish is controlled by assimilation and dissimilation processes. For example, during the last 15 - 30 days of the pre-spawn period the concentration of trace elements in gonads increased up to 2 - 6 times. Metals content in fish tissue varied within large limits. In the organs that were in direct contact with water, metal content was correlated with metal content in water and sediment (for fish skin and scales r = 0.62 - 0.87, while for gills r = 0.66 - 0.78). The distribution of trace elements content among organs demonstrated that as regarding to metal content liver was on the second place, storing most of the chemical elements, especially Cu, Fe, Co, Ni, Cd and Pb. The minimal metals content was recorded in muscles and gonads of fish.

RÉSUMÉ: Dynamique de l'accumulation des métaux dans les poissons des rivières Nistre et Prut (Moldavie, Europe).

Les modèles de la dynamique des accumulations des éléments trace dans les muscles squeletaux, le foie, les gonades, la peau et les branchies ont été établis pour des poissons des familles *Cyprinidae* et *Percidae* collectés dans les rivières Nistre et Prut, et les bassins d'accumulation de Dubăsari, Cuciurgan, Costeşti-Stânca en fonction de leur appartenance taxonomique, de l'âge, du sexe ainsi que de l'état de l'environnement. Les poissons possèdent des mécanismes d'autorégulation, des processus d'accumulation et de redistribution des éléments trace entre des différents organes par des processus d'assimilation et de dissimilation. Par exemple, pendant les derniers 15 - 30 jours avant la période de ponte, la concentration des éléments trace dans les gonades augmente de 2 à 6 fois. La concentration des métaux dans les tissus des poissons varie dans des limites assez larges. Dans les organes étant en contact direct avec l'eau, la concentration des métaux est proportionnelle à la concentration des métaux dans l'eau et les sédiments (pour la peau et les écailles r = 0,62 - 0,87, alors que pour les branchies r = 0,66 - 0,78). La distribution des éléments trace dans les différents organes montre le fait le foie se trouve à la seconde place, concentrant la plupart des éléments chimiques, plus particulièrement Cu, Fe, Co, Ni, Cd et Pb. Les concentrations les plus basses ont été retrouvées dans les muscles et les gonades des poissons.

REZUMAT: Dinamica metalelor în peştii râurilor Nistru şi Prut (Moldova).

Au fost stabilite legităţile dinamicii acumulării microelementelor în muşchii scheletici, ficatul, gonadele, pielea, branhiile peştilor din familiile Cyprinidae şi Percidae, din râurile Nistru şi Prut, cât şi din lacurile de acumulare Dubăsari, Cuciurgan şi Costeşti-Stânca în funcţie de apartenenţa lor taxonomică, particularităţile de vârstă, sex şi starea mediului de viaţă. Peştii posedă un mecanism destul de dezvoltat ce reglează procesele de acumulare şi redistribuire a microelementelor între diferite organe, în funcţie de metabolismul lor plastic şi generativ. De exemplu, în ultimele 15 - 30 de zile ale perioadei, precedând depunerea icrelor, concentraţia microelementelor în gonade creşte de 2 - 6 ori. Conţinutul metalelor variază în limite destul de mari. În organele peştilor, aflate în contact direct cu apa, conţinutul în metale este corelat cu concentraţiile lor în mediu de viaţă (pentru piele şi solzi r = 0,62 - 0,87, iar pentru branhii r = 0,66 - 0,78). Distribuţia microelementelor in diferite organe demonstrează că pe al doilea plan, se situează ficatul, în special după conţinutul de Cu, Fe, Co, Ni, Cd şi Pb. Concentraţiile minime sunt caracteristice pentru muşchii şi gonadele peştilor.

INTRODUCTION

At present the research on metal-trace element accumulation in fish is one of the most actual fields of study in ichthyology and ecology having theoretical and practical importance. Being one of the most significant steps in monitoring of ecological status of freshwater ecosystems, such studies are crucial and represent a good theoretical basis for developing of methods of intensification of fish growth and rational management of fish resources.

The trace element accumulation research in fish organs and tissue is undertaken in different directions: on the trace element accumulation capacity of aquatic organisms; on assessing the effect of trace elements on the development of fish during ontogenesis and establishing the main factors that influence accumulation of chemical elements in fish.

Due to environmental pollution, a large numbers of metals were included in the list of priority pollutants and for the purposes of protection of human and aquatic animal life, their concentration is regulated by different standards (Bestemianov and Krotov, 1985).

These facts and also the scarcity of information on the trace element composition in fish in aquatic ecosystems of Moldova stayed on the basis of current research.

The goal of this research was to investigate the accumulation dynamics of trace elements in organs and tissue of fish from Nistru/Dniester and Prut rivers and Dubăsari, Cuciurgan and Costeşti-Stânca reservoirs, these are principal water ecosystems from Moldova.

MATERIALS AND METHODS

The research was carried out during 1996 - 2007. Specimens of industrial valuable species of fish were mainly investigated: *Cyprinidae* and *Percidae*.

Samples were taken from Nistru and Prut rivers as well as from Dubăsari, Cuciurgan, Costeşti-Stânca reservoirs. Trunk muscles, skin and scales, gills, liver, gonads, blood and gut were analyzed in regard to biometrical indices. Mature and immature specimens were examined separately.

Trace elements were extracted according to Zolotov and Kuzmin (1982). Trace elements contents of the digest were determined by flame atomic absorption spectrophotometer using AA-S3 (Carl Zeiss) and X-rays fluorescent scanning spectrophotometer and Spectroscan-5 (Lomo). Minerals were quantified on the basis of peak areas and comparison with a calibration curve obtained with the corresponding standards (Hivezov and Tsalov, 1983; Semenov, 1977).

RESULTS AND DISCUSSION

Common species of icthyofauna in freshwater ecosystems of Moldova within *Cyprinidae* and *Percidae* were used in the current investigation and included: *Cyprinus carpio, Carassius auratus gibelio, Rutilus rutilus heckeli, Abramis brama, Aristichthys nobilis, Hypophtalmichthys molitrix, Ctenopharyngodon idella, Stizostedion lucioperca* and *Perca fluviatilis*. Cyprinids are of a main interest owing to their use in industrial fish farming.

The results of the current investigation indicated that the content of trace elements in fish fry belonging to the same age group collected from Cuciurgan, Dubăsari and Costeşti-Stânca reservoirs and Nistru and Prut rivers reflect the concentrations of elements measured in each freshwater ecosystems. The maximum concentrations of Mn was -3.0 µg/g wet weight, Ni - 2.4 µg/g, Pb - 1.1 µg/g, Mo - 2.2 µg/g, V - 2.1 µg/g, Cu - 2.9 µg /g, Zn - 32 µg/g, Cd - 0.25 µg/g, Cr - 0.54 µg/g wet weight was observed in fish fry of Cuciurgan reservoir.

The minimum concentrations of Zn - 13 µg/g, of Mn - 1.5 µg/g, of Cu - 0.9 µg/g and of Mo - 0.2 µg/g wet weight were observed in Dubăsari and Costeşti-Stânca reservoirs - while of Ni - 1.0 µg/g, Pb - 0.4 µg/g, V - 0.3 µg/g, Cd - 0.1 µg/g and Cr - 0.20 µg/g wet weight. The concentration in water of Ni (8.1 µg/l) and Pb (6.4 µg/l) in Cuciurgan reservoir was two times higher, Cd (3.2 µg/l) - around four times higher, V (9.4 µg/l) and Mo (14.5 µg/l) - 9 - 14 times higher than in Dubăsari and Costeşti-Stânca reservoirs.

Therefore, the analysis of results demonstrated that the level of trace elements and heavy metals accumulation in organs and tissue of immature fish collected from water ecosystems of Moldova reflected the dynamics of trace elements in water (Tab. 1).

Table 1: Average concentrations of trace elements in water (µg/l) and muscles (µg/g) wet weight of *Stizostedion lucioperca* with a body weight of 300 - 400 g, collected from Nistru and Prut rivers and Dubăsari, Cuciurgan, Costeşti-Stânca reservoirs.

	MN	CU	ZN	MO	V	NI	PB	CD
Nistru River								
water	31.6	9.1	21.5	1.6	1.8	4.7	3.8	0.9
muscles	1.52	1.84	14.6	0.21	0.22	0.87	0.68	0.17
Dubăsari reservoir								
water	28.6	7.2	18.8	1.3	1.6	3.6	2.9	0.8
muscles	1.16	1.14	12.0	0.23	0.27	0.74	0.52	0.12
Cooling reservoir Cuciurgan								
water	34.8	12.0	30.2	14.5	9.4	8.1	6.4	3.2
muscles	1.92	4.23	23.8	3.12	2.89	4.12	0.98	0.89
Prut river								
water	33.6	9.9	17.6	1.9	1.7	4.4	4.0	1.1
muscles	1.66	2.05	12.5	0.25	0.18	1.12	0.81	0.21
Costeşti-Stânca reservoir								
water	24.5	6.7	11.8	1.8	1.5	3.3	3.0	0.6
muscles	1.54	1.17	8.7	0.16	0.14	0.68	0.60	0.14

The analysis of trace element content in organs and tissue of sexually mature specimens of *Cyprinidae* and *Percidae* demonstrated that in the organs which were in direct contact with water, the trace element content is correlated with their content in water and sediment (for fish skin and scales r = 0.62 - 0.87, while for gills r = 0.66 - 0.78). Most probably in these organs the processes of elements accumulation from aquatic environment dominated.

Therefore, the sexually mature as well as juveniles posses a regulatory mechanism for chemical element uptake. However, there is no doubt that a linkage exists between trace element accumulation level in fish organs and that of the environment. In regard to the content of trace elements among organs, on the second place the liver was identified, storing most of the chemical elements, especially Cu, Fe, Co, Ni, Cd and Pb. The minimal metal content was recorded in muscles and gonads of fish (Figs. 1, 2, 3).

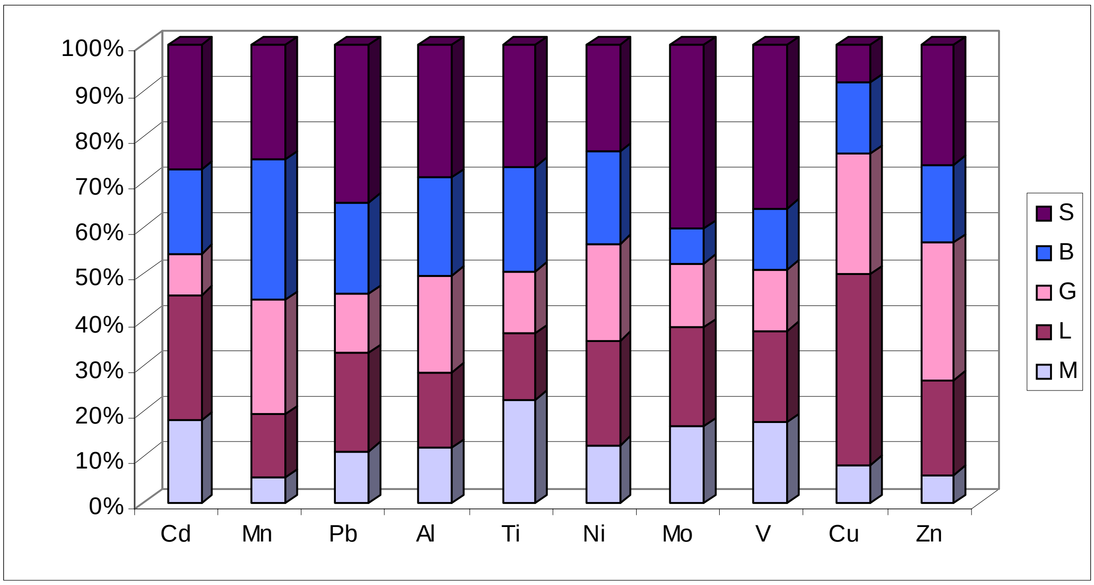

Figure 1: Ratio of average concentrations of trace elements in skin and scales (S), gills (B), gonads (G), liver (L) and skeletal muscles (M) of *Perca fluviatilis* from Nistru river.

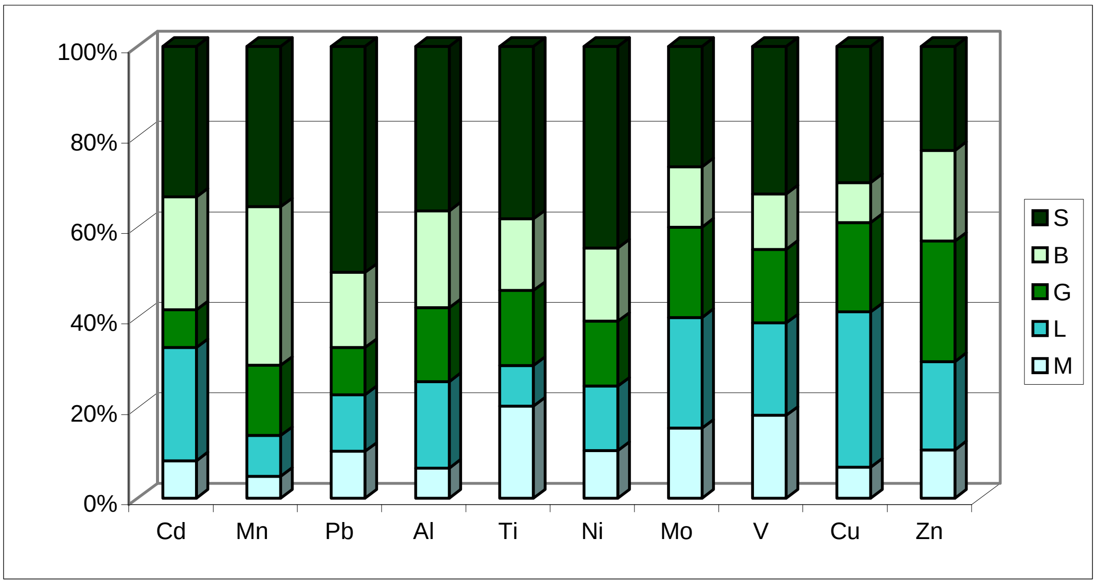

Figure 2: Ratio of average concentrations of trace elements in skin and scales (S), gills (B), gonads (G), liver (L) and skeletal muscles (M) of *Perca fluviatilis* from Prut river.

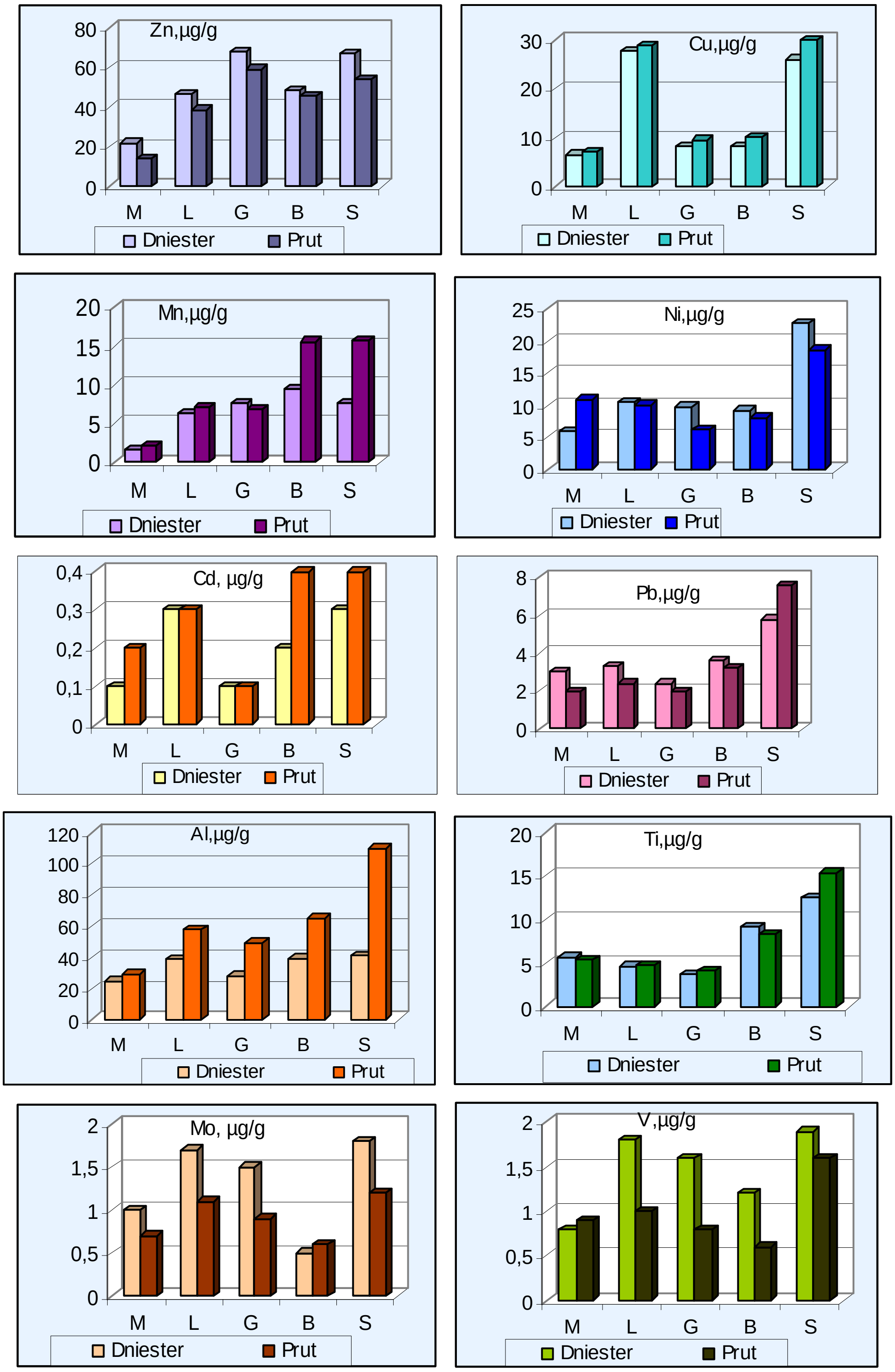

Figure 3: Trace elements concentrations in skin and scales (S), gills (B), gonads (G), liver (L) and skeletal muscles (M) of *Abramis brama* from Nistru and Prut river, µg/g of wet weight.

The results of the investigations on trace element accumulation in two age groups of *Cyprinus carpio, Aristichthys nobilis, Hypophtalmichyhys molitrix* of fish ponds demonstrated seasonal dynamics. In the majority of the cases, trace element content in fish muscles increased during summer and decreased during autumn. Seasonal patterns of trace element accumulation in organs and tissue of fish has been previously observed (Zubcov et all, 2001; Zitko and Carson, 1977; Zubcov, 2002; Moore and Ramamoorthy, 1987; Morozov and Petuchov, 1986) Dynamics of trace element accumulation is determined firstly by the growth rate of fish, which is the highest during summer. Farmer et al. (1979) observed an increase in the concentration of trace elements in fish during intense nutrition. Bodsha and Sainsbyry (1977) linked the accumulation level in fish body to their growth rate and the availability and application of fish feed.

The dynamics of trace element accumulation depend not only on seasonal variations, but also on other environmental factors (presence of pollutants, water temperature, food composition etc.) (Sapozhnikova et all., 2005). The deficit of dissolved oxygen in water also contributes to the redistribution of iron, cobalt and manganese, these elements being accumulated in gills and teguments.

The ichthyological samples of mature specimens in the current study were collected not only during specific seasonal periods, but also during spawning, pre-spawning and post-spawning periods, as the accumulation level of trace elements in mature fish depends on reproduction processes (Zubcov, 2002).

Concentrations of trace elements showed large variations within the same organ or tissue, sometimes the difference was of one - two orders of magnitude. For example, copper concentrations in *Abramis brama* collected during the same vegetation period in Dubăsari reservoir varied between 0.6 and 17.8 ug/g wet weight in muscle; between 8 to 47.6 µg/g in the liver, and between 0.3 and 54.0 µg/g in the gonads.

In the samples of *Carassius auratus gibelio* copper ranged between 0.4 - 14.3 in muscle, 1.5 - 58.0 µg/g in the liver and 1.6 - 37.8 µg/g in the gonads.

For *Rutilus rutilus heckeli,* trace element values varied correspondingly within the following range: 0.9 - 17.7; 1.0 - 52.9 and 1.3 - 27.7 µg/g wet weight respectively for muscle liver and gonad. These differences were conditioned by a complex of factors and influenced by the generative metabolism of fish.

The dynamics of trace element accumulation in the tissues and organs of sexually mature fish demonstrated that during the pre-spawning period the quantity of biologically important trace elements (Zn, Cu, Co, Mn and Mo) in fish gonads steadily increased. In the gonads of younger female carp and herbivorous fish species the concentrations of biologically important trace elements was higher than in mature females, while those of toxic elements - lower.

At the same time, the content of Zn, Cu, Mn, Mo, Ni, Pb and Cd in male gonads was 1.5 - 2.4 lower than in the female gonads; the exception being only Co - whose concentration was slightly higher than in females (Tab. 2).

The linear and weight parameters of fish gonads were undergoing dramatic changes throughout their life cycle. In order to elucidate the trace element balance in accordance to the generative metabolic activity of fish, the absolute values of trace element content in gonads during pre-spawning and fattening periods should be taken into consideration (Tab. 3).

Table 2: Concentration of trace element in gonads of *Cyprinus carpio* and *Aristichthys nobilis* collected from fish farm, using water from Nistru; µg/g wet weight.

Fish species	Age, years	Mn	Zn	Co	Cu	Mo	Ni	Pb	Cd
Cyprinus carpio ♀	3	3.4	15.6	1.2	3.2	1.2	1.5	0.4	0.10
	6	2.1	7.9	0.3	2.3	0.6	1.0	0.5	0.18
Cyprinus carpio ♂	3	2.	13.2	1.6	2.7	1.0	1.3	0.3	0.08
	6	1.4	5.7	0.7	2.0	0.3	0.5	0.5	0.12
Aristichthys nobilis ♀	5	4.8	24.0	1.5	4.0	1.4	2.2	0.6	0.13
	8	3.6	16.0	0.8	2.1	0.8	1.5	0.8	0.19
Aristichthys nobilis ♂	5	4.0	24.1	1.9	4.8	1.9	2.6	0.6	0.14
	8	2.9	17.8	1.1	2.8	1.0	1.8	0.9	0.22

Table 3: The absolute content of trace element in fish gonads from accumulation reservoir Dubăsari: 1 - during spring and pre-spawning period, during stage IV - V; 2 - summer-autumn, during stage II - III of hometogenesis , µg/g wet weight.

Body weight/ gonad, g	*Abramis brama*		*Rutilus r. heckeli*		*Carassius a. gibelio*		*Cyprinus carpio*	
	1	2	1	2	1	2	1	2
	780/180	755/48	560/132	510/36	780/114	755/30	1200/350	1250/105
Fe	2780	250	3140	248	3920	318	2980	165
Mn	760	77	705	68	775	39	790	52
Al	1840	344	2810	286	4850	344	3710	406
Zn	2560	142	2510	146	2530	124	2730	162
Co	34.5	2.8	44.5	1.6	40.7	2.1	48.0	1.9
Cu	880	72	840	67	1650	110	1420	74.5
V	66.2	5.2	59	7.6	55.3	7.1	77.0	5.6
Mo	80.2	5.6	90.2	7.3	79.1	7.3	88.1	6.8
Ni	620	73	960	68	570	59	588	72.3
Pb	66.6	28.9	116	37.2	58.2	18.9	63.2	22.1
Cd	5.9	2.7	6.5	2.8	7.2	3.5	5.2	2.8

These results indicate that the absolute content of trace elements in fish gonads during pre-spawning periods increased up to 9 - 25 times. These indices confirm that fish gonads accumulate a considerable amount of trace elements (Evtushenco, 1985; Vinicov et al, 1980) and suggest fish possess a well-developed mechanism of self-regulation of accumulation and redistribution of trace elements among different organs in accordance to the requirements of generative metabolism. The concentration of trace elements in gonads during 15 - 30 days of the pre-spawning period increased two-six times. The content of trace elements in skeletal muscles of fish do not exceed threshold concentrations, with the exception of Ni, Pb and Cd content in mature specimens of fish from Cuciurgan reservoir.

CONCLUSIONS

Therefore, trace elements accumulation processes in different organs and tissue of immature and sexually mature fish are very complicated and diverse and are influenced both by a complex of factors of the living environment and by the taxonomical, age and physico-biochemical characteristics of fish species. The current results demonstrate the scientific and practical need for a continuous monitoring of the dynamics of accumulation of trace elements in organs and tissue of fish according to specific regions.

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IMPORTANCE OF FLOODPLAINS AND FLOODPLAIN WETLANDS ALONG THE LOWER DANUBE WITH SPECIAL REGARD TO PHYTODIVERSITY

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KEYWORDS: Danube, floodplains, hydrological regime, floodplain functions, ecological gradients, flood tolerance, water dependent biocoenoses, floodplain phytodiversity.

ABSTRACT

Floodplains, i.e. lowlands along the river, are characterized by a complex framework of ecological effects that depend on the dynamics of discharge and on changing water levels. The hydrological regime is responsible for a morphological dynamic with erosion and sedimentation, for sediment and nutrient transport, organisms exchange between river and floodplains based on longitudinal and lateral connectivity and also for the dynamic of flora and fauna. Floodplains dispose of relevant hydrological, biogeochemical, ecological and socio-economic functions.

The periodical changes between high and low water levels, between floods and dry periods, provide conditions to a great number of water-dependent, dynamic life communities. Regarding the repartition of life communities along the ecological gradients, the determinant factors are water level height, duration, seasonal occurrence and frequency of floods. Due to this fact the Danube floodplains comprise a large diversity of varying macro and microhabitats with numerous niches for different species. The communities composition is changing both from the upstream to the downstream river stretches and between river and floodplain borders.

The Lower Danube between the Iron Gate and the Danube Delta comprises larger floodplains as compared to the Danube River stretches situated upstream. In the past these floodplains covered about 540.000 ha, but subsequent to the construction of hydro-technical works large areas were cut off from the river dynamics. The “Balta”, as it is called in Romanian or “blato” in Bulgarian, is formed by a complex of large water-bodies i. e. floodplain lakes, smaller water courses, called “gârla” or “prival”, broad wetland areas covered with reeds and mace reed and last but not least the dry areas. Around the mean water level are growing gallery-like white willow forests frequently mixed up with black and white poplar. These forests are relatively flood-tolerant and endure longer flood periods. Transition stands can be found on higher situated sites. Besides the softwood forest species, such as the above-mentioned poplars, they do comprise other species as well, e.g. elms (*Ulmus laevis, U. carpinifolia*). On the highest peaks of the floodplains one may also find elm, ash and oak (*Quercus robur*, *Q. pedunculiflora*) stands, the latter being very rare. These hardwood forest species are flood-tolerant to some extent, even though for shorter periods as compared to the willow stands. During low water periods (i.e. below the mean water level) numerous ephemeral pioneer communities emerge along the river banks (Nanocyperion, Chenopodion rubri). The ecological evaluation study shows a high biodiversity including species and habitats of great importance for the Natura 2000 network. They prove the need to safeguard the high natural values and by the way the imperativeness to restore the loss of functions and values of the Lower Danube floodplains.

RÉSUMÉ: Importance des plaines alluviales et de leurs zones humides le long du Danube inférieur, en considérant particulièrement la phytodiversité.

Les plaines alluviales qui longent les fleuves sont caractérisées par leur fonctionnement écologique dépendant aussi bien de la dynamique de l'écoulement que des fluctuations du niveau d'eau. Le régime hydrologique est à la base de la dynamique morphologique avec érosion et sédimentation, il implique l'échange d'organismes entre le fleuve et ses plaines alluviales dû à la connectivité longitudinale et latérale ainsi qu'une dynamique de la flore et de la faune. Les plaines alluviales disposent de fonctions élémentaires du point de vue hydrologique, biogéochimique, écologique et socio-économique.

Les fluctuations périodiques entre les niveaux d'eau élevés et bas, entre inondations et périodes sèches fournissent des conditions idéales pour grand nombre de biocénoses aquatiques dynamiques. En considérant la répartition des biocénoses le long de gradients écologiques, on s'aperçoit que les facteurs déterminants sont la hauteur du niveau d'eau, la durée, l'occurrence saisonnière et la périodicité des inondations. Les plaines alluviales du Danube hébergent une grande diversité de micro-biotopes et macro-biotopes comprenant de nombreuses niches pour toutes sortes d'espèces. La composition des communautés varie entre cours supérieur et inférieur du fleuve aussi bien qu'entre fleuve et bordure des plaines alluviales.

Le Danube inférieur situé entre la Porte de Fer et le Delta du Danube comprend des plaines alluviales bien plus vastes par rapport aux sections du Danube situées en aval. Autrefois ces plaines alluviales couvraient une surface d'environ 540 000 ha, mais suite à la construction de centrales hydro-électriques, de grandes régions ont été coupées de la dynamique fluviale. La "Balta" comme l'appellent les Roumains ou "Blato" en Bulgare est constituée par un réseau de grands plans d'eau, c'est-à-dire de lacs alluviaux, de petites rivières appelées "gârla" ou "prival", de zones humides étendues recouvertes de roseaux et de typhas ainsi que de zones sèches. A hauteur du niveau d'eau moyen on trouve des forêts-galeries composées de saule blanc, souvent associé avec du peuplier noir et du peuplier blanc. Ces forêts résistent bien aux inondations et peuvent supporter des périodes d'inondation assez longues. Des sites transitoires peuvent être trouvés dans des endroits plus élevés. Ils comprennent, outre les espèces des forêts alluviales à bois tendres comme les peupliers mentionnés, également d'autres espèces, comme par exemple des ormes (*Ulmus laevis, U. carpinifolia*). Sur les sites les plus élevés des plaines alluviales on trouve des ormes, du frêne, des chênes (*Quercus robur, Q. pedunculiflora*), ces derniers survenant assez rarement. Ces forêts alluviales à bois durs peuvent résister aux inondations, bien que moins longtemps que les peuplements de saules. Pendant les périodes d'étiage (niveau d'eau inférieur au niveau moyen) on perçoit de nombreuses biocénoses pionnières éphémères surgir le long de la rive (Nanocyperion, Chenopodion rubri). L'étude d'évaluation écologique montre une grande biodiversité avec des espèces et des habitats d'intérêt communautaire (au titre de Natura 2000). Ces espèces prouvent que la protection de ce patrimoine naturel majeur s'avère très importante et qu'il est impératif de restaurer la valeur et les fonctions écologiques perdues dans les plaines alluviales du Danube inférieur.

REZUMAT: Importanța luncilor şi a zonelor lor umede de-a lungul Dunării inferioare, cu privire specială asupra fitodiversității.

Luncile sunt caracterizate printr-un complex de interrelații, dependente de dinamica debitelor şi dinamica nivelelor de apă. Regimul hidrologic este responsabil pentru morfodinamica cu eroziune şi depunerea sedimentelor, pentru transportul sedimentelor şi a nutrienților, schimbul de organisme dintre râu şi luncă, bazat pe conectivitate longitudinală şi laterală şi de asemenea pentru dinamica florei şi a faunei. Luncile îndeplinesc importante funcții hidrologice, biogeochimice, ecologice şi socio-economice.

Schimbul periodic între ape mari şi ape scăzute, între inundaţii şi perioade de uscăciune, crează condiţii favorabile pentru existenţa a numeroase biocenoze dinamice, dependente nemijlocit de dinamica apelor. Factori determinanţi pentru repartizarea biocenozelor de-a lungul unor gradienţi ecologici sunt înălţimea stratului de apă, durata nivelelor mari, sezonul şi periodicitatea inundării. Datorită acestui fapt, lunca Dunării cuprinde o mare diversitate de macro- şi microhabitate cu numeroase nişe pentru diferite specii. Componenţa comunităţilor se schimbă din amonte în aval şi în secţiune transversală de la râu spre marginea luncii.

Între Porţile de Fier şi Delta Dunării, Dunărea inferioară este însoţită de o luncă foarte largă comparativ cu sectoarele situate în amonte. Înainte de amenajare, această luncă inundabilă avea o suprafaţă în jur de 540.000 ha. După efectuarea lucrărilor de amenajare a luncilor Dunării inferioare, suprafeţe întinse ale acestora au fost deconectate de dinamica fluviului. Balta era şi mai este în anumite părţi constituită dintr-un complex de diferite tipuri de ape şi anume lacuri de luncă (iezere), mici cursuri de apă numite gârlă sau prival, suprafeţe întinse de zone umede cu stuf şi papură şi zone de uscat. Deasupra nivelului mediu al apei, cresc păduri de tip galerie de salcie albă, deseori, în amestec cu plop alb şi plop negru. Aceste zăvoaie sunt tolerante faţă de inundaţii îndelungate. În locuri puţin mai înalte se dezvoltă păduri de tranziţie. Pe lângă esenţe moi încep să apară esenţe tari cum sunt specii de ulm (*Ulmus laevis, U. carpinifolia*). În locurile cele mai înalte ale luncii, se dezvoltă grupări cuprinzând pe lângă speciile de ulm şi frasin, specii de stejari (*Quercus robur*, *Q. pedunculiflora*), cele din urmă destul de rare în prezent. Esenţele tari sunt şi ele tolerante faţă de inundaţii într-o oarecare măsură, dar mai puţin faţă de zăvoaiele de sălcii. În timpul perioadelor de etiaj se dezvoltă pe malul apei comunităţi de specii efemere, pioniere (Nanocyperion, Chenopodion rubri). Studiul de evaluare ecologică efectuat în lunca Dunării inferioare demonstrează marea biodiversitate de specii şi habitate importante pentru reţeaua Natura 2000. Acest potenţial natural încă existent impune măsuri de conservare şi în acelaşi timp măsuri de refacere a funcţiilor şi a valorilor pierdute.

INTRODUCTION

Interest and functions of the floodplains

Floodplains, i. e. the lowlands situated along the river, are submitted to regular floods if they are left in natural conditions and are connected to the river dynamics. A determining factor of the floodplain ecosystem is the hydrological regime with periodical changes between high and low water levels. The hydrological regime (dynamics of discharge and dynamics of the water levels) is responsible for a morphological dynamics with erosion and sedimentation, with sediment and nutrient transport, exchange of organisms between river and floodplain based on the longitudinal and lateral connectivity as well as for the dynamics and diversity of flora and fauna (Dister, 1994).

Hydro- and morphodynamics are both responsible for changes in habitats and the creation of new macro- and microhabitats. The variety of macro- and microhabitats also depends on duration, height, seasonal occurrence and frequency of floods that are determinant for all ecological changes in the floodplains. Due to the complex framework of ecological effects the floodplains fulfill important hydrological, bio-geochemical and ecological functions. These again imply further relevant socio-economic functions (Schneider, 2002). Floodplains do also fulfill basic ecological functions as habitat for plants and animals (spawning, feeding, nesting grounds etc.), reservoir of biodiversity and storage for genetic resources, as a biocorridor for genetic exchanges and as places for a high bio-productivity.

Both in the longitudinal and in the lateral section the alignment of the biocoenoses follows ecological gradients. From the upstream section of the Danube River to its lower part the repartition of floodplain habitats/plant communities have commonalities, but differences as well that are related to discharge, slope of the river, climate conditions (from west to south-east) and grain size of the sediments. In the cross section of the river and its floodplain (transversal profile), from the mean water level to the highest peaks of the floodplains the repartition of species and habitats follows ecological gradients and is strongly related to the hydro and morphodynamics as well as to the flood tolerance of the species (Schneider, 2003a).

Given that flow velocity may dramatically change depending on space and time, material of varying grain sizes frequently sediments adjointly or superposedly. Accordingly changing site conditions arise on a small scale, allowing the settlement of varying species and biocoenoses in a similarly interdependent small-scale mosaic. Dependent on the river section, sediments occur in differing fractions: in the headwaters rather in the gravel and coarse sand fractions, in the middle and lower reaches of the Danube River rather in the fine sand and clayey-silty fractions. Both the site dynamics and the related dynamics of the biocoenoses with their specific flora and fauna point out the broad spectrum of floodplain sites.

The Lower Danube - a complex river and floodplain ecosystem

On its lower stretch downstream the Iron Gate, the Danube disposes of broad floodplains called “Balta”(RO) or “Blato” (BG), a complex ecosystem composed by waters, wetlands and dry lands, including the river with numerous islands, islets and banks (“grind de mal”), local dunes (e.g. between Ciuperceni and Desa, near Bechet-Balta Luminoasă, at Dăbuleni), lakes and floodplain water courses, the so called “gârla” or “prival”. Gallery-like floodplain forests become apparent along the borders and on the islands. Whereas broad and extended floodplains with numerous floodplain waters occur along its left border, they are usually much less extended along the right border of the Danube River or are even completely missing, given that in some places the Bulgarian Chalk Table Mountains reach right down to the Danube River border or even extend right into the river bed.

Loss of floodplains and consequences

The Lower Danube’s morphological floodplain comprises an area of 7862 km^2 (786.200 ha). In its original condition it has been flooded periodically and this Balta-complex, a characteristic landscape of waters, was famous for its abundant fish fauna. The cutting-off from the river gave birth to a much smaller, recent and presently still flooded floodplain, covering an area of 2200 km^2 (220.000 ha). Considering the upstream stretches, the loss of floodplains (including the loss of functions and values) is also remarkable: Upper Danube 95 %, Central Danube 75 % and Lower Danube 72 % (WWF DCP and WWF Auen-Institut, 1999; Schneider, 2002). Despite of a large-scale loss in flood prone areas on the Lower Danube, one may still find larger floodplain areas on some stretches that are subject to immediate dynamics of the Danube River, e.g. the so-called ‘Balta Geraiului’ upstream the Olt mouth (Schneider, et al. 2004). Besides the remaining areas of recent floodplains, the numerous Danube islands, many of them are still showing fairly natural conditions, are of great importance.

The cutting-off of large floodplain areas from the dynamics of the river led to a loss of characteristic floodplain habitats and their many hydrological, biogeochemical and ecological functions, which means for example: loss of water retention areas, loss of natural filtering, loss of natural habitats for organisms and going along with this the loss of spawning places for migratory fish and a drastic decrease of fish populations in the Danube Delta (Staraş, 1998). The loss of habitats and natural functions also led to a loss of natural, useable resources and, going along with this, to the loss of the floodplain’s vital socio-economic functions.

In the recent floodplain and in the floodplain that has been cut-off, the so-called former floodplain, one may still find near-natural habitats that may, given their diversity of structures and their very specific species serve as a basis for an evaluation. In its turn, this evaluation might serve as a starting point for further fundamental protection and restoration measures.

The recent floodplain (river with islands and area between river bank and flood protection dyke) comprises old river branches, oxbow lakes, temporarily dry flood channels, new sediment depositions that are free for pioneer settlings, softwood stands of different age classes (Schneider, 2003b), relicts of hardwood floodplain forests on natural high river bank levees (partly with high structural diversity) and relict areas of extensively used floodplain meadows. The latter have almost completely disappeared along the Lower Danube.

In the old floodplain cut-off by dykes from natural floods, one may find remainders of wetlands, small water courses, old flood channels, wet depressions, fallow lands, grasslands (mostly used for grazing), agricultural land as well as small patches of forests and bushes. These were left over after the drainage measures and transformation into arable land.

To get a general idea of the still existing Danube floodplain values, an evaluation of the whole Danube floodplains has been conducted within the frame of a GEF-project with regard to the ecological and restoration potential. The Lower Danube has been in the main focus of this project (WWF DCP and WWF-Auen-Institut/WWF Germany, 1999; Schneider and Günther-Diringer, 2004). The study served as a general basis for the nomination and designation of a Lower Danube Green Corridor, the Lower Danube countries Romania, Bulgaria, Moldavia and Ukraine having reached an agreement on the Green Corridor with the support of WWF on June 5th 2000. This Lower Danube Green Corridor is a large-scale initiative for the designation of an ecologically functioning biocorridor consisting in a network of protected areas, planned protected areas and restoration areas.

MATERIALS AND METHODS

For the evaluation of the ecological conditions and a possible restoration, indicator species and habitats not only of the Lower Danube but of the whole Danube have been analyzed. Major concern was put on characteristic and site-specific species (plants and animals), serving as indicator species for the dynamics (water level fluctuation, morphodynamics), nutrients and nutrient dynamics, water quality, habitat/vegetation structure (with different layers). As plant species and site-specific plant communities reflect the structure of the habitats, they may be considered as a basis for evaluation.

Inventory of floodplain biodiversity

The Danube river stretch between km 501 - 521 has been in the focus of a project on the biodiversity of the Danube floodplains. This project has been conducted during the vegetation period within the frame of a PHARE program. The pilot study was aimed at the completest possible collection of biodiversity data in the recent floodplain between river km 501 - 521 where the whole river section, the islands of Cama, Dinu and Păsărica, the river itself as well as the recent floodplain up to the dyke have been submitted to careful examination. Lower and higher plants in the aquatic and terrestrial area have been recorded, plant communities as well as various zoocoenosis' (macrozoobenthos, fish, molluscs, insects, butterflies, Carabidae, Stauhylinidae, Heteroptera, Orthoptera, Diptera, Arachnida, amphibians, reptiles, birds and mammals). Based on comprehensive studies that proved its high site-specific biodiversity, the Cama-Dinu area has been nominated as nature protection area and has lately been approved as such by order of the Romanian government number 1143 of September 18th 2007. The second part of the project comprised an evaluation based on indicator species along the whole Romanian Danube River starting downstream the hydropower station Porțile de Fier II (Iron Gate) at river km 838 to Călăraşi, river km 383.

While gathering data on species and habitats to provide the basis of the actual conditions and for evaluation, the following listings have been compiled: inventory of plant species in the pilot area Cama-Dinu and the Green Corridor area between river km 838 and 383 (as complete as possible); inventory of plant and animal species included in the annexes of the FFH Directive; species included in other international conventions; species included in national and international red lists; species with biogeographical importance; site-specific, characteristic species; inventory of habitats in the pilot area (complete) with habitat mapping; inventory of significant Natura 2000 habitats in the Green Corridor area.

RESULTS

The results of the biodiversity study with special regard to phytodiversity (habitats and plant species) and conservation relevance

When gathering the data on phytodiversity both the aquatic and the terrestrial species and habitats have been considered. For the aquatic habitats 18 water macrophyte species have been determined in the Cama-Dinu pilot area, for the Green Corridor between Calafat and Călăraşi, i.e. river km 838 - 383, the number of water macrophytes species was of 55. In the Cama-Dinu pilot area the aquatic macrophyte species are restricted to the Saica lake area, a former Danube River branch, to a few flood channels and depressions, mainly to temporary water bodies. Among them a number of significant Natura 2000 species could be found (see appendix II of the FFH Directive) such as: *Marsilea quadrifolia, Aldrovanda vesiculosa* and *Caldesia parnassifolia,* all three of them representing rarities on the Lower Danube. Among the aquatic plants a few other rare species such as *Najas minor, Utricularia minor* and *Utricularia vulgaris* could be found, each of them being mentioned in the Red List of Romanian Flora (Oltean et al., 1994). Species such as *Trapa natans* and *Salvinia natans* are listed in the annexes of the Bern Convention. The loss of water surfaces in the Romanian Danube floodplain implied a dramatic decrease of its aquatic vegetation.

The species samplings in the amphibian and terrestrial habitats showed the results:

- Mycophyta seven species (only species living on wood in the floodplain forest);
- Bryophyta seven species in the Cama-Dinu area, characteristic for floodplains and 17 mosses in the Green Corridor area, though it has to be mentioned that mosses occur rarely in floodplains in general.
- 296 species of Pteridophyta and Spermatophyta in the pilot area of Cama-Dinu;
- 906 species in the Lower Danube Green Corridor between Calafat and Călăraşi (Păun, 1967; Popescu, 1971; Popescu and Sanda, 1974; Schneider and Dihoru, 2004; Tsonev, 2001; WWF-Auen-Institut, 2001). The species listed both comprise species resulting from our own field investigations and from data gathered within the frame of other projects and studies published. The highest number of plants is given for the area of Greaca, including the whole area of the former Balta Greaca and also the border of the terrace (Popescu, 1971). The list of plants of the Lower Danube floodplain includes the whole range of floodplain-specific species, from the lowest levels around mean water level to the highest sites on the river levees and, in some stretches, large dune areas (Ciuperceni-Desa). This is why the list also contains numerous xerothermic species that are characteristic of dune areas. Besides the more common species, the list of plants of the Lower Danube stretch between river km 838 - 383 (Fig. 1) contains a large number of species that are of note from an ecological point of view as they are both characteristic for the Lower Danube floodplains and of biogeographical relevance. These are

among others *Asparagus pseudoscaber, Armoracia macrocarpa, Clematis integrifolia, Euphorbia lucida, Periploca graeca, Veronica longifolia, Galium rubioides, Vicia biennis, Glinus lotoides, Quercus pedunculiflora, Lathyrus latifolius* and *Ranunculus illyricus*.

Armoracia macrocarpa, Caldesia parnassifolia, Corispermum marschalii, Glinus lotoides, Trifolium angulatum and *Trifolium ornithopoides* are threatened species. A large number of species, such as *Convolvulus elegantissimus*, *Heliotropium supinem, Hypericum rumelicum, Leucojum aestivum, Lindernia procumbens, Ranunculus millefoliatus, Salvia sclarea, Trifolium subterraneum* and *Zingeria pisidica* are endangered species.

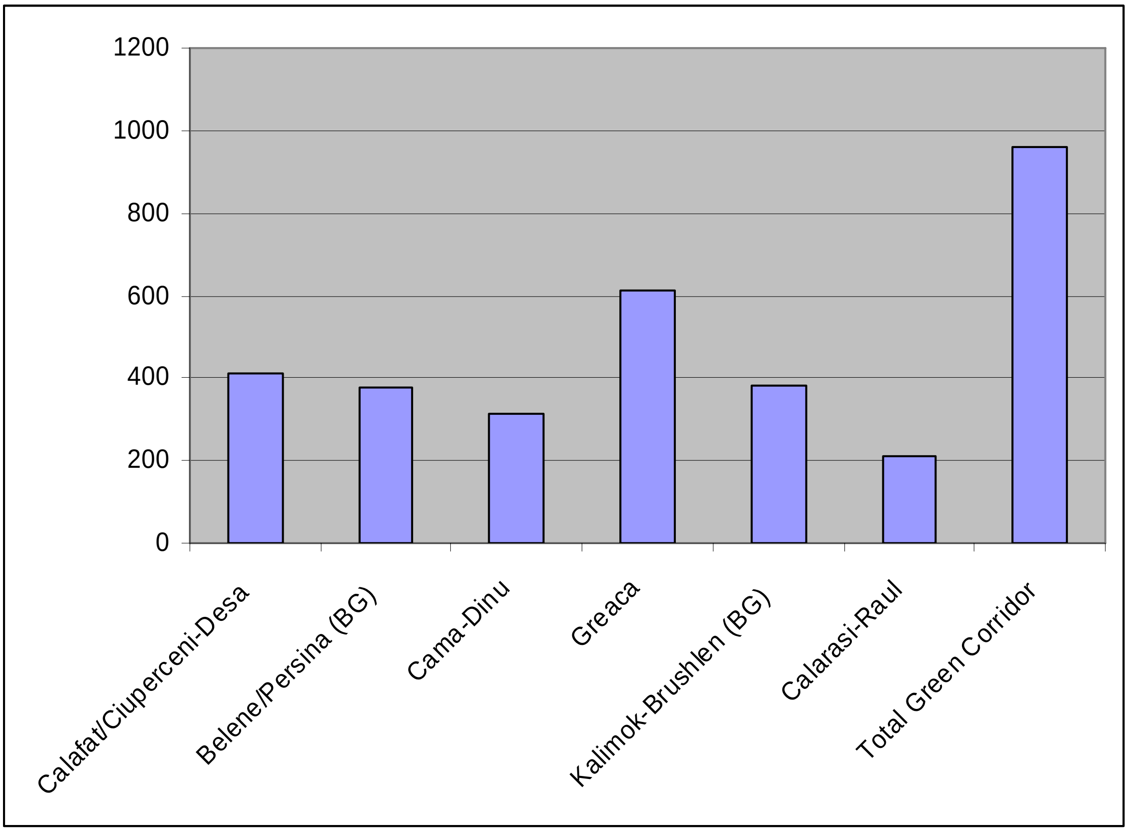

Figure 1: Plant species numbers in the Green Corridor between river km 838 - 383.

Besides the registration of flora in the aquatic, amphibian and terrestrial area, i.e. an area which is subject to periodical floods, a habitat mapping has also been realised in Cama-Dinu area (2400 ha) and all habitats have been recorded (Schneider et all., 2004). The habitats of this area are listed in the table 1. The percentage of near-natural floodplain forests is relatively low as compared to the hybrid poplar plantations dominating with 40, 46 %. This is due to the fact that broad near-natural softwood and hardwood floodplains have been transformed into monocultures. From a conservative point of view it is namely this repartition of habitats that should serve as starting point for a rebound to retransform the anthropogenic and species-poor poplar monocultures into species-abundant and well structured floodplain forests.

Table 1: Habitat surfaces in the Cama-Dinu pilot area (Giurgiu County).

1.	Flood channels and depressions (temporarily dry)	2.41%
2.	Temporarily flooded river banks, partly with pioneer vegetation	3.59%
3.	Riparian gallery-like white willow forest	6.43%
4.	Riparian forest of black and white poplar with white willow (in different proportions)	7.89%
5.	Riparian forest of black and white poplar	8.45%
6.	Riparian forest of black and white poplar with hardwood species, mainly elm / transition forest	11.56%
7.	Riparian mixed forest with elm, oak and black poplar	4.55%
8.	White willow plantation on natural sites of willow-poplar forest habitats	4.12%
9.	Hybrid poplar plantations on sites with white and black poplar and riparian hardwood forest sites	40.46%
10.	Clearings with mixed tall herbaceous and shrub habitats	0.93%
11.	Alluvial meadows	2.94%

While considering single plant communities along ecological gradients it may be established that these show different species abundances. Individual evaluations may lead to the wrong conclusion that the floodplain habitats are poor in species. The low number of species forming a plant community applies, aside from aquatic plant communities, to pioneer communities, creeping bent grasses and white willow stands (Fig. 2) that grow in proximity of the waters and are composed of very specific species that have adapted to long-time flooding periods. However, when regarding the mosaic of plant communities occurring along the ecological gradients in a dynamic floodplain as a whole, an altogether high biodiversity may be determined which is namely the result of the floodplain ecosystem dynamics.

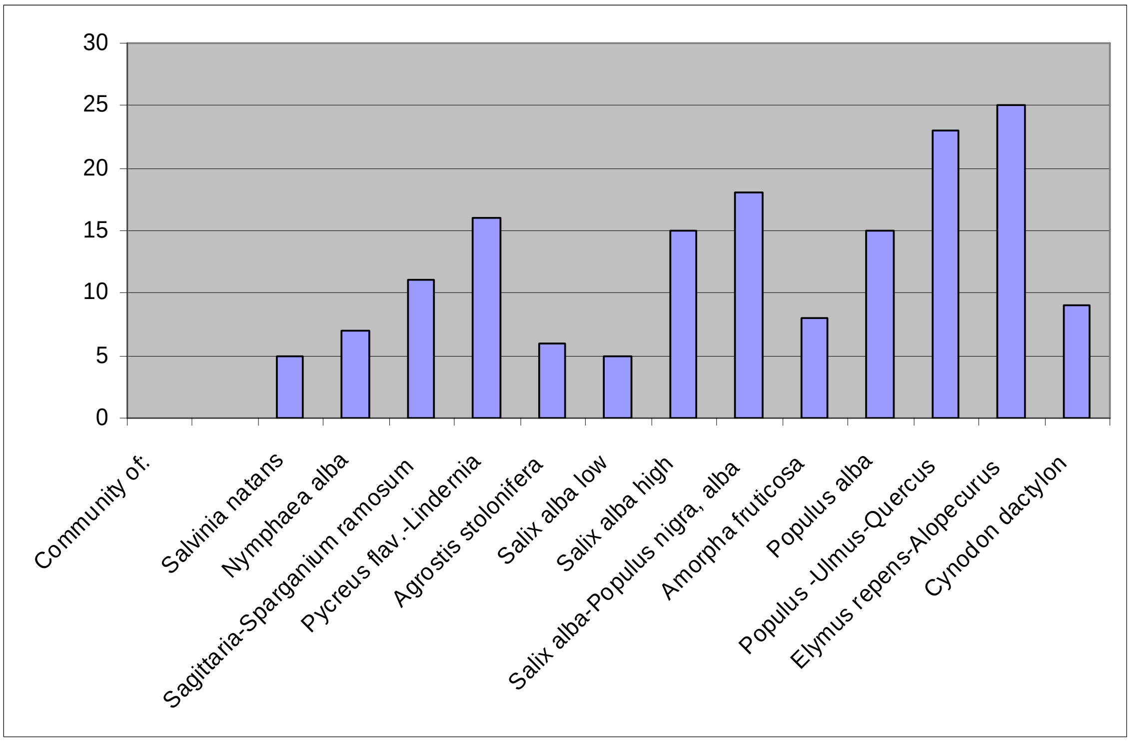

Figure 2: Species number in plant communities following a transect from low to high levels of the floodplain (area of the Cama-Dinu Nature Reserve/Giurgiu County).

In the Green Corridor, between river km 838 - 383, near-natural and representative habitats and most of all those habitats that are relevant with respect to Natura 2000 have been registered. The results of the Green Corridor habitat inventory show a large range of habitat types. Together with the relevant Natura 2000 species they form the basis for the proposal of Natura 2000 areas to be designated in the Lower Danube Green Corridor. The habitat types to be considered are the following:

Atlantic and continental salt marshes and salt meadows

1340: Inland salt meadows (near mouth of Jiu river)

This habitat type occurs on several floodplain sites of the Lower Danube. We could thus find e.g. saline spots in the area of Desa (dune area Ciuperceni-Desa) and near Ghighera or salt marshes near the Jiu mouth. Many such salt meadows are the result of a changed water balance in the floodplain and a high evaporation. This is why one has to check, based on the species composition, to what extent they respond to Natura 2000 and whether they shelter relevant species so as to be comprised within the network of habitats that are qualified for protection.

Inland dunes, old and decalcified

2340*: Pannonic inland dunes (including pannonic plain and neighbouring basins)

Major parts of the broad dune area in the great Danube bend, Calafat, Ciuperceni-Desa are to be attributed to this habitat type. Further parts are the dune areas near Bechet and Dăbuleni, with microhabitat complexes formed by various habitats such as e. g. loose, open mesophilous grasslands along the dune slopes and humid depressions between the dunes.

Freshwater habitats; Standing waters.

3130: Oligotrophic to mesotrophic standing waters with a vegetation composed by Littorelletea uniflorae and /or Isoeto-Nanojuncetea

This habitat occurs in the Lower Danube with ephemerous annual communities of Isoeto-Nanojuncetea-type vegetation represented by pioneer species of the land interface of lakes, pools and ponds. Representative species for this habitat may be found in the Lower Danube: *Lindernia procumbens, Eleocharis acicularis, Juncus bufonius, Cyperus fuscus, Cyperus flavescens, Dichostylis micheliana, Limosella aquatica, Centaurium pulchellum*, *Juncus bufonius*, etc.

Depending on water level fluctuations the association may occur or not. In some years it occurs abundantly, in other years, as a result of higher water levels, it fails to appear.

3150: Natural eutrophic lakes with Magnopotamion- or Hydrocharition-type vegetation.

On the Lower Danube this habitat type occurs in old river branches, oxbow lakes with free floating plant communities of the Hydrocharition type vegetation or/and with communities of Magnopotamion. Characteristic species are: *Lemna minor, Lemna trisulca, Spirodela polyrhiza, Hydrocharis morsus ranae, Stratiotes aloides, Utricularia vilgaris, Utricularia australis, Aldrovanda vesiculosa*, various *Potamogeton* species etc.

Running waters

3260: Watercourses of plain to mountain levels with Ranunculion fluitantis and Callitricho-Batrachion vegetation

Characteristic of the Lower Danube floodplain, with small floodplain water courses. Characteristic species are *Batrachium trichophyllum, Ranunculus fluitans, Ranunculus peltatus, Ranunculus aquatilis, Callitriche* sp, *Sium erectum, Potamogeton* spp., *Fontinalis antipyretica* and in some places *Nasturtium officinale,* characteristic of natural groundwater discharges at the toe of the terrace (only in spring). The habitat subtype with *Nasturtium* was found near Corabia and Orlea. This habitat type may usually be found in shallow waters, interwoven with flowering rush reeds (*Butomus umbellatus*) and frequently starting silting on the muddy banks.

3270: Rivers with muddy banks, with Chenopodion rubri p. p. and Bidention p. p. vegetation (ephemerous therophyte vegetation)

This habitat type is characteristic of muddy river banks along the Lower Danube. The pioneer vegetation is annual and nitrophilous. Ephermerous associations develop below the mean water level in late summer and may cover larger areas on the Danube sand banks that are covered with alluvial mud. Their whole life cycle lasts for about three months. Dependent on the water levels they may develop better or less good. In the case of lacking low water periods these associations cannot develop at all.

Semi-natural dry grasslands and scrubland facies

6210: Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco-Brometalia)

In the continental climate area this habitat type comprises dry to semi-arid calcareous Festuco-Brometea grasslands respectively Festucetalia valesiacae. Fragments of this habitat type may be found along the loess terrace slopes of the Danube floodplain borders. It has, however, to be examined to which extent these associations are near-natural and relevant as from a nature conservation point of view.

Natural and semi-natural grassland formations

Natural grasslands

6120 *Xeric sand calcareous grasslands (associated with non-coastal dune complexes)

This priority habitat is an open grassland on more or less calciferous sand, occurring frequently along with non-coastal dune complexes, where it forms mosaic-like complexes. Valuable examples of this type of habitat occur in the dune area of the large Danube bend downstream Calafat, in the Ciuperceni-Desa area.

Semi-natural tall-herbaceous humid meadows

6430: Hydrophilous tall herbaceous fringe communities of the plains to alpine levels

In the Lower Danube floodplain area this habitat can be found along the border of floodplain forests and along water courses of the recent and former floodplain. The associations that are to be attributed to this habitat type form part of the Glecometalia herbaceae and the Convolvuletalia (*Senecion fluviatilis*, *Aegopodion podagrariae*, *Convolvulion sepium* and *Filipendulion*). Specific for the Lower Danube is the tall herbaceous habitat with *Aristolochia clematitis*, occurring mainly as fringes of black poplar and white poplar stands on sandy floodplain soils.

6440: Alluvial meadows of river valleys of the Cnidion dubii

Floodplain meadows with their characteristic species of the Cnidion alliance occur in fragments along the Lower Danube. They have been documented here on small-scale meadows situated at the toe of the dyke. The eponymous species *Cnidium dubium* is not known to occur on the Lower Danube, so are, however, other characteristic species of the Cnidion alliance, such as *Scutellaria hastifolia, Allium angulosum, Gratiola officinalis, Carex praecox, Juncus atratus, Lythrum virgatum*. Other species of the river valley meadows coming along are *Clematis integrifolia, Veronica longifolia, Galium rubioides*, mainly characteristic of amaranth floodplain meadows.

Mesophile grasslands

6510: Lowland hay meadows/meadows (Alopecurus pratensis*,* Sanguisorba officinalis)

On the Lower Danube these generally species-abundant lowland meadows occur only on a very small scale, they are however documented with the example of the meadows in the Cama-Dinu nature reserve. They are closely interwoven with the species of the Cnidion meadows so that one may observe in many places meadows sheltering the characteristic species of both meadow types (6440 and 6510) at a time.

Forests

91 E0*: Alluvial forests with Alnus glutinosa and Fraxinus excelsior (Alno-Padion, Alnion incanae, Salicion albae)

The Lower Danube, a typical lowland river, is still bordered in some places by well-developed, gallery-like white willow forests. Thanks to an existing hydro- and morphodynamics they may even regenerate extendedly on emerging immature soils (Schneider, 2003b). Black alder stands may only be found in a few spots, namely in the dune area of Ciuperceni-Desa.

91 F0: Riparian mixed forests of Quercus robur, Ulmus laevis and Ulmus minor, Fraxinus excelsior or Fraxinus angustifolia along the great rivers (Ulmenion minoris)

In the most elevated places of the Lower Danube's natural levees one may find small-scale hardwood floodplain forests that are mainly composed of oaks (*Quercus robur, Quercus pedunculiflora*), small-leaved elm and white European elm (*Ulmus carpinifolia, Ulmus laevis*), but also of black poplar and white poplar. This habitat type has become very rare given that broad areas of natural floodplain forests have been transformed into hybrid poplar cultures. Remainders may be found in proximity of the Jiu-mouth, near Dăbuleni (river km. 670 - 666), in the „La nisipuri" forest/Balta Potelu, Tabonu forest/Seaca (km 584 - 583), Cioara forest (Năvodari/Teaca) (km 574 - 570), at the Vedea mouth (km 540 - 539), in the nature reserve Cama-Dinu (km 510 - 521), in the border area of the Balta Greaca and next to the Argeş mouth. Characteristic species for this type of habitat are: *Quercus robur, Ulmus laevis, Ulmus carpinifolia, Fraxinus excelsior, Fraxinus angustifolia, Populus nigra, Populus canescens, Populus tremula*. A characteristic species of the Danube floodplain forests' herbaceous layer is the summer snowflake (*Leucojum aestivum*). Further characteristic species are *Asparagus pseudoscaber* and *Asparagus tenuifolius* as well as in some spots *Periploca graeca* and the wild vine (*Vitis sylvestris*), the latter forming dense curtains in some places along the Danube River banks. This is why specific attention should be paid to the threatened remainders of these forests (Schneider and Drăgulescu, 2005).

Mediterranean deciduous forests

92A 0: Salix alba and Populus alba galleries

Gallery-like floodplain forests composed of white poplars and willows are characteristic of the Mediterranean area. In the Danube River valley and on the lower reaches of its major tributaries one may find forest stands that are mainly composed of white willows and resemble very much to the Mediterranean forests. Though some characteristic Mediterranean species are lacking, analogies may however be determined. It becomes evident that the Danube valley white poplar is very similar to the Mediterranean habitat type and may thus be classified within this category. They do somehow form a transitional stage versus the Central European forest where the white poplar occurs all the same.

CONCLUSIONS

The Lower Danube floodplains still have a high ecological and restoration potential, with a relatively high biodiversity due to the great number of different macro and microhabitats conditioned by the river dynamics, even if the recent floodplain is relatively small. The islands are characterized by a site-specific biodiversity along ecological gradients and natural processes and play an important role as a reservoir of biodiversity and a genetic pool. They are of major importance as references for the degree of naturalness and the ecological value.

The habitats of the Lower Danube are threatened all the same, despite of numerous nature protection measures taken, the declaration of new conservation areas, the declaration of Natura 2000 areas as well as restoration measures. The present endangerments are the following: sand and gravel mining (affecting the morphology of the area); river bank enforcement and bed deepening for the shipping way/TENsT; bank erosion resulting from waves created by ships and boat traffic; riverbed erosion and deepening on some river stretches, as a result of a lower bedload supply caused by the hydropower plant at the Iron Gate and the development of the tributaries that would have provided bedload (most of all Olt, Argeş); pollution caused by industry and agriculture; intensive forestry replacing natural forest ecosystems (hybrid poplar plantations).

This is why floodplain management on the Lower Danube deserves a greater attention. Conservation, restoration and sustainable development of a network of functioning floodplain areas are of major importance not only for biodiversity, but also for flood protection and the optimization of the socio-economic benefits for the local people.

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ASSESSMENT OF THE ECOLOGICAL STATUS OF SOME BULGARIAN RIVERS FROM THE AEGEAN SEA BASIN BASED ON BOTH ENVIRONMENTAL AND FISH PARAMETERS

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KEYWORDS: rivers, Aegean Sea Basin, ecological assessment, fish species diversity, fish biomass, indicative fish species, sensitive species, multivariate analyses

ABSTRACT

The goal of the present study was to assess the ecological status of the Bulgarian part of the rivers Struma, Mesta, Dospat, Tundzha, Arda and Maritsa (Aegean Sea Basin) using fish and environmental parameters. A total of 36 sites within the watersheds of the rivers were sampled. Only fish data obtained by electric fishing were used. The following environmental and biological parameters for assessment of ecological status of sites were used: presence or absence of swift current stretches and pools, underwater cavities, submerged trees, barrages, type of substratum, flow, maximum width and depth of the river stretch, temperature, pH, dissolved oxygen, conductivity, chemical oxygen demand, biochemical oxygen demand, total phosphorus, total nitrogen, suspended substances, fish diversity, density and biomass, age-size structure, ocular observed health status, abundance of juveniles. Principal component analysis was used to summarize the major patterns of variation within some of environmental parameters. The major patterns in fish species distribution within sampled sites were determined by Detrended correspondence analysis.

ZUSAMMENFASSUNG: Bewertung des ökologischen Zustandes einiger bulgarischer Flüsse des Ägäischen Beckens anhand von Fisch- und Umgebungsparametern.

Das Ziel dieser Untersuchung war, den ökologischen Zustand des bulgarischen Teils der Flüsse Struma, Mesta, Dospat, Tundscha, Arda und Mariza (Ägäisches Becken) unter Verwendung von Fisch- und Umgebungsparametern einzuschätzen. Proben von insgesamt 36 Stellen der Wassereinzugsgebiete wurden gesammelt. Nur die Ergebnisse des Elektrofischfanges wurden genutzt. Bei der Bewertung des ökologischen Standes wurden die folgenden Umgebungs- und biologischen Parameter benutzt: Anwesenheit von oder Mangel an schnell fliessenden Flussabschnitten oder Pools, unterschpülten Stellen am Ufer, versunkenen Stämmen, Staudämmen, der Substrattypus, der Abfluss, die maximale Breite und Tiefe des Flussabschnitts, die Temperatur, der pH-Wert, der gelöste Sauerstoff, die Leitfähigkeit, chemischer Sauerstoffverbrauch, biochemischer Sauerstoffverbrauch, gesamter Phosphor, gesamter Stickstoff, suspendierte Substanzen, Fischartenvielfalt, Dichte und Biomasse, Alter-Grösse-Struktur, Gesundheitszustand, Häufigkeit von Jungfischen. Die Haupttendenzen in der Variation einiger Umgebungsparameter wurden unter Verwendung von PCA ermittelt, whärend Tendenzen bei der Verbreitung der Fischarten innerhalb der untersuchten Flussabschnitte unter Verwendung von DCA festgestellt wurden.

REZUMAT: Evaluarea stării ecologice a unor râuri bulgare din bazinul Mării Egee, bazată pe parametri de mediu şi de ihtiofaună.

Obiectivul studiului a fost realizarea evaluării stării ecologice a sectoarelor bulgare a râurilor Struma, Mesta, Dospat, Tundzha, Arda şi Maritsa (bazinul Mării Egee), utilizând pametri de mediu şi de ihtiofaună. Au fost colectate probe dintr-un total de 36 de situri din bazinele acestor râuri. În analiză, au fost utilizate doar datele referitoare la peşti obținute prin pescuit electric. Au fost utilizați următorii parametrii de mediu şi biologici pentru evaluarea stării ecologice a siturilor respective: prezența sau absența pe sectoare întinse a curentului rapid şi a zonelor adânci, cavități subacvatice, copaci în apă, baraje, tipuri de substrat, curgere, lățime şi adâncime maximă a râului, temperatură, pH, oxigen dizolvat, conductivitate, deficitul de oxigen, consumul biochimic de oxigen, fosfor total, azotul total, substanțe în suspensie, diversitatea peştilor, densitate şi biomasă, structura pe vârste-dimensiuni, starea de sănătate observată vizual, abundența juvenililor de peşti. A fost urmărită rezumarea modelelor principale ale variației unor parametri de mediu. Modelele principale de distribuție a speciilor de peşti în siturile studiate au fost determinate prin analiza de corespondență.

INTRODUCTION

The present study is a part of the Supplemental Water Quality Survey which aims the preparation of the typology of surface water bodies for the East Aegean Sea River Basin District (EABD) and West Aegean Sea River Basin District (WABD) based on the European Water Framework Directive (EU-WFD). According to FAME (Fish-based Assessment Methods for the ecological status of European rivers), the European Fish Index (EFI) was selected as most suitable method (http://fame.bocu.ac.at, 2005). The EFI is based on a predictive model that derives reference conditions for individual sites and quantifies the deviation between predicted and observed conditions of the fish fauna.

The main fault of the last developed EFI is the fact that it does not yet applicable for the conditions in the South-Eastern Europe (especially for the Aegean Sea Basin), because of different fish fauna composition and specific flow regime of the rivers. The shortage of consistently gathered data about fish population characteristics in this region is a serious problem for EFI aplication too. It seems paradoxal, but for the most of the Bulgarian rivers we have only single or irregular and rare data about their fish fauna. Especially we need more regular investigations (monitoring) concerning fish population characteristics.

MATERIAL AND METHODS

Study area. Sampling both for environmental parameters and fish fauna was done synchronous at 36 sites, selected and combined with the actual monitoring sites of the WABD and EABD from the watershed of rivers and codes as folowing Tundzha (T1 - T11), Maritsa (MA2 - MA23), Arda (A1, A3), Struma (S1 - S9), Mesta (M3 - M6) and Dospat (D1) (Figs. 1, 2). The sites are situated between the following coordinates: WABD - from 41°24'32" to 42°30'27" LatitudeN and 22°47'21" to 24°08'27" LongitudeE; EABD - from 41°34'18" to 42°41'41" LatitudeN and 24°06'39" to 26°34'13" LongitudeE.

Environmental parameters. The physico-chemical samplings were carried out according ISO 5667-6: 1990. Temperature, conductivity, pH and dissolved oxygen were measured on-site by means WTW Universal Pocket Meter Multiline P4 with Conductivity Cell TetraCon 325, pH Electrode SenTix 41-3 and Oxygen sensor CellOx 325. Rough measurement of flow discharge is based on USEPA' Volunteer Stream Monitoring: A Methods Manual - Chapter 5: Stream Flow. Before field works all needed US/UK units were converted in metric units (1ft = 0.3048m; $1ft^2 = 0.0929m^2$; $1ft^3/sec = 0.0283m^3/sec$; etc).

The samples for the laboratory analyses were preserved according ISO 5667-2: 1991 and were transported into transportable refrigerator and cooler. Laboratory tests were performed according following methods: Chemical Oxygen Demand (COD) ISO 6060, Biochemical Oxygen Demand (BOD_5); EN 1899-1, 2; Total Nitrogen (TN) was performed as sum of Kjeldahl-N (ISO 5663), NO_2-N (ISO 6777 and NO_3-N (ISO 7890-3); Total Phosphorus (TP) ISO 11885; Suspended Substance (SS) was carried out by weight method. Water sample was filtered by preliminary weighted filter, than the filter is dried up (t = 105 ^oC) to constant weight and the SS are calculated.

The following environmental parameters for assessmemt of ecological status of sites were used: presence or absence of swift current stretches and pools, underwater cavities, submerged trees, barrages, type of substratum.

Fish Fauna

The ichthyological material was collected in September - October 2006 in all the above mentioned sampling sites. Only the fish data obtained by electrofishing (single upstream passing) were used in this study. The chosen river length for sampling was 100 m (excepting some small rivers or very polluted rivers, where this distance was shorter). The partial sampling method was used in the cases when different types of mesohabitats were presented.

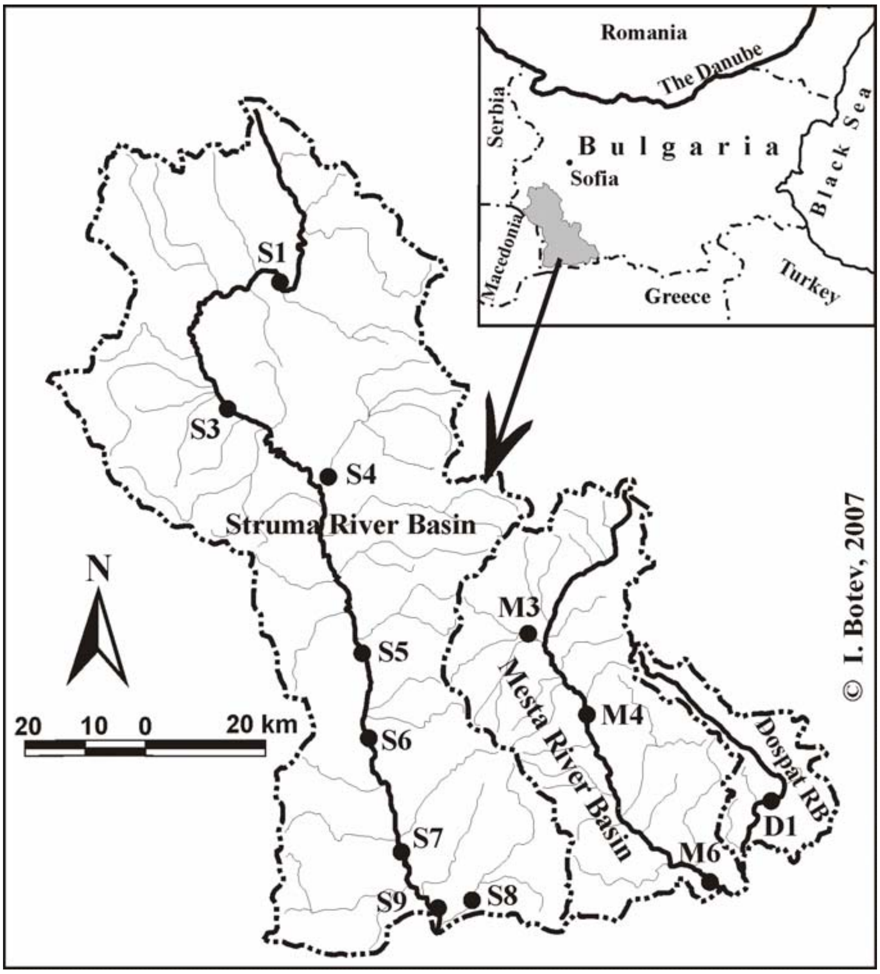

Figure 1: The West Aegean Sea River Basin District (WABD) with locations of the sampling sites.

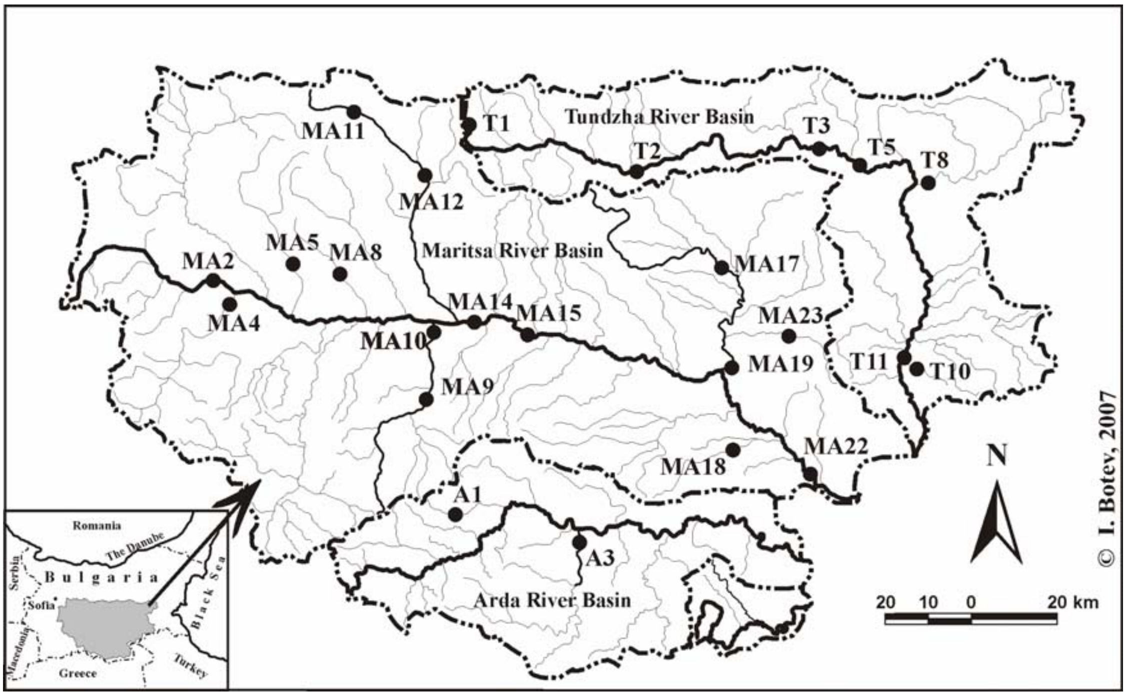

Figure 2: Map of the East Aegean Sea River Basin District (EABD) with locations of the sampling sites.

The collected specimens were identified on-site to species level. The measuring of total biomass (all fish), the length range and biomass of large species and the number of all ones have been recorded on the field protocol data sheets. The ecological status (ES) is expressed as an index ranging between 5 degrees: 5 (high), 4 (good), 3 (moderate), 2 (poor) and 1 (bad ecological status). The folowing indices have been used: (Tabs. 1a, b, c, d).

Table 1: Quantitative indices (a - trout zone, b - carp zone, c - age (size) structure of carp indicative species, d - health status.

a)	Indicative species river trout (*Salmo macedonicus*)				
ES	high	good	moderate	poor	bad
ind/ha	> 500	100 - 500	50 - 100	1 - 50	no fish
kg/ha	> 40	10 - 40	5 - 10	1 - 5	no fish
age(size) groups	> 4	2 - 4	1 - 2	1 (juveniles)	no fish

b)	Total biomass (non trout species)				
ES	high	good	moderate	poor	bad
kg/ha	> 290	100 - 290	50 - 100	1 - 50	< 1/no fish

c)	Maritsa barbel (*Barbus cylolepis*) and Aegean chub (*Leuciscus macedonicus*)				
ES	high	good	moderate	poor	bad
age (size) groups	4 - 5	2 - 4	2	1	single juv./no fish

d)	% share of fish with external marks of diseases				
ES	high	good	moderate	poor	bad
%	< 1	1 - 5	5 - 10	10 - 25	> 25

Multivariate analyses

Ordination technique based on standardized principal component analysis (PCA) was used to summarise the major patterns of variation within the environmental variables. Detrended Correspondence analysis (DCA) (Hill and Gauch, 1980) - detrending by segments, was run with fish species in order to distinguish major patterns in species distribution within each site. Species data were square root transformed to down-weight high abundances and with downweighting rare species. Ordinations were implemented by the CANOCO statistical package (Ter Braak and Šmilauer, 1998).

Samples scores from DCA and environmental parameters were correlated using Pearson product-moment coefficients to calculate how closely the shifts in fish species distribution followed the changes in environmental conditions. Correlations were carried out using the program STATISTICA (StatSoft, Inc. 2001).

RESULTS AND DISCUSSION

The physico-chemical and hydrological parameters values are summarized in table 2a, b.

Table 2: Environmental parameters at 36 sampling sites in East and West Aegean Basin Districts (Temp - water temperature; Cond - conductivity; DO - dissolved oxygen; SS - suspended substances; BOD_5 - biochemical oxygen demand; COD - chemical oxygen demand; TN - total nitrogen; TP - total phosphorus).

Sites code	Alti tude	TP	Flow	Max depth	Max width	Temp	pH	Cond	DO	SS	BOD_5	COD	TN
	m.a.s.l.	mg/l	$m^3 s^{-1}$	m	m	°C		µS/cm	mg/l	mg/l	mgO_2/l	mgO_2/l	mg/l
T1	739	0.01	0.46	1.2	8	12.7	7.77	20.5	9.78	3.4	2.0	4.8	0.86
T2	314	0.28	2.25	1.5	20	16.8	7.99	435.0	8.71	4.2	4.8	10.8	3.92
T3	168	0.02	1.60	1.0	20	17.9	8.10	402.0	10.23	2.4	2.4	5.5	1.73
T5	151	0.40	3.97	1.0	50	18.4	7.81	553.0	7.06	8.0	5.5	12.0	5.56
T8	129	0.62	4.38	1.5	15	17.1	8.08	670.0	7.16	9.2	5.7	14.1	5.68
T10	166	0.06	0.13	0.5	3	18.0	7.97	507.0	8.79	7.2	1.3	4.8	3.43
T11	81	0.38	10.00	1.5	50	18.9	8.45	651.0	11.37	6.0	1.9	7.4	5.39
MA2	254	0.12	1.80	0.7	20	12.0	8.02	191.0	10.17	31.8	12.2	45.0	3.31
MA4	238	0.07	0.24	1.0	15	13.0	7.96	258.0	9.13	7.8	4.7	15.2	2.86
MA5	258	0.04	0.46	1.0	10	19.0	7.96	838.0	10.95	33.6	3.5	10.6	6.12
MA8	215	0.61	0.05	1.5	5	16.0	7.93	635.0	8.43	6.4	15.4	44.0	5.88
MA9	349	0.12	2.05	0.8	20	11.0	8.69	280.0	9.81	4.2	3.6	13.8	3.12
MA10	158	0.05	1.32	1.5	20	16.8	7.78	451.0	8.02	10.2	4.2	11.2	4.55
MA11	493	0.04	0.80	0.5	10	14.5	7.55	83.4	9.73	8.8	2.4	6.7	1.35
MA12	270	0.05	9.40	1.5	25	16.6	7.92	241.0	9.98	10.2	3.7	8.6	3.95
MA14	146	0.22	35.00	1.5	100	18.1	7.89	370.0	8.20	14.2	5.5	18.8	3.26
MA15	119	0.18	6.66	1.0	40	18.7	8.03	413.0	7.49	10.6	19.6	58.8	3.65
MA17	115	1.05	5.00	1.0	15	16.7	7.66	543.0	0.97	10.6	13.8	30.0	4.79
MA18	129	0.04	0.06	1.0	7	18.0	8.07	616.0	9.09	8.4	13.8	38.4	2.95
MA19	86	0.64	9.00	0.5	10	18.8	7.87	802.0	5.76	24.4	13.2	38.0	4.52
MA22	56	0.25	11.25	1.5	100	18.9	8.17	514.0	8.65	24.6	17.5	61.2	4.22
MA23	134	0.05	0.00	1.2	10	18.1	7.63	671.0	9.60	1.4	1.0	3.4	2.14

Sites code	Alti tude	TP	Flow	Max Dept h	Max Wid th	Temp	pH	Cond	DO	SS	BOD 5	COD	TN
A1	883	0.03	0.16	1.0	6	13.0	7.59	129.0	9.31	3.8	1.3	3.4	2.89
A3	226	0.04	1.66	1.0	30	23.0	8.56	344.0	10.56	19.4	1.5	5.6	1.80
S1	637	0.72	1.66	1.5	15	15.3	7.85	895.0	7.90	10.0	5.5	17.2	5.15
S3	462	0.14	6.66	1.5	40	17.8	8.52	612.0	15.20	3.6	3.6	10.8	1.72
S4	418	0.35	2.22	1.2	15	22.3	9.31	555.0	12.32	11.6	5.2	15.2	3.61
S5	295	0.21	4.37	1.2	35	20.0	8.52	441.0	10.84	24.8	4.5	12.8	2.56
S6	154	0.22	28.00	1.5	30	19.2	8.50	441.0	10.34	26.4	3.8	11.2	2.65
S7	101	0.18	8.00	1.3	50	19.4	8.47	442.0	11.27	26.2	4.8	13.6	2.64
S8	125	0.05	0.82	1.0	7	15.2	8.07	138.0	9.98	84.4	3.7	13.2	1.43
S9	79	0.18	23.3	1.5	60	21.5	8.40	447.0	10.07	30.2	7.1	20.0	2.30
M3	769	0.16	7.74	1.0	15	15.0	8.19	272.0	8.30	20.0	5.1	14.4	3.50
M4	668	0.06	16.60	1.0	20	15.5	8.95	235.0	11.16	10.2	4.6	15.0	2.93
M6	425	0.10	12.00	1.2	30	16.9	8.16	272.0	9.61	23.8	5.6	14.8	2.85
D1	1044	0.14	0.20	1.0	8	12.6	7.87	137.0	9.45	13.8	6.5	18.0	4.20

The results of PCA performed are presented as a correlation biplot (Fig. 3).

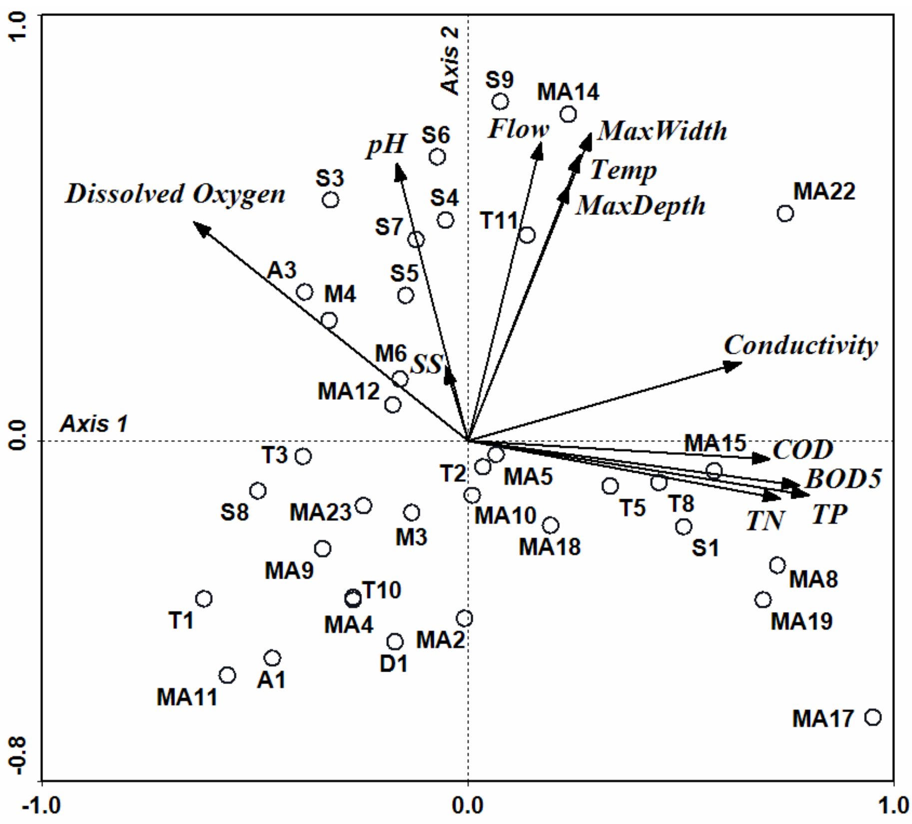

Figure 3: Principal components analysis (PCA) correlation biplot of the environmental variables.

In this kind of biplot, the angle between arrows of each pair of parameters provides an approximation of their pair-wise correlation and the parameters with high positive correlation generally have small angles between their biplot arrows. On the other hand the direction of the arrow indicates the direction in which the values of corresponding parameter increases most and the length of arrow equals to the rate of change in that direction. Parameters with long arrows have high variance, and generally the more important within the data (Ter Braak and Šmilauer, 1998). The first two principal components ($\lambda_1 = 0.282$, $\lambda_2 = 0.219$) account for 50.0% of total variance of the data and effectively capture the main patterns of the variation in the environmental data. The first axis is related to indicators of trophic status (TP, TN) as well as to oxygen condition. It contrasts the sites with high values of TP, TN, conductivity, COD, BOD_5 (Tab. 2) and with low ones for dissolved oxygen, plotted on the right part of diagram, with the rest of sites, which were with low and average values about TP, TN, COD, BOD_5, and higher values for dissolved oxygen. Far away on the right bottom of diagram is plotted site MA17, where were estimated the lowest dissolved oxygen content (0.97 mg l^{-1}, Tab. 1).

Axis two is related to pH, temperature and hydrological parameters - flow, maximum width and depth. It separates more alkaline (especially site S4 with pH = 9.31, Tab. 1) sites with higher values of temperature, flow discharge, width and depth, plotted on the top part of diagram from ones with lower values of these parameters, plotted bottom right and left of the diagram and in particular sites T1, MA11, A1, which were with the lowest values about pH or temperature (Tab. 2).

A total of 24 fish species were recorded. Among them, three species were selected as indicative for the Bulgarian rivers of the Aegean Sea Basin: Trout (*Salmo macedonicus),* Maritsa barbel (*Barbus cyclolepis*) and Chub (*Leuciscus macedonicus*). The latter two species were most abundant and widespread in the region (Mihailova, 1965; Pehlivanov, 2000; Vassilev and Pehlivanov, 2002; Apostolou, 2005).

Ordination diagram based on detrended correspondence analyses (DCA) of fish species was used in order to distinguish major patterns in their distribution within each site and the results plotted in the figure 4. The eigenvalues of the ($\lambda_1 = 0.567$, $\lambda_2 = 0.222$) and length of gradient expressed in standard deviation units of species turnover (5.2 SD) of the first three axes denote a good separation of the species along the first axis. As the gradient length of this axis is over 4 SD, there are species in the data that show a clear unimodal response along the axis and the sites such as T1 and MA17 at opposite ends of the first axis have no any species in common (Ter Braak, 1995; Ter Braak and Prentice, 1988; Ter Braak and Šmilauer, 1998). The variance explained by the two first axes is 24.6 % and 9.6 %.

The first DCA axis was positively correlated with conductivity ($r = 0.69$, $p < 0.001$), TP ($r = 0.51$, $p < 0.01$), water temperature ($r = 0.48$, $p < 0.01$), BOD_5 ($r = 0.38$, $p < 0.05$), COD ($r = 0.34$, $p < 0.05$) and negatively correlated with dissolved oxygen ($r = -0.35$, $p < 0.05$). This denote relation of this axis with changes of these environmental parameters and shift in fish species composition along this mainly trophic gradient.

The presence and abundance of trout species almost always means good ecological condition. The criteria as density and biomas are suitable for assessment the fish condition in the river zones from the Aegean Sea Basin. The presence and abundance of some sensitive (stenobiont) species like Minnow (*Phoxinus phohinus*) and Struma loach (*Barbatula bureshi*), the availability of predatory species (big Chubs, Wels catfish, Pikes etc.), just like all other species is very important and gives us some possibility to assess the ecological condition.

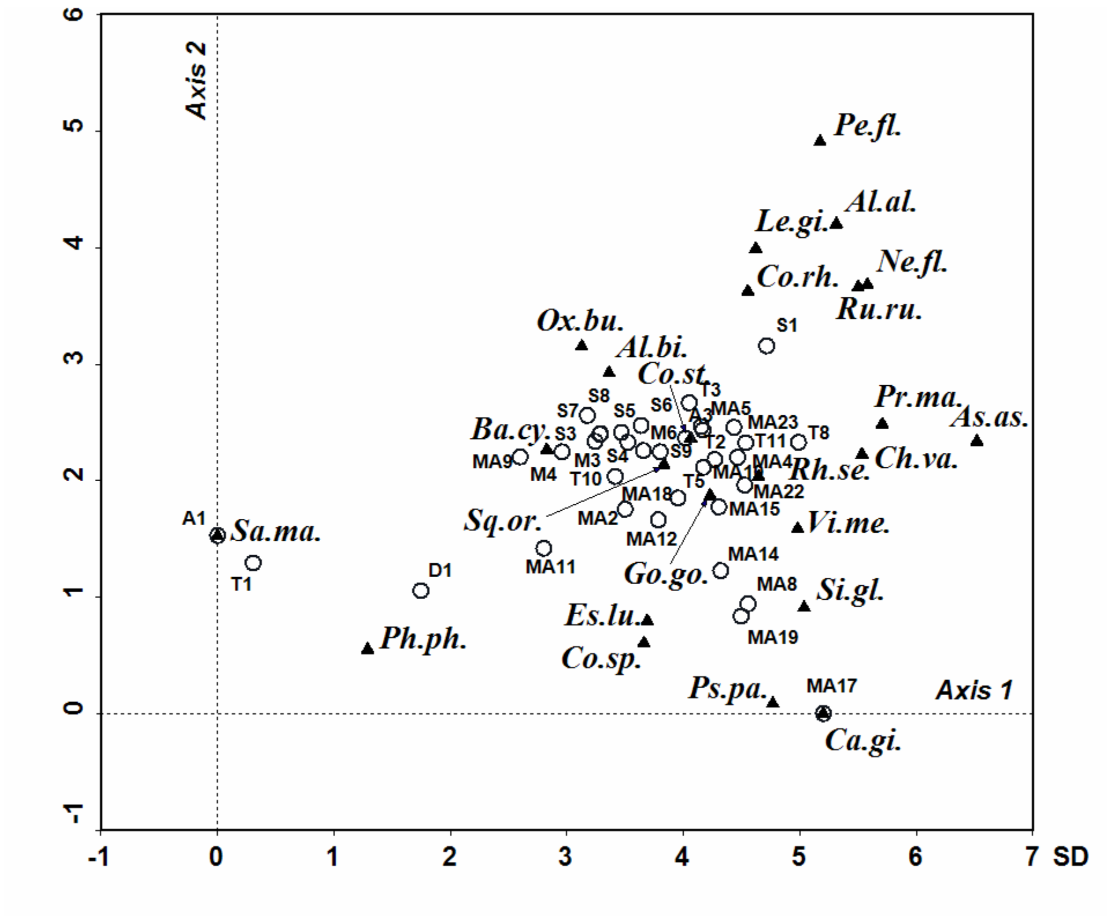

Figure 4: Detrended correspondence analysis (DCA). The fish species shown are**:** Sa. ma. (*Salmo macedonicus*); Es. lu. (*Esox lucius*); Al. bi. (*Alburnoides bipunctatus*); Al. al. (*Alburnus alburnus*); As. as. (*Aspius aspius*); Ba. cy. (*Barbus cyclolepis*); Ca. gi. (*Carassius gibelio*); Ch. va. (*Chondrostoma vardarense*); Go. go. (*Gobio gobio*); Sq. or. (*Squalius orpheus*); Ph. ph. (*Phoxinus phoxinus*); Ps. pa. (*Pseudorasbora parva*); Rh. se. (*Rhodeus amarus*); Ru. ru. (*Rutilus rutilus*); Vi. me. (*Vimba melanops*); Ox. bu. (*Oxinemacheilus bureschi*); Co. sp. (*Cobitis* sp.); Co. rh. (*Cobitis rhodopensis*); Co. st. (*Cobitis strumicae*); Si. gl. (*Silurus glanis*); Le. gi. (*Lepomis gibbosus*); Pe. fl. (*Perca fluviatilis*); Ne. fl. (*Neogobius fluviatilis*); Pr. ma. (*Proterorhinus marmoratus*).

According to the made analysis assessment of ES by sites is given in the table 3.

Table 3: Assessment of ES by sites (TB - Total Biomass; TD - Total Density; Bi - Biomass of indicative species; Di - Density of indicative species, ES - Ecological status.

Sites code	Species	TB	TD	TB/TD	Bi	Di	Bi/Di	Bi/TB	Di/TD	ES
	n	kg/ha	ind/ha	g	kg/ha	kg/ha	g	%	%	
T1	2	55	1600	34.4	55	1500	36.7	99.9	93.8	5
T2	9	300	8100	37.0	245	5900	41.5	81.7	72.8	5
T3	7	252	6900	36.5	209	5300	39.4	82.9	76.1	4
T5	9	145	12000	12.1	67	6200	10.8	46.2	51.7	4

Sites code	Species	TB	TD	TB/TD	Bi	Di	Bi/Di	Bi/TB	Di/TD	ES
	n	kg/ha	ind/ha	g	kg/ha	kg/ha	g	%	%	
T8	11	280	10800	25.9	106	600	176.7	37.9	5.6	4
T10	5	71	5000	14.2	61	3800	16.0	85.9	76.0	3
T11	13	581	10400	55.9	427	3900	109.5	73.5	37.5	4
MA2	4	57	3000	19.0	54	2000	27.0	94.7	66.7	3
MA4	9	329	10700	30.8	286	3000	95.3	86.9	28.0	5
MA5	6	145	5300	27.4	135	3700	36.5	93.1	69.8	4
MA8	8	250	27000	9.3	12	1200	10.0	4.8	4.4	4
MA9	2	140	5300	26.4	140	5300	26.4	100.0	100.0	4
MA10	9	134	9900	13.5	41	2100	19.5	30.6	21.2	4
MA11	6	37	3300	11.2	35	1400	25.0	94.6	42.4	4
MA12	10	363	11400	31.8	357	7500	47.6	98.5	65.8	5
MA14	10	144	12100	11.9	99	5300	18.7	68.8	43.8	4
MA15	10	353	8000	44.1	206	3700	55.7	58.4	46.2	5
MA17	1	2	400	5.0	0.0	0.0	0.0	0.0	0.0	1
MA18	7	60	6400	9.4	48	1900	25.3	80.0	29.7	3
MA19	4	40	2600	15.4	0.0	0.0	0.0	0.0	0.0	2
MA22	12	346	11000	31.4	117	2100	55.7	33.8	19.1	5
MA23	8	142	6900	20.6	97	2400	40.4	68.3	34.8	4
A1	1	24	100	240.0	24	100	240.0	100.0	100.0	3
A3	9	286	16400	30.8	279	10300	27.1	97.6	62.8	4
S1	7	185	6800	27.2	31	600	51.7	16.8	8.8	4
S3	7	340	7000	48.6	330	6300	52.4	97.1	90.0	5
S4	6	265	6200	42.7	235	5000	47.0	88.7	80.6	4
S5	6	350	8000	43.8	302	5300	60.0	86.3	66.2	5
S6	6	231	13200	17.5	193	7100	27.2	83.6	53.8	4
S7	4	169	9100	18.6	152	6300	24.1	89.9	69.2	4
S8	3	135	2500	54.0	131	2000	65.5	97.0	80.0	4
S9	9	263	5400	48.7	252	2500	100.8	95.8	46.3	5
M3	3	65	1400	46.4	62	1100	56.0	95.4	78.6	3
M4	2	215	9600	22.4	215	9600	22.4	100.0	100.0	4
M6	5	330	12100	27.3	290	7100	40.8	87.9	58.7	4
D1	2	5	2100	2.4	1	200	5.0	20.0	9.5	5

All sites of the Struma River basin are in high and good ecological status. About the Mesta River Basin, one site has moderate level, two sites good and one has poor ecological status. For the Maritsa River Basin we have assessed four sites with high level, seven sites have a good status. Two sites were assessed as moderate and one site with poor status and another with bad ecological status. The general situation is better, concerning the sites of the Tundzha River Basin. We have assessed three sites with high status, three sites have good level and one has a moderate one. On the Arda River System we have two sites. The first of them has a moderate level and the second has a good ecological status.

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SWAMPS BIODIVERSITY OF THE WHITE NILE (SUDAN)

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KEYWORDS: Sudan, Sudd, White Nile, wetland, biodiversity.

ABSTRACT

This paper describes vegetation and fauna in the Sudd area of the Southern Sudan. A visit by airboat was made in February 2007 along the White Nile from Akair to Zaraf; to the inflow regions of the Bahr ez Zeraf and along Khor Tem and Khor Kir river. The area gone through included swampy zones with shallow waters but stretched lakes, streams and countless canals bordered by abundant vegetation.

The Sudd is home to many migratory species; the known 5000 shoebill storks *Balaeniceps rex* in the world are only found in the Sudd. In the Sudd area have been identified over 350 plant species, over 100 fish species, 100 mammalian species, over 400 bird species and an unknown number of reptilian and amphibian species. Over 120 insect species have been identified in the Sudd area of which 63 are mosquitoes (Ramsar Convention, 2006).

The study aimed to qualitatively assess organisms (especially vegetation and water birds) in the swampy areas, flooded plains, canals, lakes and streams in the Sudd region in comparison with the previous assessments in order to establish the changing tendency in time of the studied ecosystems.

ZUSAMMENFASSUNG: Die Artenvielfalt der Feuchtgebiete des Weißen Nil im südlichen Sudan.

Der Artikel beschreibt die Pflanzen- und Tierwelt der Sudd Region des südlichen Sudan. Im Februar 2007 machte ich eine Expedition mit dem Luftboot entlang des Weißen Nil von Akair nach Zaraf, in die überflutete Region Bahr ez Zaraf und auf den Flüssen Khor Tem und Khor Kir. Das Areal enthält Flachwasser, aber auch Flüsse, weitläufige Seen und unzählige Kanäle, umgeben von einer reichhaltigen Pflanzenwelt.

Der Sudd ist Heimat einer Vielzahl von Zugarten, hier leben fast 5000 *Balaeniceps rex* exemplare, welches einzigartig auf der Welt ist. Hier findet man auch: über 350 Pflanzenarten, mehr als 100 Fischarten, 100 Arten an Säugetieren, über 400 Vogelarten und eine unbekannte Zahl von Reptilien- und Amphibienarten. Es wurden im Sudd mehr als 120 Arten von Insekten, darunter 63 Mücken, indentifieziert.

Ziel der Studie ist, eine qualitative Bewertung von Organismen (insbesondere Pflanzen und Wasservögel) der Feuchtgebiete, des überfluteten Flachlandes, derKanäle, der Seen und Flüsse im Sudd im Vergleich zu früheren Einschätzungen zu machen, um die Änderungstendenzen der untersuchten Ökosysteme im Laufe der Zeit zu ermitteln.

REZUMAT: Biodiversitatea zonelor mlăştinoase ale Nilului Alb (Sudan).

Lucrarea descrie flora şi fauna regiunii Sudd din Sudanul de Sud. În februarie 2007 am făcut o expediţie cu airboat-ul de-a lungul Nilului Alb, de la Akair la Zaraf, în regiunea apelor revărsate ale Bahr ez Zeraf, pe râurile Khor Tem şi Khor Kir. Zona străbătută a cuprins mlaştini cu ape puţin adânci, lacuri întinse şi canale mărginite de vegetaţie abundentă.

În regiunea Sudd, se află un număr mare de specii migratoare; aici trăiesc circa 5000 de exemplare de berze *Balaeniceps rex* unice în lume. Se întâlnesc, de asemenea, 350 specii de plante, peste 100 specii de peşti, 100 specii de mamifere, peste 400 specii de păsări şi un număr necunoscut de specii de reptile şi amfibieni. Au fost identificate în Sudd peste 120 de specii de insecte dintre care 63 specii de ţânţari.

Studiul a avut drept scop evaluarea calitativă a organismelor (în special vegetaţia şi păsările acvatice) din zonele mlăştinoase, câmpiile inundate, canalele, lacurile şi râurile din regiunea Sudd în comparaţie cu evaluările anterioare, pentru a stabili tendinţa de modificare în timp a ecosistemelor studiate.

INTRODUCTION

Sudd is a large area covered in aquatic plants situated in Sudan, between 06°00' and 09°08' N in latitude and between 30°10' and 31°08' E in longitude. The word "sudd" derived from the Arabic "sadd", meaning "block" (Gaudet and Falconer, 1983). The term is now use widely for large solid floating vegetation islands and mats. The Sudd region has remained unnavigable for many years because large islands of papyrus have floated downstream of the Nile and lodged in channels, effectively blocking local river traffic (Petr, 2000).

The Sudd is the first Ramsar site in Southern Sudan by 5th of June 2006 is the largest freshwater wetland in the world. The Sudd Wetland Designated Ramsar contains permanent swamps that extends from Bor to Lake No and is approximately 5,700,000 ha in size.

The survey of area generally is a flat featureless plain (about 400 m above mean sea level), a combination of flat, bush and flooded zones.

During the rainy season (from late May to November), the White Nile overflows into the vast floodplain surrounding the permanent Sudd swamps, bringing nutrients and new life to the dry. Its greatest extend occurs in September.

The swamps and floodplains of the Sudd support a rich biota, including over four hundred bird species and one hundred mammal species. Migratory birds stopover and wetland birds inhabit the extensive floodplains of the Sudd, while large populations of mammals follow the changing water levels and vegetation.

The floodplain ecosystem supports a variety of plant species with a succession from those adapted to mesic environments to those adapted to xeric environments. Moving from the interior of the swamps, the ecological zones grade from the open-water and submerged vegetation of a river-lake, to floating fringe vegetation, to seasonally flooded grassland, to rain-fed wetlands and, finally, to floodplain woodlands (Hickley and Bailey, 1987).

In the Sudd Area have been identified over 350 plant species, over 100 fish species, 100 mammalian species and 470 bird species and an unknown number of reptilian and amphibian species. Over 120 insect species have been identified in the Sudd area of which 63 are mosquitoes (Ramsar Convention, 2006).

In the Sudd area there are several species of endemic plants and animals which are important for the biodiversity of the Sudd region: *Suddia sagitifolia*, a rare plant genus belonging to the Poaceae; the Nile lechwe (*Kobus megaceros* - threatened), sitatunga (*Tragelaphus spekei)* and eight dwarf fish species of the Nile are endemic to the Sudd wetland.

The study aimed to qualitatively assess organisms (especially vegetation and water birds) in the swampy areas, flooded plains, channels, lakes and streams in the Sudd region in comparison with the previous assessments in order to establish the changing tendency in time of the studied ecosystems.

MATERIALS AND METHODS

In order to study the biodiversity in the swampy areas of the White Nile from Southern Sudan there has been carried out an ecological analysis of the area, taking into account the ecosystem types: rain flooded grasslands, permanent swamps, river flooded grasslands and river area. The observations were made in February 2007, in the middle of dry season in Southern Sudan (Fig. 1).

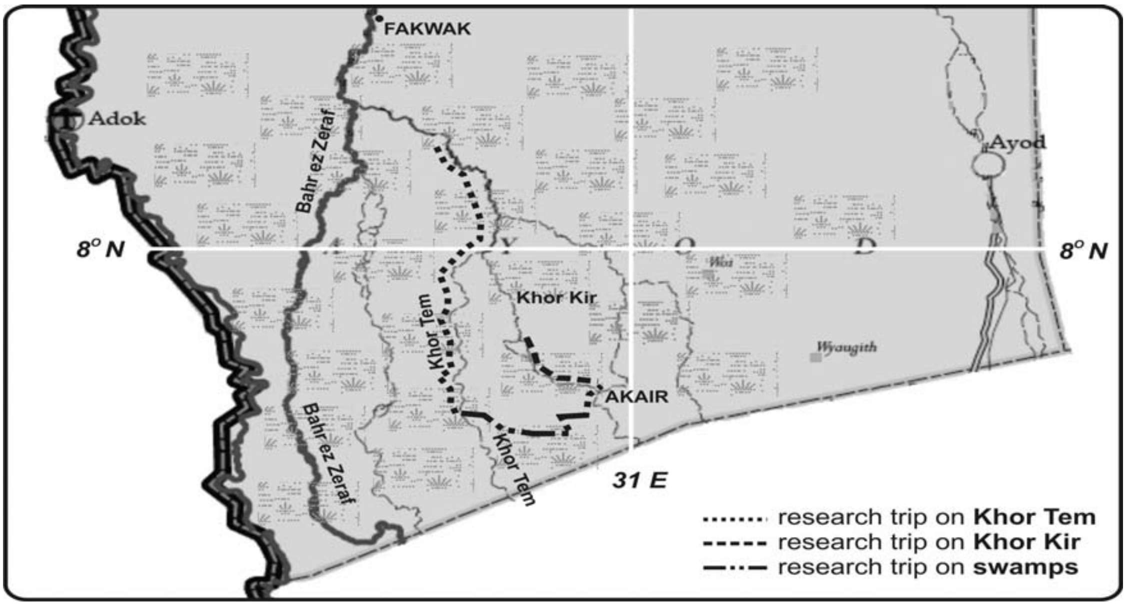

Figure 1: Research area in Sudd region.

The qualitative assessment methodology regarding the communities and populations of living organisms from the studied ecosystems has been achieved by means of direct observations in the examination points established for each studied area: seasonally flooded grasslands, river flooded grasslands, permanent swamps, open waters.

RESULTS AND DISCUSSIONS

The Sudd area is a dynamic region with a space variability according to season, precipitation level, Lake Victoria outflows, channel blockages, wind drift (Petersen, 2007). The Sudd consists of floodplains and a complex network of permanent and seasonal channels, lakes, rivers, and swamps.

Ecologically the Sudd wetland encompasses a number of different ecosystems, grading from open water and submerged vegetation, to floating fringe vegetation, seasonally inundated woodland, rain-fed and river-fed grasslands, and floodplain scrubland.

Hydrologically the Sudd wetland is a giant filter that controls and normalizes water quality and a giant sponge that stabilizes water flow. Annual floods, capable of inundating more than 15,000 km^2 of land, are crucial to the maintenance of biological diversity in the Sudd. Rainfall fills the swamps one to two months before the rivers overspill on to the floodplain. It was estimated that only 11 % of the total flooded area was permanent water, although this proportion may have increased in recent years. The floodwaters regenerate the floodplain with nutrients and allow the growth of forage plants.

The seasonally flooded grasslands of the Sudd are important habitat for numerous species of resident and migratory birds and mammals. In this area, situated near the point of our setting off - Akair - there have been observed nests of shoebill stork: *Balaeniceps rex* (Gould, 1850). Here, there is one of the largest populations of shoebill in the world, with an estimated population of roughly 5,000 (Stuart et al. 1990; IUCN Red List). This widespread but rare species has been listed as Vulnerable since 2004 (BirdLife International 2004) because it is estimated to have a single small population (individuals probably range widely within its broad extent of occurrence). The population is undergoing a continuing decline owing to hunting, nesting disturbance, capture of individuals for the pet trade and burning of its habitat.

Although it is a well-known fact that shoebill storks inhabit freshwater swamps and extensive, dense marshes, they are often found in areas of flood plain interspersed with undisturbed papyrus and reedbeds, we have noticed it only in the rain flooded grasslands.

The Sudd wetland is a wintering ground for birds of international and regional conservation importance such as *Pelecanus onocrotalus* (Linnaeus, 1758): Lower Risk/least concern (BirdLife International 2004), *Balearica pavonina* (Linnaeus, 1758): Near Threatened (BirdLife International 2004), *Ciconia ciconia* (Linnaeus, 1758): Lower Risk/least concern (BirdLife International 2004) and *Chlidonias niger* (Linnaeus, 1758): Lower Risk/least concern (BirdLife International, 2004). The endangered white pelican (*Pelecanus onocrotalus*) flies over 2,000 km from Eastern Europe and Asia to reach one of its most important wintering grounds on the floodplains of the Sudd. The area is also a stronghold for the black crowned crane (*Balearica pavonina*), a species that has been designated Vulnerable by the IUCN (http://www.iucn.org).

Birds which seem to prefer wetlands Sudd for wintering is:

- *Aquila clanga* **(**Pallas, 1811) 2007 IUCN Red List (BirdLife International 2004): Vulnerable
- *Aquila heliaca* (Savigny, 1809) 2007 IUCN Red List Category (BirdLife International 2004): Vulnerable
- *Acrocephalus griseldis* (Hartlaub, 1891) 2007 IUCN Red List Category (as evaluated by BirdLife International 2007): Endangered

Out of 350 species of birds that temporarily or permanently live in the Sudd region, 46 are to be found in the 2007 IUCN Red List of Threatened Species. The Sudd swamps of southern Sudan are among the most important wetlands for birds in Africa. Three protected areas exist within the Sudd: Shambe National Park and Fanyikang and Zeraf Game Reserves, all within the Bahr-el-Jebel system of the Sudd, the part of the swamps that will be most affected by the Jonglei canal, as and when completed. For current purposes, the core of the Sudd is treated as a single site; this includes the three protected areas and covers much of the Bahr-el-Jebel system between the towns of Malakal to the north and Bor to the south.

In rain-flooded grasslands there has been noticed wild rice species (*Oryza longistaminata*), sorghum and *Echinochloa haploclada* prevailing the seasonally inundated floodplains. Beyond these floodplains, *Hyparrhenia rufa* grasslands cover the rain-fed wetlands.

In river flooded grasslands the identified vegetation was represented by *Oryza longistaminata* associate with *Sporobolus pyramidalis* and *Echinochloa pyramidalis* grasslands. The tall grasses are dominated by *Phragmites*, *Sorghum, Hyparrhenia* and *Setaria* spp.

The diversity of plants in permanent swamps is high but the most important and prevailing types of plants are the floating and fringe vegetation, *Nimphea* genus - water lilies and Water hyacinth (*Eichhornia crassipes*). They forms an almost ubiquitous floating fringe to river channels and lakes in Sudd swamps.

In a typical river-lake, the water hyacinth (*Eichhornia crassipes)* the fringe varied between nine and 16 m in breadth with highest plant biomasses in the centre (Bailey and Litterick, 1993). But on the Khor Tem, we met in open waters and during the studied period, plants with a diameter measuring less than four metres, which have not posed any problems for the navigation on the river. At the same time, the islands formed by *Eichhornia crassipes* were rare enough, being noticed two - three small plant formations per km. The bank of the river was bordered by bigger plant formations, getting to approximately six - ten metres in length and 0.5 min in breadth.

On the other hand, along the banks of the river there are *Cyperus papyrus*, *Vossia cuspidata, Phragmites karka* and *Typha domingensis* species. In this area there can be met associates of the Cyperus swamp with climbers and also ferns. On the river bank, there are noticed, here and there, areas of single-species woodland mainly of *Acacia seyal*, or palms, or *Balanites aegyptiaca* and mixed woodland is characterized by *Ziziphus mauritiana*, *Combretum fragrans*, *Acacia seyal* and *Balanites aegyptiaca* which border the floodplain ecosystem.

In the permanent swamps zones the prevailing bird species was the African jacana (*Actophilornis africana*) which was being watched along all our expedition in such types of areas.

Although during this expedition we have not studied the communities of fish, we have noticed that a lot of fishermen from the native tribes with canoes use the channels within the wetland. Fish diversity in the Sudd is high; the fish communities in the wetland are comprised of 31 Siluroids, 16 Characoids, 14 Cyprinoids, 11 Momyrids, eight Cichlids, and seven Cyprinodonotids. The main species for the Nile wetlands are in the genera *Clarias* (catfish) and *Barbus* (barbels) together with several tilapias (*Oreochromis* spp.). Other important genera with wetland representatives are *Alestes, Labeo, Mormyrus, Schilbe* and *Synodontis* with species of *Distichodus*, *Citharinus*, *Heterotis* and *Gymnarchus* caught in the Sudd (Howard, 2004).

CONCLUSIONS

The abundance of plants and animals studied, undisturbed by the presence of man, makes this region a site of invaluable importance.

While a vast portion of the Sudd is near-wilderness, human influences on biodiversity include hunting, fishing, grazing and agriculture. Civil conflict in southern Sudan has affected the ability to manage and protect natural areas and wildlife, and increased vehicle traffic related to the conflict may have led to habitat disturbance and increased opportunities for hunting and poaching. Plans for diverting the White Nile around the Sudd via the Jonglei Canal could lead to significant habitat loss and alteration, as decreases in seasonal flooding could reduce the size of the swamps and floodplains, and also impact climate, groundwater recharge, and water quality.

We should not oppose progress, but it is important to take care of conserving the biodiversity of these places and the anthropic impact on the area be as reduced as possible.

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ECOSYSTEM SERVICES AND THEIR MAPPING IN THE TISZA/TISA RIVER BASIN - INITIAL STEPS IN HUNGARY AND ROMANIA

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KEYWORDS: ecosystem services, floodplain, GIS, Bereg Region, Crişul Negru Plain.

ABSTRACT

Ecosystems sustain human well-being by providing different services. This strongly depends on the capacity of natural ecological processes, ecosystem functioning and the way in which ecosystems are managed. In order to understand the performance of ecosystem services they should be assessed in relation to their influencing factors and also to their location within a specific area. Ecosystem services maps can integrate the available information about the natural and human related processes supporting the ecosystem services in a comprehensive way. In the Tisza/Tisa River basin such maps were generated for two cases situated in Hungary and Romania. The results prove that ecosystem services maps can be used to detect hotspots of low and high performance and to contribute to location focused spatial planning.

RESUMEN: Servicios de los ecosistemas y sus cartografia en la valle del rio Tisza/Tisa - pasos iniciales (Hungria, Rumunia).

Los ecosistemas mantienen el bienestar del ser humano proveyéndole diferentes servicios. Esto depende en gran medida de la capacidad de los procesos naturales ecológicos, del funcionamiento de los ecosistemas y de la forma en que estos son administrados. Para comprender el desempeño de los servicios de los ecosistemas, estos deben ser evaluados en relación a sus factores de influencia así como también a su ubicación en un área específica. Los mapas de los servicios de los ecosistemas pueden integrar de una manera holística la información disponible acerca de los procesos naturales y humanos que sostienen los servicios de los ecosistemas. En el valle del río Tisza dichos mapas fueron generados por dos casos localizados en Hungría y Rumania. Los resultados demuestran que los mapas de los servicios de los ecosistemas pueden ser utilizados para detectar los puntos de interés de bajo y alto desempeño y para contribuir a la planeación espacial de localidades específicas.

REZUMAT: Serviciile ecosistemelor şi cartarea lor în bazinul râului Tisa - paşi inițiali (Ungaria, România).

Ecosistemele susțin bunăstarea umană prin serviciile pe care le oferă. Acest lucru depinde în mare măsură de capacitatea proceselor naturale ecologice, de funcționalitatea ecosistemelor şi de modul în care acestea sunt administrate. Pentru a înțelege performanța serviciilor oferite de ecosisteme, acestea trebuie evaluate în relație cu factorii care le influențează, precum şi cu locația lor într-o anumită zonă. Hărți, reprezentând serviciile ecosistemelor, pot integra în mod cuprinzător informația disponibilă, referitoare la procesele naturale şi umane, care susțin aceste servicii. În bazinul Tisei, astfel de hărți au fost generate pentru două studii de caz, localizate în Ungaria, respectiv în România. Rezultatele dovedesc că hărțile, reprezentând serviciile ecosistemelor, pot fi folosite pentru a detecta puncte de interes cu performanță scazută sau ridicată şi pot contribui la o planificare spațială, detaliată.

INTRODUCTION

Ecosystem services are the benefits people obtain from ecosystems, as defined in the Millennium Ecosystem Assessment (MA) (MA 2003). The supply of ecosystem services relies on biodiversity and it is strongly dependent on the proper functioning of the related natural ecological processes and the way in which ecosystems are managed (de Groot et al., 2002). Furthermore, service provision is highly influenced by several factors such as climatic conditions and the policy context. Although it is increasingly recognised scientifically that human well-being depends critically on all ecosystem services, their continuous supply is often neglected in planning (de Groot, 2006).

The Tisa River Basin has gone through significant changes since the 19th century driven by the increasing demand for agricultural land. This took the form of river regulation and land drainage, turning the original wet forest floodplain ecosystem into arable land (Bellon, 2004). Consequently, the semi-aquatic biodiversity suffered a loss as well. Nowadays, despite the dyke protection, the Tisa River floodplain faces an increased risk of flood, drought and inland water stagnation also enhanced by climate change (Balogh, 2001). As a response, the idea of floodplain revitalisation is emerging. Some of the new water management plans aim to recreate a more natural system, which would give space for the original capacity of ecosystems to deliver their services.

The purpose of this research was to improve the understanding of the role and performance of ecosystems services in the Hungarian and Romanian parts of the Tisa River basin. This paper is aimed at drawing the attention on the contribution of GIS maps in summarizing the information regarding ecosystem services. It does so by taking initial steps towards ecosystem services mapping. Spatial visualisation is an important component in presenting and understanding the distribution and performance of ecosystem services. Moreover, map generation can be a useful tool in water and land management by offering the possibility to take location specific decisions.

The next section explains the used terms, the mapping procedure and the data sources. The results section gives an overview of the performance of two selected ecosystem services and their spatial distribution in case study areas.

MATERIAL AND METHODS

Two cases are selected for the assessment in the Hungarian and Romanian parts of the basin. These are the southern part of the Bereg Region in Hungary and part of the Crişul Negru Plain in Romania (Fig. 1). These regions share similar geographic and climatic features and are both pilot areas for new national water and land management plans with the purpose of flood mitigation and biodiversity conservation. Therefore they were considered appropriate for investigating the role of ecosystem services and their spatial distribution.

The study area in the Bereg Region extends over approximately 100 km². The strongly regulated and dyke protected region currently faces high inland water stagnation (Balogh, 2001). As a response to this, a semi-natural flood mitigating polder was designed for the Bereg floodplain in the frame of the Bereg - INTERREG project (European INTERREG Neighbourhood Programme of Hungary and Ukraine, Concept Study 2006). The chosen area would function as a water retention zone relying mainly on the natural capacity of the ecosystems. The water would follow the natural topography, while the villages would be protected by round dykes. A further step includes the re-introduction of multi-functional land use on the current mainly agricultural area.

Figure 1: Location of the two case studies in the Carpathian area (www.rec.hu)

The Crişul Negru Plain study area covers about 140 km^2. In this river section the Crişul Negru is not protected by dykes, offering a better possibility for floodplain revitalisation. The new water management plan focuses on the creation of wet areas in three artificially cut river bends partly surrounded by dykes near Tinca Village (Dimache, 2007). However, collateral works of the project such as protection dikes, bank reinforcements, possibly canals will also disrupt the natural connectivity of the riparian zones with the river. The water management plans will affect 75 % of the Hungarian case (Fig. 2) compared to only 5 % of the Romanian case (Fig. 3).

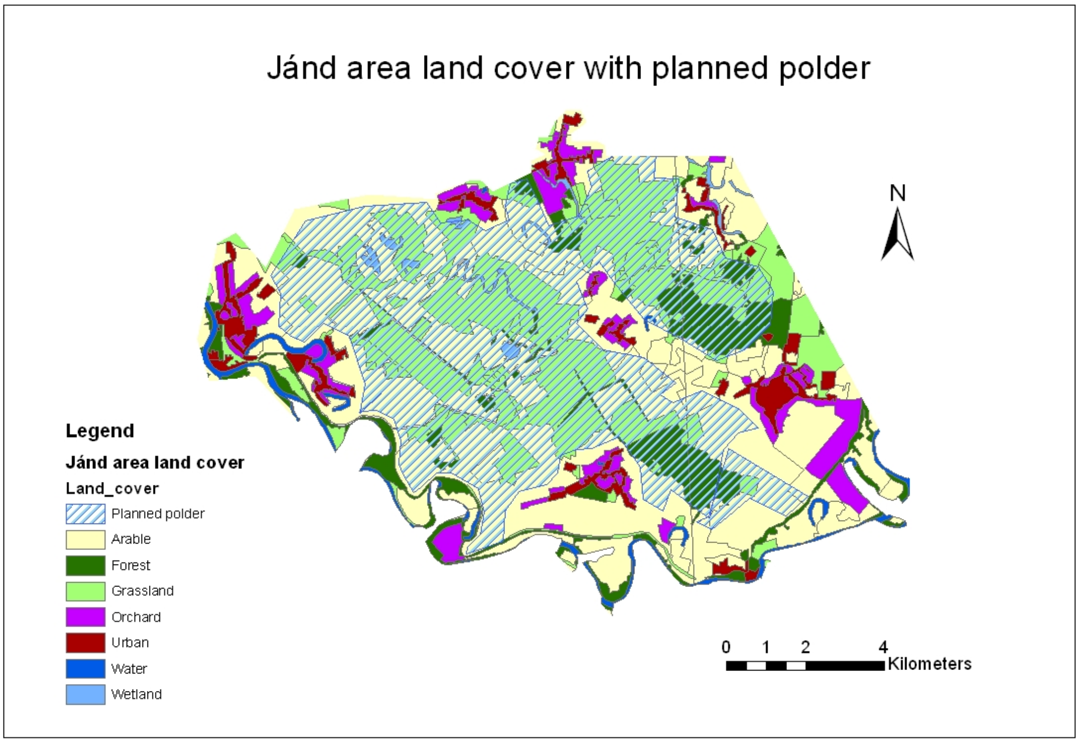

Figure 2: Bereg study area.

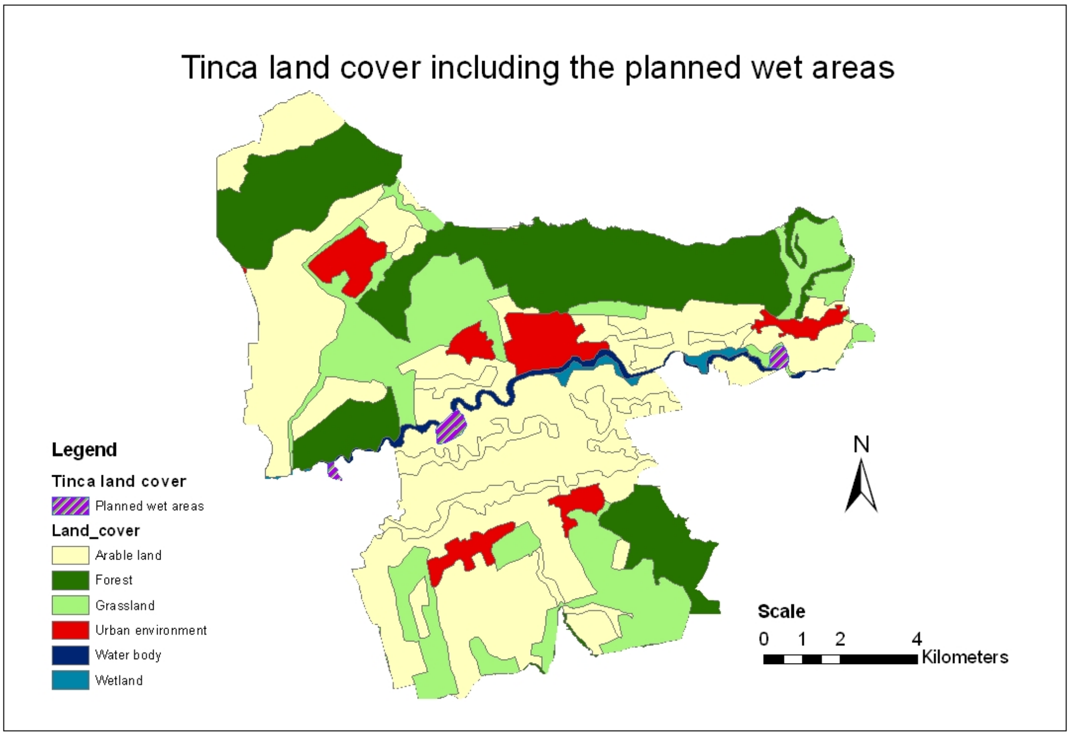

Figure 3: Crişul Negru Plain study area.

Seven land cover types - arable, grassland, forest, orchard, wetland, water body and urban environment - were investigated. For each a set of 14 ecosystem services was chosen from the categories - provisioning, regulating and cultural - mentioned in the MA. The services were analysed in terms of their current performance as a result of four influencing factors. For the purpose of this paper only two ecosystem services are illustrated, with an accent on their mapping possibilities and not on the performance assessment procedure.

In order to understand the role of ecosystem services and create their GIS maps we analysed the influence of the following factors: natural characteristics of ecosystems (affected by water management), climate related extremes (flood/drought), policy measures and human recognition. The recognition reflects the degree to which a service is recognised and used by people. The recognition of the selected ecosystem services was investigated with the help of different environmental indicators. Indicators served as a backbone of the interviews and the field observations during the three months fieldwork both in Hungary and Romania. An example for indicators is the yield/ha for the food production service. Local and regional experts were consulted on the current state of the land and water management plans and their interest in them, the awareness regarding ecosystem services and their experiences concerning climate related extremes. The interviewees ranged from scientific experts and higher level stakeholders (e. g. climatologists and water management boards) to local authorities and local agents (e. g. mayors and NGO representatives).

The collected information was used to evaluate (1) recognition of ecosystem services, (2) their coping capacity with weather extremes, (3) the natural characteristics of ecosystems on a four-step scale: no, low, medium, high. We assigned these values subjectively synthesizing all the information obtained from interviews, observation and literature. For instance, food was regarded as the most cared for service among the local experts. Furthermore, this service was mentioned the most often in the available official documents. Finally, we noted during the field visit that food crops are the most popular. Therefore we assigned “high” for its recognition.

In order to visualize the spatial distribution we generated GIS maps for the food and recreation services. First, input maps were created for natural characteristics of ecosystems, climate related extremes and human recognition. The influence of policy measures was neglected in the map generation due to the insufficient location specific information. The recognition input maps are the land cover-based spatial visualisation of the fieldwork results. The climate related extremes input map reflects the coping ability of different land cover types with flood and drought. This map was used for both food and recreation services. In addition, the natural characteristics are represented by agricultural suitability map for food and protected areas for recreation. In the Romanian case, the agricultural suitability map was generated only for the arable ecosystem taking into account the favourability for the wheat, maize and sunflower crops from hard copy maps (available as part of the Tinca Pedology Study). The protected areas maps were obtained by assigning values from 1.0 to sites with no protection until 4.0 to sites which are protected on three levels (this is the maxim level of protection in the studied areas). In the Romanian case the protected areas assignation was based on the land cover map, while in Hungary the different levels of protection - Natura 2000, Ramsar and national protected area - were drawn respectively.

All the input maps contain information in the range of 1.0 - 4.0, where 1.0 stands for no, 2.0 for low, 3.0 for medium and 4.0 for high value of a feature: recognition, ability to cope with climate extremes, agricultural suitability and protected areas. The final maps output was obtained by calculating the equal weight average of corresponding cells (one decimal accuracy).

RESULTS

Food service

The map of the food service in the Hungarian region shows a predominance of medium performance (Fig. 4). The area with the highest score is the arable/grassland in the centre of the region. This can be explained by higher suitability of this area for agricultural production indicated on the soil fertility input map. Forests score lower, due to the lack of recognition of food (berries and mushrooms) provided by the forest. Finally, wetlands and urban environment have the lowest food production because of their low coping capacity with the weather extremes and because people do not consider them as an important food source.

In the Romanian region the food service map shows a more diverse pattern (Fig. 5). The lowest performance is attained in the arable lands with poor soil quality, wetlands and in the villages due to their vulnerability to weather extremes. The highest performance is achieved in arable and grasslands with very good agricultural suitability and more valued by local people. However, the low amount of information used as input leads to some inconsistencies, such as the comparability of forest provided food with some arable lands, due to the increased capacity of forest to cope with weather extremes. The difference between the Hungarian and Romanian output maps resides in the more heterogeneous land cover of the first one.

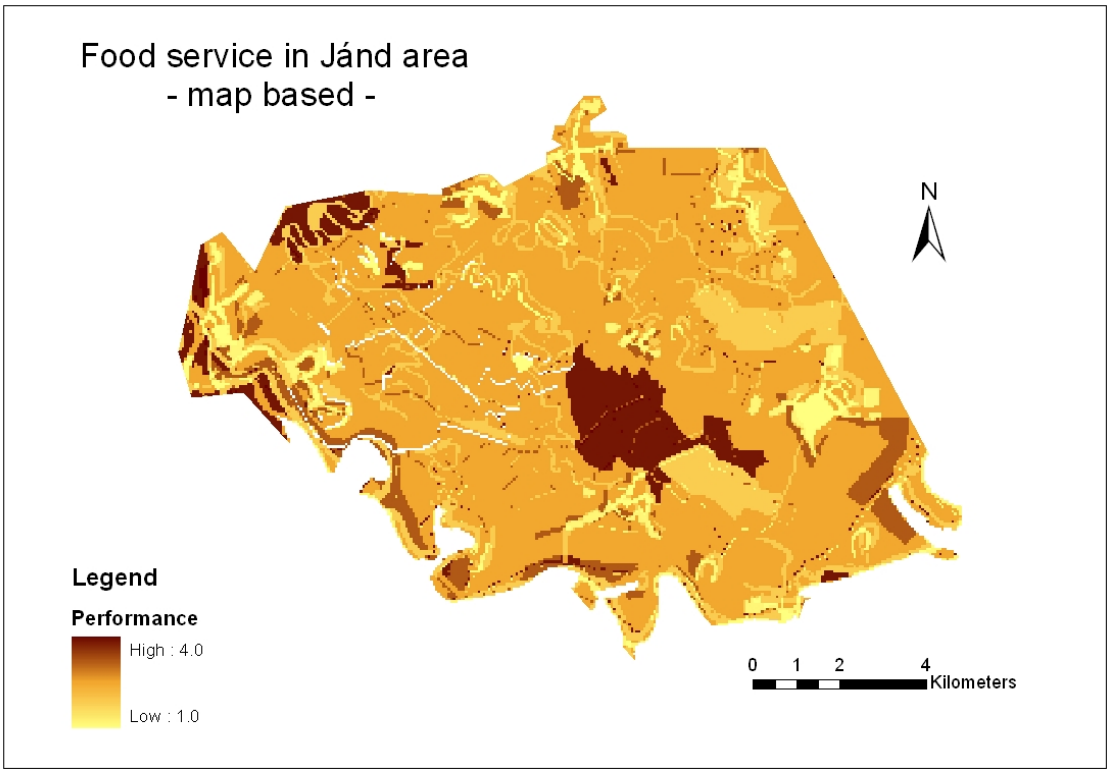

Figure 4: The map based food service performance in Jánd.

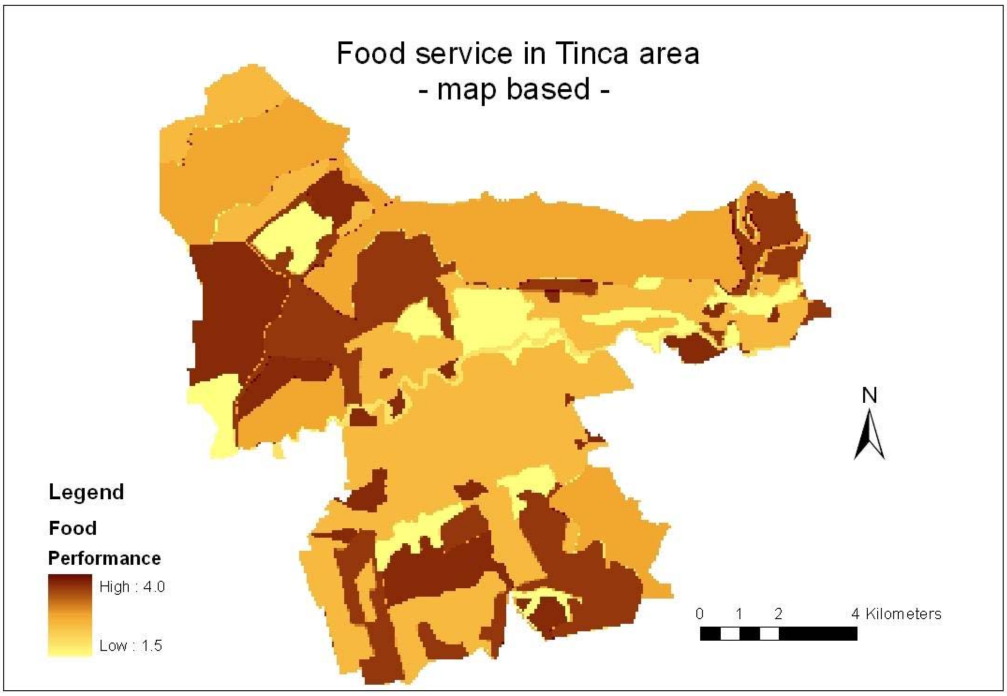

Figure 5: The map based food service performance in Tinca.

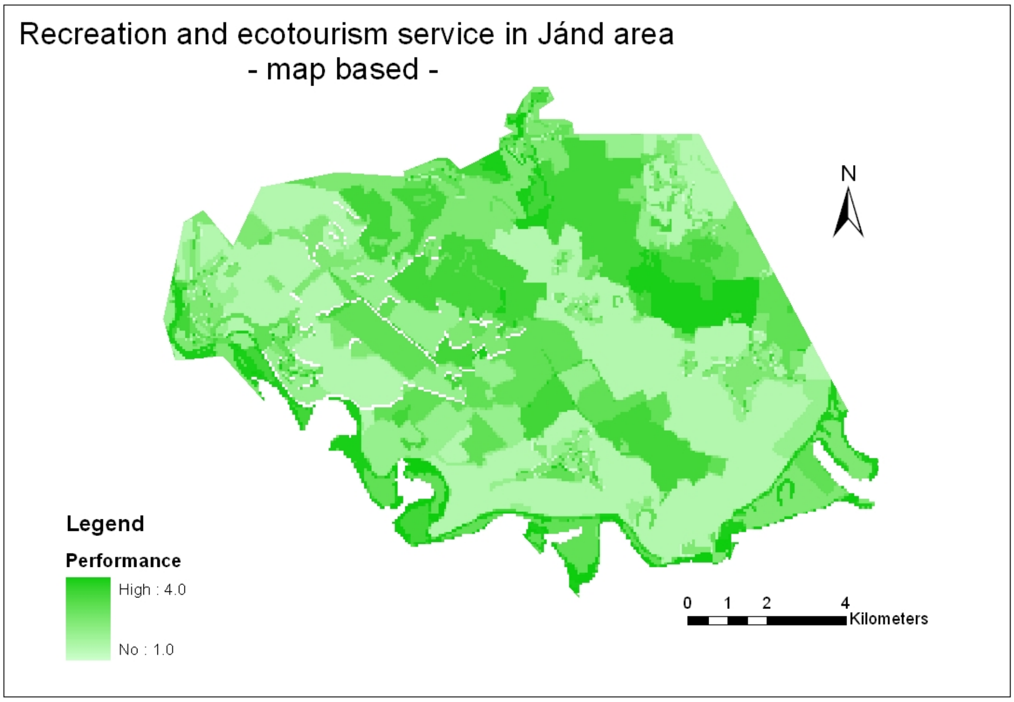

Figure 6: The map based recreation and ecotourism service performance in Jánd.

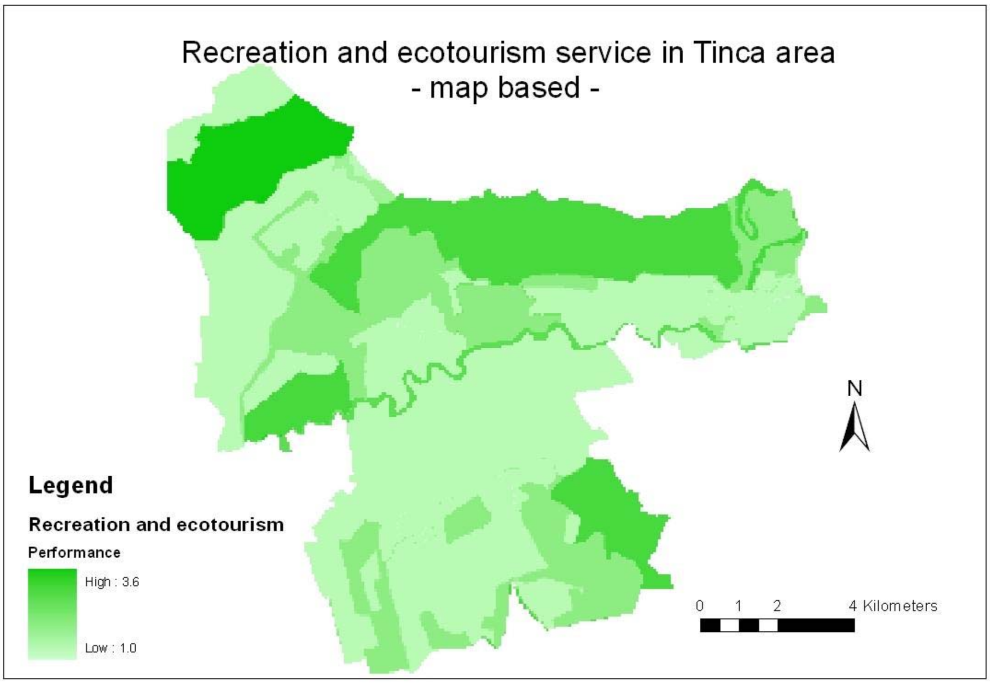

Figure 7: The map based recreation and ecotourism service performance in Tinca.

Recreation and ecotourism service

In Hungary the visualisation follows rather the pattern of the plot-size protection, where protected areas were assigned to provide more recreation opportunities (Fig. 6). Particularly, the riparian areas have a high recreational value because of the three-fold protection and appreciation by locals and tourists. Furthermore, forest also offers good recreational opportunities. In the Romanian case the recreation is the poorest in the arable land and the highest in the forest, depending to a large extent on people's opinion and the exposure to weather extremes (Fig. 7). The level of protection increases the service delivery in the north-western forest. Moreover, the river surroundings also have a high recreational significance.

An interesting aspect is to compare the information provided by ecosystem services maps, which are completely dependent on the scores of the input maps, with the information gathered during the fieldwork. Many of the hotspots detected on the maps coincide with the actual performance of the ecosystem services assessed through interviews and observations. However there are also inconsistencies due to the restricted range of information available for the input maps.

DISCUSSION

Mapping ecosystem services is a fairly new approach with no established methodology. Ecosystem services maps can be generated in many different ways, depending on the message to be delivered and the target group using them. These maps often represent a sole land cover type, based on the natural characteristics of an area, such as vegetation, elevation, soil quality. In paralel studies, such as the Peak District National Park or the University of Almeria initiatives, ecosystem services maps have been created based on a single indicator (e. g. one input map). Such maps are able to offer a powerful insight into the ecosystems natural delivery capacity, but they overlook the social aspect, namely the extent to which people actually recognize and use what the ecosystems provide. Moreover, concepts such as “service providing units” and “beneficiaries of ecosystem services” are emerging to support the mapping process (Kremen, 2005).

In our study in order to draw a more realistic picture we considered all the influencing factors as inputs. However, this can lead also to a higher uncertainty. Furthermore, our assessment shows the high dependency of the output maps on the input features. Therefore, the selection of the input data and their quality is very important in the map generation process. In this study, the lack of homogenous information (e. g. there are no precise GIS maps available for protected areas), the poor data quality, the obsolete information (e. g. CORINE GIS land cover map) led to less accurate results. Moreover, the map generation is based on numerous assumptions regarding the factors and their way of influencing the ecosystem services delivery (e. g. assigning an equal weight for all the factors). In this respect, the output maps may carry a deceiving message, depending on the assumptions and interpretation.

The application of ecosystem services maps can prevent shortcomings in the water management and land use plans development. In addition, they can sustain the efforts of biodiversity conservation. However, ecosystem services maps are slightly acknowledged for their provided opportunities and rarely used in practice. A further step would be the detailing of the maps, which require also accurate spatial information gathering. Moreover, the combination of the location specific fieldwork results with the readily available digital maps would give a more realistic output. Finally, the appropriate scale at which ecosystem services are mapped should be chosen.

CONCLUSIONS

Ecosystem services maps can integrate the available information about the natural and human related processes supporting the ecosystem services in a comprehensive way. This study offers an insight on the possibilities of creating ecosystem services maps based on readily accessible data, such as the digital land cover map. The ecosystem services maps created for food and recreation and ecotourism services in the Hungarian and Romanian areas, even if not the most accurate, can be used to detect hotspots of low and high performance and to contribute to location focused spatial planning.

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WATER POLLUTION IN THE MUREŞ CATCHMENT AND ITS IMPACT ON THE AQUATIC COMMUNITIES (ROMANIA)

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KEYWORDS: Romania, Transylvania, Mureş River basin, hydromorphology, water quality, pollution, saprobic index.

ABSTRACT

A literature study, data of the national monitoring authority and a pilot project of International Asociation for Danube Research provided the water quality in 2004 for the Romanian part of the Mureş River and its major tributaries. High pollution with nutrients was found downstream of Azomureş Târgu Mureş factory and on the Canal Mureşul Mort and heavy metal contamination in Arieş and Târnave sub-catchments and Certej tributary.

The impact of poor water quality on aquatic biocenoses is emphasized. Microbiological parameters showed high organic contamination, mostly of faecal origin. Plankton and benthos evaluation revealed mostly beta-mesosaprobic conditions for the investigated river stretches, except for the sections highly affected by pollution where beta-alpha-mesosaprobic or alpha-mesosaprobic conditions were recorded; on stretches with severe heavy metals contamination no benthic life was found.

Fish are even more sensitive to pollution than plankton and benthos. Our pilot project carried out in 2004 revealed sub-lethal effects on fish (histopathological damage in livers and gills as well as proteotoxic damage, i. e., increased biochemical markers such as hsp 70 and hepatic EROD activity) proving that current monitoring techniques should be up-graded with modern methods in order to assess the ecological effects of environmental pollution.

RĖSUMĖ: Pollution aquatique dans le bassin hydrographique de Mureş et son impact sur les communautés aquatiques (Roumanie).

Une étude bibliographique, des données de l'autorité nationale de monitoring et un projet pilote de l'IAD ont étudié la qualité de l'eau de la rivière Mureş et ses affluents majeurs en 2004. Une pollution élevée en substances organiques en aval d'Azomureş Târgu Mureş et dans le canal Mureşul Mort, et une contamination en métaux lourds dans les sous-bassins de l'Arieş et du Târnave ainsi que dans l'affluent Certej ont été mis en évidence.

L'impact de la faible qualité de l'eau sur les biocénoses aquatiques a été souligné. Les paramètres microbiologiques ont indiqué une contamination organique élevée, constituée principalement de matières fécales. L'évaluation du plancton et du benthos a révélé des conditions beta-mésosaprobes pour la plupart des rivières examinées, à l'exception des sections montrant une contamination élevée où ont été trouvées des conditions beta-alpha-mésosaprobes ou alpha-mésosaprobes; dans les sections avec une concentration très élevée en métaux lourds les organismes du benthos n'ont pas été trouvés.

Les poissons sont même plus sensibles à la pollution que le plancton et le benthos. Notre projet pilote réalisé en 2004 a révélé des effets non léthaux sur les poissons (modifications histopathologiques du foie et des branchies ainsi que des niveaux élevés des marqueurs biochimiques comme hsp 70 et EROD), prouvant que les méthodes actuelles de monitoring devront être révisées en appliquant des méthodes modernes pour évaluer les effets écologiques de la pollution sur l'environnement.

REZUMAT: Poluarea apei în bazinul hidrografic Mureş şi impactul acesteia asupra comunităților acvatice (România).

Un studiu bibliografic, datele autorității naționale de monitoring şi un proiect pilot al Asociației Internaționale pentru cercetarea Dunării au oferit imaginea calității apei în partea română a râului Mureş şi a afluenților săi principali în anul 2004. Poluarea ridicată cu nutrienți a fost identificată în aval de întreprinderea Azomureş Târgu Mureş şi pe Canalul Mureşul Mort, iar în sub-bazinele Arieş şi Târnave, ca şi pe afluentul Certej, s-au înregistrat contaminări puternice cu metale grele.

Este prezentat impactul calității scăzute a apei asupra biocenozelor acvatice. Parametrii microbiologici au semnalat o contaminare organică puternică, în special, cu materii de origine fecală. Evaluarea planctonului şi bentosului a relevat condiții beta-mezosaprobe pentru majoritatea sectoarelor investigate, cu excepția zonelor puternic afectate de poluare, unde s-au înregistrat condiții beta-alfa-mezosaprobe sau alfa-mezosaprobe; în zonele contaminate sever cu metale grele nu au fost găsite organisme bentonice.

Deşi planctonul şi bentosul par să se fi adaptat la poluare, peştii sunt mai sensibili la calitatea mediului lor de viață. Proiectul pilot derulat în 2004 a relevat efecte sub-letale la peşti (modificări histopatologice ale ficatului şi branhiilor, ca şi creşteri ale conținutului de biomarkeri moleculari cum ar fi hsp 70 sau EROD), demonstrând că metodele actuale de monitoring trebuie actualizate cu metode moderne pentru a estima efectele ecologice ale poluarii mediului.

INTRODUCTION

The Mureş River came into the attention of the International Association for Danube Research (IAD) in 2004, after performing a pilot study in its lower stretch near Arad, aiming to assess the ecological effects of pollution on aquatic biocenoses by combining classic monitoring analyses with modern techniques of biomarkers analyses (Köhler et al., 2005).

To identify the sources of pollution and provide basic information at catchment level, a literature study was performed during 2005 - 2006, compiling data of the monitoring authority and published articles (Sandu and Bloesch, 2006). The study revealed that, in spite of the decreasing economic activity after 1990, pollution impacts due to mining, metallurgy, chemical factories, old waste deposits and diffuse sources are still high, affecting water quality and consequently aquatic biocenoses (Sandu, 2007). This paper presents the actual state of water quality in rivers and streams and its impact on aquatic communities.

MATERIAL AND METHODS

The transboundary Mureş River is the main tributary of Tisa/Tisza River has a catchment of 28,310 km^2 and a length of 789 km, of which 761 km are located in Romania and a small sector of 28 km in Hungary (Fig. 1). In the Romanian part of the Mureş Catchment, water quality is monitored by Mureş Waters Directorate and classified in five classes according to the Water Framework Directive (EU - WFD) and Romanian standards (class I - high, II - good, III - moderate, IV - poor, V - bad).

Based on the sensitivity of aquatic communities to environmental stress, several biological criteria to assess water quality were applied - amongst other the saprobic system that is based on organic pollution (Pantle and Buck, 1955; Sladecek, 1973): according to the benthos species, water is usually classified in five classes (some authors use seven classes, see e. g. Schmid 2004 - IAD map): class I - oligosaprobic, class II - beta-mesosaprobic, class III - beta-alpha mesosaprobic, class IV - alpha mesosaprobic and class V - polysaprobic. In Romania, the water quality monitoring includes the assessment of saprobiological status using the method of Pantle and Buck (1955).

The database of Mureş Water Directorate provides the best overview of the actual chemical condition of Mureş River and its tributaries in the Romanian part of the catchment. The monitored parameters include for chemistry a general physico-chemical characterization (temperature, pH, suspended solids, major anions and cations, oxygen balance, nutrients), inorganic and organic pollutants (heavy metals, phenols, ANA detergents), priority substances (Cd, Hg, Ni and Pb) and for biology the analyses of plankton, benthic algae and macrozoobenthos (abundance and saprobic index). The chemical analyses are carried out monthly, while the biological investigations are carried out seasonally (maximum four times/year for plankton and two times/year for benthos) (MWDR, 2005).

The map (Fig. 1) shows the location of sampling sites along the Mureş River according to MWDR (2005). The monitoring data of the 2004 period are compared with our local study of the lower stretch (Zam - Pecica localities) in 2004 (Köhler et al., 2005) for Mureş River, while for the tributaries the paper focuses mostly on monitoring data of 2004 (MWDR 2005).

Figure 1: Mureş River Basin, with insert showing the location on the Romanian territory. The sampling sites 1 - 16 are according to MWDR (2005) (Sandu and Bloesch, 2007)
1 - Izvorul Mureşului, 2 - Gălăuțaş, 3 - Stânceni, 4 - Brâncoveneşti, 5 - Glodeni, 6 - Ungheni, 7 - Cipău, 8 - Chețani, 9 - upstream Ocna Mureş, 10 - Mihalț, 11 - upstream Alba Iulia, 12 - Gelmar, 13 - Brănişca, 14 - upstream Lipova, 15 - upstream Arad, 16 - Nădlac.

RESULTS

In 2004, 10 % out of 2320 km monitored water courses in the Mureş Catchment area were considered of poor or bad quality, affecting severely the local biota.

However, according to the general physico-chemical characterization, the water quality of Mureş River can be classified mostly in class I or II, except the stretch between Mihalţ and Gelmar localities, where high content of sodium, chlorides, sulphates and total solids were found, classifying this section as a class III (Tabs. 1a, b). According to the chemical oxygen demand (COD) and nutrients content, most parts of the Mureş River are in class II even in the headwater area (due to the COD values above 10 mgO/l), except the stretch between Ungheni and Cheţani where the water quality decreases to class III due to the high content of nitrogen and phosphorus. The heavy metals content is high, especially in the lower stretch of the river, classifying the section between Ocna Mureş and Gelmar as class IV (copper content up to 93.5 µg/l) and the section between Lipova and Nădlac as class V (lead content up to 32.1 µg/l).

In the Mureş River tributaries the pollution impact is much higher, many of them draining industrial, mining and agricultural areas (Tabs. 2a, b). The general characterization shows a high content of magnesium and sulphates on Lechinţa, Pârâul de Câmpie and Certej, placing these streams in class V, and a high content of sodium and chlorides on Canal Mureşul Mort, Canal Ier, Lechinţa, Pârâul de Câmpie and Târnava Mică (between Sărăţeni and Petrisat), corresponding to class IV or V. The oxygen and nutrients criteria show Canal Mureşul Mort and Canal Ier as the most polluted sites (class V, respectively IV). The pollution with heavy metals is significant in the Mureş Catchment as many stretches were evaluated as class IV or V, the concentrations surpassing the admitted limits at European level and the Romanian standards. Critical values were recorded on Arieş (Mn, Cu, Zn and Pb), Abrud (Fe, Mn, Cu, Zn and Cd), Târnava Mică (Cr, Cu, Mn and Pb), Ampoi (Cu and Pb) Certej (Fe, Mn, Cu, Zn, Cd and Pb) and Canal Mureşul Mort (Fe, Mn, Cu and Cd). The left side tributaries are less polluted than the right ones coming from Trascău and Metaliferi Mountains: Cugir, Geoagiu, Oraştie, Strei, Cerna have maximum 0.11 mg/l Fe and no dangerous concentration of the investigated heavy metals.

Table 1a: Critical sections along **Mureş** River (MWDR, 2005).

River Mureş	Total solids	Na^+	SO_4^{2-}	Cl^-	DIN
Station	dr.105 °C (mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg N/l)
Izvorul Mureşului	175.1	6.2	12.7	7.7	0.997
Gălăuţaş	129	7.7	13.6	10.6	1.141
Stânceni	120.3	8.8	11.1	11.5	1.299
Brâncoveneşti	102.8	11.9	8.4	17.9	0.915
Glodeni	153	16.4	18.9	23.5	1.285
Ungheni	201.9	23.1	21.9	29.4	5.569
Cipău	244.7	26.5	19.3	37.5	5.72
Cheţani	318	34.1	53.9	43.7	5.284
Upstream Ocna Mureş	302.7	39.7	53.9	70	1.888
Mihalţ	577	80.8	153.7	144.7	2.26
Upstream Alba Iulia	544.7	84.3	101.3	147.4	2.363
Gelmar	432.4	59.1	63.5	121.9	2.991

Table 1b: Critical sections along Mureş River (MWDR, 2005) (in italics - class IV).

River Mureş	PO_4^{3-}	TP	FE	MN	CU	ZN
Station	(mg P/l)	(mg P/l)	(mg/l)	(mg/l)	(μg/l)	(μg/l)
Izvorul Mureşului	0.022	0.063	0.3	0.028	14.23	74.25
Gălăuţaş	0.054	0.091	0.28	0.021	19.93	71
Stânceni	0.049	0.11	0.26	0.023	14.63	128.25
Brâncoveneşti	0.032	0.073	0.24	0.016	11.03	85
Glodeni	0.044	0.117	0.18	0.019	13.6	67.78
Ungheni	0.152	0.281	0.18	0.026	20.36	109.58
Cipău	0.136	0.269	0.19	0.036	16.82	43
Cheţani	0.116	0.25	0.21	0.033	18.07	91.67
Upstr. Ocna Mureş	0.043	0.06	0.22	0.032	*93.5*	144.5
Mihalţ	0.03	0.039	0.11	0.022	*76.25*	156.92
Upstr. Alba Iulia	0.033	0.042	0.14	0.024	*76.08*	146.83
Gelmar	0.04	0.132	0.15	0.057	*50.15*	104.18
Brănişca	0.038	0.133	0.15	0.079	23.28	124.58
Upstream Lipova	0.021	0.048	0.14	0.029	32.14	108.42
Upstr. Arad	0.016	0.042	0.13	0.018	*68.51*	102.03
Nădlac	0.016	0.042	0.14	0.016	*46.32*	105.27
Brănişca	345	42.8	50	83.7	2.404	
Upstream Lipova	328.5	38.5	116.1	69.5	1.212	
Upstream Arad	329.9	38.5	120.1	69.1	1.38	
Nădlac	326.4	37.6	112.3	71.7	1.329	

Table 2a: Critical sections along the monitored tributaries (MWDR, 2005) (in italics - class IV, in bold - class V).

Tributary	Station	Tot. solids	Na^+	Mg^{2+}	SO_4^{2-}	Cl^-	COD-Cr	DIN
		dr. 105˚C (mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	mg/l O_2	(mgN/l)
Lechinţa	Upstream Mureş confluence	**1383**	*119*	*76*	**433**	152	31.5	3.368
Pârâul de Câmpie	Avrămeşti	**1455**	*126*	**108**	**555**	81.1	41.8	3.299
Arieş	Scărişoara	101.6	3.7	7.2	11.9	5.9	4.2	0.597
	Downstream Mihoieşti Res.	100.9	3.9	6.8	6.5	6.6	5.8	0.451
	Upstream Baia de Arieş	166.5	4.7	10.1	68.8	9.2	6.7	0.799
	Buru	168.7	5.2	9.6	55.9	10.5	7	0.733
	Luncani	216.2	7.6	11.2	63.8	15.2	8.9	1.169
Abrud	Upstream Arieş confluence	339.7	6.5	28.8	202.1	12.7	9.7	2.949

Tributary	Station	Tot.solids	Na^+	Mg^{2+}	SO_4^{2-}	Cl^-	COD-Cr	DIN
Iara	Upstream Arieş confluence	143	7.7	10.3	23.5	12	7.8	0.843
Hăsdate	Petreşti	379.7	17.1	14.4	36.4	29	11.2	1.02
Târnava Mare	Ustream Blaj	461.7	25.7	26	97.3	45.4	13.3	2.076
Târnava Mică	Sărăţeni	525.3	*171*	3.9	14.4	*263*	20.8	0.981
	Bălăuşeri	502.7	*128*	6.4	15.8	198.3	15.1	1.114
	Upstream Târnăveni	550.9	*120*	8.7	26.3	186.7	15.3	1.329
	Crăieşti	588.4	*130*	9.2	30.6	201.3	15.6	1.537
	Petrisat	549.8	*102*	24.7	54.7	175.7	12.3	1.696
Târnava	Mihalţ	543.7	64.8	32.5	105.8	120.5	15.7	2.054
Ampoi	Ampoi spring	155.7	6.3	11.7	20.5	10.4	5.8	0.58
	Bărăbanţ	353.7	18.1	23.1	101	40.2	9	1.375
Sebeş	Upstream Gâlciag confluence	88.7	4.5	6	15.3	7.7	8	0.758
	Oarda	210.5	23.4	10.8	20.9	43.4	9.5	1.37
Cugir	Upstream Cugir	75.5	7	5.5	7.2	11.5	7.9	0.668
	Upstream Mureş confluence	93	6.9	7.4	18.1	11.5	7.9	0.79
Certej	Upstream Mureş confluence	**1553**	29.8	**101**	**1025**	25.9	33.9	2.896
Mureşul Mort	Upstream Mureş confluence	*1091*	*176*	25.9	**329**	204.7	**376.8**	**55.09**
Canal Ier	Turnu	750	*150*	19.9	*255*	131.3	*62.2*	5.544

Table 2b: Critical sections along the tributaries (MWDR, 2005) (italics - class IV, bold - class V).

Tributary	Station	TP	Fe	Mn	Cr	Cu	Zn	Cd
		(mgP/l)	(mg/l)	(mg/l)	(µg/l)	(µg/l)	(µg/l)	(µg/l)
Lechinţa	Upstream Mureş confluence	0.236	0.03	0.07	0.76	20.5	59	0
Pârâul de Câmpie	Avrămeşti	0.247	0.16	*0.18*	1.02	20.5	102	0.1
Arieş	Scărişoara	0.015	0.04	0.02	1.6	35.52	117.6	*2.2*

Tributary	Station	TP	Fe	Mn	Cr	Cu	Zn	Cd
Arieş	Downstream Mihoieşti Res.	0.012	0.12	0.02	0.8	*49.3*	93.14	0.1
	Upstream Baia de Arieş	0.01	0.16	**0.44**	1.27	**272**	*302*	0.8
	Buru	0.017	0.27	*0.27*	1.03	**197**	199.2	0.3
	Luncani	0.025	0.17	0.103	1.24	**130**	194.3	0.3
Abrud	Upstream Arieş confluence	0.014	*0.56*	**4.58**	1.61	**169**	**1204**	*3.5*
Iara	Upstream Arieş confluence	0.026	0.04	0.005	0.7	*74.3*	126.8	0.1
Hăsdate	Petreşti	0.07	0.05	0.004	1.06	*57.2*	115	0.1
Târnava Mare	Upstream Blaj	0.053	0.28	0.035	1.69	*44.12*	188.4	**6.8**
Târnava Mică	Sărățeni	0.174	0.16	0.041	0.65	13.73	67.83	0.1
	Bălăuşeri	0.143	0.25	0.077	0.89	15.64	133.9	0.1
	Upstream Târnăveni	0.11	0.19	*0.11*	1	14.2	66	0.3
	Crăieşti	0.136	0.2	0.098	**610**	16.74	66.42	0
	Petrisat	0.064	0.23	0.024	**392**	*41*	90.87	0.2
Târnave	Mihalț	0.048	*0.33*	0.041	*138*	*47.6*	120.8	*3.1*
Ampoi	Ampoi spring	0.012	0.06	0.001	1.62	*59.1*	141	0.2
	Bărăbanț	0.018	0.21	0.03	1.71	*90.7*	***188***	0.5
Sebeş	Upstream Gâlciag confluence	0.013	0.08	0.001	0.62	39.5	93.67	0.1
	Oarda	0.039	0.11	0.008	0.92	*48.8*	90.08	0.1
Cugir	Upstream Cugir	0.017	0.05	0.001	0.66	*55.3*	83.75	0.1
	Upstream Mureş confluence	0.032	0.1	0.001	13.23	*58.5*	77.25	0.1
Certej	Upstream Mureş confluence	0.036	**2.55**	**15**	4.09	**475.1**	**6205**	145
Mureşul Mort	Upstream Mureş confluence	**4.75**	*0.43*	*0.23*	41.84	*57.8*	123.8	*3.5*
Canal Ier	Turnu	*0.65*	0.16	0.095	18.68	21.43	86.28	1.3

The saprobiological investigations carried out by the monitoring authority reflected the reaction of plankton and benthic communities to the environmental stress. Most stretches along Mureş River can be considered as beta-mesosaprobic, except for the sections Stânceni, Ungheni - Chețani classified as alpha-mesosaprobic and Gălăuțaş, Glodeni, Mihalț and the lower stretch of Mureş River downstream Lipova, which were beta-alpha-mesosaprobic (Tab. 3).

Table 3: Saprobiological index along Mureş River in 2004 (MWDR, 2005), (in italics - class III, in bold - class IV).

River Mureş	Plankton	Benthic algae	Macrozoo benthos
Station			
Izvorul Mureşului	1.86	2.19	2.07
Gălăuțaş	1.98	1.9	*2.42*
Stânceni	1.91	2.03	**2.72**
Brâncoveneşti	1.84	1.93	2.16
Glodeni	1.96	*2.33*	*2.44*
Ungheni	2.11	**2.74**	**3.12**
Cipău	1.99	2.09	**2.86**
Chețani	2.07	1.99	**3.02**
Upstream Ocna Mureş	1.82	2.25	1.61
Mihalț	2.02	1.91	*2.5*
Upstream Alba Iulia	2.07	2.12	2.08
Gelmar	2.2	2.01	2.07
Brănişca	2.21	2.08	2.13
Upstream Lipova	2.29	*2.36*	2.12
Upstream Arad	2.24	*2.4*	1.86
Nădlac	*2.31*	*2.36*	1.95

On tributaries, few stretches, usually in the headwater region, can be classified as oligosaprobic; most of the investigated sites are beta-meso-saprobic, except for stretches severely affected by pollution, which belong to the beta-alpha-mesosaprobic category (e. g. Pârâul de Câmpie, Târnave, Canal Mureşul Mort - Tab. 4). On Abrud, Cerna (Sântuhalm) and Certej, highly polluted with heavy metals, no benthic species could be found as a consequence of the acidic pH.

Though the classic monitoring results (plankton, benthos and water chemistry) were not alarming, our microbiological investigations have shown faecal contamination (Sandu et al., 2007), while the biomarkers and histopathological analyses have indicated the environmental stress in the area (Köhler et al., 2007; Triebskorn et al., 2002).

Table 4: Saprobiological index on the investigated tributaries (MWDR, 2005) (in italics – class III, in bold - class IV).

Tributary	Station	Plankton	Benthic algae	Macrozoobenthos
Gurghiu	Lăpuşna	1.78	1.84	2.09
	Solovăstru	1.77	1.73	*2.39*
Niraj	Eremitu	1.73	1.9	*2.41*
	Ungheni	1.92	2.12	*2.65*
Lechinţa	Upstream Mureş confl.	2.19	*2.31*	2.06
Pârâul de Câmpie	Avrămeşti	*2.31*	2.24	**2.94**
Arieş	Scărişoara	1.63	1.91	1.55
	Downstr. Mihoieşti Res.	1.68	2.09	1.88
	Upstream Baia de Arieş	1.78	1.99	2.09
	Buru	1.51	1.38	1.52
	Luncani	1.82	1.79	1.45
Abrud	Upstream Arieş confl.	1.93		n.a.
Iara	Upstream Arieş confl.	1.61	1.74	1.36
Hăjdate	Petreşti	1.85	1.72	1.67
Târnava Mare	Downstr. Zetea Res.	1.72	1.8	*2.31*
	UpstreamCristuruSecuiesc	1.9	2.07	**2.91**
	Vânători	1.86	1.8	*2.6*
	Upstream Mediaş	2.28	*2.39*	*2.52*
	Upstream Blaj	2.18	2	2.27
Târnava Mică	Sărăţeni	1.98	1.72	**2.84**
	Bălăuşeri	1.81	2.26	*2.47*
	Upstream Târnăveni	1.99	2.12	*2.63*
	Crăieşti	2.02	2.03	2.24
	Petrisat	2.01	1.96	1.88
Târnava	Mihalţ	2.11	2.27	*2.31*
Ampoi	Ampoi spring	1.56	1.83	2.11
	Bărăbanţ	1.8	1.66	1.44
Sebeş	Upstream Gâlciag confl.	1.78	1.68	1.72
	Upstream Petreşti Res.	1.79	1.6	1.58
	Oarda	1.92	1.64	1.77
Cugir (Râul Mare)	Upstream Cugir	1.54	1.36	1.53
	Upstream Mureş confluence	2.07	2.07	*2.25*
Geoagiu	Balşa (upstream Geoagiu)	2.1	2.19	1.67
	Upstream Mureş confluence	2.23	2.02	1.85
Orăştie	Costeşti	1.87	1.32	2.11
	Downstream Orăştie	1.99	1.92	2.16
Strei	Pui	1.92	1.74	1.75
	Petreni	1.92	2.06	1.86
Râul Galben	Haţeg	2.12	2.08	*2.33*
Canal Batiz	Simeria	*2.32*	2.13	n.a.
Cerna	Teliucu Superior	2.05	1.89	1.68
	Sântuhalm	*2.41*		n.a.
Certej	Upstream Mureş confluence	*2.54*		n.a.
Canal Mureşul Mort	Upstream Mureş confluence	*2.49*	*2.5*	**2.92**
Canal Ier	Turnu	*2.55*	*2.6*	*2.6*

DISCUSSION

The high content of sodium and chloride on Târnava Mică might be due to substrata characteristics, the tributary crossing a region known for its geological salt deposits. The increased values of sodium and chloride recorded for Mureş River between Mihalţ and Gelmar, are probably a consequence of Târnava Mică inflow and also to UPSOM Ocna Mureş pollution (chemical factory for chloride - sodic products). Due to the significant discharge of Târnava River (about one third of Mureş discharge before the confluence), this tributary has a major influence: all parameters that surpassed the limits in Târnava River have shown increased values in Mureş River (Tabs. 1, 2).

The unusually high content of nutrients between Ungheni and Cheţani is most probably due to Azomureş fertilizers factory (located in Târgu Mureş), and at a lower extent to agricultural inflow. The release of N and P of this factory is the highest source of nutrient pollution in the whole catchment and affects also the groundwater.

Although Canal Mureşul Mort bears a severe organic contamination, due to its low discharge a very rapid dilution occurs downstream the confluence with Mureş River and no influence on nutrient concentration, chemical oxygen demand and dissolved oxygen could be detected except that of ionic composition; similar situations occur at the confluence of Certej and Canal Ier with Mureş.

The high content of heavy metals is a consequence of mining activities in the area. Though after 1990 these activities declined, the metals accumulated in sediments and metallurgical and mining wastes deposited in abandoned mines are continuously contaminating the middle and lower stretch of Mureş River via its tributaries Târnava, Ampoi, Abrud, Arieş and Certej. The high metal content found along Târnave tributaries is due to Sometra Copşa Mică and Bicapa Târnăveni (though the last factory was closed in 2001). An ESTROM project, running in the Apuseni Mountains on Crişul Alb and Certej catchments, revealed a high level of metal contamination in Certej River due to the active tailing dams and mining facilities.

Though EU - WFD recommends that poly-aromatic hydrocarbons (PAH) and poly-chlorinated biphenyls (PCB) are included in the monitoring program (as priority substances), these analyses are not performed in the current monitoring. Our study carried out in 2004 on the lower stretch of Mureş River (Zam - Pecica) revealed that the concentration of these pollutants was very low, sometimes below the detection limits (Sandu et al., 2007).

Water quality has a strong effect on aquatic biocenoses, major pollutants affecting the biodiversity in many ways, despite dispersion and dilution. The saprobiological classes reflect qualitatively the five chemical classes. Though the regular monitoring of chemical and biological parameters did not indicate alarming situations on the lower stretch of Mureş River, the investigations carried out in our pilot project showed high organic contamination, mostly of faecal origin (threatening human health) and sub-lethal effects of pollution on fish. Microbiological contamination was evident as we recorded up to 1300 faecal coli and 490 faecal streptococci per 100 ml, classifying the stretch between Zam and Mândruloc as critical, according to the European bathing water quality directive (EEC 1975). More sensitive to the water quality than plankton and benthos, both fish species selected for investigations, sneep *(Chondrostoma nasus)* and European chub *(Leuciscus cephalus),* presented histopathological damages in liver and gills (Triebskorn et al. 2002), as well as increased levels of stress protein hsp70 and hepatic EROD activity (Köhler et al., 2007).

Hence, while traditional chemical-biological monitoring (MWDR 2005) did not reflect pollution, new sensitive methods using biomarkers and cell analysis of sensitive organs can be used as early indicators (Burkhardt-Holm and Bloesch, 2000; Triebskorn et al., 2002).

CONCLUSIONS

In view of integrated water protection strategies, it is generally accepted that a combination of physico-chemical, biological and hydromorphological analysis is needed to define/reach “good ecological status” according to the EU-WFD (Bloesch, 2004).

The first steps to implement the EU-WFD in Romania were done by the National Administration Romanian Waters and chemical characterization of the river catchment is improving every year (due to the new equipment bought by water authorities, new analyses could be performed, according to the EU-WFD requests). Although scattered basic catchment and river information is available, the ecological assessment of the river is still missing. Biological data are still few: several PhD studies and research articles on tributaries or small river stretches and the data basis of Mureş Water Directorate (Hamar and Sarkany-Kiss, 1995; Telcean, 2001; Curtean-Bănăduc et al., 2005; Bănăduc et al., 2006; Curtean-Bănăduc et al., 2007; Curtean-Bănăduc et al., (2009 in printing); etc. - a reference list is available in Sandu, 2007).

There is a strong need of interdisciplinary cooperation between chemists, biologists, aquatic ecologists, hydrologists, geographers in order to succeed, and IAD, by its expert groups, has the potential to play an important role in such a project, not only by providing expertise to the local universities and authorities but also by being actively involved in this assessment.

A complementary work on the complex ecosystem function, limnological concepts and new methods (e. g., biomonitoring and ecotoxicology) to get a holistic catchment view in the long-term will help both countries, Romania and Hungary, to implement the river basin management according to the EU-WFD and to obtain the “good ecological status”.

The Mureş River is well suited as it is large, transboundary, moderately regulated and highly polluted, hence providing a variety of sub-basins and research topics.

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EFFECT OF METAL POLLUTION ON AQUATIC MICROORGANISMS: A CASE STUDY IN MINING AREAS (ROMANIA)

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KEYWORDS: mining area, rivers, heavy metals, bioluminescence, bacteria, toxicity.

ABSTRACT

The results with respect to the toxicity effects of metal pollution on microorganisms in the Lăpuş and Săsar rivers, from the Baia Mare mining area are reported in this paper. Toxicity tests were conducted using the ToxTracer system, which is based on the inhibition of *Vibrio fisheri* luminescence. The bioluminescence inhibition of *Vibrio fisheri,* ranged between 30 - 80 % and 50 - 80 % for Lăpuş and Săsar respectively. The inhibition data was then compared with the concentrations of heavy metals (Fe, Mn, Zn, Cu, Cd, Cr, Pb and Ni), known as the most common pollutants present in the investigated ecosystems, as the bioluminescence inhibition is probably linked to the sensitivity of microorganisms to the high levels of toxic metals in the rivers (e. g. 0.5 - 4.3 mg/l Fe and 15 - 380 μg/l Cu for the Lăpuş River or 0.6 - 5.4 mg/l Fe and 40 - 140 μg/l Cu in the Săsar River). The results suggested links between ToxTracer and metal data in both of the rivers. Thus the bioluminescence assay applied here is a promising tool for screening the toxicity of surface waters in the mining areas dominated by metal pollution.

RÉSUMÉ: Effet de la pollution aux métaux sur les micro-organismes aquatiques : étude de cas dans les régions minières (Roumanie).

Dans cette publication sont présentés les résultats de la toxicité des métaux sur les micro-organismes, dans les rivières Lăpuş et Săsar de la région minière Baia Mare. Les tests de toxicité ont été effectués à l'aide du système ToxTracer, dont la méthode consiste en la réduction de la luminescence émise par la bactérie *Vibrio fisheri.* L'inhibition de la bioluminescence, dans l'intervalle 30 - 80 % (Lăpuş) et 50 - 80 % (Săsar), a exprimé la sensibilité des microorganismes aux grandes concentrations de métaux lourds dans les deux rivières (par exemple 0,5 - 4,3 mg/l Fe et 15 - 380 μg/l Cu dans le Lăpuş ou 0,6 - 5,4 mg/l Fe et 40 - 140 μg/l Cu dans le Săsar). Les données ToxTracer ont été ultérieurement comparées avec des données concernant la concentration des métaux (Fe, Mn, Zn, Cu, Cd, Cr, Pb et Ni) connus comme des polluants spécifiques aux écosystèmes étudiés. Les résultats ont suggéré des relations de dépendance entre les données ToxTracer et les données obtenues par des analyses chimiques, dans les deux rivières. En conséquence, le test de bioluminescence pourrait devenir une modalité rapide d'examen des eaux de surface dans les régions minières caractérisées par une pollution intense aux métaux.

REZUMAT: Efectul poluării cu metale asupra microorganismelor acvatice: studiu de caz în regiuni miniere (România).

În această lucrare, se prezintă rezultatele toxicităţii metalelor grele asupra microorganismelor, în cazul ecosistemelor lotice Lăpuş şi Săsar, situate în regiunea minieră Baia Mare. Testele de toxicitate au fost realizate cu sistemul ToxTracer, bazat pe reducerea luminiscenţei, emise de bacteria *Vibrio fisheri.* Inhibiţia bioluminiscenţei, cuprinsă între 30 - 80 % (Lăpuş) şi 50 - 80 % (Săsar) a exprimat sensibilitatea microorganismelor la concentraţiile mari de metale grele din ambele râuri (de exemplu 0,5 - 4,3 mg/l Fe şi 15 - 380 µg/l Cu în Lăpuş sau 0,6 - 5,4 mg/l Fe şi 40 - 140 µg/l Cu în Săsar). Datele ToxTracer au fost, ulterior, comparate cu date asupra concentraţiei de metale (Fe, Mn, Zn, Cu, Cd, Cr, Pb şi Ni), cunoscute ca poluanţi caracteristici ecosistemelor investigate. Rezultatele au sugerat dependenţe între datele ToxTracer şi datele obţinute prin analize chimice, în ambele râuri. Prin urmare, testul de bioluminiscenţă poate deveni o modalitate rapidă de evaluare a apelor de suprafaţă, din zonele miniere, în care poluarea cu metale grele este dominantă.

INTRODUCTION

Mining wastes deposited on river floodplains and in river channels are a major component of riverine contamination with heavy metals and represent an important source of metal toxicity to aquatic and riparian biota (Hochelle et al., 2004). In Romania one of the impact areas of mining activities is the region of Baia Mare, which is the convergence area of the rivers Someş, Săsar and Lăpuş. The main polluting sources are a number of mines situated in the nearby mountain region, two smelters specialized on copper and lead production, two large flotation plants and a number of decantation ponds, some of them still active (Cordoş et al., 2003), e. g. E. M. Baia Sprie, E. M. Aurum, E. M. Băiuţ, E. M. Cavnic, S. C. Cuprom, S. C. Romplumb, S. C. Transgold.

As a consequence the rivers Săsar and Lăpuş are heavily polluted with metals. Among the heavy metals produced by mining industry in this region the most harmful to humans include cadmium, lead, nickel and manganese, which are toxic even at small doses. Zinc, lead, aluminum, chromium and iron are also present and all these are toxic especially to plant growth (UNEP/OCHA report, 2000). Higher concentrations of Mn and Fe provided by natural resources are still enhanced by present and past mining activities in both water and sediment (Labunska et al., 2000). As a consequence in some sections of these rivers the benthos and plankton abundance and diversity considerably decreased (Cordoş et al., 2003). In Romania permissible limit are settled for each metal through the national normative for surface waters 161/2006 above which the metals are generally toxic.

Living organisms face high risks with acute and chronic exposure to heavy metals. With chronic exposure toxin levels build up in an organism over time, increasing its toxicity and threat to local ecosystems (report UNEP/OCHA 2000). Despite this, few studies were done on the toxicity of waters in the region of Baia Mare (Astratinei and Constantinescu, 2004). Taking into account that among biological populations, bacteria have a higher ability to resist high levels of metal toxicity, they can be used as a valuable tool to identify the impact of heavy metals on living organisms. To the best of our knowledge bioluminescent-based assays have been hardly used in Romania for the monitoring of contaminated media while other countries widely apply them for the biomonitoring of polluted sediments, plant effluents, leachate toxicity, soil contamination and remediation processes (Winger et al., 1993; Ulitzur et al., 2002; Blaise et al. 2006).

The goal of our research is to identify the adequacy of the bioluminescence test for the rapid screening of metal toxicity in the rivers of the Baia Mare mining area. Variation in the light emission of bacteria is used as measure for the influence of pollutants on their metabolism. Therefore we used bioluminescent bacterium *Vibrio fisheri* as test organisms in order to detect the toxicity of water samples taken from Lăpuş and Săsar rivers. Additionally the heavy metals concentrations are obtained to link with the bioluminescence decrease.

MATERIALS AND METHODS

Sampling. Lăpuş River is 119 km long and has a basin area of 1.875 km^2. Taking into account the pollution sources, six sampling sites were selected for Lăpuş River: upstream Băiuț (Izvorul Alb-Negru); downstream Băiuț (confluence Botiza); Târgul Lăpuş (Rogoz); downstream Târgul Lăpuş (Răzoare); upstream Cavnic (in the area Valea Mesteacăn); downstream confluence Lăpuş-Săsar.

Săsar River is one of the main tributaries of the Lăpuş River having a length of 31.6 km and a total basin area of 311 km^2. Five sampling sections were selected for Săsar River: upstream Baia Sprie; downstream Baia Sprie; downstream confluence with Firiza River; downstream S. C. Cuprom; downstream Baia Mare. For both of rivers the samples were taken at the end of March 2007. The sampling protocol for estimation of heavy metal content has been performed according to ISO 5667-4:1987 and ISO 5667-4:1991. For the toxicity tests the samples were collected in sterile bottles. Prior to the toxicity tests the pH of samples was set between 6.0 and 8.0 and the osmolarity was adjusted by adding 0.1 ml NaCl solution (22 %).

Toxicity tests. The assessment of river water toxicity was done using a rapid test of bioluminescence performed with the ToxTracer equipment provided by Skalar Company (Netherlands). The ToxTracer system consists of a luminometer, a cooling block and a reagent kit, which includes the freeze-dried bacteria (*Vibrio fisheri*). However, in the studies performed on Săsar and Lăpuş systems we used freshly prepared bacteria directly from the plate according to Broers (2001). A standard cell suspension was mixed with the water samples and luminescence was measured after 30 minutes, according with Ulitzur et al. (2002). The inhibition of the luminescence was estimated with the ToxTracer luminometer.

Isolation and culturing of *Vibrio fisheri.* In this study the cultivation of the light emitting bacterium *Vibrio fisheri* was performed as an alternative to the use of the reagent kit. The lyophilised bacteria were re-suspended in a protective medium containing (g/100 ml): NaCl (0.4), D-glucose.H_2O (6.6), L-histidine (0.2), albumine (0.05). By using the streaking tehnique the luminescent bacteria was transferred on a agar medium containing (g/100 ml): NaCl (3); $NaH_2PO_4.H_2O$ (0.61); K_2HPO_4 (0.208); $MgSO_4.7H_2O$ (0.0204); $(NH_4)HPO_4$ (0.05); caso-peptone (5); yeast extract (0.05); agar (1.5) and 0.3 ml glycerol. The agar plate inoculated with bacteria was incubated at 22 ^oC for 48 hours. The growth of bacteria was checked in a dark room. A single luminescent colony was transferred to 0.5 ml of fresh medium HBS-G, which contained (g/100 ml demiwater): hepes (1.19), D-glucose.H_2O (0.8), NaCl (2), $MgCl_2.6H_2O$ (0.2) and KCl (0.03), according to Broers, 2001. The last mixture was the standard cell suspension that subsequently was used for the toxicity tests.

Heavy metals. Atomic Absorbtion Spectrometry (AAS) according to ISO 15586: 2003 was performed in order to determine the concentrations of heavy metals (Fe, Mn, Zn, Cu, Cr, Pb, Ni and Cd) in Lăpuş and Săsar rivers. The results were reported to the standard limits settled by the national normative 161/2006.

RESULTS

The toxicity results, expressed as % light inhibition are presented within the proposed toxicity range (Tab. 1). Criteria for water toxicity ranges were derived from similar data obtained within previous investigations (Broers, 2001; Astratinei and Constantinescu, 2004; EU SWIFT project, 2004).

Table 1: Toxicity limits after a 30 minute contact time; limits were based on previous reports: Broers, 2001; Astratinei, 2004; Astratinei and Constantinescu, 2004; SWIFT-WFD data project, 2004; Blaise et al., 2006; negative values (< 0) can be obtained due to the bioluminescence stimulation by a high organic matter content.

Range of inhibition (%) / toxicity	Significance
0-20	No toxicity
20-30	Low toxicity
30-50	Moderate toxicity
50-80	Critical toxicity
> 80	Maximum or excessive toxicity

Table 2: Distribution of bioluminescence inhibition of *Vibrio fisheri* (%) in Lăpuş River system.

No toxicity	Low 15 - 30%	Inh. %	Moderate 30 - 50%	Inh. %	Critic 50 - 80%	Inh. %
	Upstream Târgul Lăpuş	21	Upstream Băiuț	47	Downstream Băiuț	75
			Upstream Cavnic	39	Upstream Târgul Lăpuş	58
					Downstream Săsar confluence	68

The results of toxicity tests performed with water samples collected from Lăpuş and Săsar rivers are shown in the tables 2 and 3, respectively. By comparing the bioluminescence level (%) of the water samples with that of a clean-water control sample, different levels of water toxicity, expressed as % inhibition of the bacterial light were measured.

The following distribution of toxicity was obtained for the Lăpuş River: three sampling sites downstream Băiuț, upstream Târgul Lăpuş and downstream to the confluence Lăpuş-Săsar presented critical toxicity (50 - 80 %); two sampling sites, upstream confluence Cavnic and upstream Băiuț corresponded to the moderate water toxicity (30 - 50 %); a low level of toxicity (20 - 30 %) was identified downstream Târgul Lăpuş. Considering the whole river highest toxicity (75 %) was detected downstream the mining site of Băiuț (Fig. 1A).

Tab. 3: Distribution of bioluminescence inhibition of *Vibrio fisheri*(%) in Săsar River system.

No toxicity	Low 15-30%	Inh.%	Moderate 30-50%	Inh.%	Critic 50-80%	Inh.%
	-	-	Upstream Baia Sprie	45	Downstream Baia Sprie	60
					Downstream Romplumb	70
					Downstream Cuprom	80
					Downstream Baia Mare	75

Table 4 (A, B): Metal concentration in water samples of Lăpuş and Săsar rivers; #reference; ## detection limit; 1L to 6L: sampling sites on Lăpuş; 1L - upstream Băiuț; 2L - downstream Băiuț; 3L - Upstream Târgul Lăpuş; 4L - downstream Târgul Lăpuş; 5L - upstream confluence Cavnic; 6L - downstream confluence Săsar; 1S to 5S: sampling sites on Săsar; 1S - upstream Baia Sprie; 2S - downstream Baia Sprie; 3S - downstream Romplumb; 4S - downstream Cuprom; 5S - downstream Baia Mare; shading indicate moderate to high metal contents (quality clases from III to V).

A. Lăpuş								
Sampling sites	Fe (mg/l)	Mn (mg/l)	Zn (µg/l)	Cu (µg/l)	Cr (µg/l)	Pb (µ/l)	Ni (µg/l)	Cd (µg/l)
1L#	1.81	0.16	96	36.23	1.46	8.99	2.66	0.99
2L	4.37	0.62	404	376.4	3.14	13.83	9.83	3.77
3L	1.80	0.33	258	217.2	1.48	2.22	7.65	2.12
4L	0.50	0.09	33	15.87	0.74	1.96	1.41	0.51
5L	2.67	0.19	169	91.09	2.34	4.42	3.78	1.24
6L	3.73	0.69	358	127.3	2.98	24.5	5.87	3.49
DL##	0.01	0.01	0.01	0.20	0.20	0.31	0.38	0.12
Normative 161/2006	IV-V	III-IV	II-III	IV-V	I	II-III	I	III-IV
B. Săsar								
Sampling sites	Fe (mg/l)	Mn (mg/l)	Zn (µg/l)	Cu (µg/l)	Cr (µg/l)	Pb (µg/l)	Ni (µg/l)	Cd (µg/l)
1S#	0.59	0.34	56	46.18	0.45	0.39	< DL	0.32
2S	1.84	0.73	856	65.20	1.06	5.90	1.39	3.86
3S	0.94	0.55	294	55.81	0.83	4.12	1.85	2.44
4S	5.44	2.04	1994	143.9	3.07	2.20	7.59	9.49
5S	2.35	0.92	422	80.55	1.13	11.27	3.43	3.31
DL	0.016	0.014	0.010	0.2	0.2	0.31	0.38	0.12
Normative 161/2006	IV-V	IV-V	IV-V	IV	I	II-III	I	IV-V

Toxicity was present as well in the water of Săsar River (Tab. 3; Fig. 1B) with following distribution: critical levels of toxicity (50 - 80 %) were found in four sampling sites (downstream Baia Sprie, downstream Romplumb, downstream Cuprom and downstream Baia Mare) and only upstream Baia Sprie was identified a moderate level of toxicity (45 %). The highest level of toxicity (80 %) was found downstream S. C. Cuprom, a unit for processing non-ferrous ores.

The obtained metal concentrations are presented in the table 4. High values for Fe, Cu, Mn and Cd were identified in Lăpuş River (Tab. 4A). When compared with the Romanian normative 161/2006, Fe and Cu concentrations were assigned to the quality classes IV - V and Mn and Cd were assigned to the quality classes III - IV. In order of severity four sampling sites were found to be heavily contaminated: downstream Băiuț (4.4 mg/l Fe and 376 µg/l Cu), upstream Târgul Lăpuş (1.8 mg/l Fe; 217 µg/l Cu), downstream confluence Lăpuş-Săsar (3.7 mg/l Fe; 127 µg/l Cu) and upstream confluence Lăpuş - Cavnic (2.6 mg/l Fe; 91 µg/l Cu).

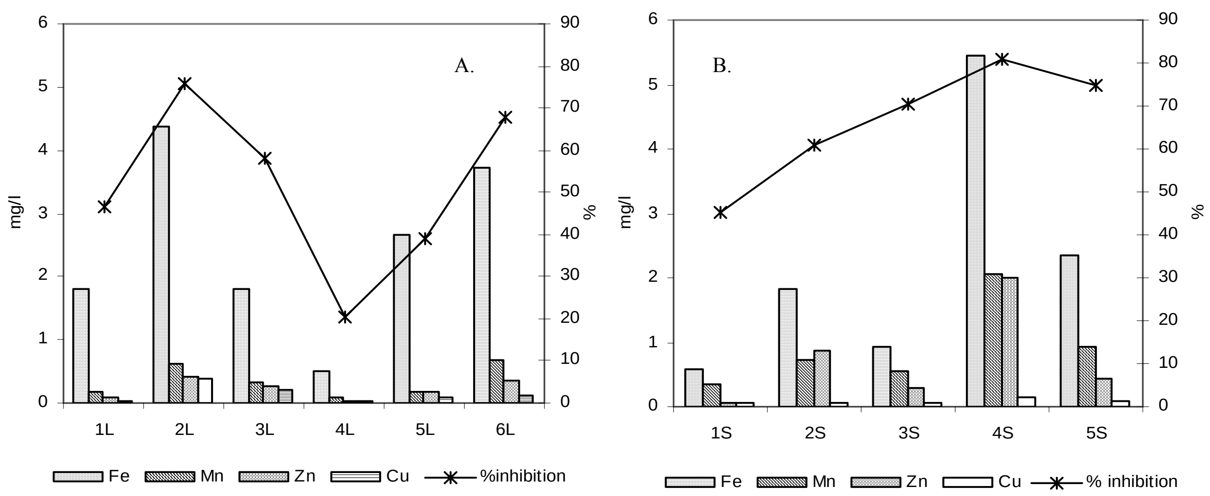

Figure 1: The bioluminescence inhibition (%) distribution and heavy metal concentrations in Lăpuş (A) and Săsar (B); 1L to 6L - sampling sites on Lăpuş; 1L - upstream Băiuţ; 2L - downstream Băiuţ; 3L - Upstream Târgul Lăpuş; 4L - downstream Târgul Lăpuş; 5L - upstream confluence Cavnic; 6L - downstream confluence Săsar; 1S to 5S - sampling sites on Săsar river; 1S - upstream Baia Sprie; 2S - downstream Baia Sprie; 3S - downstream Romplumb; 4S - downstream Cuprom; 5S - downstream Baia Mare.

In Săsar River (Tab. 4B), extremely high values were obtained for Fe, Mn, Zn, Cu, and Cd, which assigned most of the sampling sites to the quality classes IV and V of the national normative for surface water quality (161/2006). For example downstream Baia Sprie, Fe, Zn and Cd measured 1.8 mg/l, 850 µg/l and 3.86 µg/l, respectively. Downstream the industrial site Cuprom, the metal concentration fall into class V of surface water quality.

Lead (Pb) was measured at relative high concentrations in both rivers. The highest concentration of Pb (24.5µg/l) was obtained downstream confluence with Săsar, for Lăpuş River, and downstream Baia Mare (11.3 µg/l) for Săsar. In general higher concentrations of Fe (5.4 mg/l), Mn (2.0 mg/l), Zn (1994 µg/l), and Cd (9.5 µg/l) were determined along Săsar while Cu was higher (380 µg/l) in Lăpuş River.

DISCUSSION

Among aquatic organisms bacteria are involved in the main processes of bioconversion and therefore plays a major role in the self-purification potential of the rivers (Fisher et al., 2000). On the other hand their rapid response to the toxic compounds gives essential biological indications about the level of toxic pollution reached in different ecosystems.

In this work the toxicity tests for the Lăpuş and Săsar rivers were conducted using the ToxTracer system, which is based on the inhibition of bacterial luminescence. Thus the bioluminescence of *Vibrio fisheri* can be seen as expressing the sensitivity of microorganisms, and more in particular bacteria, to the high levels of toxic metals.

For Lăpuş River system the highest toxicity levels were detected in the samples from Băiuţ, Cavnic and Baia Mare (Tab. 2, Fig. 1A) suggesting the strong influences of the mining activities performed by industrial sites such as E. M. Băiuţ, E. M. Cavnic and S. C. Transgold, respectively etc. Considering the range of bioluminescence inhibition (30 - 80 %), Lăpuş River water had a moderate to critical toxicity for bacteria.

Critical levels of toxicity were found as well in the samples from the lower Săsar River (Tab. 3), respectively downstream the main industrial sources of pollution (E. M. Baia Sprie, S. C. Romplumb, S. C. Cuprom and S. C. Transgold). An elevated toxicity level (68 %) was found before the confluence of Săsar with Lăpuş. For Săsar the tendency of the toxicity to increase along the river was clearly noticed (Fig. 1B). Few toxicity assays were performed in the region to allow data comparison. Previous unpublished work on Săsar (Astratinei, 2004) reported a 50 % toxicity level downstream Baia Sprie, 20 % lower than the toxicity detected in this study.

The toxicity of the water samples was compared with the metal content determined by AAS. The studied metals are responsible for the water degradation in both rivers. Literature show no metal input, fate and toxicity for the region concerned (Labunska et al., 2000). In both of rivers significant concentrations of heavy metals are systematically mentioned in different reports, following mining accidents or after routine monitoring (UNEP/OCHA report 2000; Garvey et al., 2000; Bud et al., 2002; reports APM Baia Mare 2000 - 2006).

The toxicity level of the samples (Tab. 2, 3) was linked with the concentration of heavy metals (Tab. 4A, B). Higher concentrations of heavy metals (Fe, Mn, Cu and Cd) coincided with a relatively higher toxicity in Lăpuş River (Fig. 1A). The sampling sites, which showed high concentrations of metals, such as downstream Băiuț, upstream Târgul Lăpuş and downstream confluence Lăpuş-Săsar presented critical levels of toxicity as well represented by, 75 %, 58 % and 68 % luminescence decrease, respectively. The comparison between the toxicity data and the metal concentration in case of the Lăpuş River shows a clear link between metal concentration and the toxicity level (Fig. 1A), despite the fact that Lăpuş is a longer river implying more complex hydrogeomorfological and physico-chemical conditions.

Correlations between toxicity data and metals concentrations were identified as in the Săsar River (Fig. 1B). As heavy metals concentrations increased in the samples the light of the *Vibrio fishery* declined. The major contaminations of Săsar were the high Fe, Mn, Zn, Cu, Cd concentrations (Tab. 4B). The critical toxicity of samples downstream Baia Mare (75%), Baia Sprie (60 %), S. C. Romplumb (70 %) and S. C. Cuprom (80 %) corresponded to the metal concentrations of quality classes IV to V, according to the national normative 161/2006.

Previous monitoring reports showed that despite the lately reduction of mining in Baia Mare area, no improvement was observed in the ecological status of both of rivers (APM Baia Mare reports, 2000 - 2006; project PROECO PN05, 2006). The metals content corresponding to the high quality classes (IV, V) identified in this work and confirmed in other studies (Cordoş et al., 2003) for the Săsar and Lăpuş indicated the elevated degradation in these ecosystems.

In this work results on the toxicity effects of metal pollution on microorganisms have been reported for the Lăpuş and Săsar Rivers, from the Baia Mare mining area. Similar to this research, toxicity assays based on bacteria luminescence were previously performed for freshwater (AFNOR, 1991; Ulitzur, 2002) and fresh sediments (Winger et al., 1993; Blaise et al., 2006). Data obtained within previous investigations (Broers et al., 2001, Astratinei and Constantinescu, 2004; EU SWIFT project, 2004) were used in our work to derive criteria for classification of water toxicity based on decreased bioluminescence of *Vibrio fishery* (Tab. 1). However more of these bioluminescence tests have to be performed on the Romanian mining sites in order to achieve a larger data set, allowing a more accurate classification.

The bioluminescence assay used here is a promising tool for screening the toxicity of surface water of the mining areas dominated by metal pollution. These relatively simple bacteria tests, could be easily applied for rapid identification-classification of toxic water samples. When required, key pollutants can be determined by chemical tests or traditional toxicity tests.

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THE POLLUTION DEGREE OF THE ROMANIAN SEASIDE LAKES WATER AND ITS CONSEQUENCES

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KEYWORDS: Romania, Black Sea seaside lakes, eutrophication, water quality parameters, nutrients.

ABSTRACT

Data were collected from 1995 to 2004 regarding the Corbu, Taşaul, Siutghiol, Tăbăcărie, Hagieni and Limanu lakes. From time to time, the Nuntaşi, Agigea, Tatlageac, Neptun, Golovița, Zmeica, Razim, Sinoie and Belona lakes were also investigated. These lakes are located in the central and southern part of Romanian Black Sea coast and represent ecosystems contaminated by the anthropic influences.

There have been investigated threats by different kinds of anthropic activity on the Romanian seaside lakes, such as: agriculture, pisciculture and waste discharge.

Mean values of inorganic constituents (including the pH, alkalinity, hardness, salinity, ammonium, nitrate, nitrites and the total nitrogen, phosphorus and silicium), and global organic pollution (the dissolved oxygen, biochemical oxygen demand and the chemical oxygen demand) in correlation with measured biological parameters (primary production) are reported.

CODMn concentration where in the range of 10 - 25 mg O_2/l, BOD concentration between 5 - 12 mg O_2/l and DO concentration in the range of 7.5 - 10.3 mg/l). According to these parameters, Seaside lakes water can be included in the second/third category of surface waters.

The maximum fluctuations of the waters' transparency varied from 30 to 40 cm, with maximum fluctuations between 19 and 112 cm. The primary plankton production is achieved mainly in the 0 - 50 cm of the water body (euphotic area), where the transparency is also the best.

The data indicate that the most eutrophicated lakes are Tăbăcărie and Taşaul. The values of the parameters analyzed in the Razim Lake are contradictory as they indicate the existence of an intense process of eutrophication here as well.

In the seacoast lakes, the number of taxons of the phytoplankton organisms is relatively reduced. It varies within very wide limits, from 12 species in the Corbu Lake, up to 119 species in the Razim Lake. The aquatic basins most affected by the high input of exogenous organic substances have a lower number of species (Tăbăcărie Lake - 52 species; Corbu Lake - 35 species).

Therefore it is imperious to take urgent steps, specific for every lake, to efficiently fight against the process of eutrophication and organic silting in order to achieve systems for the retention rainfall waters and polluted waters and the extraction of the nutrients which might reach the lakes.

RÉSUMÉ: Degré de pollution de l'eau des lacs de la côte de la Mer Noire et ses conséquences.

Des données ont été récoltées de 1995 à 2004 concernant les lacs Corbu, Taşaul, Siutghiol, Tăbăcărie, Hagieni et Limanu. Les lacs Nuntaşi, Agigea, Tatlageac, Neptun, Goloviţa, Zmeica, Razim, Sinoie et Belona ont également été examinés à l'occasion. Ces lacs sont situés dans les zones centrales et méridionales de la côte roumaine de la Mer Noire et ils représentent des écosystèmes contaminés par les influences anthropiques. Il a été déterminé que les menaces venaient de différents types d'activités humaines sur les lacs littoraux roumains, telles que : agriculture, aquaculture, décharges sauvages. Il a été rendu compte des valeurs moyennes des constituants inorganiques (incluant pH, alcalinité, dureté, salinité, ammonium, nitrates, nitrites et les totaux d'azote, phosphore, et silicium) ainsi que la pollution organique globale (oxygène dissout, Demande Biochimique en Oxygène DBO, Demande Chimique en Oxygène DCO) mis en corrélation avec des paramètres biologiques mesurés (production primaire). Les mesures de DCO effectuées au moyen de permanganate de potassium ont montré des concentrations de l'ordre de 10 à 25 mg O_2/l, celles de DBO ont montré des concentrations entre 5 et 12 mg O_2/l et enfin celles d'oxygène dissout ont montré une concentration allant de 7,5 à 10,3 mg/l. D'après ces paramètres, l'eau des lacs littoraux peut être classée dans la seconde ou la troisième catégorie des eaux de surface. Les fluctuations de la transparence de l'eau varient de 30 à 40 cm, atteignant parfois des valeurs extrêmes allant de 19 à 112 cm. La production primaire planctonique est principalement réalisée dans la couche des 50 premiers centimètres de la masse d'eau (dans la zone photique), où la transparence est optimale. Les données indiquent que les lacs les plus eutrophisés sont ceux de Tăbăcărie et de Taşaul. Les valeurs des paramètres analysés dans le lac Razim sont contradictoires puisqu'elles indiquent dans celui-ci également l'existence d'un intense processus d'eutrophisation. Dans ces lacs côtiers, le nombre de taxons d'organismes phytoplanctoniques est relativement réduit. Il varie très largement de 12 espèces dans le lac Corbu à 119 espèces dans le lac Razim. Les bassins les plus affectés par l'introduction massive de substances organiques exogènes possèdent un nombre d'espèces réduit (Lac Tăbăcărie: 52 espèces; Lac Corbu: 35 espèces). Par conséquent il est impératif de prendre des mesures urgentes, spécifiques à chaque lac, afin de combattre efficacement le processus d'eutrophisation et d'envasement de ces milieux. Il faut restaurer les systèmes d'extraction des nutriments et de rétention des eaux de pluie et eaux polluées qui peuvent atteindre les lacs.

REZUMAT: Gradul de poluare şi consecinţele acesteia în lacurile de la litoralul românesc al Mării Negre.

Datele au fost colectate între anii 1995 - 2004 şi se referă la lacurile Corbu, Taşaul, Siutghiol, Tăbăcărie, Hagieni şi Limanu. Ocazional au fost făcute investigaţii şi asupra lacurilor Nuntaşi, Agigea, Tatlageac, Neptun, Goloviţa, Zmeica, Razim, Sinoie şi Belona. Toate acestea sunt situate în zonele centrală şi de sud ale litoralului românesc al Mării Negre şi sunt ecosisteme afectate de influenţe antropice. Au fost investigate ameninţările diverselor tipuri de activităţi antropice asupra lacurilor paramarine din România: agricultură, ferme piscicole, deversarea apelor uzate menajere. Sunt raportate valorile medii ale constituenţilor anorganici (inclusiv pH, alcalinitate, duritate, salinitate, amoniac, nitraţi, nitriţi şi azotul total fosforul şi siliciul), ca şi încărcătura organică totală (oxigen dizolvat, consumul biologic şi chimic de oxigen) în corelaţie cu parametrii biologici măsuraţi (inclusiv productivitatea primară). Concentraţia CCO-Mn s-a situat în limitele de 10 - 25 mg O_2/l, valoarea CBO s-a situat între 5 - 12 mg O_2/l, iar concentraţia oxigenului dizolvat a avut valori în intervalul 7 - 10.3 mg/l. În concordanţă cu aceşti parametri, apa lacurilor paramarine poate fi încadrată în categoria a II-a sau a III-a de ape de suprafață. Fluctuațiile maxime ale transparenței apei au variat între 30 - 40 cm, cu diferențe maxime între 19 - 112 cm. Productivitatea primară planctonică este obținută în cea mai mare parte în stratul 0 - 50 cm a coloanei de apă (zona eufotică), în care şi transparența are cele mai bune valori. Datele indică lacurile Tăbăcărie şi Taşaul, ca fiind cele mai eutrofizate. Valorile parametrilor analizați în cazul Lacului Razim sunt contradictorii, deoarece indică şi aici existența unui proces intens de eutrofizare. În lacurile litorale româneşti, numărul taxonilor organismelor fitoplanctonice este relativ scăzut. Totuşi, acesta variază în limite foarte largi, de la 12 specii în Lacul Corbu şi până la 119 în Lacul Razim. Bazinele acvatice cel mai afectate de aportul de substanțe organice din exterior au un număr redus de specii (Lacul Tăbăcărie - 52 specii, Lacul Corbu - 35 specii). Aşadar este necesar să se ia măsuri de urgență, aparte pentru fiecare dintre lacurile analizate, pentru a lupta eficient cu procesul de eutrofizare şi cu cel de îmbogățire cu substanțe organice.

INTRODUCTION

Water is one of the most important environmental factors that contribute to the quality of life. For this reason the legislation worldwide protects the water resources against any form of pollution. Surface water quality monitoring has the aim to evaluate the “state of the art” for each river, lake etc. in order to protect aquatic ecosystems, maintaining and improving their quality and natural productivity (Perniu, 2002; Sica et al., 2002).

The economic development of Dobrogea County, particularly of its seacoast, during the last 4 - 5 decades had a high impact on the natural environment. As there has been practically no concern regarding the protection of the environment, this impact manifested with all the intensity, which has lead to the occurrence of degradation processes that in accordance with their intensity have altered the environment in different ways.

Agriculture leaded in Dobrogea to an increased erosion process. The administration of chemical fertilizers was added, which, washed down by the rain from the slopes, has led to the silting of the aquatic basins, plus an intensification of the anthropic eutrophication process of the respective basin. Such a situation can be seen in Razim and Taşaul lakes.

Another form of alteration of the aquatic basins is the establishment of the fish farms, which besides the dames and the portioning of the lakes, has resulted in fertilizing the basin. This process consists in throwing into the water substantial quantities of manure or nutrients. This is how man with a view to increasing the fish production deliberately accelerates the eutrophication process. Such a situation can be seen at the Tatlageac Lake.

A third form of accelerating the eutrophication process is achieved by the input of liquid or solid wastes from the localities situated in the close vicinity of the aquatic basins. In human settlements, people throw various wastes: garbage, manure etc. on the shores of the lakes. The rainwater wash down such waste, which reach the lake, causing the loading of the waters with organic matters, carbohydrates, oils, detergents, household chemicals etc. If there are factories in the riparian localities, their liquid wastes are also disposed of in the nearby lake, or in one of its tributaries. Such situations occurred at Corbu, Taşaul and Siutghiol. The Tăbăcarie Lake represents an extreme case, where part of the drain waters brought from the northern part of the city of Constanța have been discharged for over three decades. As a result, this is the most degraded lake due to the impacts of anthropic pollution on the Romanian seacoast of the Black Sea.

MATERIALS AND METHODS

The investigated Seaside lakes (Fig. 1) are located in the southern part of Romanian Black Sea coast with reduced anthropic influence at Limanu and Hagieni (Fig. 2), followed by the big lakes in the northern part of the seacoast at Razim and Sinoe which are direct or indirect feeding, with Danube water. The Corbu and Taşaul lakes (Fig. 3), Siutghiol and Tăbăcarie (Fig. 4), situated in agricultural or suburban areas, evolve rapidly to eutrophication.

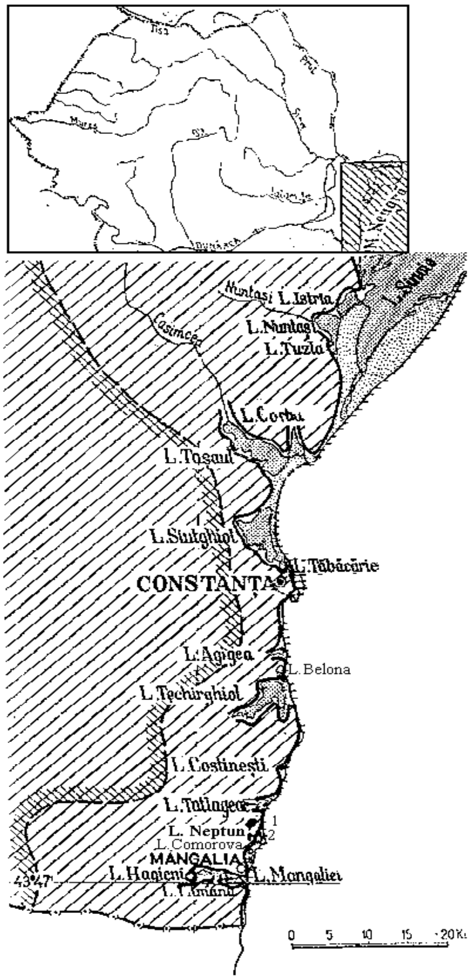

Figure 1: Sampling sites from Seaside Lakes.

Alkalinity, total and calcium hardness and salinity were the monitored parameters using standard titration analytical methods according Romanian regulations: the alkalinity was determined by titration of neutralization with HCl 0.1N to pH 8.3 ("p" alkalinity) or 4.5 ("m" alkalinity); the total hardness was measured by complexation titration with disodium salt of EDTA at pH 10 in the presence of Eriochrome Black T, and calcium hardness by the titration with the same reagent at pH 12 in the presence of murexide; Chlorides were determined by precipitation titration with silver nitrate 0.01 in the presence of chromate ions; the salinity was calculated using empiric formula: $S = Cl\ (g/l) \cdot 1.8 + 0.03$.

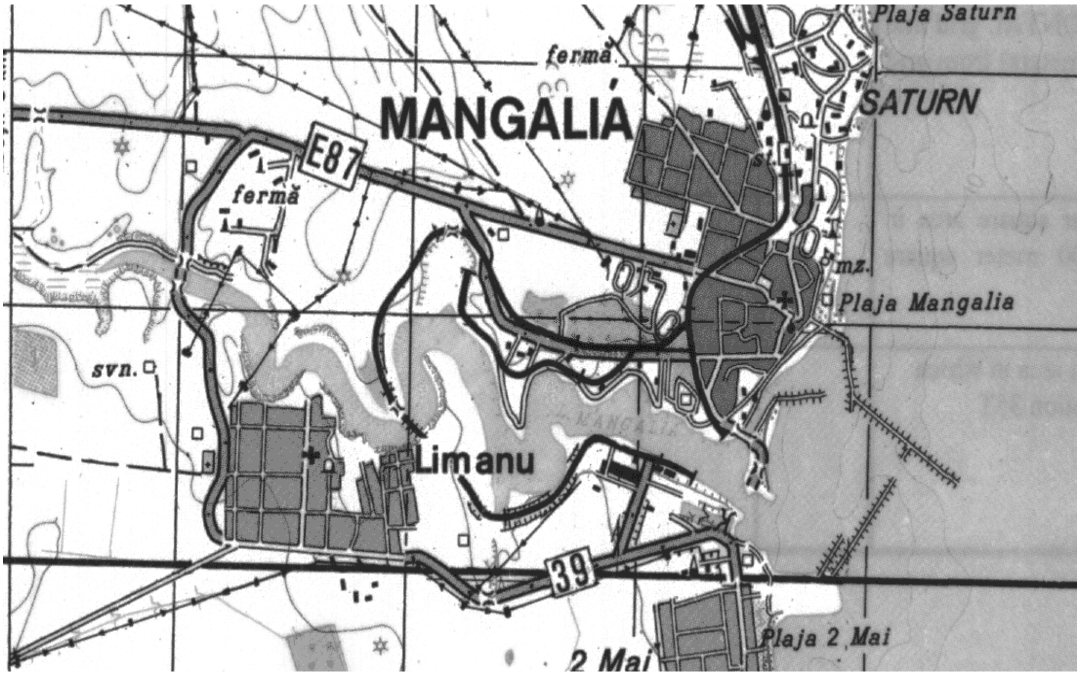

Figure 2: Limanu and Hagieni ponds
- sampling sites.

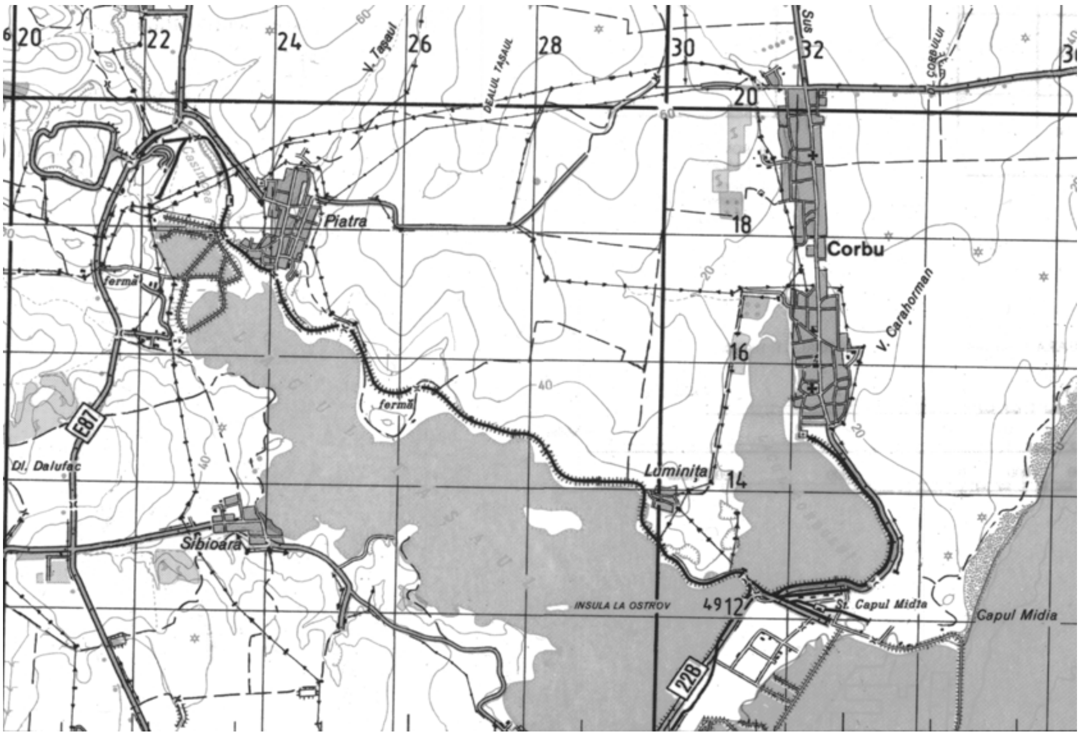

Figure 3: Corbu and Taşaul lakes
- sampling sites.

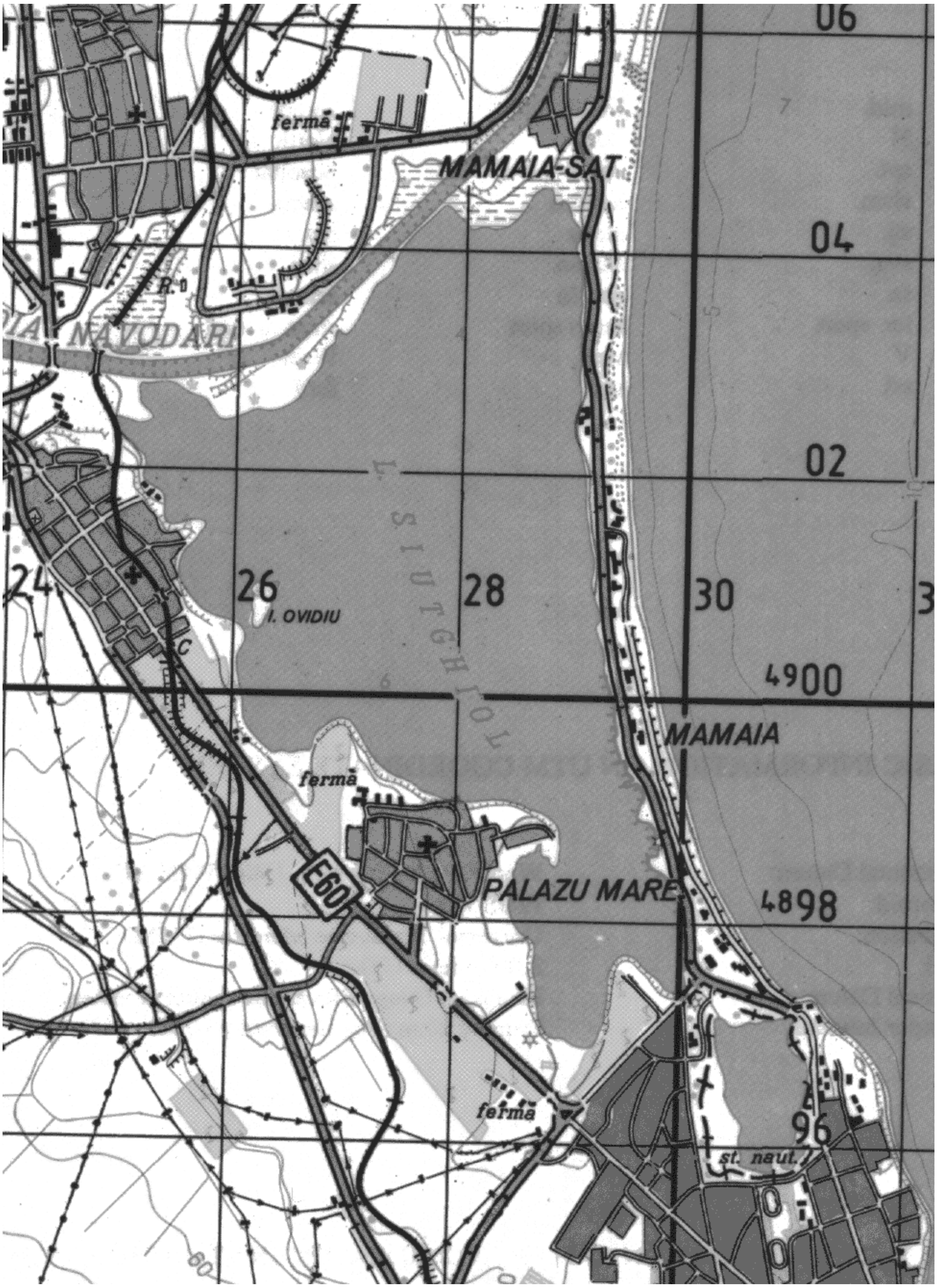

Figure 4: Siutghiol and Tăbăcarie lakes
- sampling sites.

Nitrogen occurs primarily in the oxidized forms of nitrates (NO_3^-) and nitrites (NO_2) or the reduced forms of ammonia (NH_3) or, where the nitrogen is part of an organic compound such as an amino acid, a protein, a nucleic acid, or one of other compounds. All of these can be used as nutrients, although the organic nitrogen first needs to decompose to a simpler form. The studied nutrients were measured by spectrometric methods.

Phosphorus is biologically important in the form of phosphate, its most oxidized state. The most biologically available form is dissolved orthophosphate, (PO_4^{-3}). There are forms of condensed phosphate, with more than one phosphorus atom per ion, like pyrophosphate and polyphosphates. There are also organic phosphates, and all of these forms can be dissolved or particulate (i. e., insoluble). The sum of all the forms is known as total phosphorus.

The choice of an analytical method on metals depends on its characteristics (detection limits, accuracy and precision, speed, etc.). Other conditions to be reached are the concerned element, the concentration in the sample of interest, the variability of their concentration. The concentration of metal ions in studied seaside lakes were determined by flame atomic absorption spectrometry (FAAS) (Chirilă et al, 2003a), inductively coupled plasma atomic emission spectrometry (ICP-AES) (Chirilă et al, 2002), molecular absorption spectrometry in visible (Chirilă and Cărăzeanu, 2001). These investigations were carried out in the biotope (sediment and water) and biocenosis (different plants and fish) from one ecosystem (Tăbăcarie Lake) and in water samples from the other seaside lakes.

From Tăbăcarie Lake ecosystem significant samples of water, sediment and different fish species were collected during 1997 - 2002 for Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn analysis. In 1997 for the first time in Tăbăcarie Lake sediments were analyzed 18 chemical elements (Al, B, Cd, Cr, Cu, Fe, Mg, Mn, Mo, Ni, Pb, Sb, Si, Ti, Zn and Zr) by ICP-AES method (Birghila and Chirilă, 1997) (Fig. 5).

Also micro and oligoelements analysis were realised in Nuntaşi, Corbu, Siutghiol, Agigea, Tatlageac, Neptun and Belona seaside lakes (Chirilă et al, 1998a; Birghila et al, 1998).

Iron, chromium and copper concentrations were determined during 2003 - 2004 from Tăbăcarie Lake water. In this purpose eight sampling sites were established around the lake and analyses were carried out weekly, three month per year. The location of the sampling points is presented in the figure 5.

Romanian rules on water quality protection show that between the strictly surveyed parameters that can indicate organic pollution degree are: chemical oxygen demand (CODMn), dissolved oxygen (DO), and biochemical oxygen demand (BOD).

Dissolved oxygen represents one of the pollution indicators; oxygen is consumed in the dissolved organic compounds' chemical, photochemical or biochemical oxidation processes (Chirilă, 2000). Oxygen becomes dissolved in surface waters by diffusion from the atmosphere and from aquatic plant photosynthesis.

DO was measured by a fairly tricky wet chemical procedure - Winkler titration. The DO is first trapped ("fixed"), as an orange-colored oxide of manganese. This is then dissolved with sulfuric acid in the presence of iodide ion, which is converted to iodine by the oxidized manganese. The iodine is titrated using standard sodium thiosulfate. The original dissolved oxygen concentration is calculated from the volume of thiosulfate solution needed.

The biochemical oxygen demand is a test for measuring the amount of biodegradable organic material present in a sample of water. The results are expressed in terms of mg/l of dissolved oxygen which microorganisms, principally bacteria, will consume while degrading these materials.

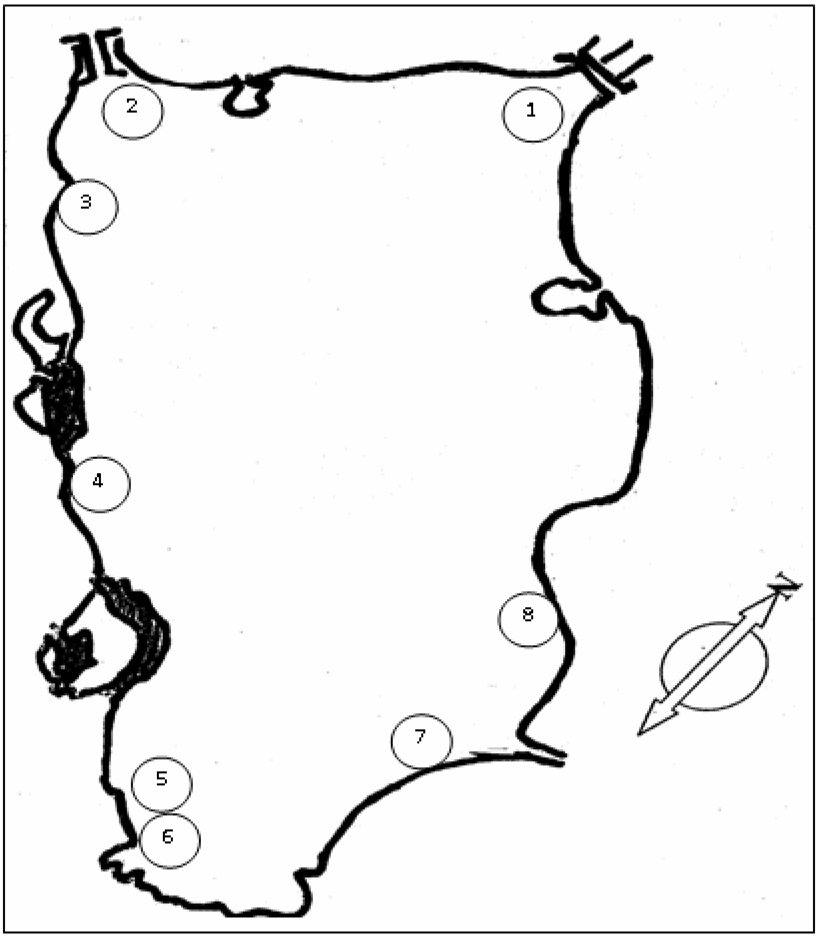

Figure 5: The sampling sites of the Tăbăcărie Lake.

The BOD test is performed in a specially designed bottle with a flared cap, which forms a water seal to keep out air. The bottle is filled completely with sample, which must be near neutral pH and free of toxic materials. After an initial measurement of the DO, the bottle is sealed and stored in a dark incubator at 20 °C for five days. The dissolved oxygen is measured again after this incubation period. The difference is the BOD. (The bottles are kept in the dark because algae that may be present in the sample will produce oxygen when exposed to light). Since most wastewaters have BOD's which are much higher than the limited solubility of oxygen in water, it is necessary to make a series of dilutions containing varying amounts of sample in a nutrient-containing, aerated "dilution water." The measured BOD's are then multiplied by the appropriate dilution factors. A variation of this test, called the carbonaceous BOD, adds an inhibitor, which prevents the oxidation of ammonia, so that the test is a truer measure of the amount of biodegradable organic material present. Samples that do not contain enough bacteria to carry out the BOD test can be "seeded" by adding some from another source. Examples of samples which would need seeding are industrial wastewaters at high temperatures or high or low pH, or samples which have been disinfected. If there is residual disinfectant present, it must be neutralized before testing.

As the BOD test is a fairly long-term bioassay test (five days), a more rapid one is often used to estimate the BOD and it is known as the COD, or chemical oxygen demand test. CODMn test was done by oxidation-reduction titration.

In order to determine the phytoplankton, samples of one liter of water were collected, in which, after treatment with IIK, formaldehyde fixing, a 30 - day decantation and the concentration of the material, the components were identified quantitatively and qualitatively. For the determination of the zooplankton, water was collected using a device of the Patalas type and filtered through plankton net with 40 mesh. The quantitative and qualitative determinations were performed with a Kolkvitz chamber in the laboratory.

RESULTS

In order to monitor the inorganic chemistry of the Romanian seaside lakes water, we have performmed analyses on pH, alkalinity, hardness, salinity, nutrients concentrations (ammonium, nitrate, nitrites and total nitrogen, phosphorus and silicium) and also the metals.

The table 1 presents the annual mean values for four quality parameters in Tăbăcarie Lake water: "m" alkalinity, total and calcium hardness and salinity.

Table 1: Annual mean values for some water quality parameters for Tăbăcarie Lake.

		Hardness, meq/l		Salinity g/l
Year	"m "Alkalinity meq/l	Total	Calcium	
1995	6.15	7.66	2.68	0.27
1996	5.86	7.14	2.14	0.28
1997	6.17	7.00	2.82	0.32
1998	5.08	7.09	3.52	0.33
1999	5.49	8.00	2.95	0.37
2000	5.57	6.66	2.14	0.27
2001	5.18	6.53	2.00	0.25
2002	5.04	5.50	2.10	0.28
2003	6.39	8.27	2.24	0.36

The table 2 presents the annual mean values for pH and salinity in Corbu, Limanu, Hagieni, Taşaul and Sinoe lakes water. These two parameters were studied in Razim, Sinoe, Zmeica and Goloviţa lakes water only in the year 2000.

Table 2: Annual mean values for some water quality parameters for some seashore lakes.

Year	Corbu		Limanu		Hagieni		Taşaul		Siuthiol	
	pH	Salinity g/l	pH	Salinity g/l	pH	Salinity g/l	pH	Salinity g/l	pH	Salinity g/l
1997	8.1	0.4	8.20	0.30	8.20	0.28	7.65	0.30	8.30	0.50
1998	8.0	0.5	8.30	0.30	8.30	0.27	7.80	0.40	8.20	0.40
1999	8.0	0.9	8.40	0.49	8.10	0.38	8.00	0.35	8.10	0.37
2000	8.2	0.8	8.10	0.31	8.20	0.28	7.90	0.30	8.10	0.35

The data show lower concentration of phosphorus than those imposed for all studied lakes and maximum concentration values were registered in 1999 for all lakes (Tab. 3).

Table 3: Annual mean values for nutrients in Hagieni, Corbu, Limanu, Taşaul, Tăbăcarie and Siutghiol lakes water, during 1997 - 2000.

Station	Year	N - NO_2^- (µg/l)	N - NO_3^- (µg/l)	N - NH_4^+ (µg/l)	Total N (µg/l)	P - $PO4^{3-}$ (µg/l)	Si - $HSiO_3^-$ (µg/l)
Hagieni Lake	1997	80.7	1022.0	87.4	1180.1	11.4	1308.0
	1998	59.8	1023.2	59.7	1142.7	20.1	2194.0
	1999	102.0	1089.9	126.5	1329.4	16.7	2077.0
	2000	49.4	911.5	65.9	1007.3	14.5	1083.0
Corbu Lake	1997	167.3	1064.8	503.5	1735.6	15.7	1394.0
	1998	50.1	1140.8	64.6	1255.5	21.4	1117.0
	1999	25.0	801.0	113.5	939.5	52.0	2182.0
	2000	100.8	1362.4	112.1	1575.3	11.5	696.0
Limanu Lake	1997	39.0	512.0	36.6	587.6	11.1	1044.0
	1998	20.5	730.2	63.8	813.6	9.7	1402.0
	1999	45.7	904.5	37.8	983.0	26.2	1955.0
	2000	92.1	1026.4	236.5	1355.0	10.9	1914.0
Taşaul Lake	1997	4.4	40.2	17.5	62.1	213.7	1875.0
	1998	10.3	432.4	117.3	560.12	124.5	542.2
	1999	68.2	608.8	335.1	1012.2	269.8	2033.5
	2000	4.9	22.7	8.6	36.2	179.1	1949.5
Tăbăcarie Lake	1997	83.0	445.5	2943.0	3471.5	215.2	2736.5
	1998	202.2	2192.1	1551.5	3945.8	513.5	3546.2
	1999	198.7	2686.4	3450.2	6335.3	1033.2	4522.2
	2000	140.6	1610.3	1408.0	3158.9	616.6	4106.0
Siutghiol Lake	1997	6.2	40.5	92.4	139.1	24.4	1540.0
	1998	69.1	288.7	89.9	447.7	85.7	529.0
	1999	14.9	147.7	18.7	181.3	156.4	667.7
	2000	7.9	104.7	132.0	244.6	45.1	126.0

From the research concerning the application of ICP-AES method (Birghila and Chirilă, 1997) and visible molecular absorption spectrometry (Chirilă et al, 1997) within Taşaul Lake it has been noticed that the micro and oligoelements content is variable from or element or sample to another (Tab. 4).

Table 5: Multiannual average values (1997 - 2000) for DO, BOD and CODMn in some lakes.

Station	Dissolved oxygen (mg/l)	BOD (mg O_2/l)	CODMn (mg O_2/l)
Razim	7.5	3.3	6.7
Goloviţa	9.3	5.6	5.1
Zmeica	8.8	4.0	4.7
Sinoe	8.2	5.7	27.9
Corbu	8.9	5.0	3.7
Taşaul	7.8	3.9	5.7
Tăbăcarie	9.3	7.1	8.2
Hagieni	10.3	6.7	3.5
Limanu	10.0	7.2	2.7
Siutghiol	8.5	4.7	7.8

In order to highlight the main elements characterizing the biology of the Romanian seaside lakes water, there have been identified the thickness of the euphotic layer (Tab. 6), the taxonomic composition of the phytoplankton and its biomass, and the chlorophyll “a” concentration.

Table 6: Transparency and thickness multiannual average values (1997 - 2000) of euphotic layers.

Lake	Transparency (cm)	Thickness of the euphotic layer (cm)
Razim	25.0	30.0
Golovița	29.3	35.2
Zmeica	30.6	36.8
Sinoe	35.0	42.6
Corbu	26	31.2
Siutghiol	38.0	46.9
Tăbăcarie	78.3	93.5
Hagieni	51.0	61.2
Limanu	51.0	61.2
Taşaul	35.7	43.1

DISCUSSION

The Razim Lake is feeding, directly or indirectly, with water from the Danube River and so the lake water hardness increased due to the high calcium and magnesium ions concentrations. In Sinoe Lake the ratio between calcium and magnesium ions is keeping constant, due to the seawater influence (Chirilă et al. 1998a).

Previous works of the authors about these quality parameters from Nuntaşi, Agigea, Tatlageac, Neptun and Belona lakes (Mihăiesi et al, 1992; Chirilă et al, 1998a) when was observed a high variety of concentration salinity from 0.52 g/l to 9.32 g/l.

The salinity for Razim, Zmeica and Golovița lakes water is 0.5 g/l and for Sinoe Lake is 4.3 g/l and pH varies from 7.6 (Razim) to 8.3 (Sinoe).

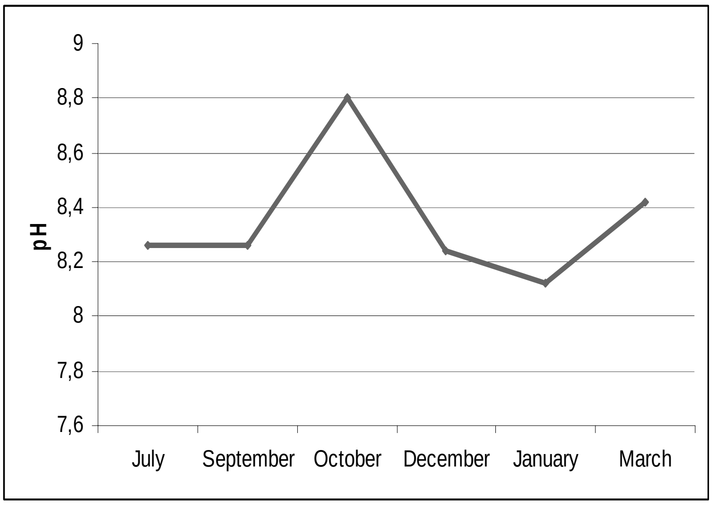

Figure 6: Mean values for pH in Lake Taşaul for the period July 2006 - March 2007.

The pH values are strongly influenced by the metabolic activities of the aquatic photosynthetic organisms, therefore at an intense metabolic activity, the pH rises, as a consequence of CO_2 assimilation.

The hydrogen proton concentration in water represents an important factor which determinates the reactivity capacity of water, the capacity of water to sustain an adequate medium for the growing and development of different organisms. The pH of natural water bodies varies between 6.5 and 8. As we know microorganisms present an optim activity at a neutral pH, but there exists some species which are evolving normal at a value of pH between 8 and 8.5. The values of pH vary from 7.65 to 8.40. With a mean value of 8.13, the value of pH from lake waters shows an alkaline character (Fig. 6).

As to Tăbăcarie Lake the values of pH ranged from 7.8 to 8.5 and these values are higher than those encountered in 1992 by Mihăiesi et al. Variation of pH values can be correlated with the primary production values, based on the link that exists between the dissolved CO_2 consumption and pH value increase (Fig. 7).

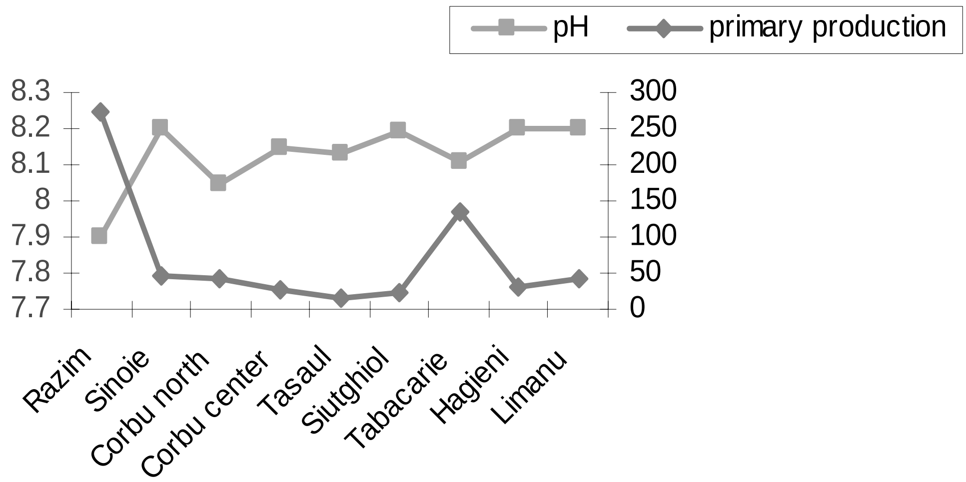

Figure 7: Multi annual average values of pH and primary production in some Romanian coastal lakes (1997 - 2000).

Nutrients are usually thought of as compounds of nitrogen or phosphorus, although certainly other elements, such as iron, magnesium, potassium and silicium are also necessary for bacterial and plant growth.

These nutrients are important in natural waters because, in excess, they can cause nuisance growth of algae or aquatic weeds. In wastewater treatment, a deficiency of nutrients can limit the effectiveness of biological treatment processes. In some plants treating industrial wastewater, ammonia or phosphoric acid must be added as a supplement.

The evolution of nutrients in Razim, Sinoe, Zmeica and Goloviţa lakes water were studied only in 2000. Nitrate, nitrite and total nitrogen concentration in effluents discharged in natural waters must be lower than 37 mg/l, 2 mg/l, respectively 15 mg/l (HG 188/2002) (Fig. 8).

These parameters have lower concentration values than those imposed in all cases. In Goloviţa Lake there are registered the lowest nitrate (47.0 μg/l), nitrite (6.1 μg/l) and total nitrogen (136.7 μg/l) concentration (Fig. 9). According to this parameter, all lakes water can be included in the 1st category of surface waters (STAS 4706/88).

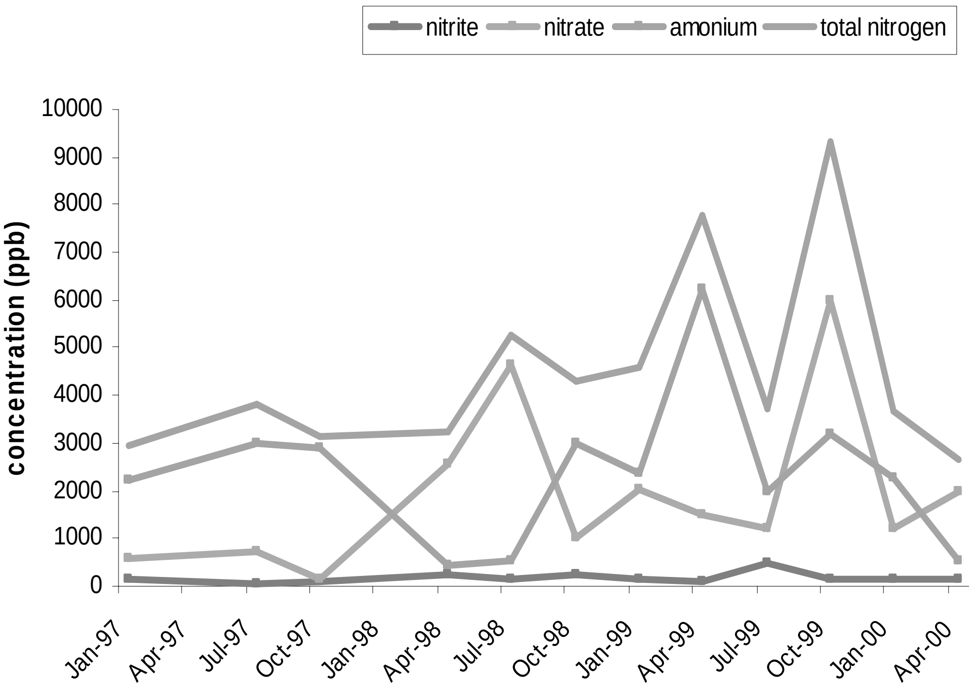

Figure 8: Evolution of nitrite, nitrate, amonium and total nitrogen concentration in Tăbăcarie Lake (1997 - 2000).

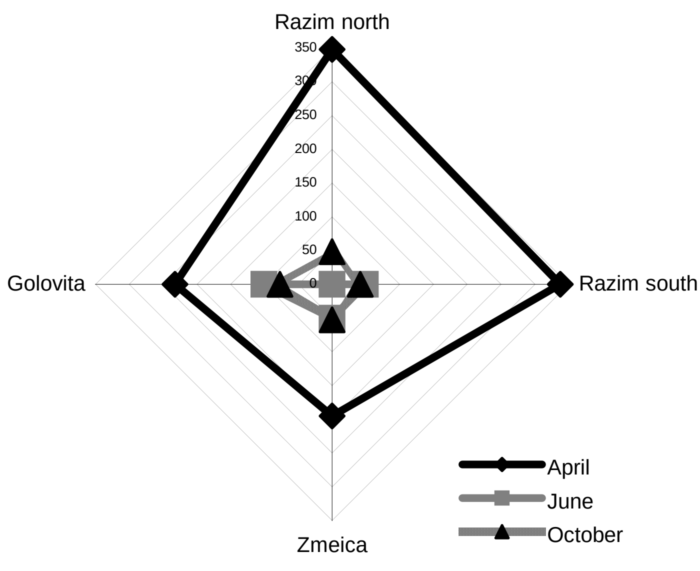

Figure 9: Evolution of nitrogen concentration in Razim, Golovița and Zmeica lakes in 2000.

Ammonium ions concentration in effluents discharged in sewage system must be under 30 mg/l and in effluents discharged in natural waters lower than 2 - 3 mg/l (HG 188/2002). Higher concentrations values than those imposed were observed in case of Tăbăcarie Lake in 1997 and 1999 (Tab. 3). Total nitrogen varies seasonally from the minimum of 9.6 µg/l (Razim Lake) to a maximum of 6335.3 µg/l (Tăbăcarie Lake) (Fig. 10). Higher concentrations were noticed in spring.

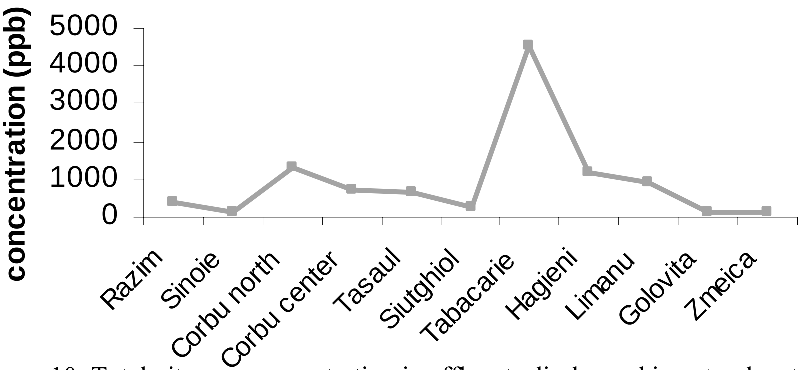

Figure 10: Total nitrogen concentration in effluents discharged in natural waters.

Phosphorus concentration in effluents discharged in sewage system must be under 5 mg/l and in effluents discharged in natural waters lower than 2 mg/l (HG 188/2002).

It can be noticed higher phosphorus concentration in summer (Fig. 11). Razim Lake in north area has very low phosphorus concentration in spring (1.3 µg/l) followed by huge concentrations in summer (749.7 µg/l) contrary to nitrogen concentration, which are huge in spring (Fig. 9). The same effect of phosphorus exces is presented in Goloviţa Lake ($\Sigma N/P < 1$ in summer), but in autumn the ratio $\Sigma N/P$ return to normal ($\Sigma N/P=15$). Zmeica Lake is isolated and this way the influence of phosphorus is not so high.

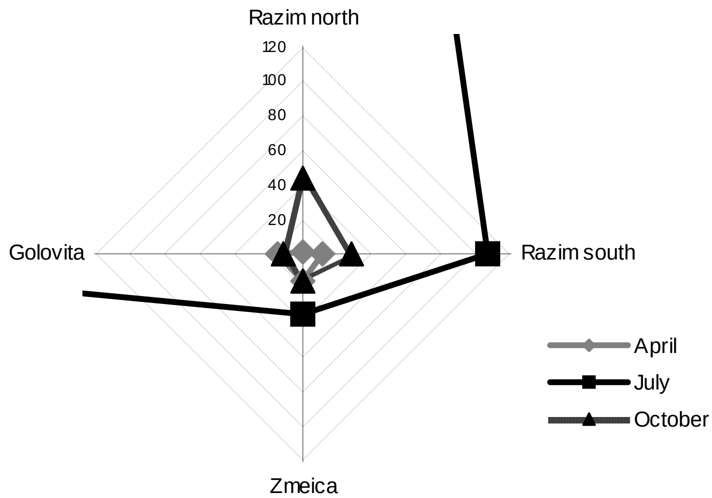

Figure 11: Evolution of phosphorous concentration in Razim, Goloviţa and Zmeica lakes in 2000.

Concerning the Sinoe Lake, the variation of nitrogen and phosphorus concentrations has minor amplitude (in summer ratio ΣN/P = 15 followed by increasing of phosphorus concentration in autumn) (Fig. 12).

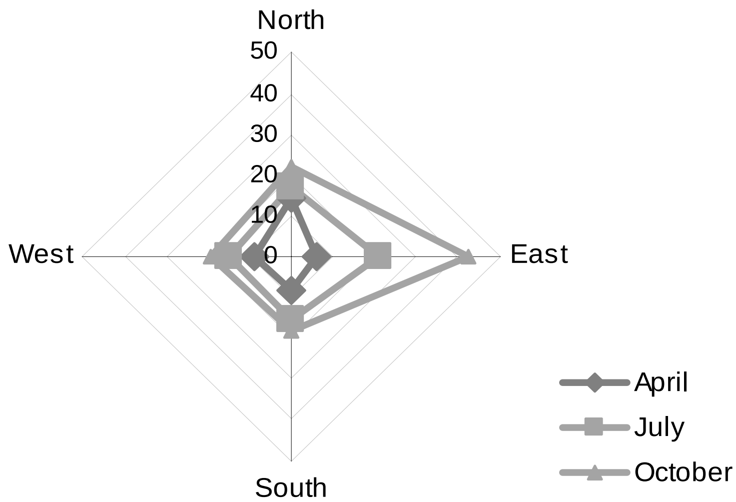

Figure 12: Evolution of phosphorous concentration in Sinoe Lake in 2000.

In the Hagieni Lake total nitrogen concentration was huge comparatively with phosphorus concentration (ΣN/P = 59.75). These paradoxical values are absolute adversary to a good reproductivity and are critical for biosynthesis. Also, for the Limanu Lake ratio ΣN/P is far from optimal value (being higher from normal value) (Fig. 13).

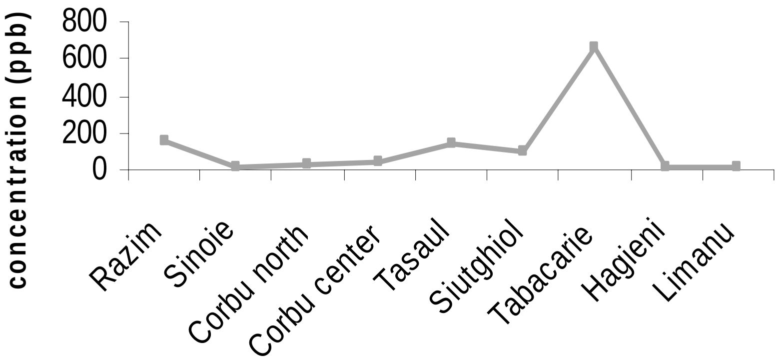

Figure 13: Multi annual average values of phosphorus concentration in the Romanian coastal lakes (1997 - 2000).

According to phosphorus maximum admissible concentration in surface waters (0.1 mg/l), only Hagieni, Corbu and Limanu lakes can be included in the 1st category (STAS 4706/88).

Silicium is an important element for some primary producers of planktonic synthesizer being an essential factor in primary production. This element was found in similar concentrations in all lakes, with maximum value in the Tăbăcarie Lake (4522.2 µg/l) (Fig. 14). If silicium is in low concentration in lake water (1.5 - 3.5 mg/l), the diatomee population decreases (Moss, 1988). The optimal concentration of silicium varies from a primary producer of planktonic synthesizer to another and in water this concentration has to range from 30 to 40 mg silicium/l (Horne and Goldman, 1994).

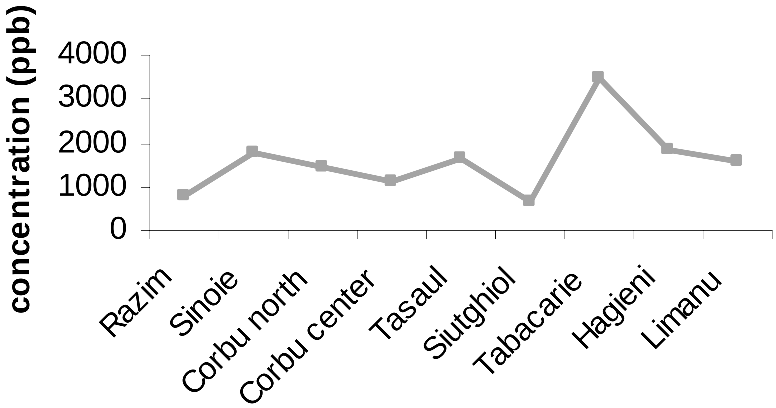

Figure 14. Multi annual average values of silicium concentration in the Romanian coastal lakes (1997 - 2000).

Most metals are discharged to the environment as a consequence of urbanization and industrial activity but the metals themselves, unlike some organic micro pollutants are no biodegradable and are readily accumulated within ecosystems. Metal interaction with biological systems, may be of greater concern because of their toxicity and bioaccumulation potential.

It was noticed that the analyzed elements have slightly high concentration, which proves their accumulation by physical, chemical and biochemical processes. As shown by Chirilă et al. (1998b) the metal capacity of accumulation in sediment increases in order: lead, cadmium, nickel, zinc, chromium and copper. Metal concentrations in plants and fish varied widely, both within and between species, but in general higher metal burdens were observed for essential (Fe, Mn and Zn) rather than non-essential one (Cd). Variations in essential metals within species were low, but different plant species accumulated variable quantities of these metals (Chirilă et al, 2003b).

Chromium concentration in the Tăbăcarie Lake water varies between 0.11 and 0.40 mg/l and all founded concentrations are under the limits for surface waters (0.5 mg/l). Copper concentration varies from 0.29 to 1.80 mg/l and iron from 0.009 to 1.08 mg/l and these concentrations are higher than those imposed in almost all sampling sites.

The mean values of the dissolved oxygen show that all the lakes are well oxygenated (they have mean values of 7.5 - 10.3 mg/l).

The DO concentration in Razim, Zmeica, Hagieni, Corbu and Siutghiol is lower in July than in April and in autumn increases again. Unlike these lakes, in Goloviţa, Tăbăcarie , Sinoe and Limanu were observed an increase of DO concentration in summer followed by lower values in October (Fig. 15). The balance of DO concentration is the most favorable for Siutghiol Lake water because the multi annual average is 8.5 mg/l, value which can assure all forms of biologic and biochemical consumption of organic substances in lake water.

Measuring the quantity of DO from the surface layers to the bottom layers of a lake a slight decrease was observed and also a difference in the repartition of DO between the cold and warm seasons. Thus, for Taşaul Lake the quantity of DO ranged from 18 mg/l at 0 meters to 11 mg/l at 2.5 meters in July (2006) and from 15.9 mg/l at 0 meters to 15.3 mg/l at 2.5 meters in March (2007) (Fig. 16).

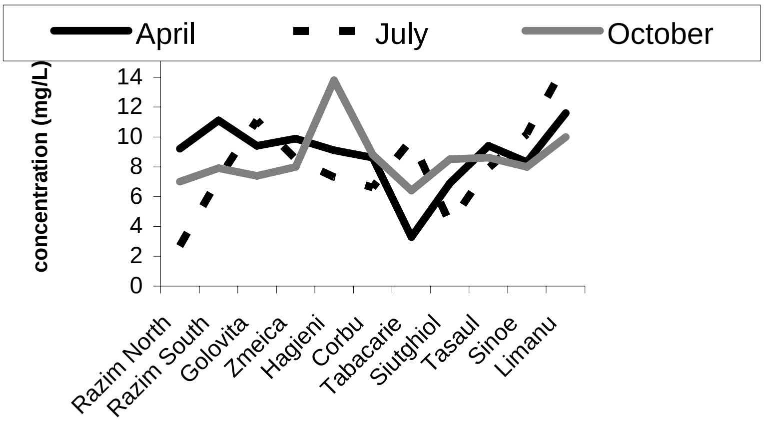

Figure 15: The distribution of dissolved oxygen in the seaside lake waters with season.

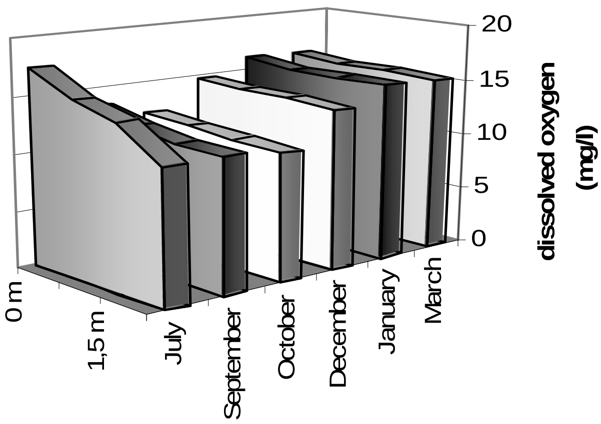

Figure 16: Depth variation of dissolved oxygen for Taşaul Lake in the period July 2006 - March 2007.

The Razim and Taşaul lakes have lower values of BOD (3.3, respectively 3.9 mg O_2/l), the Limanu and Hagieni lakes have the maximum values of BOD (7.2, respectively 6.7 mg O_2/l). We estimate that this value is the result of the way in which the areas of reed through which the water passes to reach the lake and which retain a large part of the biodegradable organic substances filter the water from the Danube (which feeds the lake) (Fig. 17).

The accepted values of DO concentration in surface waters vary between 4 - 7 mg/l, of CODMn concentration vary between 10 - 25 mg O_2/l and BOD concentration vary between 5 - 12 mg O_2/l (STAS 4706/88). According to these parameters, seaside lakes water can be included in the 2nd - 3rd category of surface waters.

The Tăbăcarie Lake situation is different, this being the most polluted lake on the Romanian seacoast of the Black Sea (the quality parameters indicate this fact). Chirilă et al. (2005) showed the evolution of annual averages of CODMn in eight sites from Tăbăcarie Lake during 1995 - 2003. This evolution indicates that in 2003 the Tăbăcarie Lake quality was the worst and CODMn vary in a large interval, between 3.91 and 15.57 mgO_2/l.

The analysis of the chemical oxygen demand shows a very wide variation of the values of this parameter, both from one lake to the other, and from one sample taking to another. The maximum values were recorded in the Sinoe Lake, followed by those of the Tăbăcarie Lake. The minimum values were found in the lakes situated in the southern part of the Romanian seacoast, at Hagieni and Limanu. We estimate that the extremely high values recorded in the Sinoe Lake are due to the presence of the humic substances carried over by the water currents at the surface of the benthos and not by excessive pollution. This is confirmed by the values of the biochemical oxygen demand, which are not higher than the values recorded in the other lakes (Tab. 5). The situation of the Tăbăcarie Lake is, obviously, different, this being the most polluted lake on the Romanian Black Sea coast.

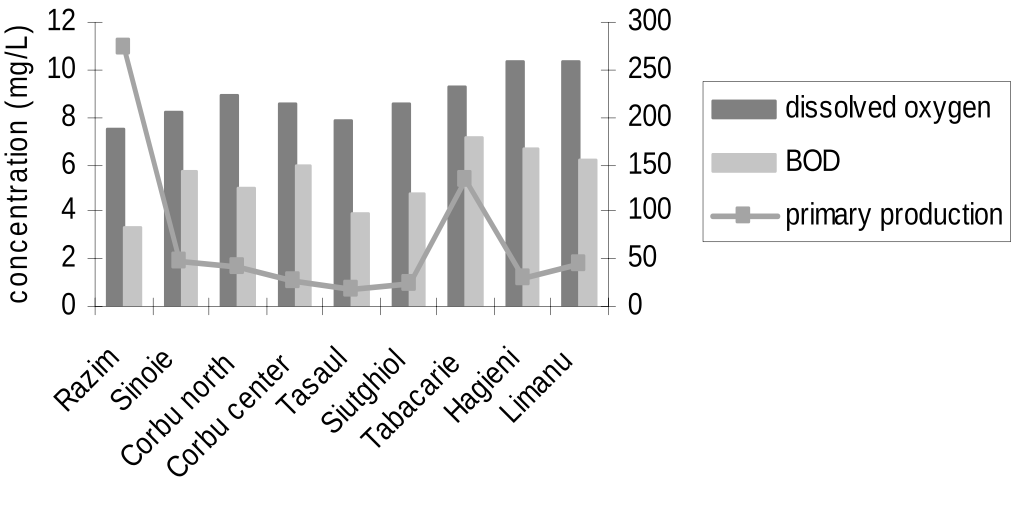

Figure 17: Multi annual average values of dissolved oxygen, biochemical oxygen demand and primary production in the Romanian coastal lakes.

It can also be noticed that the CODMn values of the lakes north of Constanța are higher than those of the lakes in the southern part of the Romanian seacoast (Limanu and Hagieni), which are less damaged by the human impact.

The measurements carried out to determine the thicknesses of the euphotic layer were especially performed because this is where the main biological processes, particularly the primary production of phytoplankton, are achieved. So, the thickness of this layer has a decisive influence on the primary production of the lakes and, implicitly, on the fish productivity. The thickness of the euphotic layer is relatively uniform (Fig. 18), 32 - 61 cm on the average, which indicates that the productivity of these lakes obviously depends on their size and not on their absolute depth. The minimum values of the euphotic layer are found in the Razim (21.6 cm), Sinoe (34.8 cm) and Corbu (16.8 cm) lakes; the mean values are in the Tăbăcarie Lake, and the maximum values are in the Taşaul (79.2 cm), Siutghiol (88.8 cm), Limanu (9143.4 cm) and Hagieni (123.6 cm) lakes (Godeanu and Galațchi, 2007).

The mean transparency in the seacoast lakes varies between 19 and 42 cm in the Razim Lake and 21 - 112 cm in the Limanu Lake (Fig. 19). On the overall, the Razim, Sinoe and Corbu lakes (all of them strongly exposed to dominant winds) have transparencies under 40 cm (usually 26 - 37 cm), and the others have mean values of 38 - 51 cm (Tab. 6). The limits between the minimum and the maximum transparency vary little (except for the Limanu Lake, followed by the Hagieni and Siutghiol lakes) (Godeanu and Galațchi, 2007).

It can be noticed that is a consistency between the values of the mean transparency and those of the thickness of the euphotic layer, which is slightly higher than the first one.

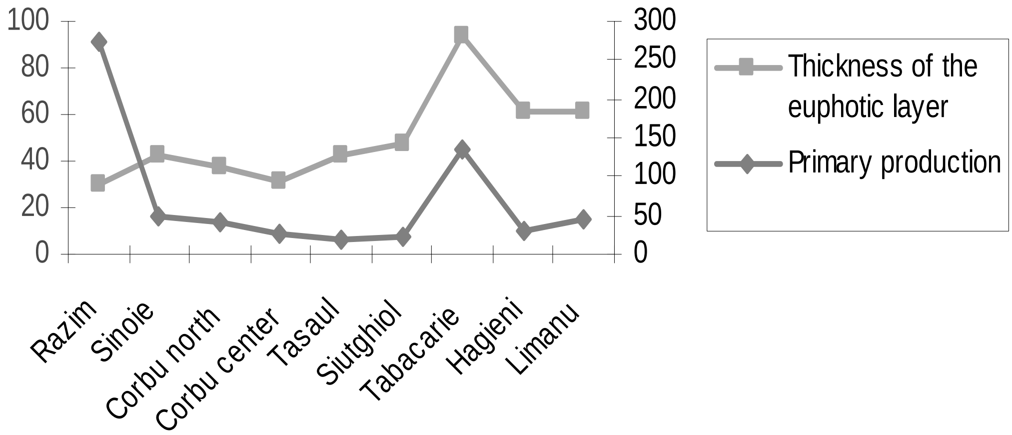

Figure 18: Multi annual average values for thickness of the euphotic layer and primary production in the Romanian coastal lakes (1997 - 2000).

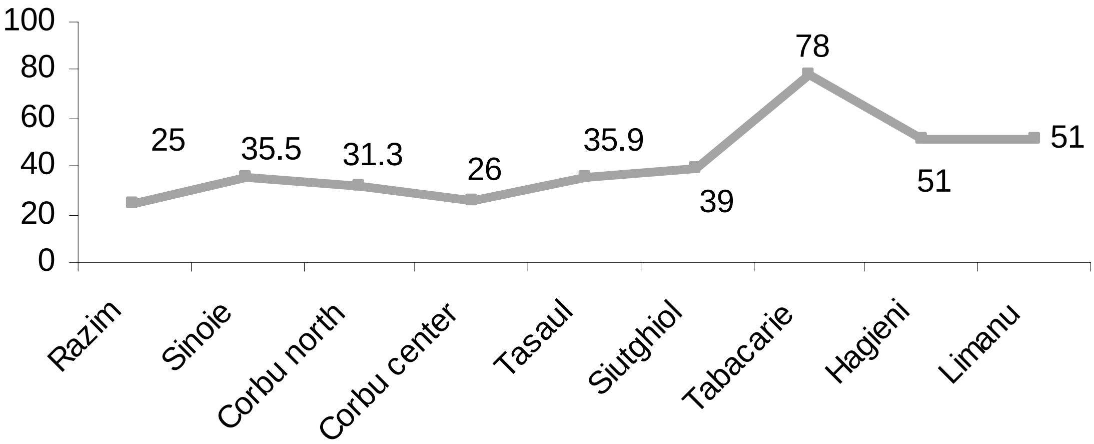

Figure 19: Multi annual average values of water transparency (cm) in the Romanian coastal lakes (1997 - 2000).

The examination of the mean values of the number of species of phytoplankton organisms shows that this varies within very wide limits, from 12 species in the Corbu Lake, up to 180 species in the Taşaul Lake (Fig. 20). The aquatic basins most affected by the high input of exogenous organic substances have a lower number of species (there are 52 species in the Tăbăcarie Lake and 35 species in the Corbu West Lake), whereas the cleaner fish basins have a higher biodiversity (119 species were identified in the Razim Lake, 81 species in the Hagieni Lake, 105 species in the Siutghiol Lake). Phytoplankton is the most perceptive group to the overall changes of the quality of lake water parameters. In order to appreciate the quality and trophic state of a lentic ecosystem, it is important to determine which the dominant phytoplanktonic group is (Fig. 21).

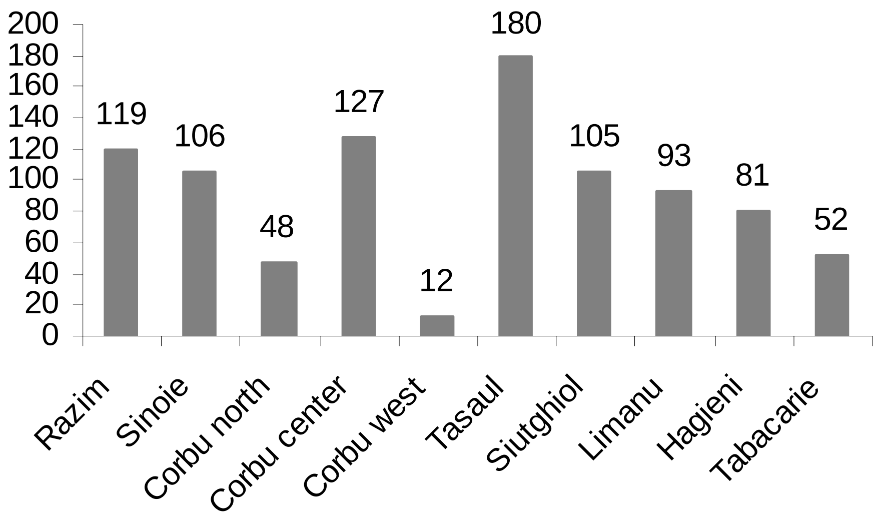

Figure 20: Number of phytoplankton species identified in the Romanian coastal lakes (1997 - 2000) (multi annual values).

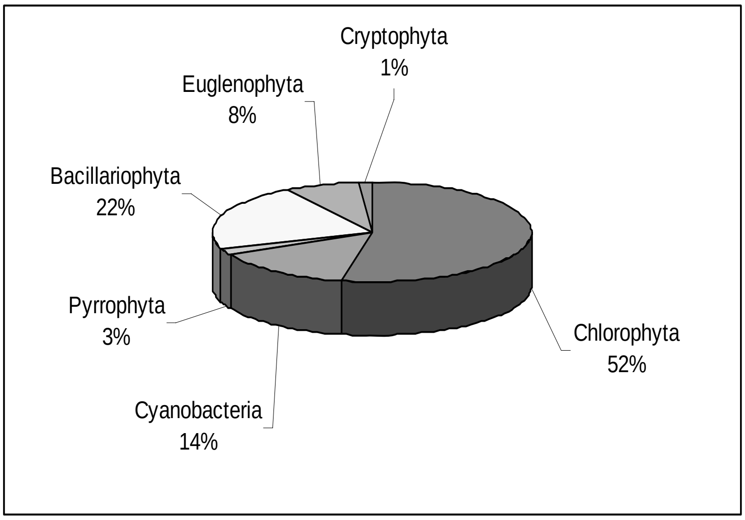

Figure 21: Species ratio divided in taxonomic groups in Taşaul Lake observed during 2006 - 2007.

The biomass of the phytoplankton (that of the primary producers in the water mass/ euphotic layer) is relatively similar in point of mean values between the lakes, fluctuating between 28.56 g/m^3 in the Siutghiol Lake and 106.12 g/m^3 in the Tăbăcarie Lake (Fig. 22).

As against the overall mean value of 53.69 g/m^3, the Sinoe, Corbu, Siutghiol, Limanu and Hagieni lakes are below this mean value, whereas the Razim, Taşaul and Tăbăcarie lakes are above the mean value. It should be noticed that the Taşaul Lake has the highest absolute values (Fig. 23), followed by the Razim and Tăbăcarie. The minimum absolute values are recorded in the Razim, Sinoe and Hagieni lakes, which we consider to be the less polluted lakes on the Romanian coast of the Black Sea (Godeanu and Galaţchi, 2007).

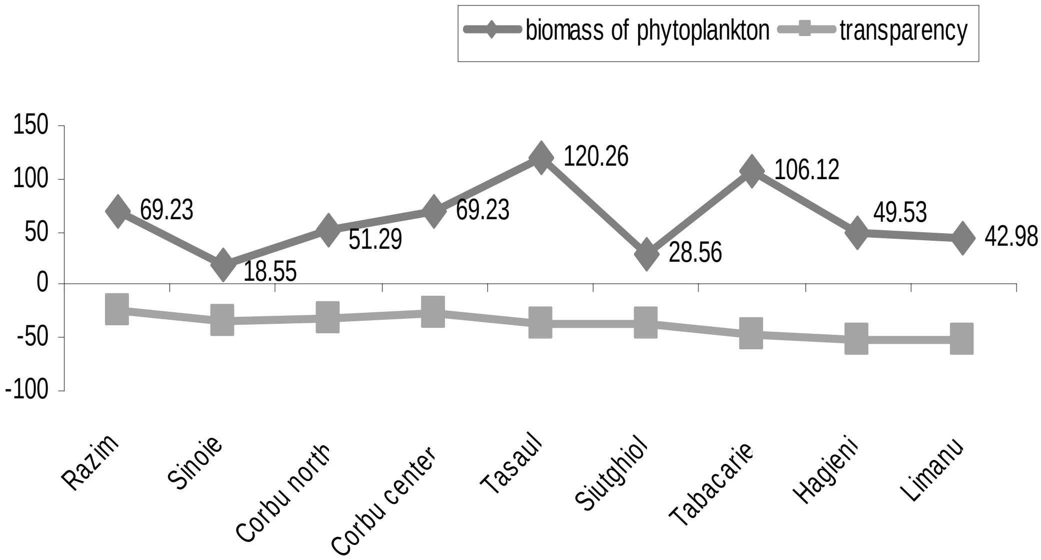

Figure 22: Annual biomass of the phytoplankton (mg/l) and average transparency (cm) in the Romanian coastal lakes (1997 - 2000).

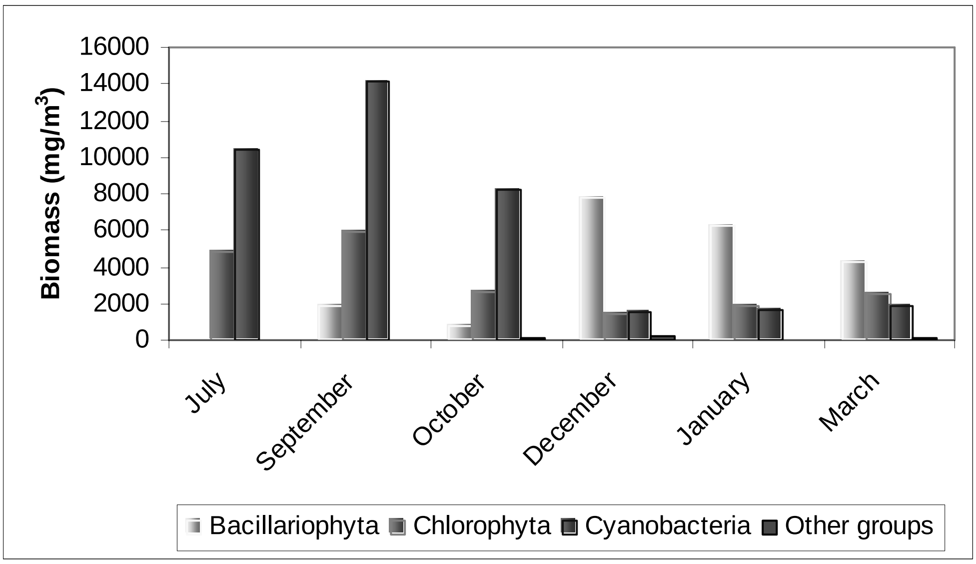

Figure 23: Biomass taxonomic groups variation for Taşaul Lake (2006 - 2007).

In the seacoast lakes, the number of taxons of the zooplankton organisms is relatively reduced. It varies between 12 (in the Hagieni Lake) and 44 (in the Năvodari Lake). The green biomass of the zooplankton is much reduced in the Corbu Lake (7.21 mg/mc), the maximum values being recorded in the Tăbăcarie Lake (9028.2 g/m^3). In the other lakes the mean biomass is around 300 - 600 g/m^3. The Hagieni and Corbu lakes have values below 100 g/m^3. The zooplankton furnishes the lake water with dissolved phosphates, which are then eliminated and are used as foodstuff for algae (Lahman and Scavia, 1982).

The values of chlorophyll "a" are extremely unequal as they depend on the group of phytoplankton organisms (compare the quantity of chlorophyll "a" found in the same quantity of biomass of diatoms or Peridinea with that from the green algae) and the total biomass of the phytoplankton organisms at the time of the sampling. The minimum values are encountered in the lakes in the southern part of the sea coast, the maximum ones in the northern lakes (Razelm, Tăbăcarie and Corbu). Since chlorophyll "a" is the main producer of organic carbon, we attempted to see whether there was any correlation between these two parameters (Fig. 24). We found that indeed there was a linear correlation (Godeanu and Galaţchi, 2007). Moreover, we noticed that most of the lakes were grouped in the lower part of the correlation value, a mean value was recorded in the Tăbăcarie Lake, whereas the maximum value, very far from the others. If in the case of the Tăbăcarie Lake the explanation lies in the very high degree of eutrophication it has at present, in the case of the Razelm Lake there is no such explanation.

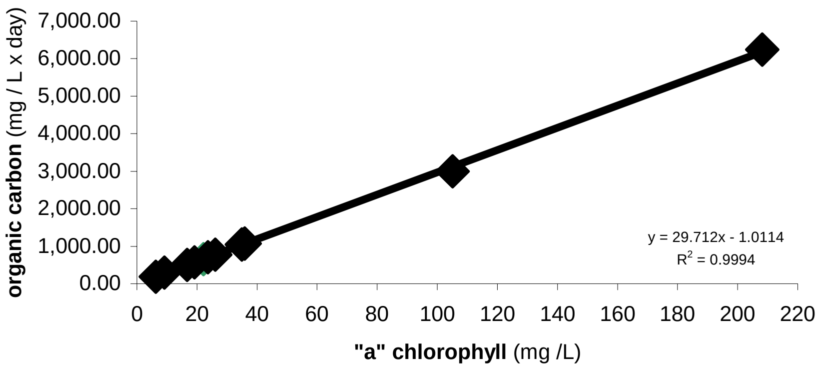

Figure 24: Correlation between "a" chlorophyll concentration and organic carbon in seaside lakes, during 1997 - 2000 (Godeanu and Galaţchi, 2007).

When attempting to correlate the mean values of the concentration of chlorophyll "a" with the mean annual biomass of the phytoplankton (Fig. 25), we noticed that this is less strict in comparison with that seen between chlorophyll "a" and organic carbon, the deviations from the mean value being, obviously, higher (Godeanu and Galaţchi, 2007). Nevertheless, in this case as well, most of the lakes have minimum values, although they are more spread out (the non-correlation is most obvious in the case of the Taşaul and Tăbăcarie lakes).

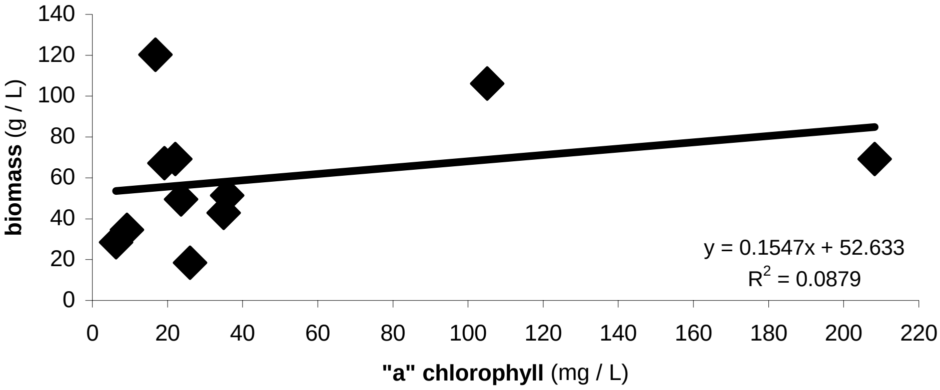

Figure 25: Correlation between "a" chlorophyll concentration and annual average biomass in seaside lakes, during 1997 - 2000 (Godeanu and Galațchi, 2007).

CONCLUSIONS

The general state of the lakes that were studied is extremely different: there are lakes with reduced anthropic influence (Limanu and Hagieni), all of them situated in the southern part of the Romanian sea coast, which are the cleanest; they are followed by the big lakes in the northern part of the sea coast (Razim and Sinoe). The other lakes, being situated in agricultural or suburban areas, evolve more rapidly towards eutrophication. The lake that is in the most advanced stage of eutrophication is the Tăbăcarie Lake, as it has been under the influence of the wastewaters discharges of the municipality of Constanța for many years.

The organic load of the waters of the seacoast lakes is relatively high (CODMn concentration varies between 10 - 25 mg O_2/l, BOD concentration between 5 - 12 mg O_2/l and DO concentration between 7.5 - 10.3 mg/l). As a consecuence the seaside lakes water can be included in the 2^{nd} - 3^{rd} category of surface waters.

The nutrients availability in Razim and Golovița was influenced by phosphorus exces.

The values of quality-monitored parameters are variable in quasi-large ranges, depending on the position of the sampling sites and the seasonal characteristics, but except Cu and Fe, all of them are in the limits imposed by the last regulations.

Most of the primary plankton production is achieved, in the first 50 cm of the mass of water from the surface (in the euphotic area), where the transparency is also the best.

The mean transparency of the waters of the lakes is 30 - 40 cm, with maximum fluctuations between 19 and 112 cm, but which varies from one lake to the other (the highest fluctuations are usually recorded in the cleanest lakes).

The data indicate that the most eutrophicated lakes are Tăbăcarie and Taşaul. The values of the parameters analyzed in the Razim Lake are contradictory as they indicate the existence of an intense process of eutrophication here as well.

Based on the last decade studies concerning the lakes on the Romanian Black Sea coast it is imperious to take urgent steps, specific for every lake, to fight against the process of eutrophication and organic silting in order to achieve systems for the retention rainfall waters and polluted waters and the extraction of the nutrients which might reach the lakes.

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DECLINE OF BIODIVERSITY AS A RESULT OF VARIOUS HUMAN IMPACTS RELATED TO RIVER REGULATION - EXEMPLIFIED BY SEVERAL SMALL RIVER CATCHMENTS (AUSTRIA)

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KEYWORDS: Austria, longitudinal integrity, impoundment, residual water, biodiversity.

ABSTRACT

Unimpaired water bodies are characterized by a natural, heterogeneous morphology, an intact water-land-connectivity and moreover by longitudinal integrity. Most running waters in Austria, especially in densely populated areas, are, by contrast, heavily affected by various human impacts, including amongst others channelization, habitat fragmentation by dams and other barriers as well as the alteration of the natural flow regime by residual waters or impoundments. Fish and other aquatic organisms are therefore no longer able to longitudinally migrate within the watercourse, which often makes successful reproduction impossible.

In applied research projects, there are always precisely defined questions, which makes research for more scientific questions very difficult. We tried to analyse data from applied projects in order to find out about the effects of human impacts on running waters, concerning the fish fauna.

ZUSAMMENFASSUNG: Biodiversitätsverlust als Konsequenz verschieder anthroponer Eingriffe in Zusammenhang mit Flussregulierungen - am Beispiel einiger kleiner Einzugsgebiete (Österreich).

Unbeeinträchtigte Fließgewässer zeichnen sich durch eine natürliche, heterogene Morphologie, eine funktionierende Gewässer-Umland-Vernetzung und vor allem durch eine uneingeschränkte Längsdurchgängigkeit aus. Die meisten Bäche und Flüsse in Österreich hingegen, vor allem jene in dicht besiedelten Gebieten, wurden in der Vergangenheit und werden teils noch in der Gegenwart durch verschiedenste menschliche Eingriffe massiv belastet. Die wesentlichsten Eingriffstypen umfassen Gewässerbegradigungen, die Fragmentierung des Lebensraumes durch Dämme und andere Querbauwerke, sowie die massive Veränderung der natürlichen hydrologischen Bedingungen durch Restwasser- und Staustrecken. Fischen und anderen aquatischen Organismen wird dadurch die Möglichkeit genommen, innerhalb des Gewässers Längswanderungen durchzuführen, was in vielen Fällen eine erfolgreiche Reproduktion unmöglich macht.

Angewandte Projekte beschäftigen sich immer mit genau definierten Fragestellungen in Hinblick auf konkrete (Bau-)Projekte, weshalb in den meisten Fällen wissenschaftliche Aspekte weitestgehend unberücksichtigt bleiben. Die Autoren haben versucht, Daten aus solchen angewandten Projekten zu analysieren und zusammenzuführen, um die Effekte, die genannten menschlichen Eingriffe auf die Fischfauna eines Gewässers haben, aufzeigen zu können.

REZUMAT: Declinul biodiversității ca rezultat a variate impacte antropice legate de regularizarea râurilor - exemplificate prin câteva bazine de râuri mici (Austria).

Cursurile de apă neafectate sunt caracterizate de o morfologie naturală heterogenă, o conectivitate apă-uscat intactă şi de altfel şi de integritate longitudinală. Cele mai multe ape curgătoare din Austria, în special în ariile dens populate, sunt dimpotrivă grav afectate de variate tipuri de impact antropice, printre care şi canalizarea, fragmentarea habitatelor, de către baraje şi alte bariere, alterarea regimului natural de curgere, de apele reziduale sau retenții de apă. Peştii şi alte organisme acvatice nu mai sunt de aceea capabile să migreze de-a lungul cursului de apă, fapt care face adesea ca reproducerea să fie imposibilă.

În proiectele de cercetare aplicată, există întotdeuna întrebări bine definite, care fac cercetarea relativ la mai multe întrebări foarte dificilă. Noi am încercat să analizăm datele unor proiecte de cercetare aplicată, în vederea identificării efectelor impactelor umane asupra apelor curgătoare, în legătură cu fauna de peşti.

INTRODUCTION

Currently, most of the rivers and brooks in middle Europe are affected by lots of various human impacts. Some of the most common influences concern river regulation for flood protection purposes, river fragmentation and the alteration of the flow regime in order to produce energy, as well as the overload with waste waters.

In Austria, there are only a few and locally restricted problems with bad biological water quality, due to the nationwide installation of waste water treatment plants. On the contrary, we mostly have to deal with morphological and hydrological problems (Dynesius and Nilsson, 1994), like most countries in the western world. Those problems result from river regulations and their accompanying measures, for example from the erection of ramps and weirs in order to prevent the river bed from erosion due to regulation and river straightening measures. Because of the enormously high numbers of physical obstacles, almost all running waters in Austria are exceptionally fragmented, with barriers occurring - on average - every 300 m (e.g. Gumpinger and Siligato, 2005). Regarding just catchment areas that are larger than 100 km², we have to deal with about 38.350 obstacles in Austria that impede the longitudinal migration of the aquatic fauna.

Some of the effects of river fragmentation, commonly combined with dams and the alteration of the flow regime, are shown and discussed in this article.

Another currently rising problem, the thermal pollution of our rivers, is also mentioned. In times when the climate change and the need for energy saving are discussed intensively, it seems absurd, that heated water is disposed of in rivers instead of utilizing any available temperature gradient for heating purposes or energy recovery.

MATERIALS AND METHODS

In applied research projects, there are always precisely defined questions, concerning either the possible ecological effects of individual measures, for example dam constructions, diversions or hydropower plants on aquatic ecosystems or - currently of particular interest - the development of methods for the implementation of the EU Water Framework Directive.

Trying to identify the effects of human impacts on running waters, we analysed data that we had gained from four small river catchments in Austria in which we had carried out applied research projects. Some specifications of these watercourses are shown in the table 1.

Table 1: Name, size of catchment area, mean discharge and investigated impacts of the concerned watercourses.

Watercourse	Catchment area (km^2)	Mean discharge (m^3/sec)	Investigated impacts
Antiesen	285.8	5.0	impoundment, residual flow stretch
Erlauf	620	8.6	impoundment, residual flow stretch
Krems	377.9	6.0	impoundment, residual flow stretch
Vordernbergerbach	191.6	3.4	thermal pollution

As fish are the most important indicator group concerning questions about channel morphology, applied surveys almost always include the assessment of the fish fauna, which is to be examined according to the European Standard EN 14011 (Water Quality - Sampling of Fish with Electricity; CEN 2003). At this, the surveying and mapping of the morphological situation is always the first step in field work, focussing mainly on barriers, as longitudinal integrity is one of the major claims of the Water Framework Directive.

The method of electrofishing is based on the fact that fish are forced to swim towards a current source along an electric field line. By the use of a power engine that produces a direct current, fish are allured and narcotized, immediately lifted out with the aid of a landing net and transferred to buckets. They are determined, measured and weighed and finally released.

In addition to the biotic data, abiotics like morphological conditions and physico-chemical terms are methodically collected by default.

The synopsis of the biotic and non-biotic data collected during several applied projects admits the evaluation of different impacts on the fish fauna and the biodiversity in general.

In the four chosen running waters we compared the fish biodiversity in impoundments, residual flow stretches and in one thermally polluted reach with the fauna in close-by sections that have been left in their natural state.

RESULTS

Dams/Impoundments

It has turned out that each of the surveyed impoundments was dwelled by indifferent and limnoparous fish species like the Prussian carp (*Carassius gibelio*) or the pike (*Esox lucius*) and even by limnophilic and limnoparous species like the rudd (*Scardinius erythrophthalmus*) - all of which are completely atypical of the studied reaches.

On the contrary, some of the most typical rheophilic and rheoparous species like the grayling (*Thymallus thymallus*), the bullhead (*Cottus gobio*), the barbel (*Barbus barbus*) or the lamprey (*Eudontomyzon mariae*), that frequently occurred in adjacent undisturbed reaches, were totally missing in the impoundments.

The nase (*Chondrostoma nasus*), another rheophilic species, was found in seven consecutive sampling sites in the lower reaches of the river Antiesen, representing one of the most typical (although at the same time one of the most highly endangered) fish species in that region. Its intrinsically conjunct range within the river is solely interrupted by the only reservoir in the concerning section, where this rheophilic species is completely lacking (Siligato et al., 2008).

Furthermore, the fish biomass and the number of individuals in the observed impoundments was significantly lower than in the adjacent free flowing sections. As an example, the situation in the river Erlauf is outlined in the figure 1.

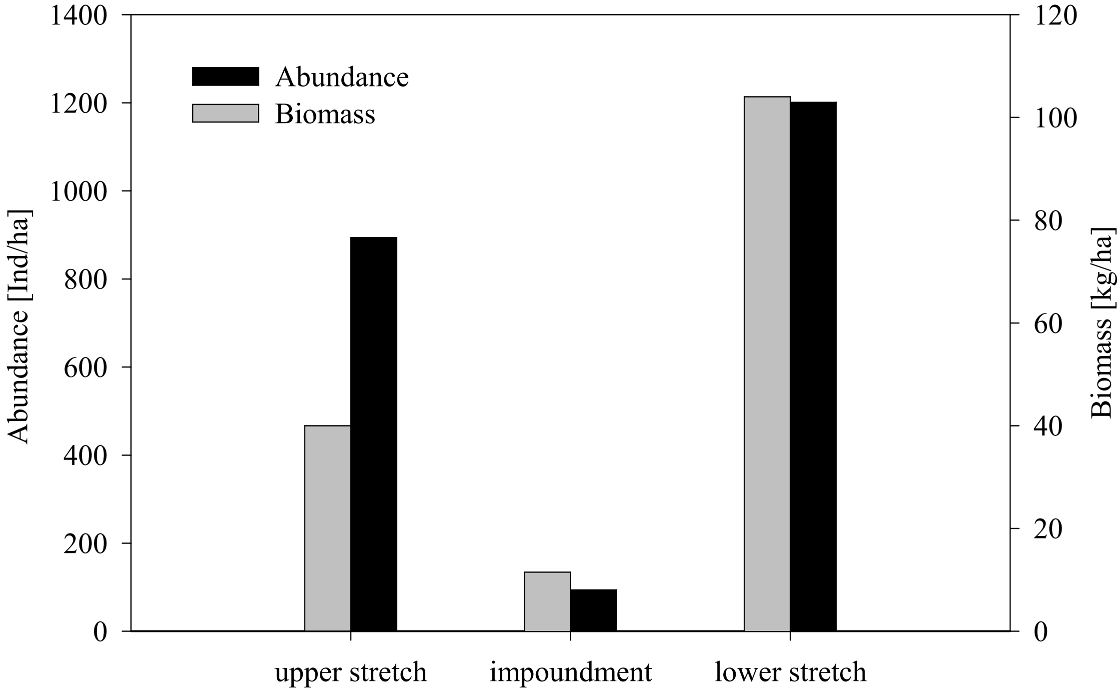

Figure 1: Fish abundance and biomass in an impoundment
and the two adjacent free flowing sections (up- and downstream) in the river Erlauf.

Residual flow stretches

Similar effects could be shown in residual waters, where rheophilic species were significantly underrepresented. In the river Krems, the nase could not be detected in any reach with restitution discharge, whereas it occurred quite frequently in free flowing sections (Siligato and Gumpinger, 2006). Most noticeably, the fish assemblages in residual waters consisted mainly of small-growing species, often comprising limnophilics like the bitterling (*Rhodeus amarus*), that once dwelled in meanwhile vanished anabranches or oxbow lakes. In heavily constructed reaches, sections with restitution discharge can obviously offer surrogate habitats to such species, which prima facie seems to be a positive aspect. But it must be regarded that at the same time residual waters represent an often impassable migration barrier for larger individuals and show atypical hydrological and morphological characteristics that are intolerable for most of the stream dwelling species.

In the investigated diverted reaches, the populations of large-growing species consisted mainly of juveniles, as the water column in such a stretch is usually far too small for adults. This effect is shown in the figure 2, which compares the population structures of the barbel in a residual stretch and a free flowing section in the river Krems.

As a result of the dominance of small-growing and the lack of adults in large-growing species, the mean fish weight in the residual waters we examined was significantly lower than in the adjacent flowing sections.

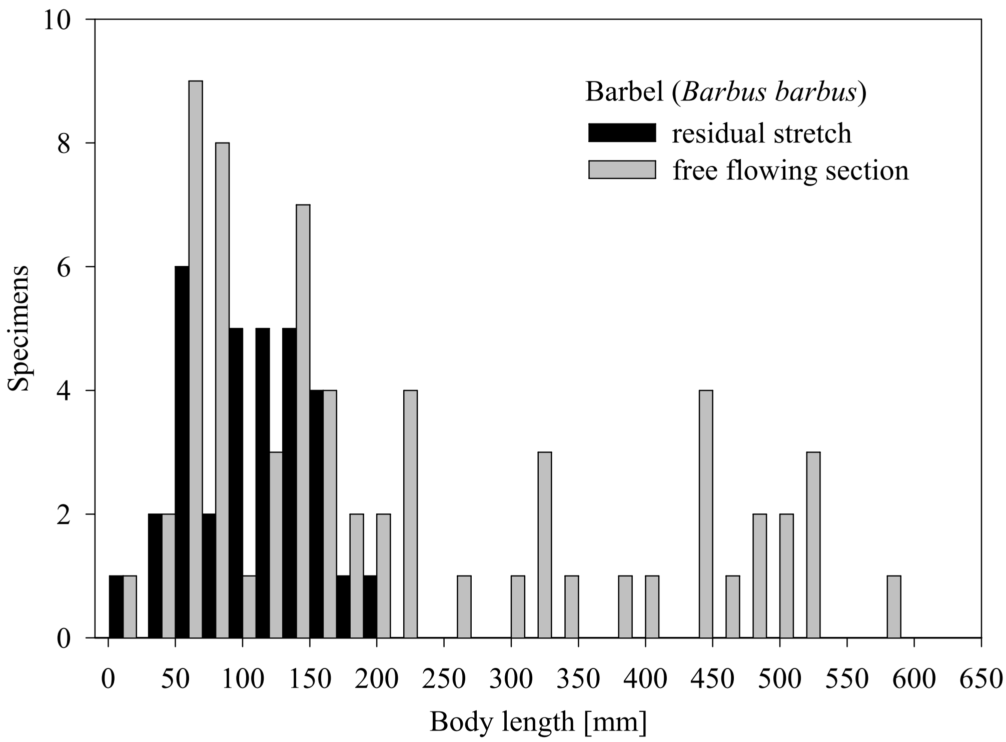

Figure 2: Population structures of the barbel in a residual stretch and an adjacent free flowing section of the river Krems.

Thermal pollution

In thermally impaired sections we detected an abrupt change in species assemblages in comparison with the unimpaired upstream reaches (Gumpinger et al., 2007). The natural fish fauna in the Vordernbergerbach brook, a typical trout stream in Styria, consists of brown trout (*Salmo trutta* forma *fario*) and bullhead. As the water temperature increases abruptly due to the discharge of circulating water from a steelworks, those autochthonous species are almost totally displaced by epipotamal species like barbel and chub (*Leuciscus cephalus*), as shown in Fig. 3.

The abrupt rise in temperature results in a shift of the fish region from the metarhithral to the epipotamal from one meter to the other. Furthermore, the specimens in the warmed stretch show a higher mean individual weight, resulting from the better food supply, as densities of algae, macrophytes and benthic invertebrates also increase due to the higher temperature. The brook has lost its natural biocoenosis because of the altered temperature regime.

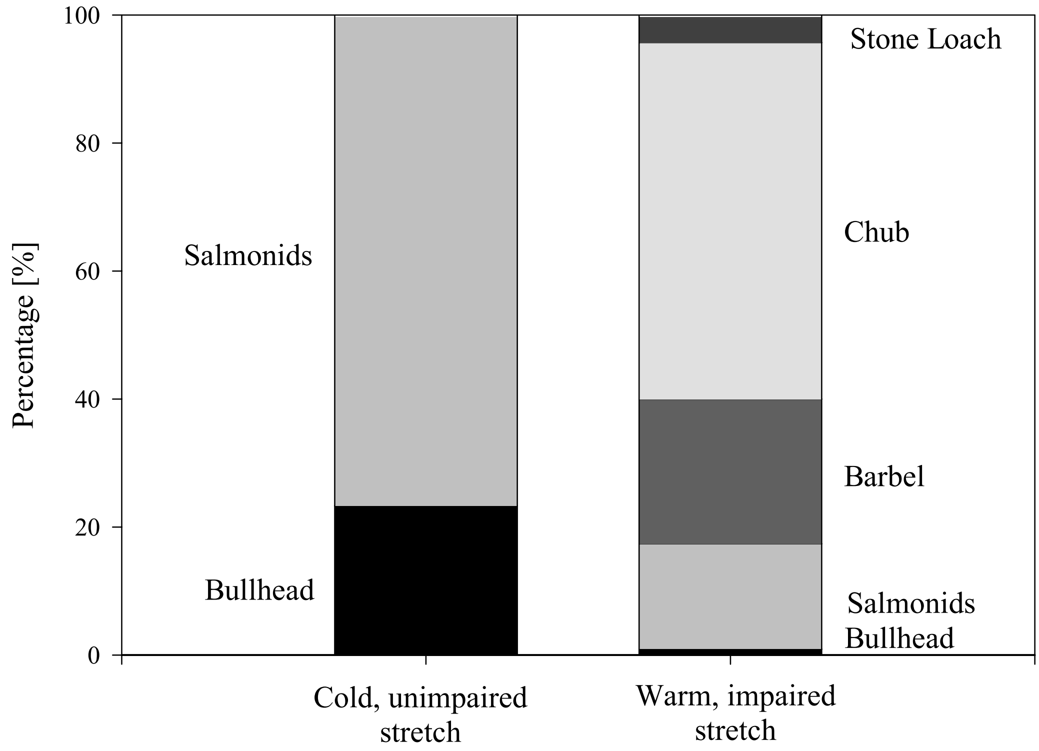

Figure 3: Shift in species composition due to the discharge of warm water in the Vordernbergerbach brook.

DISCUSSION

Dams/Impoundments

Apart from a shift in the species composition, impoundments are characterized by significantly lower numbers of individuals and decreased biomass (Kubecka et al., 1997). Some of the reasons for that phenomenon are discussed below.

The most important factor that impairs aquatic organisms in impoundments and their adjacent stretches is the river continuum disruption (Strohmeier, 2002; Kolbinger, 2002; Jungwirth et al., 2003). Fish and benthic invertebrates are not able to pass dams, which is a particular problem during the spawning migration. The grayling, for example, needs to carry out an upstream migration, that can make up to few kilometres, to find spawning grounds, and after that, it performs a post-spawning homing movement (Ovidio et al., 2004). Essential reproduction migrations are made impossible for all migrating fish species by the dams. Natural reproduction can therefore often not take place upstream of dams.

Further on, fish that dwell in or upstream of an impoundment and are washed away during deluges are no longer able to reach their former habitats. The washing down of fish and the failure of reproduction can finally lead to a massive decline of biomass and population size and can (in the worst case) even result in species extinctions in the upstream river reaches.

Based on our observations, we suppose that not only the dam is a problem for the upstream migration, but also the impoundment as such, that must be regarded a discrete migration barrier. Due to its aberrant hydrological conditions, it prevents the migrating fish, that orientate towards the direction of the current, from finding the right course. Furthermore, an impoundment causes a time delay in both directions, up- and downstream, because of reduced flow patterns. That the altered hydrological situation is the reason for the displacement of rheophilic species by indifferent and limnophilic ones as well, goes without saying.

Moreover, the alteration of the sediment composition (grain size decreases in impoundments from the head of the reservoir to the dam wall due to decreasing flow velocity and shear stress) must be considered a major problem, because of the massive habitat loss for spawning adult fish as well as for juveniles. Gravel banks, that are necessary for the successful reproduction of gravel spawning species, are covered with fine sediments like silt, mud and sand and hence cannot be used for oviposition any more. The nase, an anadromous and rheophilic fish species, needs riffle structures comprising of gravel with a grain size of 2 - 6.3 cm, on which they attach their adhesive eggs (Hauer et al., 2007). In impoundments, there are neither possibilities for a successful reproduction nor any habitats for young-of-the-year individuals.

Residual flow stretches

The decreased biomass and fish abundance in residual flow stretches can be understood as a result of the reduced volume of the waterbody. Such stretches may offer habitat to species that used to dwell in meanwhile lost anabranches and oxbow lakes. Residual stretches that are situated in hyporhithral reaches may simulate former branches of furcation situations with shallow water levels. But above all, they represent an alien type of watercourse within the river continuum. In fact, any diversion creates a stretch with unnaturally low discharge and water level, metaphorically speaking: a small brook within a large river bed. Those stretches do not offer appropriate habitats and often not even a migration corridor (Ebel et al., 2006) to adults of fish species that ought to occur in the respective region and must therefore be regarded a massive migration barrier, similar to impoundments, as discussed above.

Thermal pollution

The effects thermal pollution can have on the aquatic fauna are complex and reach from higher growth rates and an abrupt shift in the species composition to a temporal shift in spawning habits. Water temperature is a key factor for aquatic organisms, as they are poikilotherm and hence respond sensitively to temperature changes (Schmutz et al., 2004). Most notably, in virtually all native fish species temperature is the trigger for the reproduction cycle. If the water temperature is artificially raised, fish cannot synchronize their propagation properly any more and might start their migrations too early. Furthermore, the available spawning grounds might in many cases not be adequate. If a metarhithral stream, for example, is artificially warmed by human impact, fish species, that normally occur in epipotamal stretches, will immigrate to it. But the substrate they would need for a successful reproduction is then not expected to be available. That can lead to the paradox situation that the species that could reproduce in the reach are not there any more because of the excessive temperature, while the species that can cope with the thermal conditions might not be able to reproduce.

But thermal shifts are not only caused by the discharge of warm industrial waters. They can also result from river deforestations along the river banks and from impoundments, in which the direct solar radiation leads to an unnaturally high increase of the water temperature (Berg and Gumpinger, 2007).

CONCLUSIONS

The fish biodiversity can change perceptively depending on the kind of human impact. Either population structures or species assemblages - or both - show significant changes in anthropogenically impaired running waters. The most evident negative effects of dams and impoundments are a shift in the species composition as well as a decline of biomass and numbers of species. In residual flow stretches, individuals may outnumber populations in reference sections, but the mean individual weight is much lower due to the large amount of juveniles and small-growing species, resulting in an overall reduced fish biomass. In thermally impaired stretches, there is often an abrupt change in the species composition, as cold-stenothermous species are eliminated by either warm-stenothermous or eurythermous ones.

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THREATS FOR DANUBE REGION BIODIVERSITY - GLOBAL TRENDS AND LOCAL IMPACTS AND CHANGES IN BIOGEOGRAPHICAL PATTERNS

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KEYWORDS: Danube Basin, species community, biogeography, biodiversity, landscape change.

ABSTRACT

The Danube Region shows a specific richness in many aspects. The catchment and its tributaries touch eighteen countries, and due to this fact the Danube Region is the most international river system in the world. This plurality is also shown in populations, cultures and land-use. The present dynamics of economic development meets a biogeografical richness with Alpine, Pannonian, Continental, Steppic and Mediterranean characteristics. But as ecological systems never have static character, there are continuous changes within the species communities.

Biogeografical patterns in the Danube Region are discussed on the basis of species from different taxa. A main focus is laid on their relation to biogeografic regions and the identification of "Danubian species". Biodiversity has different aspects: the common, the typical and the unwanted.

The common and the typical: *Hucho hucho, Gymnocephalus schraetser, Triturus dobrogicus, Ophiogomphus cecilia, Parapleurus alliaceus, Bombina bombina, Trichia rufescens danubialis* and *Bithynella austriaca*. Distribution patterns of characteristic species of riverine landscapes in the Danube Region show basic informations or species protection and ecological indication.

The unwanted biodiversity - "aliens" and neotaxa: *Impatiens glandulifera, Solidago anadensis, Proterorhinus marmoratus, Dreissena polymorpha* and *Arion lusitanicus*. Reasons and strategies of migration: human transport and climate change.

Besides these dynamics in species communities there are global trends that cause local impacts in nearly every part of the Danube region. Not only along the river concerning black and white navigation and its infrastructure, but also gaps in local landscape planning and public participation can bring dramatic losses in biodiversity. To face these challenges and to build up a Danubian Identity an interdisciplinary crossborder cooperation is needed. The International Association for Danube Research (IAD) is a Danube wide network of scientists who search for answers on the complex questions of riverine landscapes. Set up in 1956, some 500 members from 18 countries, 36 international conferences and 12 expert groups are a strong fundament to develop a flexible scientific network. Aims are initiatives like the Sturgeon Action Plan and key-projects to support the implementation of the European Water Framework Directive as well as the transnational exchange of knowledge and experience. The IAD obtains observership status in the governmental platform of the International Commission for the Protection of the Danube River (ICPDR).

ZUSSAMMENFASUNG: Zur Gefährdung der Biodiversität im Donauraum - globale Trends und locale Auswirkungen sowie Veränderungen in biogeografischen Verbreitungsmustern.

Der Donauraum zeigt in vielfacher Hinsicht einen besonderen Reichtum. Das Einzugsgebiet und seine Zubringer berühren achtzehn Länder. So ist der Donauraum das internationalste Flusssystem der Welt. Diese Vielfalt umfasst auch die Bevölkerungen, Kulturen und Landnutzungsformen. Die gegenwärtige Dynamik der wirtschaftlichen Entwicklung trifftauf einen biogeografische Reichtum mit alpinen, pannonischen, kontinentalen, steppigen und mediterranen Merkmalen. Und da ökologische Systeme niemals statisch sind, zeigen die Artengemeinschaften permanenten Wandel.

Auf der Grundlage beispielhafter Arten aus unterschiedlichen Gruppen werden biogeografische Muster im Donauraum diskutiert. Ein Schwerpunkt liegt dabei in ihrer Beziehung zu biogeografischen Regionen und der Identifizierung typischer „Donau-Arten“. Biodiversität hat verschiedene Aspekte: das gewöhnliche, das typische und das ungewollte.

Das gewöhnliche und das typische: *Hucho hucho, Gymnocephalus schraetser, Triturus dobrogicus, Ophiogomphus cecilia, Parapleurus alliaceus, Bombina bombina, Trichia rufescens danubialis* und *Bithynella austriaca*. Die Verbreitungsbilder dieser charakteristischen Arten der Flusslandschaften des Donauraumes lassen grundlegende Informationen zum Artenschutz und zur ökologischen Indikation erkennen.

Die ungewollte Biodiversität: *Impatiens glandulifera, Solidago canadensis, Proterorhinus marmoratus, Dreissenia polymorpha* und *Arion lusitanicus*. Ursachen und Strategien der Wanderung: Menschliche Verfrachtung und Klimawandel.

Neben dieser Dynamik in Artengemeinschaften verursachen weltweite Entwicklungen Auswirkungen in nahezu jedem Bereich des Donauraumes. Nicht nur entlang des Flusses selbst mit seiner Personen- und Güterschifffahrt und der dazugehörenden Infrastruktur, sondern durch fehlende Landschaftsplanung und Bürgerbeteiligung drohen dramatische Verluste an Biodiversität. Um diesen Herausforderungen zu begegnen und eine regionale Identität im Donauraum zu entwickeln, bedarf es grenzüberschreitender Kooperation. Die International Association for Danube Research (IAD) ist ein Donau-weites Netzwerk von Wissenschaftern, die nach Antworten auf die komplexen Fragen der Flusslandschaften suchen. Gegründet 1956, bilden etwa 500 Mitglieder aus 18 Ländern, 36 internationale Konferenzen und 12 Expertengruppen eine starke Grundlage für ein flexibles wissenschaftliches Netzwerk. Ziele sind Initiativen wie der „Sturgeon Action Plan” und Schlüsselprojekte zur Unterstützung der Umsetzung der Europäischen Wasser-Rahmen-Richtlinie wie auch der internationale Austausch von Wissen und Erfahrung. Die IAD besitzt Beobachterstatus in der Donauschutzkommission (IKSD).

REZUMAT: Ameninţări pentru biodiversitatea regiunii Dunării - tendinţe globale, impacturi locale şi schimbări ale modelelor biogeografice.

Regiunea Dunării prezintă o bogăţie în specii din multe puncte de vedere. Bazinul şi tributarii acestuia ating optsprezece ţări şi datorită acestui fapt, regiunea Dunării este sistemul fluviatil cel mai internaţional din lume. Această pluralitate există şi la nivelul populaţiilor, culturior şi a folosinţei terenurilor. Dinamica prezentă a dezvoltării economice vine în contact cu caracteristicile bogăţiei biogeografice alpină, panonică, coninentală, stepică şi mediteraneeană. Ca sistem ecologic nu are niciodată un caracter static, existând o dinamică continuă la nivelul comunităţilor speciilor.

Modelele biogeografice din regiunea Dunării sunt discutate pe baza speciilor din diferite grupe taxonomice. Accentul se pune pe relaţia acestora cu regiunile biogeografice şi pe identificarea "speciilor Dunărene". Biodiversitatea include aspecte diferite: comune, tipice şi nedorite.

Comune: *Hucho hucho*, *Gymnocephalus schraetser*, *Triturus dobrogicus*, *Ophiogomphus cecilia*, *Parapleurus alliaceus*, *Bombina bombina*, *Trichia rufescens danubialis* and *Bithynella austriaca.* Modelele de distribuţie ale speciilor caracteristice pentru ariile limitrofe regiunii Dunării relevă informaţii de bază pentru protecţia speciilor.

Biodiversitatea nedorită "străinii" şi neotaxa: *Impatiens glandulifera*, *Solidago canadensis, Proterorhinus marmoratus*, *Dreissena polymorpha* and *Arion lusitanicus*. Motive şi strategii de migraţie: transport antropic şi schimbarea climei.

Dincolo de aceste dinamici, în comunităţile de specii sunt tendinţele globale în aproape fiecare zonă a regiunii Dunării. Nu doar în lungul râurilor, referitor la navigaţie şi infrastructura acesteia, dar şi deficienţele în planurile de amenajare teritorială şi în participarea publică pot aduce pierderi dramatice în biodiversitate. Pentru a face faţă acestor provocări şi a construi o Identitate Dunăreană, este necesară o cooperare interdisciplinară şi transfrontalieră. Asociaţia Internaţională petru Cercetarea Dunării (IAD) este o reţea largă de cercetători, la nivelul Dunării, care caută răspunsuri legate de ariile limitrofe. Înfiinţată în 1956, cu 500 de membrii din 18 ţări, 36 conferinţe internaţioale şi 12 grupuri de experţi sunt un fundament solid pentru dezvoltarea unei reţele ştiinţifice flexibile. Obiectivele sunt iniţiative ca Planul de Acţiune Sturion şi proiecte cheie pentru implementarea Directivei Europene Cadru Apă şi schimbul transnaţional de experienţă şi cunoştinţe. IAD a obţinut statutul de observator în platforma guvernamenală a Comisiei Internaţionale pentru Protecţia Fluviului Dunărea (ICPDR).

What is specific in the Danube Region?

The Danube Region shows a specific richness in many aspects. Today the catchment of the river Danube with all tributaries touchs eighteen countries. So the Danube Region is the most international river system in the world. This plurality is also shown in populations, cultures and land-use. The dynamics of economic development offers many opportunities, but also meets a biogeografical richness with diverse characteristics. And as ecological systems never have static character, there are continuous changes within the species communities.

Biogeography of Danube Region

The only existing monography of the Danube system was the result of a ten years lasting cooperation of all Danubian countries in the frame of the International Association for Danube Research (Liepold, 1967). The complexity of the area was analysed in the main aspects of the riverine characteristics and still waits for a successor.

Coming back to the biocoenotic characteristics we find five biogeographic regions touching the Danubian catchment. Three of them are mountainous regions with the Alpine, Carpathian and Dinarian areas and they cover the main parts of the region. Their geological diversity with various silicious and calcareous rock formations inherit a multitude of fountains, bogs and streams. The Pannonian, Continental and Steppic biogeographic regions complete the low areas with characteristic parts in Hungary and Romania.

Species from different taxa can help to show the characteristics of biogeografical patterns in the Danube Region. A main focus is laid on their relation to biogeografic regions and the identification of “Danubian species”. Biodiversity has different aspects. From a practical view we can classify the common, the typical and unwanted aspects of biodiversity.

The common and the typical: What are typical species? There is a plenty of cases where distribution areas move and in fact the borders of distribution are with many species highly dynamic. Just within the last thirty years the western border of *Cepaea vindobonensis* has moved backwards for more than sixty kilometres from Passau, Germany to Linz, Austria (Klemm 1974, Kutzenberger 1996). In this case structural changes in habitat quality are of main importance. On the other hand the beaver *(Castor fiber)* regained wide parts of the former territory in Austria after reintroduction in the 1980s. So it needs to take a look at the very different strategies and life-cycles within the species community. Both mentioned species are widely distributed. *Cepaea vindobonensis* inhabits semi wet grasslands in riverine landscapes, sometimes also dry pastures up to the mountainous region eg. the Enns Valley in the south-east of Upper Austria. The beaver is strictly bound to large rivers, but from these core-populations also small rivers floodplain forests are used as a habitat. So today we find beavers in Austria not only along the Danube river, but also in smaller tributaries in the northern parts of the Mühlviertel close to the Böhmerwald.

Semi aquatic and aquatic species mainly show azonal distribution patterns. A main focus for species protection lies on endemic ones. In the Danube Region the *Hucho hucho* is one of the major species. Others with typical Danubian distribution are *Gymnocephalus schraetser*, *Triturus dobrogicus*, *Trichia rufescens danubialis* and *Bithynella austriaca*.

The distribution of many more common distributed species is related to biogeografic regions. Especially the glacial periods influenced their distribution patterns, and the areas are still characterized by ongoing processes. A characteristic postglacial distribution pattern we find with *Bombina variegata* and *Bombina bombina*. Like with many other species the East-Western barriere of the Alpine Bow has lead to two refuge area in southeast and southwest.

The unwanted biodiversity - "aliens" and new species: recently invading or introduced species show very different characteristics. Their lifecycles are very different. *Solidago canadensis*, originated in north American semi-wet plainlands, was planted by bee-keepers and gardeners and turned out to be ecologically successful especially in disturbed floodplains due to both seeds and rhizoms: so this species is able both to invade open soil and established plant communities. The reasons and strategies of migration are various: important aspects are human transport and climate change. With all problems related to new species we have to be aware that most species fail to establish populations and that in many cases the success of introduced species is related to habitats with high disturbance - often broken land-use systems. One main question is: how do we prepare the soil for expansive species?

A changing Environment

Besides these dynamics in species communities there are global trends that cause local impacts in nearly every part of the Danube region. Not only along the river concerning black and white navigation and its infrastructure, the worldwide economic development can bring dramatic losses in biodiversity. To show the width of relations the following examples are presented: balancing needs of inland navigation and the riverine landscape system; upstream dams und downstream lack of gravel; static and dynamic land-use systems - in alpine and carpathian areas; spatial planning and flood risk management; managing the structural change in all parts of the region.

1. Improvement of inland water transport. There is a general agreement among all stakeholders on the importance of raising the transport capacity of the Danube River. This aim affords measures for the improvement of the navigation conditions in several parts of the river. From the view of a secure navigation nearly 30 "bottlenecks" (= nearly all natural river-sections) of TINA corridor VII are under discussion to set technical measures. For the lower

Danube section there is still unclear if this would cause cutting off most sidearms, stabilising riverbed and banks, industrial dredging. In this case the state of the art would have been ignored and severe damages to biodiversity would follow, including the extinction of the sturgeon in Danube.

2. Improving infrastructure along the river. Economic growth depends on modern infrastructure. As a precondition ports, power plants, roads, railways and industrial areas are necessary. To reach this balance between economic and ecological needs, integrated landscape planning approaches have been developed with Strategic Environmental Assessments and Environmental Impact Assessments. These are part of the European legislation to reach sustainable solutions. Their implementation is on the way.

This does not only mean that big projects cause severe impacts. It is also necessary to take care of local projects. *Natrix tesselata* has one of three remaining populations in Vienna port. Due to the adaptation of the port to modern vessels the habitat will be destroyed. To avoid the extinction, new habitats have been initiated in advance.

3. Change of dynamic land-use systems. In the mountainous regions of Alpine, Carpathian and Balkan as well as the Steppic zone dynamic land use systems still exist. Shepherding is a main factor and also reason of the high biodiversity of these landscapes. If the European common agriculture policy does not integrate these systems it might cause a severe loss of biodiversity. These is also a fact for short-sighted or missing landscape planning on municipial level.

4. Settlements growing into floodplains. Planless growth of settlements into the floodplains of small streams and large rivers causes severe problems to sustainable rural development and raise the risk of floods. Many small catchments are changed and the relation between upstream retention and downstream floods is ignored. A Danube-wide exchange in integrated planning is urgently needed.

5. Lack of public involvement in decisions and implementation. To reach acceptance in the local population it is important to improve structures for participation and active citizenship (Local Agenda 21, Global Marshall Plan) in the Danube Region. The personal identification is a key factor to support development and avoid depopulation of rural areas. In the Danube Region the reality of sustainable development will be prooved: a concept of an European identity including social, economic and ecological aspects, respecting the local traditions in a rapid change of structures.

Towards Sustainable Solutions

Since 1956 the International Association for Danube Research (IAD) has provided numerous scientific investigations of the complex eco-system of the Danube River and contributed to the river protection in the whole Danube Basin. Country representatives and twelve expert groups are the foundation of a Danube-wide network of scientists. In 1998 the International Commission for the Protection of the Danube River (ICPDR) was set up to ensure "the sustainable and equitable use of waters and freshwater resources in the Danube River Basin". From the beginning IAD obtained observer-ship status in ICPDR. Their delegates actively participate in various standing and ad hoc Expert Groups of the ICPDR to discuss and develop tools and measures to obtain the protection of the Danube River and to reach a sustainable river basin management as the ultimate goal of the Water Framework Directive (EU-WFD) implementation. With the foundation of an expert group on "Sustainable development and public participation" in 2008 the IAD works on a multidisciplinary approach to support implementation on local and regional level in the Danube region.

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CONSIDERATIONS CONCERNING THE WETLANDS IMPORTANCE, PROTECTION AND SUSTAINABLE MANAGEMENT (ROMANIA)

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ABSTRACT

This paper treats the wetlands in general with some exemplifications at regional and local level which aims the territory of Romania. These areas present a special interest both at national and global level through the ambience characteristics, the landscape, the scientific and economic value. The main objective is to highlight the importance of these areas especially as habitat and place of refuge for species of plants and animals, especially birds, and their role in the conservation of the biodiversity. Since 1971 (Ramsar Convention) the necessity of the conservation and the protection of these ecologic systems were brought to the public attention. The subsequent international directives known as “Birds” and “Habitat” represent the concrete answer of the international community at the necessity of the biodiversity conservation. The protection of the wetlands has a special importance because these are vulnerable environments, subject continuously to the atrophic pressure manifested by different activities into these areas or beyond their limits. The elaborate knowledge, the understanding of the structure and functioning of the ecologic systems specific to wetlands, the quantification and the qualification of the pressures and of the impact of the anthropic activities, the investigation of some problems that derive from the economic utilization of these areas etc., constitute the fundamental premises of the analysis to elaborate a sustainable development of the wetlands.

RÉSUMÉ: Considérations sur l’importance, la protection et la gestion durable des zones humides (Roumanie).

Cette publication ouvrage traite des zones humides en général illustré d’exemples au niveau régional et local en Roumanie. Ces zones présentent un intérêt spécial tant au niveau national qu’au niveau mondial du fait de leurs caractéristiques culturelles, et de leur valeur paysagère, scientifique et économique. Le sujet principal est de souligner l’importance de ces zones en tant qu’habitat et lieu de refuge pour la faune et la flore, spécialement les oiseaux et donc leur rôle dans la conservation de la biodiversité. Dès 1971, avec la signature de la Ramsar Convention, l’attention de l’opinion publique sur la nécessité de conserver et protéger ces systèmes écologiques a été attirée. Les directives européennes ultérieures dites “Oiseaux” et “Habitat” ont représenté une réponse concrète de la communauté internationale à la nécessité de la conservation de la biodiversité. La protection des zones humides a une importance spéciale parce que celles-ci sont des environnements vulnérables, soumis en permanence à la pression anthropique, qui se manifestent par différentes activités dans ou en dehors de ces zones. La connaissance approfondie, la compréhension de la structure et du fonctionnement des systèmes écologiques spécifiques aux zones humides, la quantification et la qualification des pressions exercées par l’homme et l’impact des activités anthropiques, la mise en lumière de certains problèmes découlant de l’utilisation économique de ces zones etc., constituent les bases fondamentales de l’analyse en vue d’élaborer une gestion durable des zones humides.

REZUMAT: Considerații asupra importanței, protecției şi managementului durabil al zonelor umede (România).

Lucrarea de față tratează zonele umede, la modul general, cu unele exemplificări la nivel regional şi local, care vizează teritoriul României. Aceste zone prezintă un interes deosebit atât la nivel național, cât şi la nivel mondial prin caracteristicile ambientale, prin valoarea peisagistică, ştiințifică şi economică. Obiectivul principal este acela de a evidenția importanța acestor zone mai ales ca habitat şi loc de refugiu pentru speciile de plante şi animale, în special, păsări şi rolul lor în conservarea biodiversității. Încă din 1971, odată cu semnarea Convenției de la Ramsar, a fost supusă atenției opiniei publice şi oamenilor de ştiință, necesitatea conservării şi protejării acestor sisteme ecologice. Directivele europene, ulterioare cunoscute sub denumirea de ”Directiva Păsări” şi ”Directiva Habitat”, reprezintă răspunsul concret al comunității internaționale la necesitatea de conservare a biodiversității. În acest context, protecția zonelor umede are o importanță deosebită, deoarece acestea sunt medii vulnerabile, supuse în permanență presiunii antropice manifestate prin diferite activități în interiorul acestor arii sau dincolo de limitele lor. În acest sens, cunoaşterea aprofundată, înțelegerea modului de structurare şi funcționare a sistemelor ecologice specifice zonelor umede, cuantificarea şi calificarea presiunilor exercitate de către om şi a impactului activităților antropice, investigarea unor problematici care derivă din utilizarea economică a acestor zone etc. constituie premisele fundamentale ale analizei în vederea elaborării unui management durabil al zonelor umede.

THE PRESENT SIGNIFICANCE OF THE WETLANDS

Wetlands represent geographic spaces larger or smaller in surface characterized by certain morpho-hydro-climatic peculiarities that are reflected in ecosystems typology and in their functional character. Characteristic for these areas is the association between the water resources (ground water, surface water) and the climatic regime (expressed quantitative and qualitative through climatic parameters (moist, temperature, evaporation, quantity of precipitations, etc.) in conditions of a hydric balance in excess (the quantity of precipitations exceed the quantity of evaporated water).

Therefore, wetlands have a distribution at the level of the terrestrial globe conditioned by the super unitary ratio between precipitations and evaporation, depending on the general geographic laws: zoning, altitudinal leveling, azoning and interzoning, being distributing unequal on the Earth surface. They are well represented especially in the equatorial zone, in humid tropical zones and sub polar zones, as well as in altitude, and also all along the hydrographic network in river meadows where the surplus of water is determined by the continuous circuit between the river and the groundwater layers.

Wetlands include areas occupied by water or those under the incidence of the hydric flow situated in the interior of the continents or at their borders and according to Ramsar Convention 1971, article 1, they are represented of marshes, swamps, peat bogs, natural and artificial, permanent or temporary waters where the water is stationary or flowing, fresh, brinish, salty, including the sea water which depth at the reflux doesn’t pass six meters.

The International Conventions like: Ramsar Convention (1971), followed by IUCN Convention (1986), UNESCO Program (1991) “Man and Biosphere Program” and others, specify the importance of the wetlands as habitats with special natural value for the aquatic flora and fauna, but mainly for water birds. For this reason wetlands have a very important role through their biodiversity as a patrimony of vegetal and animal species, through the habitat conditions for the birds that stagnate in these areas or for those that are in transit and through the completion of the biologic cycle. But their importance consists especially in the mechanism that adjust the functional character of the ecosystems through the nutritive content and the quality of the overflowing waters, through the refreshing of the stagnant water after the overflows, through the quality of filter for the organic substances nutritive or even toxic, through the capacity of supplying and equilibration of the subterranean hydric balance and last but not least, wetlands present importance through their special landscape value.

TYPES OF WETLANDS

At the global level the typology and the extension of the wetlands is much diversified as a result of the differentiation with the latitude, the longitude or the altitude of the environment conditions that generates them. An important criterion of classification that is at the basis of the identification of the wetlands type is the geographic criterion, especially the geomorphologic and morphohydrographic one, on the basis of which they differentiate according to the forms of relief of I type (continents and ocean basins), the wetlands from the borders of the continents and from the interior of the continents, and in this frame we can realize a hierarchy according to the forms of relief of II type (mountains, hills, plateaus and plains) and of III type (dunes, glacial cirques, major river beds etc.) and the dominant morphohydrographic system (fluvial, lacustrine basin, swamp, etc.).

The biologic criterion has in view the classification of the wetlands depending on the presence of some species of plants and animals, vegetal associations or floristic and fauna habitats. In this category we mention the CORINE classification used at European level, which includes the following categories of wetlands differentiated exclusively on the basis of the relation between the environment conditions and the vegetal associations: the coastal environment, the saliferous environment, the non/sea aquatic environment, wet bushes and meadows, forests, swamps and peat bogs, rocks, cavernicolous habitats, agriculture lands and lands with other uses (human settlements, ways of communication, mines, etc.). The EUNIS classification was realized on the basis of CORINE classification, which was improved and adapted to the reevaluation requirements according to the integrated study of the animal and/or vegetal communities, and with special references upon the landscape elements, considered development support of these communities (www.wetlands.org/).

The ecologic criterion is at the basis of wetlands classification depending on the degree of nourishment of waters (eutrophic, oligotrophic), of chemism, salinity, hydrologic regime, of the biodiversity conservation and especially of the aquatic fauna (www.ramsar.org). Side by side with the natural conditions, the degree of anthropization of the geographic space conditions of the wetlands, especially their functionality vary.

Taking into account the definition given by the Ramsar Convention the criteria of classification enumerated above and the general characteristics of the wetlands, these can be grouped in the following categories according to RAMSAR classification:

1. **littoral wetlands -** generally situated at the border of the continents, at the contact between the land and the bordering ocean and sea basins, areas of transition with limits hard to trace, characterized by a spatial and temporal variability dependent on the exchange of matter and energy realized between the two environments; we include in this category all types of shores and aquatic surfaces being under the rhythmic influence of the waves, tides as well as under the influence of the liquid and solid supply of the rivers: the continental platform and the slightly deep sea waters characterized by the presence of the tides (depth of maximum six meters at the reflux) the low sandy shores, estuaries, deltas, high rocky shores, brinish and/or salty lagoons, fluvial-maritime coasts, forest, swamp and mangroves surfaces etc.;

2. **wetlands inside the continents -** permanently or temporary covered by running or stagnant water being under the direct incidence of the hydrographic artery and dependent of the hydrologic balance of the continental surfaces; in this category there are the fluvial systems of different orders respectively all the minor riverbeds with permanent, semipermanent and temporary drain (rivers, brooks), major riverbeds (meadows), deltas from inside the continents, lakes with fresh and salty water, swamp areas and peat bogs situated at different altitudes and latitudes, springs with diverse typologies including geothermal waters and karstic springs, underground fluvial systems from karst regions, etc.

3. **artificial wetlands -** issued as a result of human intervention by works of drainage, draining organization and piscicultural exploitation, constructions and hydroenergetic exploitation etc; in this category there are: aquatic surfaces used in pisciculture (fishing ponds) and aquaculture (lagoons, bogs), lakes of anthropic dam organized for water supplying or for hydroenergetic purpose, irrigated lands, drained lands, periodically overflowed surfaces, anthroposalty lakes, sea salts, etc.

From the definition and classification of wetlands it follows that at the level of the terrestrial globe and implicitly on the territory of Romania there are all types of wetlands with differentiated zonal or azonal extensions.

FUNCTIONS OF WETLANDS

The wetlands are characterized by a continuous dynamic, both in space and in time, conditioned by natural and anthropic factors, and have multiple functions: hydrologic, geomorphologic, biologic, ecologic, climatic, etc., but also economic.

The hydrologic function derives from the position of the wetlands inside the hydrographic, lacustrine or sea basins, these being submissive permanently to the hydrologic flux by flow and level oscillations, overflowing, floods etc. They function as real reservoirs that store important quantities of water and have the role to regulate the hydrologic balance of the morphohydrographic basins and to diminish the high flood wave or the water waves delaying or even preventing their transmission downstream or in borderland.

The geomorphologic function consists in the territory morphology represented by fluvial relief forms - minor and major riverbeds with low dips, unplaiting, meander flows, lacustrine cuvettes, etc., from the geomorphologic processes associated to the hydrologic flux (liquid and solid) - erosion, transport and accumulation with sectors differentiations as well as from the collateral effects that these processes can have upon the wetlands and the riparian spaces (chaotic agglomerations in riverbeds and forming of islands, forming of beaches, migration of thalwegs, flooding of some areas and periodical stagnation of waters, etc.).

The biologic importance of the wetlands consists in the conservation and increasing of biodiversity by the richness of plant and animal species, their diversity and the dimensions of the populations, connected directly to the habitats resulted from the water and interference. The wetland supply food resources that determine the colonization of some shelter habitats, the seasonal establishment and the reproduction of the species that depend of this environment. These lands also represent points of support for birds or other species of aquatic fauna migration, by their geographic position along or near some migration corridors.

The wetlands have a special value for the functioning and the regulation of regional ecosystems, but also for the global ecosystem, by their **ecologic function.** They contribute to the improvement of the waters quality by the decantation of the organic and toxic substances and by their retention at the level of the radicular system of the hydrophilic and hygrophile plants, by the refreshment of the groundwater, by the influence of the cycles of some chemical elements like carbon, sulphur, nitrogen, carbon dioxide, etc.

The climatic function of the wetlands derives from the caloric and thermic properties of the water and from the quality of thermic moderator of the aquatic surfaces, being known that the water accumulates more difficult the heat but it also cools harder, and the thermic amplitudes from wetlands are more reduced. Also, in the regions inside the continents or under the influence of the excessive continental climate, the processes of evaporation and evapo-perspiration increase the air humidity, attenuate the climatic continentality and generate specific topoclimates and mocroclimates with more moderate character.

Not last, **the economic function** consists in the vegetal and animal resources of which these areas dispose as well as in the turistic potential, possible to be capitalized at regional or local level by fishing, aquaculture, reed exploitation, hunting, piscicultural and cynegetic tourism, ecologic tourism, etc.

ANTHROPIC EXPLOITATION OF THE RESOURCES AND THE EXPOSURE TO RISK OF THE WETLANDS

In the course of history (Mesopotamia), and even in the recent past (Mississippi, Paraná, Pad, Danube, etc.), wetlands, especially marshes, were considered hard accessible areas, unproductive and diseases areas (malaria). The high moistness, the periodical floods and the overflowing hindered the human activity and endangered his existence. But meadows of the rivers and of the large rivers of the Terra are even since the antiquity a special attraction by the natural riches (water resources, vegetal resources, piscicultural resources, aquatic fauna (especially birds and mammals) of cynegetic interest, vegetal and animal species of economic or scientific interest) and by the habitat potential (favoring of the relief for disposing of the human settlements, moderate climatic conditions, etc.).

These constituted in time the main motives that were at the basis of the change of the wetlands landscape by works of territorial organizing, embanking, draining, canalization systems that on one side led to the concentration of the population and the development of the human settlements along the hydrographic arteries and to the polarizing of the socio-economic activities in rural or urban settlements. Thus, the archeological proves testify the multitude of transformations that took place in time and the establishment and the development of the biggest civilization of the world along the large rivers: the Egyptian civilization on Nil, the Mesopotamian civilization on Tigris and Euphrates, the Roman civilization on Tibru, the Venetian Republic on the Adriatic Sea shore, etc.

The relation between man and territory was always characterized by a large scale of ways of land use. In the second half of the XIXth century and the first half of the XXth century, the demographic increase, the economic development and especially the demands of agricultural products necessary to feeding entailed the so-called “hungry of land”. In this sense, important surfaces from the overflowing meadows were drained or surfaces in littoral areas were organized in polder system, which later were meant to agriculture or to the urban-industrial expansion, thus the ecologic balance in that areas being changed (the Pad Delta in Italy, polder systems in Holland). The wetlands are very vulnerable when the human’s action is a factor of stress. Their fragility depends directly of the quantity and the quality of the hydrologic exchanges which realize among the anthropic system, the aquatic units (ocean, sea, river, lakes, swamp etc.) and the specific ecologic systems. In these conditions the capacity to bear a natural or anthropic event of certain intensity that an ecologic system or one of its components (either natural or anthropic: the animal component, the vegetation, the population, etc.) is different from one system to another. In other words, vulnerability highlights the degree of exposure of the wetlands to different hazards and expresses the potential losses that an element or a group of elements can suffer when an event of a determined intensity expressed on a scale from 0 (no losses) to 1 (total damaging) takes place (Ştef and Costea, 2006).

The biggest lack of balances in the ecologic systems from the wetlands are induced by the anthropic activities for the purpose of intensive economic capitalization of these areas by draining and agricultural use, urbanization, placing some industrial objectives, construction of the communication ways, harbour accommodation, touristic activities etc. These actions realized in an uncontrolled way represent a factor of stress for the ecologic systems from the wetlands and most of the time there were disastrous secondary effects (the technological accidents from Bozânța and Novăț, Maramureş, 2000). The direct negative consequence is the loss of the natural initial functionality of these areas, followed by secondary effects distinguishable in short time like pollution, aridization and salinization (Ialomiței Bog), disappearance of the marshy areas from the major riverbeds, pollution of waters and soils as a result of the flowing of the used waters, of the use of chemical fertilizers and pesticides in agriculture, reduction of the surfaces occupied by natural riverside coppice and lawns, decrease of the biodiversity by numeric reduction of the populations and even the disappearance of some native plants and animal species, appearance and development of some species foreign to wetlands, etc.

In Romania, the diminution of the wetlands as a surface took place even from historical times, but with a rhythm clearly inferior to 1960 - 1990, when it has been intervened in the minor riverbeds by the dam building, the organizing of some navigable canals (Sulina, Canal Dunăre - Marea Neagră), the organizing of piscicultural ponds, or in the major riverbeds by draining, canalizations, the use of chemical fertilizers, etc. (Danube meadow, Ialomiței Bog and Brăilei Bog, Danube Delta, easily flooded meadows of the interior rivers Siret, Prut, Ialomița, Argeş, Olt, Jiu, Mureş, Timiş with Bega, Crişuri, Someş). The man intervened by these modifications changing the environment conditions essential to the balance of the riverine aquatic and terrestrial ecosystems dependent of the humid environment and imposing a new state in the dynamic of the respective ecosystems.

In the meadow and the Danube Delta a surface of approximately 6000 km^2 was pulled out from the hydrologic incidence of the stream. The Danube Meadow in Calafat - Isaccea sector, with the exception of the Brăila Little Bog, was embanked and drained on approximately 5000 hectares (Gâştescu and Ciupitu, 2004;). Also the deltaic geosystem of the Danube showed in time a certain capacity of reaction to the changes made by man through draining, embanking, canalizations for the purpose of the agricultural use (39800 hectares, meaning 11 % from the surface of the Danube Delta comprised between Chilia and Sfântu Gheorghe arms) determining partly new fazes of dynamic equilibrium.

With all the anthropic interventions mentioned, in Romania the wetlands are well represented by approximately 5000 hectares of oligotrophic swamps, 460000 hectares aquatic surface corresponding to 3450 natural and anthropic lakes, riverbeds with permanent and semipermanent letting outs on a length of approximately 115000 km, approximately 460000 hectares from the coast maritime area with a depth of six metres (Bălteanu, et al., 2005).

THE PROTECTION, RECONSTRUCTION AND CONSERVATION OF THE WETLANDS, WITH REFERENCE TO THE ROMANIAN TERRITORY

Measures of protection of the wetlands at global level and in Europe have been taken even since the end of the ‘60s and aimed the ecologic function of some important habitats for the survival and the migration of avifauna. These initiatives were concretized through the “Ramsar Convention for saving and protection of the wetlands of international interest, especially as habitat for birds, irrespective of season” (1971) and through the I.U.C.N. Convention (International Union for the Conservation of Nature, 1986).

In the last few years the most important projects have an interdisciplinary character and were directed to the protection, conservation and integrated management of the wetlands in the context of the geographic space from which the wetland takes place. These approaches contribute to the understanding of the wetlands as geoecological systems especially as the “Strategic Ramsar Plan 1997 - 2004” ratified at Brisbane acknowledge besides the ecologic importance the social-economic and cultural one of these areas and promote the concept of rational use and sustainable exploitation. In this sense the necessity of the identification of some protection and ecologic rehabilitation impose not only at the level of the birds population or vegetal association but also at the level of the environment conditions that are at their basis (the quantity and quality control of the water) and of the extension of the protection, conservation and sustainable management actions beyond the limits of the wetlands.

The most important wetland well individualized from Romania is represented by the Danube Delta appointed natural reservation by the Law 9/1973 with stipulations of landscape, flora and fauna preservation proposed by the Romanian Academy (Fig. 1). The three legislative measures were important moments for the protection of the Danube Delta and led to the extension of the protected surface of the Danube Delta (to 41500 hectares through the Decision 524/1975 of the Council of ministers), by the initiation in 1979 of other protected surfaces (18475 hectares), through the declaring of the Danube Delta as “Biosphere Reservation” with a surface of 500000 hectares (Resolution of the Romanian Government 853/1990, articles 5 and 6).

The importance of the wetlands and the amplitude of the changes happened in these spaces at the level of the Romanian territory led to some measures of protection in accordance with the solicitations of the RAMSAR Convention. In this sense, Romania adhered, through the Law number 5 on 25 January 1991, at the Convention of the wetlands, of international importance, especially as habitat of the aquatic birds, concluded at Ramsar on 2 February 1971, under the aegis of UNESCO, and amended through the Protocol of Paris on 3 December 1982.

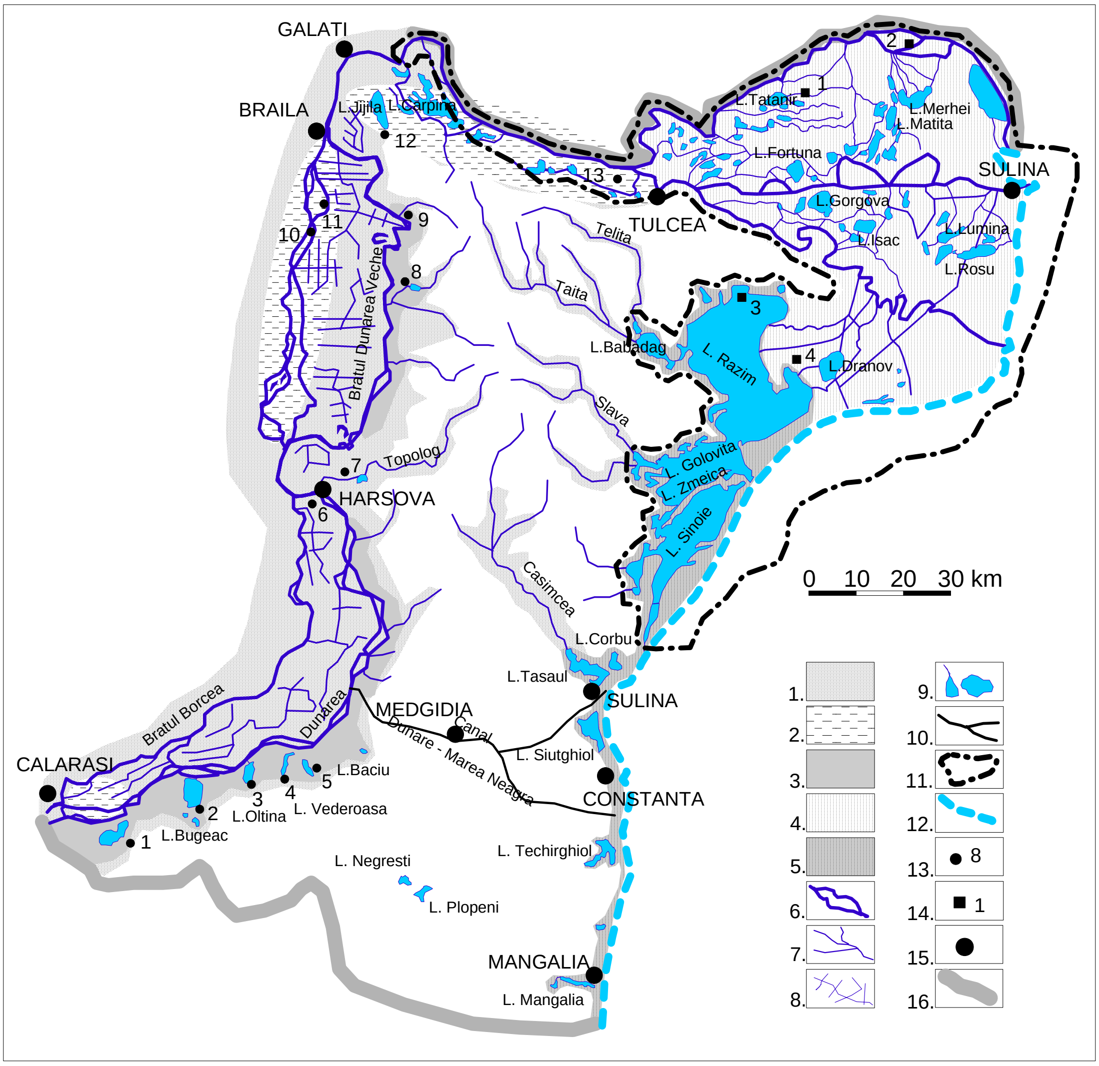

Figure 1: Wetlands from Dobrogea and Danube Delta: 1. River meadows with islets, swamps, meanders, oxbow lakes and excess of humidity, directly influenced by the river courses; 2. Floodplain with high frequency of overflowing; 3. Wetlands from Danube swamps influenced by the leakage of the Danube arms and fluvial limanes hydrologic regime; 4. Wetlands from Danube Delta with river arms, natural channels, lakes and marshy areas; 5. Coastal wetlands with fluvio-maritime limanes and lagoons, influenced by the sea waves; 6. River bed of Danube arms; 7. Hydrographic network and natural channels; 8. Antrophic channels; 9. Lakes (from delta, from floodplains, limanes, lagoons, natural dam lake); 10. Danube - Black See Channel; 11. Limit of DDBR (Danube Delta Biosphere Riserve); 12. Black See coastline and marine water until six metres depth; 13. Wetlands recently protected - proposal for their including in the Green Corridor of the Danube: (lakes and swamps of: 1. Bugeac; 2. Oltina; 3. Mârleanu; 4. Vederoasa; 5. Baciu; 6. Borcea Swamp; 7. Hazarlâc; 8. Peceneaga; 9. Turcoaia ponds; 10. Fundu Mare Islet; 11. Măcin - Smârdan Swamp; 12. Jijila; 13. Old Danube arms) (Gâştescu and Ciupitu, 2004); 14). Wetlands - proposal for the ecological reconstruction (1. Pardina area; 2. Islets of Babina and Cernovca; 3. Popina inland; 4. Holbina - Dunavăţ area); 15. Towns; 16. Romania’s border.

This Convention acknowledges the ecologic functions of the wetlands in the regulation of the letting out regime of the waters and as a habitat of some species of flora and fauna and obliges the countries engaged to supply a list of the main wetlands taking into account their relevance from the ecologic, botanic, zoological, limnologic, hydrologic point of view and especially of their capacity to support big populations of aquatic birds in any season of the year.

Ulterior, through the extension of the Biosphere Reservation at the whole surface of the Danube Delta [1] (Law 264/1991 and Law 983/1991), Romania compiled with the international policy regarding the environment. The international acknowledgement of the natural and scientific value of the Danube Delta is highlighted by the inclusion in "World Heritage List" as "wetland of international importance" and by the acknowledgement of the statute of "Biosphere Reservation" by UNESCO and the integration in the program "Man and Biosphere Program" of this deltaic space. The supporting and the perpetuation in the last years of the wetlands of the Danube Delta of great natural-scientific value both on national and international plan are connected of the policy of administration, compatible with the protection and the preservation of the landscape and the biodiversity promoted by D.D.B.R.A. (the Authority Biosphere Reserve Danube Delta founded through the Decree 264/1991) and by I.N.C.D.D.D. (the National Institute of Research Development Danube Delta).

Alongside the Convention from Rio de Janeiro (June 1992) the Romanian legislation regarding the environment protection begins to harmonize with the one of the European Convention. The Law 82/1993 and the Government Resolution number 248/1994 declare that the policies of environment development and protection must be based on the principles of the sustainable development. In 2000 Romania was on the Ramsar List only with the Danube Delta. Later the proposals were made regarding the introduction on the Ramsar List of 150 sites that comprise wetlands of international importance (Tőrők, 1999, 2000; Gâştescu and Ciupitu, 2004). Through the present projects that aim the ecologic reconstruction from the Biosphere Reserve of Danube Delta, from the Green Corridor of the Danube and from the Mureş Meadow, Romania rally to the international concerns of protection and conservation of the biodiversity and the habitats in the sense of the Frame Directive 2000/60/EC.

From 2001 the "Green Corridor of the Danube" is one of the most important projects of international collaboration on environment issues that involve all the riverane countries of the inferior Danube under the coordination of the National Institute of Research Development Danube Delta. The Project enjoys the cooperation of the World Wide Fund for Nature (WWF) and aims the problems of ecologic reconstruction, protection and conservation of the wetlands from the Danube Meadow and Delta. Through this project they follow the integration of the areas that are already under protection in the "Green Corridor of the Danube" (the sector

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[1] The development and the evolution in time and space of the delta are tightly connected to the palaeogeography evolution of the Predobrudja Depression and of the Danube Valley in the inferior sector, to the supplying and letting out regime of the stream, to the non-periodic variability of the liquid and especially solid flow that supplied the necessary material for the deltaic building and not at last to the configuration of the shore line and the amplitude and the intensification of the sea processes to which it is submissive the interface land-sea. This constituted the genetic context of the formation and evolution of the Danube Delta as a dynamic complex of great fragility formed by an alternance of marshy surfaces, main arms, canals, stream mouths, lakes and lagoons, sandy deposits under the form of spits, offshore bars, bars etc. But this system also registers a great productivity, having at the base organic and inorganic sediments with a big degree of fertility that allow the development of some vegetal biodiversity and on their basis a certain faunistic variety of great ecologic value.

Baziaş - Calafat, the Little Island of Brăila, etc.), the identification and the proposal of new protected areas on the whole route of the inferior Danube with a total surface of approximately 68344 hectares, especially in the sector Călăraşi - Brăila - Galați of the Danube Bogs by the comprising the fluvial shore on the Dobrudja riverside of the Danube, the Măcin Arm (the Old Danube) as well as the Brateş Lake in north of Galați.

As regarding the ecologic reconstruction there are proposed some surfaces from the easily flooded meadow of the Danube and the Danube Delta that totalize 129600 hectares. In the meadow of the Danube the ecologic reconstruction aims the following sectors: Drobeta Turnu-Severin - Calafat (Hanove - Ostrovu Corbului, 1981 hectares and Gârla Mare Salcia, 1618 hectares), Bistreț - Măceşu (1080 hectares), between Bechet and Zimnicea (the Potelu complex 23330 hectares, La Nisipuri 117 hectares, Suhaia organization 17490 hectares), downstream Giurgiu (Greaca complex 33891 hectares), Călăraşi Islet (13050 hectares), Galați - Isaccea sector (Carpina organized complex), and in Danube Delta surfaces like: Babina and Cernovca islets, piscicultural abandoned organizations Popina, Holbina - Dunavăț, Pardina precincts (32400 hectares) (Fig. 1).

The wetlands management must be analyzed on long term and the plan of administration of the wetlands must combine the actions of protection and conservation of the nature and biodiversity with the sustainable socio-economic activities. For this, besides the legislative support there is the necessity of the application of some strategies that support the accomplishment of the managerial objectives on long term, like: the active implication of the local, regional and national communities in the conservation and protection of the natural patrimony by means of education and consultation of the application methodologies of the legislative measures and of the management plan; the development of the administrative capacities; the carrying on of some sustainable activities based on sustainable exploitation, correct administration of the resources; the permanent monitoring of the water quality and especially of the risk factors for the wetlands (waste recycling, sources of pollution, natural processes of euthrophization, industrial and agricultural organizations, etc.); the development of the system of ecologic corridors of connection between the protected wetlands and the increase of the buffer surfaces; the promotion of the ecologic tourism adapted to the biologic exigencies of the ecosystems by the protection of the sensitive areas to touristic exploitation, the canalization of the touristic flux on resistant and easy to control itineraries, by the organizing of touristic spaces and infrastructures that integrate in the wetlands landscape.

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6. Hotărârea Guvernului României 853/1990

REACTIVE BARIERS USED IN THE PROTECTION OF AQUATIC ECOSYSTEMS (ROMANIA)

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KEYWORDS: bioremediation, reactive barriers, aquatic ecosystems.

ABSTRACT

Reactive barriers are a passive method of restraining the advancement of contaminated groundwater fronts, representing one of the most vantage methods of protection „in-situ” of sensible aquatic areas, especially when the remediation of polluted area is difficult or expensive.

The method is based on making, across the direction of groundwater flow, of a impermeable screen system for directing the polluted plume, in which are incorporated permeable reactive areas, where the pollutant is neutralized. The bioremediation is made with the aid of microorganisms, injected in reactive areas, which through catalytic activities, ensure the removal of pollutant from the groundwater.

Here are presented two solutions of making the reactive areas with protection role of ecosystems downstream from the polluted area. The first solution involve the making of a treatment gate, composed of two compartments, one who represent a geotextile filtering screen and the other the bioremediation zone. The geotextile screen has the role of retaining the free-phase petroleum products and the reactive medium is represented of a material with a permeability superior of the one of the aquifer, in which are inserted microorganism cultures.

The second technologie involve a reactive barrier compose from multi-strata biological filters, wrap with geotextile. In these filters are inserted the microorganism cultures witch are involved in the remediation process. Upstream from the barrier, on the groundwater flow, a concrete screen is ensured, acting as a barrier for the free petroleum products floating at the surface of the groundwater. The gathering of the petroleum products from the surface of the groundwater, accumulated up-stream of the screen, is made through a perforated well, so made that permits the accumulation and extraction of the products.

The advantage of this solution is he fact that the aquatic ecosystem protection is realized through passive methods, the natural flow of groundwater suffering unimportant modifications. Monitoring the efficiency of treatment is most important in exploitation of this system.

These systems can be applied in perimeter of surface aquatic ecosystems in cases in which are supplied with contaminated groundwater due to accidents or historic human activities.

ZUSSAMEFASSUNG: Verwendung reaktiver Sperren im Schutz aquatischer Ökosysteme.

Reaktive Sperren stellen eine passive Methode im Rückhalt sich ausbreitender, kontaminierter Grundwasserfronten dar. Es handelt sich um eine der günstigsten Methoden des "in-situ"-Schutzes sensibler aquatischer Bereiche, vor allem, wenn die Sanierung des verschmutzten Gebietes schwierig oder teuer ist. Quer zur Richtung des Grundwasserstromes wird eine impermeable Oberfläche zur Lenkung der Schmutzwasserfahne errichtet. In dieser Oberfläche befinden sich durchlässige reaktive Areale, in denen der jeweilige Schadstoff neutralisiert wird. Die biologische Reinigung findet unter Zuhilfenahme von Mikroorganismen statt, die in die durchlässigen Bereiche injiziert werden und durch ihre katalytische Aktivität die Entfernung der Schadstoffe aus dem Grundwasser gewährleisten. Im vorliegenden Artikel werden zwei mögliche Arten der reaktiven Sperren vorgestellt, mit Hilfe derer Ökosysteme flussab von kontaminierten Gebieten geschützt werden können. Der erste Ansatz stellt eine zweigeteilte Sperre dar, die aus einem Geotextilfilter und einer separaten bioaktiven Reinigungszone besteht. Die Aufgabe des Geotextilfilters besteht im Rückhalt freier Erdölverbindungen; die bioaktive Reinigungszone, in die Kulturen von Mikroorganismen eingebracht werden, stellt ein Material dar, dessen Durchlässigkeit höher ist als jene des Aquifers. Im zweiten Ansatz setzt sich die reaktive Sperre aus einem viellagigen biologischen Filter mit eingeimpften Mikroorganismen zusammen, der von einem Geotextilfilter umhüllt wird. Flussauf dieser Sperre gewährleistet im Grundwasserstrom ein Betonschirm den Rückhalt freier Erdölprodukte, die auf der Oberfläche aufschwimmen. Die hier akkumulierten Schadstoffe können über einen perforierten Schacht abgezogen werden. Der Vorteil dieser Methode ist, daß der passive Schutz aquatischer Ökosysteme durch vernachlässigbare Modifikationen des Grundwasserstroms ermöglicht wird. Eine Überprüfung der Effizienz ist bei der Umsetzung des Systems von größter Wichtigkeit. Die beschriebenen Systeme können im Umkreis von Oberflächengewässern installiert werden, wenn es in der Nähe zu Grundwasserverschmutzungen aufgrund von Unfällen oder anderen grundwasserbeeinträchtigenden menschlichen Aktivitäten gekommen ist.

REZUMAT: Bariere reactive utilizate pentru protecția ecositemelor acvatice.

Barierele reactive sunt o metodă pasivă de limitare a avansării fronturilor de ape subterane contaminate, reprezentând una din cele mai avantajoase metode de protecție in-situ a zonelor acvatice sensibile, îndeosebi, atunci, când remedierea este dificilă sau costisitoare.

Metoda se bazează pe realizarea, transversal pe direcția curentului subteran, a unui sistem de ecrane impermeabile pentru direcționarea penei de poluant, în care se integrează zone de reacție permeabile, unde contaminantul este neutralizat.

În lucrare, se prezintă două soluții tehnologice de alcătuire a zonelor de reacție cu rol de protecție a ecosistemelor din aval de zona poluată. Prima soluție implică realizarea unei porți de tratare, alcătuită din două compartimente, unul reprezentând mediul de reacție, iar celălalt un ecran filtrant de geotextil. Cea de-a doua tehnologie implică o barieră reactivă, compusă din filtre biologice multistrat, învelite cu geotextil. În aceste filtre, se introduc culturile de microorganisme care participă la procesul de bioremediere. Avantajul soluției constă în faptul că se realizează protecția ecosistemelor acvatice prin metode pasive, curentul natural al apei subterane, suferind modificari nesemnificative. Monitorizarea eficienței tratării este deosebit de importantă în exploatarea acestui sistem.

Sistemele pot fi aplicate ecosistemelor acvatice de suprafață, alimentate de ape subterane, contaminate ca urmare a unor accidente sau a activităților antropice istorice.

INTRODUCTION

The significant pollution of groundwater following the anthropic activities begun approximately two centuries ago, together with the development of the industrial sector. In the last 20 years this problem became prioritary for the environmental protection experts. At the basis of this fact, one can find especially the importance these water resources got in global context, situation generated by the demographic and the increasingly pollution of the surface sources, but also the awareness about their influence on other environmental factors. Thus, the groundwater pollution will lead sooner or later at the surface water quality alteration.

One of the pollution sources with major effects on the groundwater and, generally speaking, the environment is made up of the damaged tanks and pipelines used for the storage and transporting of oil products, during operation time. The negative effects generated by this category of pollution sources occur due to the contaminant physical-chemical properties in association with the duration required to detect the damages produced, which is generally long. This fact leads in many cases at the chronicisation of the phenomenon, by transforming the site in one affected by a long time pollution, over decades, named „historical pollution”.

This paper present a technical solution for stopping the extension of pollutant frontline and decreasing the inherent effects appearing downstream a site, affected by the undergound media historical pollution following the damages suffered by the oil transportation pipelines towards the industrial processing platform.

THE DESCRIPTION OF THE CURRENT SITUATION

Geologically, the studied site is in an area belonging to a structural unit with a bottom made up of granitic and crystalline formations. Over the crystalline-magmatic bottom there are sedimentary rocks belonging to the Silurian (clayey schists, quartzites), Devonian (sandstone, lime-marl), Jurassic (limestone), Cretacic (limestones, lime-marls, sandstones, conglomerates, chalk, glauconitic rocks), Eocen (limestones, glauconitic sands), Tortonian (clay, lime sandstones, sands), Sarmatian (marls, sandy clay, bentonite, lumaselic limestones) and Plyocen (marls, sands, lacustrine limestones). The surface is covered with a thick layer of loess.

The groundwater level in the area is located at 0.8 m average depth having the general flow direction from south to north, where it is collected by a surface water course.

Still from the late 60’s within the studied site there were pipelines transporting oil towards the industrial processing platform. In time, as a result of the inherent damages produced at the mentioned system, in the ground gathered some contaminant quantities which transformed the area in a site affected by historical pollution.

After 1990 the pipeline’s owner replaced them, and consequently the pollution sources were removed. Nevertheless, following the historical characteristics of pollution, the contamination of the ground media with oil products still remains an open problem. This fact leads currently at the slow pollution of the groundwater flow in the area, and at its discharge by drainage into the stream that flows at the site’s northern boundary.

The effect of pollution on the groundwater and surface water can be found by watching (Fig. 1a, b), but quantitatively its size has been established through laboratory analyses.

(a) (b)

Figure 1: The pollution effects. (a) - Groundwater monitoring well;
(b) - Surface water stream; actions aim to diminish the downstream pollution extending by using floating booms for collecting the oil products.

The monitoring of the groundwater quality was accomplished by the means of two wells with the diameter of 0.60 m and respectively 0.75 m and the depth of 3.7 m and respectively 3.9 m (Fig. 1a). In order to decrease downstream the effect generated by the presence of pollutant in the stream, it was provided a floating boom for collecting the contaminant at the surface of the water (Fig. 1b).

From the analysis of samples drawn both from the monitoring wells and the area upstream the floating booms it was confirmed the presence of oil products.

Following some discussions between all the decision factors in the area, involved in oil products transport activities, at one side, and the authority for environmental protection, at the other side, it was decided to start some actions aiming to reduce as much as possible the site contamination and protect the downstream areas affected by pollution.

Currently, in case of pollution with oil hydrocarbons there are known several methods that can be adopted for the decontamination of aquifer strata or limiting the extension of pollutant frontline. Among these, the most applied in the past were pump-and-treat methods at the ground surface, with or without recovering the pollutant and more newly the bioremediation and the reactive barriers or the impervious screens with treatment gates.

The reduced distance between the polluted area and the stream (surface water course) which is a priority element that should be protected, as the lack of possibility to provide some permanent above ground constructions following the activities unfolded on site, have been just few of the determining factors that have shown the impossibility to apply in this case the above mentioned methods. Hence, it was required to conceive and adopt a new solution, meant to reach the proposed goal. In order to work out this new solution an interdisciplinary team was formed with specialists from various fields such as: hydro-technical engineering, environment protection, bio-technologies engineering, biology and chemistry, all of them working within some important institutes.

THE PRESENTATION OF THE SOLUTION PROPOSED

The method is based on a system (to be built) of impervious screens positioned across the direction of groundwater flow having the role to direct the pollutant frontline towards a permeable reaction area, where the contaminant is to be neutralized (Fig. 2).

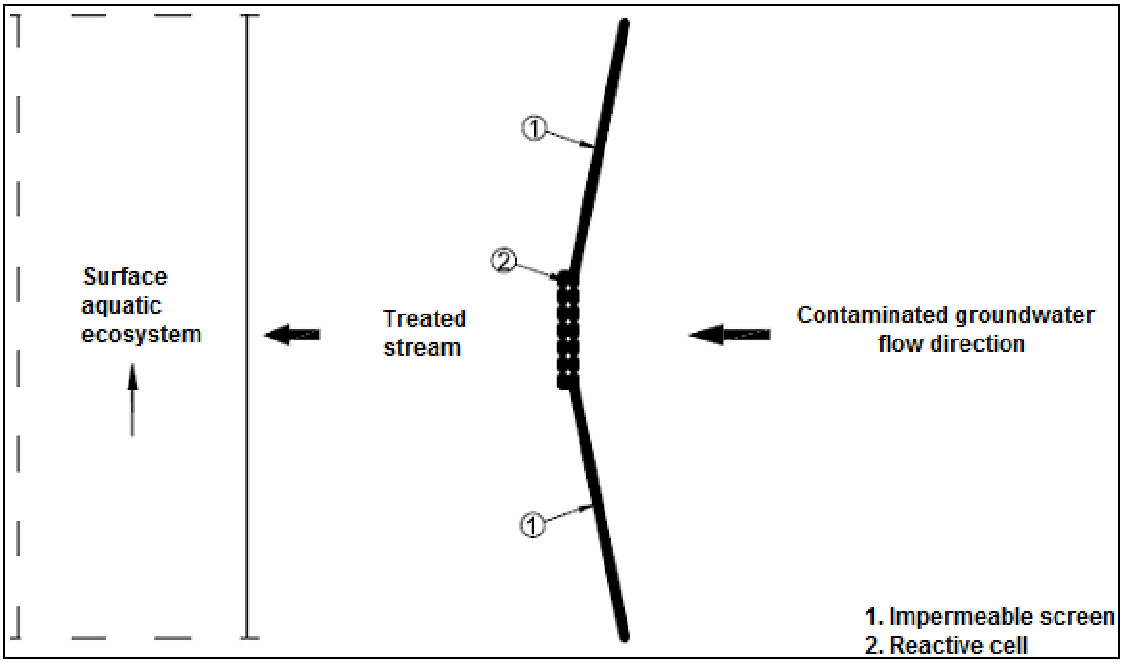

Figure 2: The principle scheme of the method.

The system has a passive characteristic, its operation being based on the filtration processes and biological reactions produced in the treatment media.

At the same time it should be mentioned that the system operation doesn't require usually external interventions exempting rare, special cases such as the cleaning/unclogging of the filtering elements at the treatment gates area or introducing some nutrients and bacterial inoculi in the ground. As regarding the heterotrophic microorganisms existing in the water samples drawn, the lab results of the tests carried out have shown their capacity to adapt in the presence of oil pollutants.

The efficiency in applying this solution depends firstly on the screens' depth, the groundwater retention time and the treatment capacity of the reactive medium which the screens are made up from.

In order to achieve the proposed solution there were conceived two constructive variants which are operationally similar, the differences resulting from the design of the reactive cells/rooms and the materials used for the reactive medium.

From the operational point of view, the impervious screens role is to direct the groundwater towards the treatment gates so that all the flow passes through this area. In order to prevent the flow of water under it, the screen will be rigidly fixed into the impervious bottom rock.

The treatment gates will be in a suspended position, without reaching the impermeable layer, the proposed depth being sufficient for treating the water flow. The impervious screens will be designed and built such as the pollutant flow cannot avoid the treatment gate.

By modeling the flow phenomenon and calculation, in the case of one single gate treatment system it was established that each impermeable screen should have a thickness of 40 m, a width of 0.4 m and a depth of 5 m. As materials used for constructing the sealing screens it will be used a mixture of soil and bentonite.

The first constructive variant, presented in the figure 3, provides at the entrance to the treatment gate some filtering panels made up from geotextile. These have the role to retain the coarse part of pollutant i. e. the free petroleum product.

A treatment gate is composed of two reactive rooms/cells, each one being made up of two compartments, one representing the reactive medium and the other the geotextile screen.

The geometric dimensions of a treatment gate resulted as it follows: 7.6 m total length, 1.5 m width and 5 m in depth.

The treatment gate will have reinforced concrete walls with a thickness of 0.25 m. The walls that are perpendicular on the groundwater flow direction will be provided with outlets, in order to ensure the passing of water flow through the treatment gate.

For the room where the reactive medium is sheltered it resulted from calculations a length of 3.5 m, a width of 0.7 m and a depth of 5 m. In the case of the rooms dedicated to the geotextile screens the length adopted is 3.5 m, the width is 0.8 m and the depth is 5 m.

In order to create a preferential flow direction for the groundwater, the reactive medium from the treatment gates will be made up of granular materials having a bigger permeability than the underground medium from the site (the permeability coefficient's value of the reactive medium is with one order of magnitude bigger than the one corresponding to the underground media). The oil substance entering this biological activity zone will be biodegraded, thus resulting an effluent with a more improved quality.

The treatment gates will be provided with a vertical supply system used for introducing into the ground the necessary nutrients and possibly new micro-organisms, if this aspect required.

In the second variant proposed, the treatment gate is composed of two cells/rooms, each of them being made up of an imermeable concrete screen having the role to retain the oil products. This is executed with at least 1 m under the groundwater table level. The room where are to be developed the biodegradation processes will be coated with a geotextile material and filled with bales from a special rigid or semi-rigid plastic material, which will constitute the reaction medium. (Fig. 4)

After the dimensioning calculations performed it resulted a length of treatment gate of 7.6 m and a width of 1.25 m. The dimensions of the room for the reactive medium are the following: length - 3.5 m, width - 1 m. The required depth will be, as in the first case, 5 m. The room has at the bottom an impervious screen that can be made up of bentonite, but also of concrete mixed with polimers.

As in the case of the first variant proposed, within the reaction room it will be provided a nutrients supply system.

In conformity with the conditions that led to the impossibility of applying one of the already established/acknowledged solutions, the designed system, is in both cases of passive type and built underground. Thus there are no special operational conditions stipulated. Also, the system wouldn't require the permanent presence on site of staff or some operational outfit.

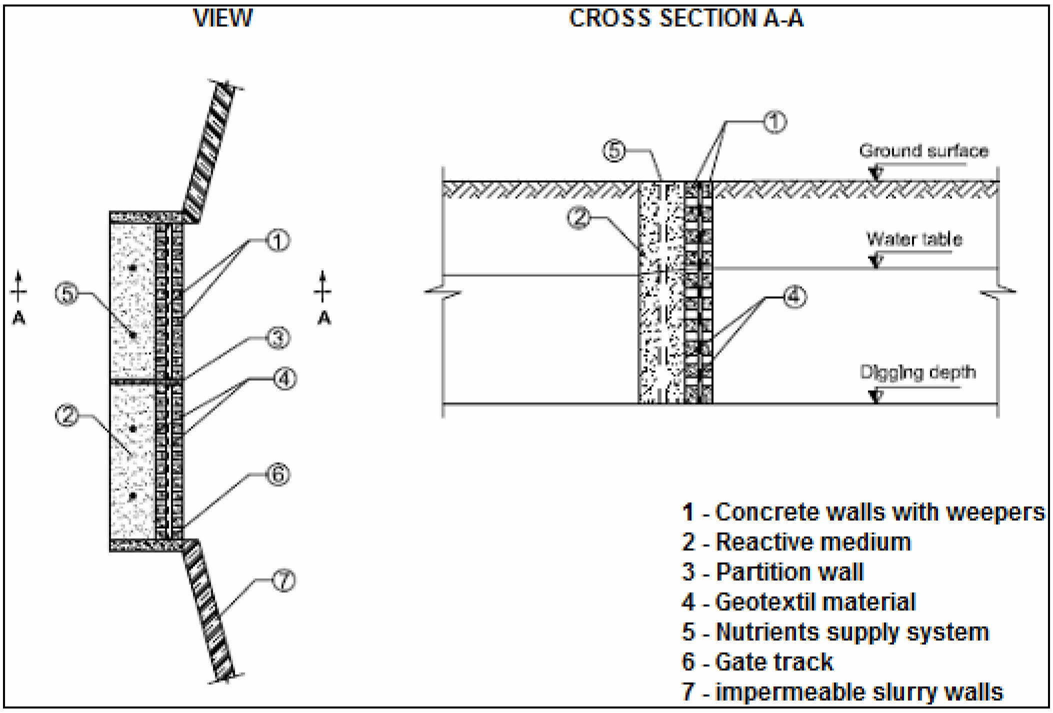

Figure 3: The construction scheme - solution 1.

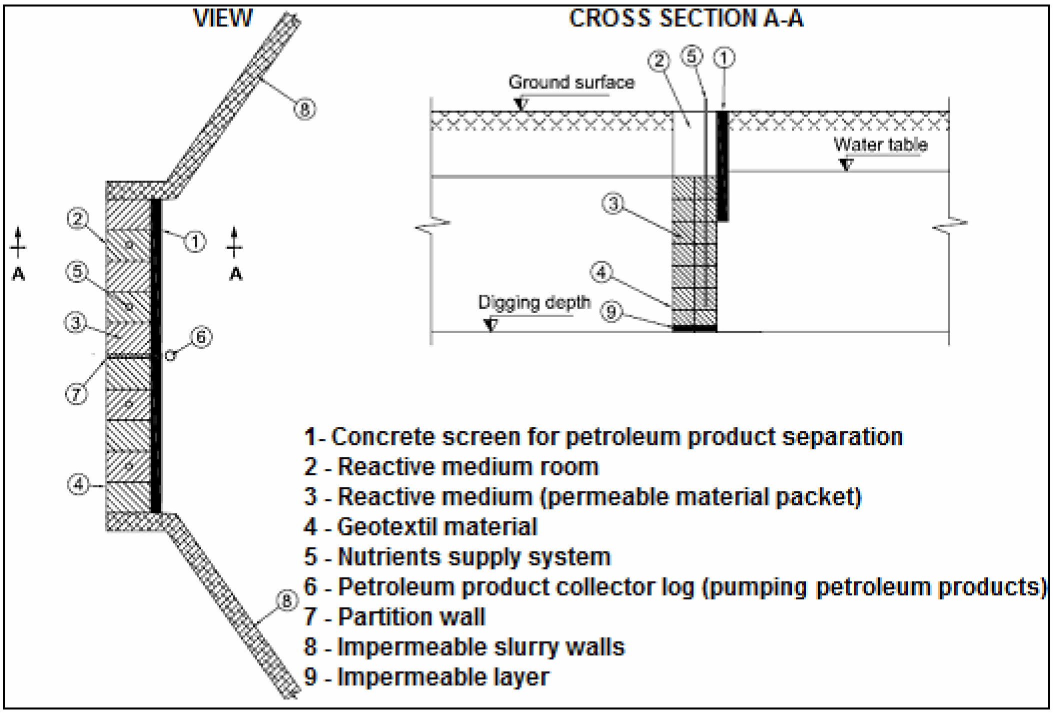

Figure 4: The construction scheme - solution 2.

The efficiency and good operation of the proposed system will be established based on the analyses carried out on the collected water samples. In order to establish these elements one can resort to: 1 pollutant monitoring; 2 the monitoring of the hydraulic and geochemical performances from the system's area; 3 monitoring the biological activity inside the reactive medium room. In case of casual disfunctions logged at the monitoring points (Fig. 5), actions should be taken in the treatment area. Based on these measurements one can use nutrients or microorganisms addition by the means of the distribution system provided or, if required, the reactive medium can be replaced.

Besides monitoring the elements before mentioned, is important to follow the possible by-products (cross-pollution) that might appear after the reactions unfolded in active medium. The monitoring system shall be made up of wells located at and in the vicinity of treatment gates and near to the impermeable screens (Fig. 5). The monitoring wells shall be made up of PVC pipes with diameter of 40 - 50 cm. Their positioning in the respective area shall be done before introducing the active medium. Following the economical calculations performed in this respect, it resulted a cost of 66325 Euro for the first described variant and 80700 Euro for the second one.

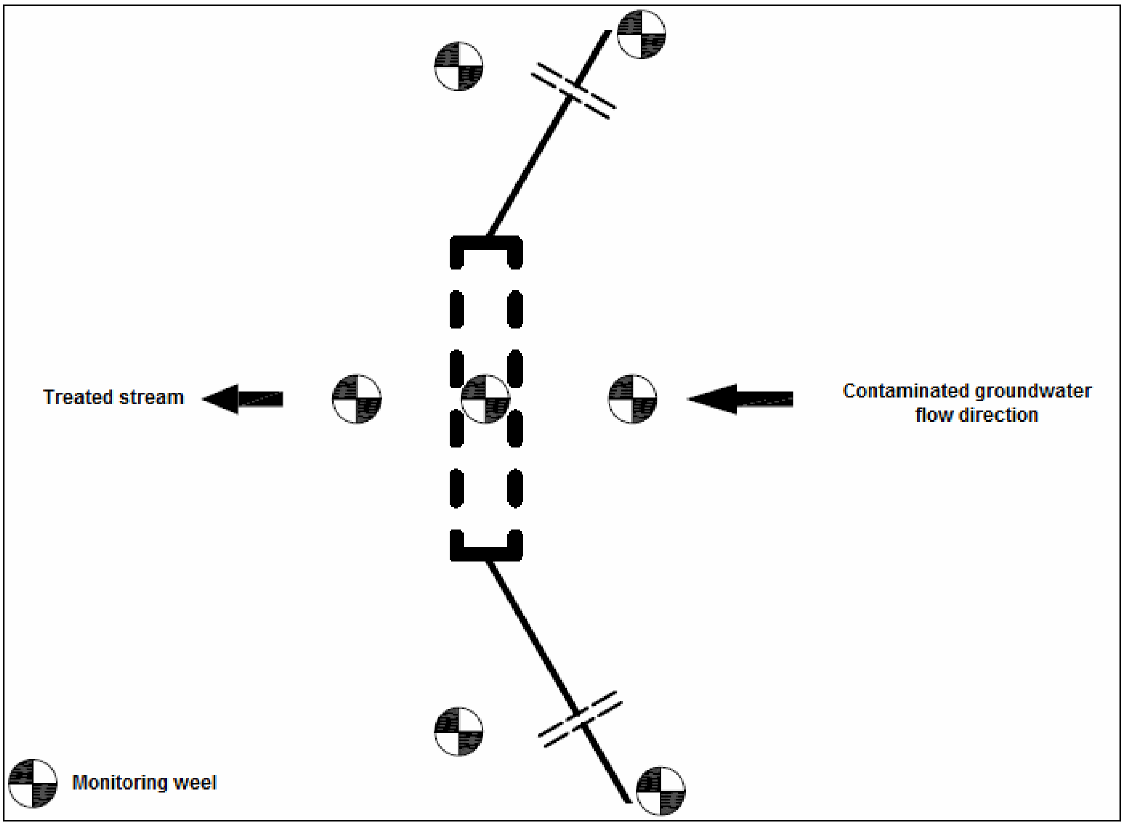

Figure 5: The positioning monitoring wells during the system's operation period scheme.

CONCLUSIONS

It was found the viability of solutions based on the pollutant biological degrading. The availability of indigenous microorganisms to adapt in the presence of oily contaminants and contribute to their degrading enhances the successful remediation efforts. The location of all constructions in the ground, the needlessness of permanent staff as the presence of outfit on site just in case of some interventions required by the results obtained after the monitoring process, confirm the long term system viability. The total investment costs in both variants as the reduced operation costs as a consequence of its passive operational way, recommends both solutions as advantageous.

REUSE OF ABANDONED QUARRIES AND GRAVEL-PITS FOR THE UTILISATION OF THEIR (LIMNO-)ECOLOGICAL POTENTIAL (AUSTRIA)

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KEYWORDS: Austria, revitalisation, rare habitats, threatened species, succession, backup-habitat, quarries, gravel-pits, habitat restoration.

ABSTRACT

The mining of gravel, sand and other loose stone material leaves its marks on the appearance of the landscape. Abandoned excavations are generally recultivated for agrarian or forestry uses and then most often lack valuable structures. In contrast to that, gravel pits typically provide highly differentiated habitats for notable and rare species as long as mining activities are still in progress. Active gravel pits and quarries offer a wide range of habitats from wet to extremely dry conditions, which are particularly colonized by species quoted in The IUCN Red List of Threatened Species. With those facts in mind, it seems absolutely essential to involve ecologists in the restoration of abandoned quarries and gravel pits in order to ensure the evolvement of the maximum ecological potential.

ZUSAMMENFASSUNG: Die Wiederverwendung aufgelassner Kies- und Schottergruben zur Nutzung ihres (gewässer-) ökologischen Potenzials (Österreich).

Der Abbau von Schotter, Sand und anderem Sedimentmaterial hinterlässt seine Spuren in der Landschaft. Aufgelassene Abbaugruben werden üblicherweise zu land- und forstwirtschaftlichen Zwecken rekultiviert und lassen in den meisten Fällen ökologisch wertvolle Strukturen vermissen. Im Gegensatz dazu weisen Schottergruben typischerweise in hohem Grad differenzierte Habitate für besonders seltene Arten auf, solange die Abbauarbeiten noch im Gange sind. In Betrieb befindliche Kies- und Schottergruben bieten der Artengemeinschaft eine breite Palette an Habitaten, die alle Übergänge von nassen bis zu extrem trockenen Bedingungen abdecken und oftmals bevorzugt von bedrohten Arten der Roten Liste besiedelt werden. In Berücksichtigung dieser Fakten erscheint es unerlässlich, Ökologen in die Renaturierung aufgelassener Schotter- und Kiesgruben einzubinden, um die Entwicklung eines größtmöglichen ökologischen Potenzials zu gewährleisten.

REZUMAT: Refolosirea carierelor abandonate şi a gropilor de pietriş pentru utilizarea potenţialului lor (limno-) ecologic (Austria).

Exploatarea pietrişului şi nisipului îşi lasă amprenta asupra peisajului. Excavaţiile abandonate sunt, în general, recultivate pentru folosințe agrare sau silvice, având cel mai adesea structuri fără valoare. În contrast cu acestea, gropile de pietriş oferă într-un mod tipic habitate foarte diferenţiate pentru specii notabile şi rare, atât timp, cât actvitățile de exploatare sunt în derulare. Gropile de pietriş şi carierele, aflate în exploatare, oferă o mare varietate de condiţii de habitat de la cele umede la cele de extremă uscăciune, care sunt, în mod particular, colonizate de specii cuprinse în Lista Roşie UICN de specii ameninţate. Cu aceste lucruri în minte, pare absolut esenţială implicarea ecologilor în restaurarea carierelor abandonate şi a gropilor de pietriş, în vederea asigurării evoluării la maximum a potenţialului lor ecologic.

INTRODUCTION

Cultivated landscapes in Austria (as well as in Europe in general) are characterised by an increasing lack of structures, and constantly turn into wide open monotonous areas (Broggi and Schlegel, 1989). Structures like boundary ridges, hedges, acclivities, natural streams, small stagnant waters or wetlands, all of which are preceedingly vanishing, are of importance for the biodiversity of ecosystems. Natural ecosystems are composed of a mosaic of small-scale habitats in different stages of development. There are plenty of interactions between the particular ecosystem-complexes and also between the particular habitats (Ulmann and Peter, 1994). Transition areas between distinct habitats, the so-called ecotones, are characterised by a high biodiversity and a specialised fauna. Such ecotones (e. g. river banks, edges of wood, hedges) offer a large number of ecological niches, hence their total of species is always higher than in the neighbouring habitats.

The progressing decline of biotopes and ecotones results in increasing distances between them, isolated habitats are constantly getting smaller, and the missing contact between populations finally leads to their isolation. Wide open monotonous areas turn out to be barriers for migrating animals and for the distribution of plant species. In consequence, these isolating effects lead to genetic impoverishment, and consequently the subsistence for the flora and fauna gradually decreases (Mader, 1980). The decline of habitats and populations nowadays is one of the main reasons for the extinction of animal and plant species. Isolation effects can be reduced by providing connecting mosaic areas (like groups of trees and hedges or strips of alluvial forests along running waters).

Quarries offer an enormous ecological potential during and after mining activities. They contain ecosystems with different habitat types in different stages of succession, which are precious backup-habitats or refuge areas on the one hand, and hot spots (initial points) for the spread of species on the other hand. Furthermore, they can be important stepping stone biotopes for migrating species by connecting widespread biotopes, thereby providing for the genetic exchange (Zwölfer, 1981).

The ecologists and owners cooperation allows the development of profitable quarries and a high biodiversity too. Mining and revitalisation are to be coordinated in order to tap the full ecological potential by revitalising the former mining areas step by step. After abandoning mining activities in a certain area, revitalisation has to be started there immediately where is possible. This phased proceeding leads to a mosaic of diverse stages of development, which causes a high biodiversity and a large variety of structures. Below, two applied sample studies, dealing with the reuse of abandoned quarries and gravel-pits in Upper Austria, are presented as examples for a successful fusion of technical and ecological requirements.

PROJECT AREA

Both sample cases are located in Austria (Fig. 1). The first sample case (A) is situated in the south-east of Upper Austria, in the township of Steyrling. The pit delivers gravel for the fabrication of concrete, asphalt and other road building materials. It currently covers an area of about 82.500 m² and will be expanded to approximately 138.200 m² in the upcoming 40 years, during which the digging activities are going to be carried out. The whole area will be layered stepwise, and upon completion of each digging step, the recultivation of the concerned stretch of land will follow immediately. A special feature of this project is the integration of the river Steyr, for which a new sidearm is going to be established in the course of the revitalisation of the gravel-pit. Between the existing riverbed and the planned anabranch a gravel bank will be heaped up, consisting of massive rocks, which will be covered with autochthonous gravel.

A dynamic relocation of the gravel is made possible without risking a complete bank erosion. A dynamic balance of sedimentation and erosion will be reached by these means. The area of the gravel-pit will be inclined from the slopes in the west to the east. Additionally, the terrain will be diversified by creating variable levels and initialising different habitats.

The second sample case (B) also deals with the recultivation of a gravel-pit. This quarry is situated in an intensively agriculturally used landscape near the city of Steyr. The area presently equals 115,000 m² and will be enlarged to 180,000 m² in the next 30 years, whereat the expansion area is located in the east of the current mining area. The mining will be carried out step by step, and after termination of each mining step, the excavated area will be refilled. In order to create a polymorphic landscape with a variety of biotopes, the area will be structured as variably as possible. The particularity of this expansion area is a tubed brook that currently runs 2.5 m below surface. Now, this brook flows into the river Enns, what does not comply with the natural mouth situation. In former times, the Dietachbach brook drained away into the gravel masses sedimented by the river Enns, not showing a distinct mouth, but seeping into its receiving water through the gravel plain. In the course of its regulation, the brook´s mouth was tubed and connected to the river Enns. The Dietachbach brook will be excavated during the mining process and its mouth will be restored to its former appearance, so that it will flow into the newly created revitalised area and will drain away again like it did before.

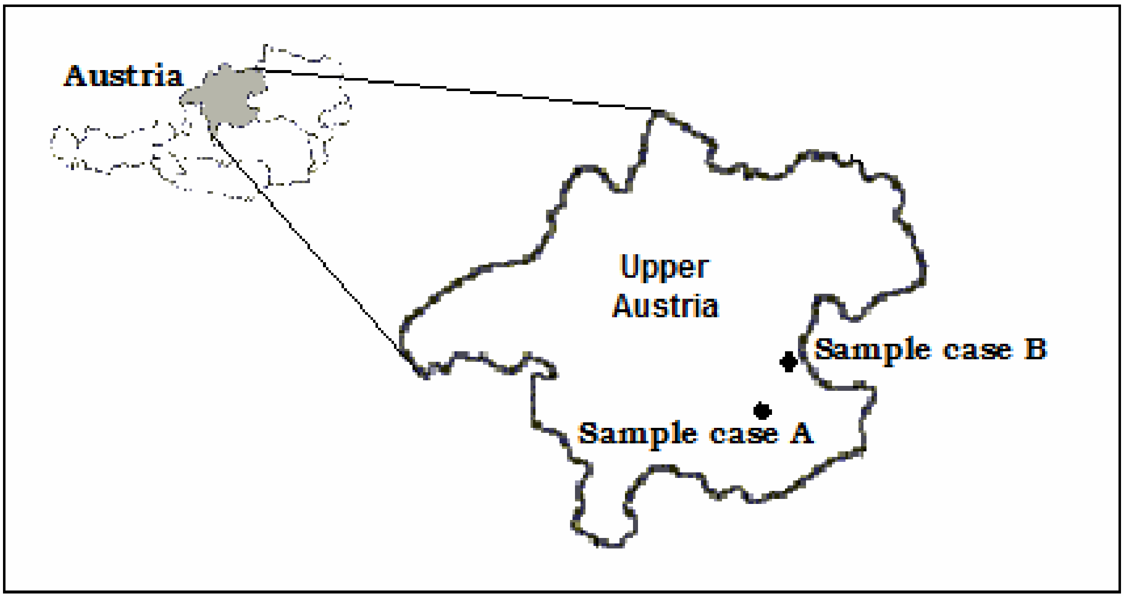

Figure 1: Position of the two sample cases in Upper Austria.

PROJECT AIMS

Sample case A: Due to the integration of the river into the terrestrial area a wide range of joined biotopes from wet to extremely dry were established. By conducting the mining-process step-wise, dozens of biotopes in different stages are created, which in turn offer a large variety of structures and result in a high biodiversity. Rare habitats will be established, and the resettlement of threatened species will be provided. An additional positive effect is the creation of a retention area for floods. In the past, big areas of former permeable soil has been sealed for infrastructure, settlements or agriculture, what has led to a big reduction of the retention area. About 70,000 m^2 will be re-offered after the mining due to a sustainable restoration.

Sample case B: The variety of newly created elevations and the reconstruction of the natural mouth situation of the Dietachbach brook will ensure a multitude of habitats with variable conditions from dry to wet. Especially the draining area of the Dietachbach brook will provide precious and rare structures as well as habitats for specialised plant and animal species. Small stagnant waters and wet areas, the dimensions and location of which will permanently change, will develop in the sink.

The phased proceeding in both sample cases leads to a mosaic of diverse stages of development, which will cause a high biodiversity due to a large variety of structures. Thus, an ecosystem with different habitat types in different stages of succession will be generated (Ward and Stanford, 1995). They will be precious backup or refuge habitats on the one hand and initial points for the spread of species on the other hand. Furthermore, they will act as important stepping stone biotopes for migrating species and connect widespread biotopes, thus providing the genetic exchange between populations.

DISCUSSION AND CONCLUSIONS

It is necessary to involve ecologists in gravel-pit restoration projects in order to achieve the maximum benefits. Unprofessional restoration can easily lead to monotonous, ecologically worthless areas with low biodiversity. Gravel-pits carry an enormous ecological potential that must be recovered by experts. An attending ecological planning is moreover not only important for mining activities, but for building projects in general. Almost every building project has an impact on nature, and therefore a comprehensive ecological planning and supervision is essential to guarantee a minimum interference. The recent enlargement of the European Union, comprising mostly countries that once were part of the Eastern bloc, carries enormous ecological and economic opportunities, but can also contain hidden risks. The economic upswing and several EU-sponsorships will result in an increase of building activities in the new member countries, that can easily lead to undesirable developments. For this reason, bringing in ecologists from the very beginning of a building project is inevitable in order to obtain maximum ecological benefit.

ACKNOWLEDGMENTS

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CHALLENGE FOR ECOLOGICAL RECONSTRUCTION OF THE LARGEST AGRICULTURAL POLDER IN THE DANUBE DELTA (ROMANIA)

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KEYWORDS: Romania, Danube Delta, hydrological scenarios, ecological reconstruction, vegetation succession.

ABSTRACT

A research study was supported by the Romanian Ministry of Environment in order to develop hydrological scenarios and to assess habitat distribution after reconnection of the largest agricultural polder of the Danube Delta (27,000 ha) to the Danube River flood pulse. The main result of the study was the creation of a new elevation map and an elevation model of the area as well as the hydraulic schematization and the delivery on a hydraulic model of the area. The new elevation map shows that a significant soil subsidence occurred in the range of 0.60 - 0.90 m, mainly on former areas covered by organic soils that represented only 5.7 % of the total area. The flooding period under present elevation conditions as they were predicted by hydrological scenarios is in accordance with the original one; this leads to the assumption that the development of habitat distribution could be also in conformity with the pattern before the embankment.

ZUSSAMEFASSUNG: Herausforderungen für die Renaturierung des größten Landwirtschaftspolders im Donau-Delta (Rumänien).

Eine vom Rumänischen Umweltministerium unterstützte Studie hatte zur Aufgabe, hydrologische Szenarien zu entwickeln und die mögliche Verteilung der Habitate nach der Wiederanbindung des größten landwirtschaftlichen Polders im Donau-Delta (27.000 ha) an die Dynamik der Donau zu beurteilen. Das Hauptergebnis der Studie war die Erstellung einer neuen Höhenstufenkarte und eines digitalen Geländemodells für das Gebiet sowie die hydraulische Darstellung und Ausarbeitung eines hydraulischen Modells. Die neue Höhenstufenkarte zeigt, dass eine signifikante Bodenabsenkung im Bereich von 0,60 - 0,90 m stattgefunden hat, vor allem in Bereichen ehemaliger organischer Böden, die nur 5,7 % des Gesamtgebietes bedeckten. Die Überflutung ist, entsprechend den gegenwärtigen Geländehöhen, so wie sie von den hydrologischen Szenarien vorausgesagt wird, in Übereinstimmung mit den ursprünglich im Gebiet vorhandenen Bedingungen. Dieses führt zu der Annahme, dass die Entwicklung der Lebensraumverteilung ebenfalls nach den vor der Eindeichung vorhandenen Mustern verlaufen könnte.

REZUMAT: Provocare pentru reconstrucția ecologică a celui mai mare polder agricol din Delta Dunării (România).

Un program de cercetare a fost susținut de Ministerul Mediului din România, în vederea dezvoltării de scenarii hidrologice şi evaluare a distribuției habitatelor, după reconectarea celui mai mare polder agricol al Deltei Dunării (27.000 ha), la pulsul revărsărilor Dunării. Principalele rezultate ale acestui studiu au fost crearea unei noi hărți a înălțimilor şi a unui model al înălțimilor ca şi a unei scheme hidraulice şi oferirea acesteia pentru un model hidraulic al ariei. Noua hartă a înălțimilor arată faptul că o subsidență semnificativă a solului apare în intervalul de 0,60 - 0,90 m, în principal în fostele zone, acoperite de soluri organice, care reprezintă doar 5,7 % din totalul ariei. Perioada de revărsări în condițiile actuale, previzionate de scenariile hidrologice, este în concordanță cu cea originală; acest fapt, ducând la ipoteza că dezvoltarea distribuției habitatelor poate fi de asemenea în coformitate cu modelul existent inițial îndiguirii.

INTRODUCTION

The damages caused by the extreme flooding of the Romanian rivers during the last years and the related heated debates lead at political level to the elaboration of a strategy to restrict the flooding risk and increase the safety. The "Lower Danube Green Corridor" initiative (an initiative of the governments of Romania, Moldova, Bulgaria and Ukraine, signed in 2000) and the new concept "Room for Water" aim to re-naturalize some larger former wetlands in order to lower the flood peak and protect the localities exposed to the flood.

The Romanian Ministry of the Environment and Sustainable Development has supported some studies in order to predict the development of several polders located along Danube river flood plain in case of their connection to the flood pulse of the rivers.

This paper presents the results of such a hydrological scenario for the largest agricultural polder (27,032 ha) in the Danube Delta Biosphere Reserve.

The main scientific challenge deals with the prediction of the hydrological regime and the habitat distribution, under the consideration of a specific change in the topography (elevation) of the area.

DESCRIPTION OF THE AREA

The study area named Pardina is located in the northern part of the fluvial sector of the Danube Delta (Fig. 1). The area which consisted under natural conditions of many small lakes and extensive reed beds was isolated by a surrounding dyke in 1970 and was converted into an agricultural polder between 1979 and 1983.

Originally, following an elevation gradient from lower depression to higher river levee, 11 % of the area was covered by lakes, 70 % by reed beds, and the river levees were covered by miscellaneous wet meadow vegetation, soft wood forest and grassland.

Following the same gradient most characteristic types of soils (Munteanu, 1976) were represented by underwater soils which correspond to the lake surfaces, Histosols and Gley soils with a peat layer up to 1 m and corresponding to reed beds areas, furthermore Alluvial soils on river levee which were covered by forest and grassland.

Nowadays the land use of the polder consist of 84.32 % agriculture land, 15.46 % grassland and 0.22 % vineyards and orchards.

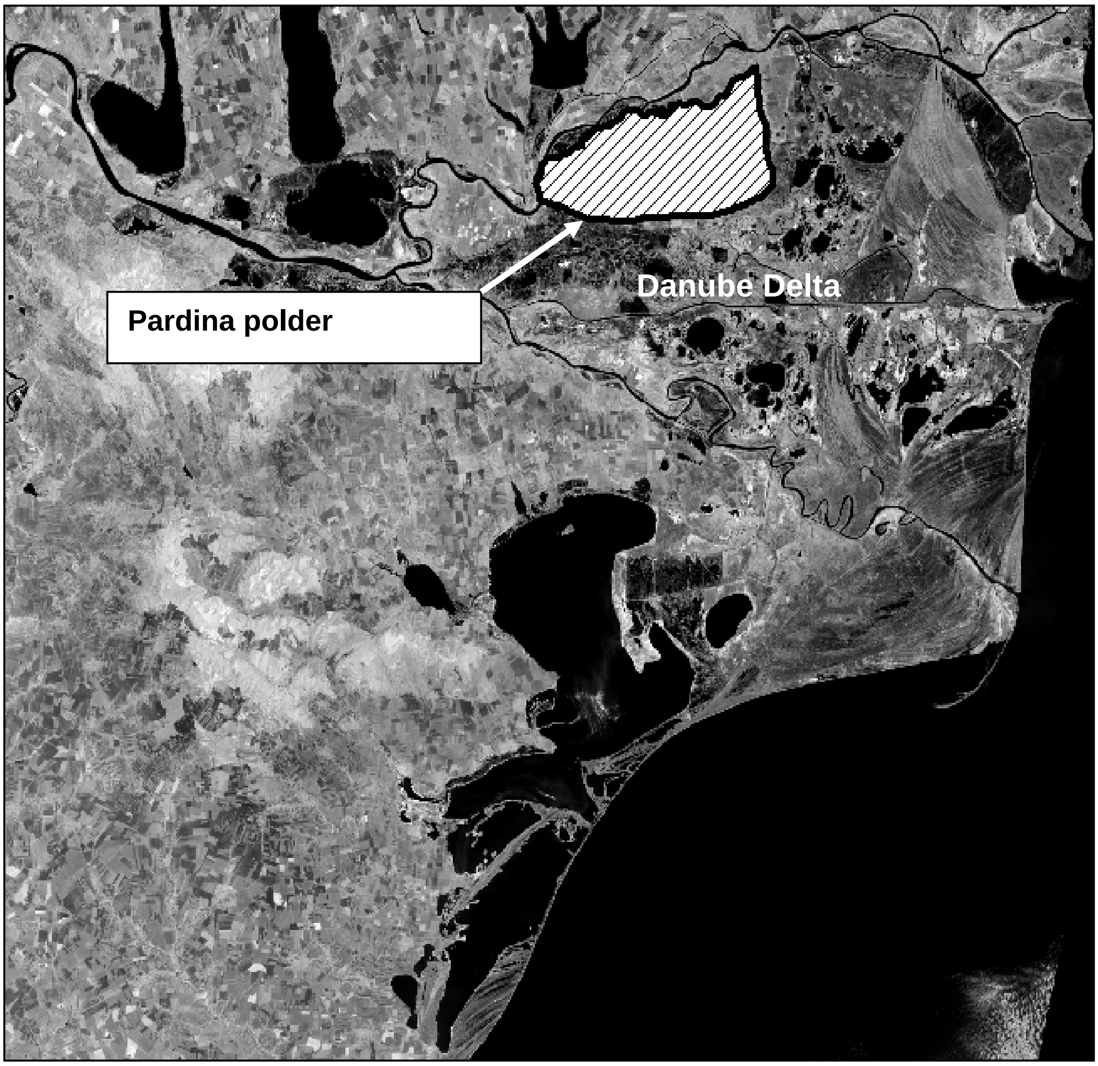

Figure 1. Location of the studied area.

METHODOLOGY

The prediction of the hydrological regime was performed using the Danube Delta hydrological model (1D_Sobek software) Constantinescu and Gils, 2003. The GIS layers include the hydrological maps which resulted from a modeling and an update elevation model of the study area. At first the hydraulic schematization of the model was updated with the channels network of the studied area (Fig. 2).

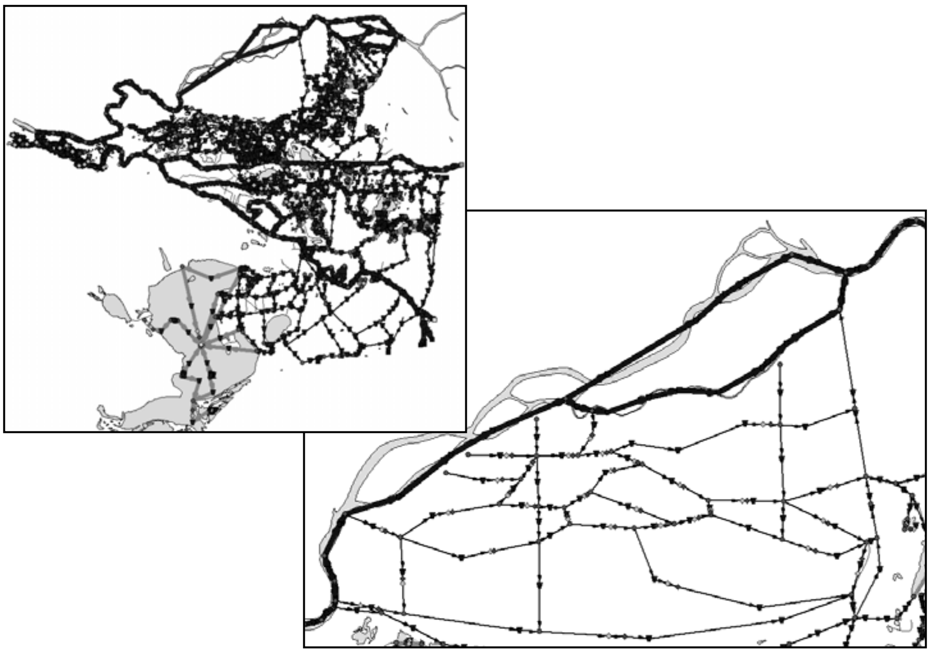

Figure 2. Up-date the hydraulic schematization of the model.

The hydrological data for modeling consist of the daily water level values measured between 1932 and 2006. The extreme high and low values of the Danube River as well as the average values of the characteristic years and periods have been selected to highlight the hydrological dynamic of the area. Because the flooding scenarios should reveal the correlation between the water level, depth and water residence time not only at a given extreme moment but for a significant season or period of the year, the average daily maximum values and respectively minimum values for the 1932 - 2006 period have been added in the analyses. The hydrological scenarios of connecting the study area to the Danube River (Sfântul Gheorghe arm) have been run with data assuming an open connectivity between river and polder. The period of flooding and the water depth were considered to be the main steering factors for the prediction of the vegetation succession. The flooded surfaces were calculated by GIS spatial analyses intersecting 30 m grid files and classified eight water depth classes: 0.01 m - 0.25 m; 0.25 m - 0.5 m; 0.5 m - 1 m; 1 m - 1.5 m; 1.5 m - 2 m; 2 m - 3 m; 3 m - 4 m; 4 m - 5 m.

The assessment of vegetation succession was based on two assumptions: first that there is a specific correlation between a type of hydrological regime and the development of a vegetation type and second that the establishment of a vegetation type in a re-flooded area of the Danube Delta will be similar to the vegetation in a natural area in the same hydrological conditions. A hydro period map of the Pardina area at the present elevation conditions was produced, and for each hydro period a vegetation type was assumed being established after re-flooding the area. The results were compared with the vegetation map of the area before the embankment and with corresponding hydro periods for the original elevation.

RESULTS AND DISCUSSIONS

The change of the hydrological regime by embankment and construction of a network of drainage canals has lead to a major loss of natural wetland habitats and wetland functions (e. g. nutrient sink and trapping of sediments, water reservoir), soil subsidence, increase of salts content in soils and drought under the exudative climate regime of the area (440 mm rain fall per year and 1000 mm evapotranspiration per year).

A rehabilitation of the natural values and wetland functions of the area could be reached by an ecological reconstruction which implies the re-connection (re-flooding) of the area to the Danube River. The most important change which is supposed to influence the hydrological regime and habitat distribution after re-flooding is the alteration of the elevation due to subsidence (mainly caused by mineralization and burn of the upmost peat layer of the Histosols and Gley soils shortly after the area was dried. This lead to the major question on the extent of differences caused by these changes and how they will influence the hydrology and the function of the new wetland, mainly in terms of vegetation succession and water quality.

To predict the vegetation succession it was assumed that in wetland areas the hydro period is the steering factor (Eastman, 1995). In the Danube Delta the size of a lake and the type of connectivity were demonstrated being an important factor (Oosterberg et. al., 2000). A clear distinction was found in three different lake types: 1 inflow lakes at short distance to the river, with a high flushing rate, high load of suspended minerals but low chlorophyll concentrations; 2 large, relatively deep lakes with moderate long residence time and high chlorophyll concentrations; 3 smaller, isolated lakes at the longest distance from the river, with long residence time, of which the water quality is strongly influenced by water flows through large floating reed beds ('black water'). For the Pardina area we considered it as very important to know if flooding will result in a large shallow lake which would be sensitive to alga blooming or in smaller lakes and an elevation and hydrologic gradient that would allow development of vegetation and a good water quality. The concern arose because the top peat layer of the soil has been burnt and the elevation level of the area has been changed.

Results of different hydrological scenarios (based on the new elevation map of the area) show that at maximum water level, the whole area is covered with water (Tab. 1) and at medium level the flooded area still covers 89 % revealing the wetland character of the zone.

Table 1: Flooded area for characteristic water levels of Danube River.

Water level class	S(ha)	%
H minim	13965	51
H medium	24555	89
H maxim medium	27032	100

Previous studies (Rudescu, 1965) have shown that the helophytes vegetation (*Phragmites australis*) in the Danube Delta does not grow if the water depth exceeds 1.5 m. Shay and Shay (1986) found that no reed survives three years of inundation by water deeper than one meter which means in our case that we would get open water areas (lakes) above these permanent depths. In our calculation the depth of water anticipated to result in permanent open areas was 1.25 m. Assuming that the area with a permanent water depth more than 1.25 m will consist of open water, and the succession of any vegetation type except aquatic vegetation will just start at lower water levels, the distribution map of these areas were calculated (Fig. 3).

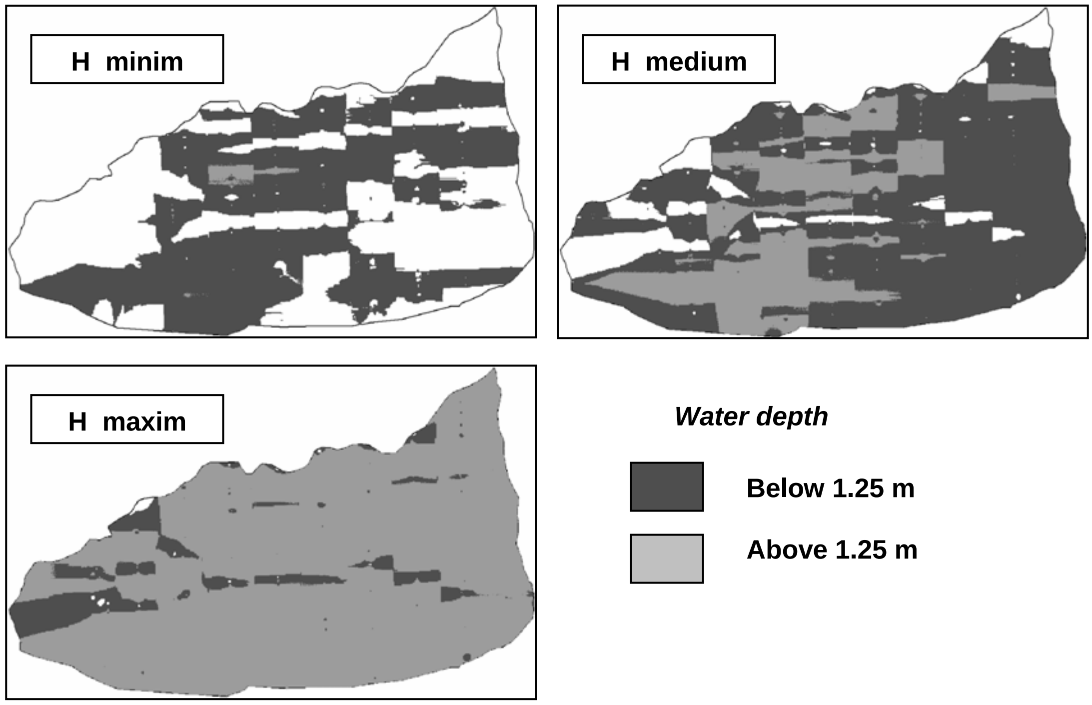

Figure 3: Flooded maps of Pardina area (bellow and above 1.25 m water depth) for different hydrological regimes of the Danube River.

However, to predict the vegetation succession, the hydro period has to be known. The hydro period maps for the Pardina area (Fig. 4) were calculated for three flooding period classes: one - three months flooding period with a water level over 1.25m; three to six months flooding period with a water level over 1.25 m; over six months flooding period with a water level higher than 1.25 m.

By intersecting natural vegetation type classes of the Danube Delta (Hanganu et al., 2002) with the Danube Delta's flooding map we could assign a corresponding hydro period for the main vegetation types. Results were extrapolated to the study area, and a hydro period was assigned for each original vegetation type of Pardina (Tab. 3).

Table 3: Vegetation classes before embankment and corresponding assigned hydro period.

Vegetation type	S(ha)	%	Hydro period (months)
Grassland	4208	16	1-3
Agriculture land	500	2	1-3
Reed, typha	9183	33	3-6
Forest and grassland	536	2	3-6
Typha	449	2	3-6
Reed stand	9619	35	6-8
Water	3065	11	> 8

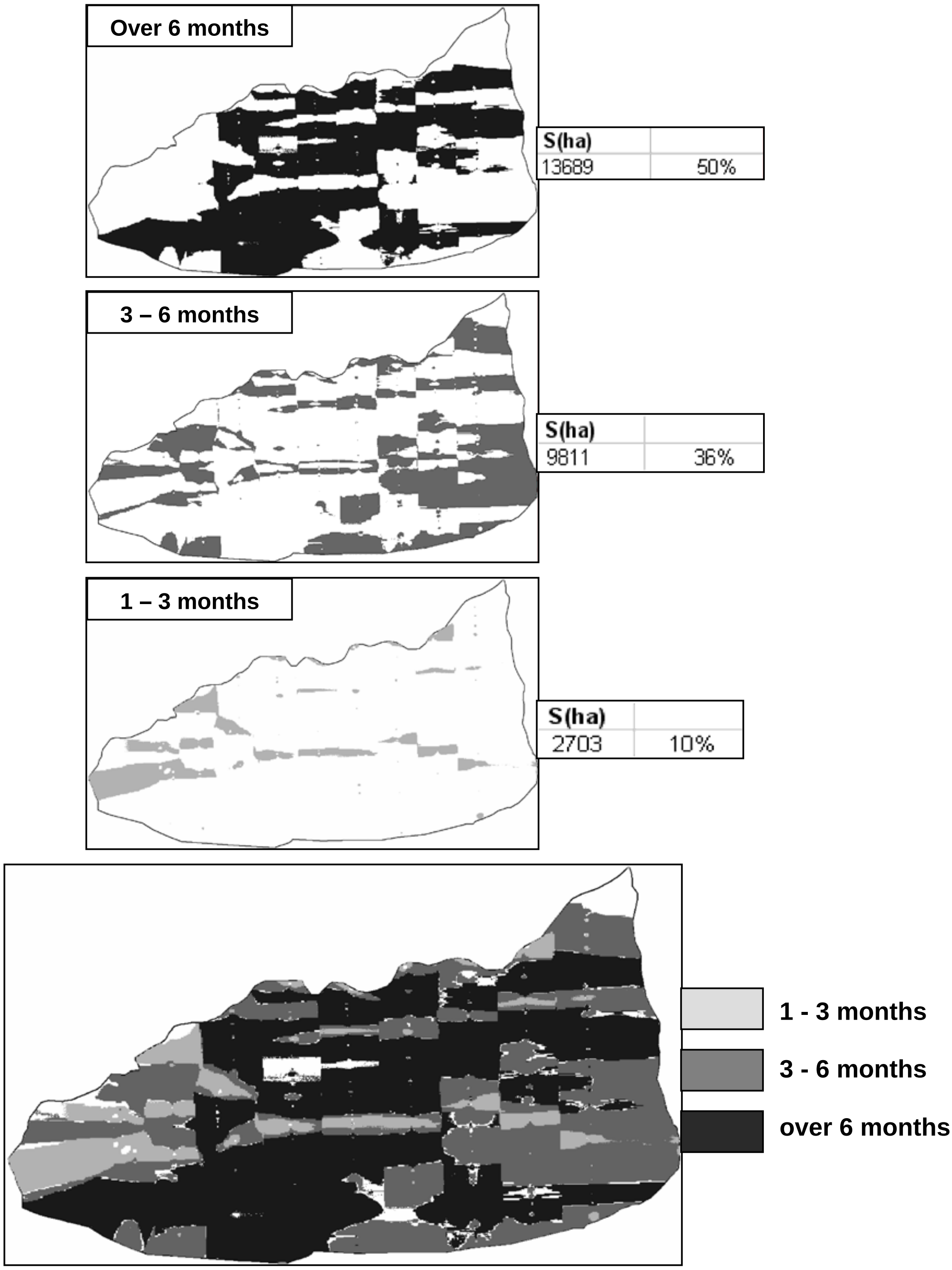

Figure 4: Results of hydrological scenarios showing the hydro period map of Pardina area after re-flooding.

Table 4: Prediction of re-flood areas.

Hydro period	Before embankment		Predicted after re-flooded	
	S(ha)	(%)	S(ha)	(%)
> 6 months	12684	46	13689	50
3-6 months	10168	37	9811	35
1-3 months	4717	17	4053	15

The final distribution of hydro period classes at the original elevation and actual elevation were calculated and compared (Tab. 4).

This shows that the area being covered for more than six months with a water level > 1.25 m would be increased by 4 % compared to the original elevation level. The difference is small and may be explained by accuracy of the modeling and what seems to be more likely, by certain change in the elevation due to loss of peat. It was assumed that the change in elevation will be in the range of 0.5 - 1 m, however, by comparing the two elevation maps of the area before and after embankment we found that only for areas covered by organic soils which represents just 5.7 % of the entire zone (Munteanu, 1976) an elevation range between 60 and 90 cm occurred. It has to be mentioned that these 50 % contain areas with a more than six months residence time of the water; these areas are supposed being covered mainly with reed stands and just partly with open water. From hydrological modeling aspect, the area covered permanently with a water depth of 1 - 1.5 m at low water level of the Danube River, forms only 12 % of the area which represents the distribution of lakes. This size and distribution correspond to the former lake pattern of this area; they are similar in their dimensions and not form larger lakes as it was suspected in worst scenarios.

CONCLUSIONS

Despite a loss of organic matter, the subsidence (after embankment) was not very high. Only for areas with organic soils and peat layers which occur just at the edge of former lakes as small expanses, elevation has changed significantly.

Our hydrological scenarios and topographical studies show that the new elevation gradient and flooding period will not result in one or few large and deep lakes but in separated smaller water basins with an elevation and hydrological gradient that may allow development of vegetation. We expect that after a re-flooding the wetland functions and development of habitat types will recover most probably in accordance to the original pattern. In addition, the hydraulic model provides data on the expected water retention capacity, on the influence of this zone to lower the flooding peak on surrounded areas and to develop retention capacity of the area for nutrients and sediments by activating the specific modules of SOBEK model.

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DATA ABOUT THE DESIGNATION OF DUMBRĂVIȚA (ROMANIA) COMPLEX AS RAMSAR SITE

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KEYWORDS: Romania, wetlands, Dumbrăvița Fishing Complex, Ramsar Site, criteria.

ABSTRACT

This paper presents the most important data concerning the designation of the "Dumbrăvița Fishing Complex" as Ramsar Site, such as: criteria, justification, wetland types and general ecological features. These data have been included within the official Ramsar Information Sheet (RIS) for designation of this site. New results of the researching and monitoring of this area are also noted.

RÉSUMÉ: Données sur la désignation du complexe du Dumbrăvița (Roumanie) comme site Ramsar.

Cette publication présente les données importantes concernant la désignation du complexe piscicole du Dumbrăvița comme site Ramsar: critères Ramsar, justifications, typologie des zones humides, données écologiques générales. Ces données ont été formalisées dans le formulaire d'information Ramsar RIS (Ramsar Information Sheet). Des données plus récentes du suivi de ce site sont aussi présentées.

REZUMAT: Date privind desemnarea "ComplexuluiDumbrăvița" ca Sit Ramsar.

Lucrarea tratează cele mai importante date, privind desemnarea "Complexului Piscicol Dumbrăvița" ca Sit Ramsar, printre care: criteriile şi justificarea desemnării, tipurile de zone umede şi structura ecologică generală. Aceste date au fost cuprinse în documentația oficială pentru desemnarea ariei ca Sit Ramsar (RIS). Sunt notate de asemenea, unele rezultate, recente ale cercetărilor şi monitorizărilor efectuate în această zonă.

INTRODUCTION

The man-made wetland, such as the fishponds and reservoirs could be areas of national and international importance especially for water birds. Some of these are known as stop over points for many migratory birds or very important breeding places for others. From this point of view they could replace some natural lost wetlands.

The main aim of this paper is to present the most relevant data concerning the designation of "Dumbrăvița Fishing Complex" as Ramsar Site.

STUDY AREA

Dumbrăvița Fishing Complex is located in the central part of Romania, in Transylvania, Braşov County. It is also part of the Olt River basin, Bârsei Depression. The Bârsei Depression is a component of a big depression (Braşov Depression) from the internal curvature of the Carpathians. The fishing complex is situated in the middle valley of the Hamaradia Rivulet surrounded by crops, meadows and other grasslands. It is compound mainly by a reservoir (dam artificial lake) and a fishpond system and has a total of 414 ha.

For the reservoir the main habitat is the open water (about 120 ha) but the western shore is covered by dense emergent vegetation with Typhaetum - Phragmitetum, Scirpo - Phragmitetum dominant plant community. The most important plant species are: *Phragmites australis*, *Typha latifolia*, *Typha angustifolia*, *Phalaris arundinacea*, *Glyceria maxima*, etc. On the same shore there is a marsh area and wet grasslands as flood plain very rich in plant species, such as: *Pedicularis sceptrum - carolinum*, *Ligularia sibirica* (included in the Annexe II of the Habitat Directive), *Comarum palustre*, *Senecio fluviatilis*, *Senecio paludosus*, *Carex davalliana*, *Carex rostrata*, *Carex flava*, *Carex panacea*, *Fritilaria meleagris*, *Trolius europaeus*, etc. Some of these species are rare in Romania, as part of the national red List. Submerged and floating communities also occured and are represented by: *Elodea canadensis*, *Ceratophyllum demersus*, *Potamogeton* spp., *Hydrocaris morsus - raene*, *Myrriophyllum spicatum*, etc. The Hamaradia Rivulet is characterized by tree - dominated habitats with *Salix* spp. and *Alnus glutinosa*. Another isolated or groups of *Salix cinerea* and *Salix fragilis* are characteristic for reed beds and marshes.

The fish pond system has unstable hydrological conditions especially during autumn fish harvest (September - November), high productivity and mudflats. The habitats diversity is also a characteristic of this part of the wetland. All ponds are used for aquaculture and there is no abandoned pond. The largest fish ponds (over 35 ha) are well covered by reed beds, represented by *Phragmites australis*, *Typha latifolia*, *Typha angustifolia* and other vegetation types. These plant communities cover almost or more than a half of these ponds. The reed beds have also shrubs or trees (*Salix* spp.). The small fish ponds has only small area of reed or reed mace. The total emergent vegetation, marsh vegetation and other types on the fishponds and reservoir have about 60 ha.

Concerning the protection status of the area, there are three level of protection. Thus, there is a national protected area (414 ha), a Natura 2000 Site (Special Protection Area) formed by three different areas (named "Dumbrăvița - Rotbav - Măgura Codlei"), the first one of them is with a larger area than the national one and a Ramsar Site (Wetland of International Importance, 413.5 ha). All these protected areas are designated by Gouvernment Resolutions at the national level. Dumbravița was the 5th Ramsar Site within Romania at the level of 2008 year.

MATERIALS AND METHODS

Several methods were used for the ornithological studies, for the identification of the main factors affecting the biodiversity and the habitats and for other aspects (Ionescu 1999, 2002, 2003a, 2003b; Ionescu et al., 2004).

RESULTS AND DISCUSSION

Wetland types

In accordance with the Ramsar Classification System for Wetland Type, there were identified two main wetland types: inland wetlands and human-made wetlands. The first type includes: permanent streams, permanent freshwater marshes, seasonal/intermittent freshwater marshes, freshwater- tree-dominant wetlands, freshwater springs. The second type is represented by: aquaculture ponds, water storage areas (reservoirs/barrages/dams), canals and drainage channels/ditches. There are also non-wetland habitat types, such as: crops, hay fields, pastures, dams, roads, buildings, etc. The largest area within the inland wetlands is occupied by permanent and seasonal freshwater marshes (about 20 % from the total area of the Ramsar Site) and the largest area within the human-made wetlands are represented by aquaculture ponds (about 46 %) and water storage (about 31 %).

Ramsar Criteria

From the total of eight Ramsar Criterion for identifying wetlands of international importance, three are achieved for this site.

Criteria 2: A wetland should be considered internationally important if support vulnerable, endangered, or critically endangered species or threatened ecological communities (RIS, 2006).

This criteria is applied within this site for a few water birds species. Concerning birds populations, there are species vulnerable, endangered and critically endangered, based on SPEC Category, European Threat Status, Birds Directive - annex I. Thus, the most important species (breeding - Br or non breeding - NB) are (the maximum number per observation day or pairs are noted): *Gavia stellata* - NB (5 individuals), *G. arctica* - NB (10 - 15 ind.), *Botaurus stellaris* - Br (2 pairs), *Ixobrychus minutus* - Br (10 - 20 p.), *Nycticorax nycticorax* - NB (30 - 40 ind.), *Ardea purpurea* - Br (5 - 15 p.), *Egretta garzetta* - NB (40 ind.), *Casmerodius albus* - NB (80 ind.), *Ciconia nigra* - NB (35 ind.), *C. ciconia* - NB (40 ind.), *Aythya nyroca* - Br (1 - 2 p. some years, most abundant in the past), *Mergus albellus* - NB (10 ind.), *Circus aeruginosus* - Br (5 - 8 p.), *Crex crex* - Br (10 - 15 p.), *Porzana porzana* - Br (15 - 20 p.), *P. parva* - Br (20 - 30 p.), *Tringa totanus* - NB (10 ind.), *T. glareola* - NB (30 ind.), *Larus minutus* - NB (30 ind.), *Chlidonias niger* - NB (300 ind.), *C. hybridus* - NB (60 ind.).

Among the most important bird species included in annex I of the Birds Directive (79/409/CEE) are:

- *Botaurus stellaris*. Dumbrăvița is an old breeding site for this species; the specific habitat is very good (it could breeds in 4 - 5 different reed beds from fish ponds at least). Dumbrăvița is one of the few breeding sites of this species from Brașov County and maybe from a large area of the central part of Romania. Nevertheless, this is a vulnerable species concerning some human activities and disturbance.
- *Ardea purpurea*. This is the largest colony from Transylvania (central part of Romania) together with Rotbav heronery. The total number of breeding pairs from Rotbav and Dumbravița fishponds could exceeds 1 - 2 % of the national breeding population (BirdLife International, 2004). Fishing management and human disturbing have generated yearly fluctuation of the breeding population. The number of breeding pairs could be higher if a good conservation management is applied.
- *Casmerodius albus*. More than 1 - 3 % of the central European population (Austria, Poland, Latvia, Hungary) passes each autumn from here as a population which could passing during autumn migration on Dumbrăvița site. The calculation is based on the BirdLife International publication (2004). One pair unsuccessfully bred on a fishpond within the 2006 season.

- *Ciconia nigra*. Tens of individuals stop-over during autumn migration and pre-nuptial migration, but only in favorable conditions (shallow water, mudflats, abundant small fish). Sometimes solitary individuals forage here during breeding season.
- *Aythya nyroca*. It irregularly breeds on small or medium-sized ponds. The breeding and foraging habitats should be improved in the next years.
- *Porzana parva*. It breeds in permanently flooded reed beds and reed mace from the large overgrown fishponds and reservoir. Relative high density occurs.
- *Crex crex*. High breeding density of these species occurs on the western shore of the reservoir. The habitats, such as: moist regularly cut meadows and marshlands provide very good conditions for this species.

The most important mammals are otter (*Lutra lutra*) and biver (*Castor fiber*), both species listed in Habitat Directive-annex II and Bern Convention.

Criteria 4: A wetland should be considered internationally important if support plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions (RIS).

There are only a few wetlands with such habitat's features and security for water birds in the whole Transylvania (central part of Romania) and this site is considered one of the most important wetland from this area as a stop over point for migratory water birds. Dumbrăvița wetland is also an obliged point for water birds that follow a central Romanian migratory route from NW to SE crossing Transylvania and Bârsei Depression and the Carpathians. This is a very important site especially for water birds due to its almost singleness at the internal curvature of Carpathian Mountains. The well security conditions for water birds and the total surface of water deprive from other wetlands from the central part of Romania. More than 70 water birds species (without passerines) are migratory (staging) on Dumbrăvița wetland. Due to the fish harvesting during autumn and sometimes in spring tens hectares of mud arise annually by the decreasing of water level. This temporary habitat provides a good food supply and secure resting places for many migratory water birds, mainly waders. Thus, 80 - 100 *Casmerodius albus* annually arrive between August and December; many species of waders and gulls also feed on mud. Large flocks of *Anser albifrons* (sometimes more than 500 - 1000 birds in a flock), *Ciconia nigra* (tens of birds are feeding and resting during autumn migration in good habitat conditions), *Anas platyrhynchos* (thousands of birds in both spring and autumn migration), *Vanellus vanellus* (hundreds of individuals), *Philomachus pugnax* (hundreds of individuals), *Chlidonias* spp. (hundreds of individuals) and *Larus ridibundus* (sometimes thousands of individuals) also occur in different habitats. Flocks of waders are annually stop over birds on the mud or shallow water.

Beside the most frequently and abundant species there are some rare or vagrant water birds for internal and especially central part of Romania, which are here also rare or very rare species, such as: *Pelecanus onocrotalus*, *Platalea leucorodia*, *Plegadis falcinellus*, *Cygnus cygnus*, *Branta ruficollis, Clangula hyemalis*, *Melanitta fusca*, *Grus grus*, *Haliaeetus albicilla*, *Haematopus ostralegus*, *Glareola* pratincola, *Arenaria interpres*, *Limicola falcinellus*, *Calidris alba*, *Calidris temminckii*, *Limosa lapponica*, *Phalaropus lobatus*, *Stercorarius parasiticus*, *Larus fuscus*, *L. melanocephalus*, *Gelochelidon nilotica*, *Sterna caspia* and *Sterna albifrons*.

The actual conditions for migratory water birds could be improved in the future by management actions and conservation activities imposed by the status of Special Protection Area (SPA) and Ramsar Site.

Criteria 5: A wetland should be considered internationally important if it regularly supports 20,000 or more waterbirds (RIS). Concerning this criterion guidelines indicate that the actual total number of waterbirds should be stated, and preferably, when available , the average total number of several recent years (RIS). There is also stressed that it is not sufficient simply to restate the criterion, i. e., that the site supports > 20,000 waterbirds (RIS).

For this criteria there are presented below (Tab. 1) the total counted or estimated number of waterbirds for three different years (2002, 2003 and 2004) as a sum of each species number. These numbers should be considered only to prove the achievement of this criteria. Thus, it is very difficult or impossible to know exactly the annually, monthly or seasonally total individuals number of a species.

Between 2005 - 2008 the counted/estimated populations of some species were larger or smaller than in the previous period (2002 - 2004).

Table 1: Criteria number 5 - its achievement for the years 2002, 2003 and 2004.

No.	Species	The number of individuals			The average total number 2002 - 2003 - 2004
		2002	2003	2004	
1.	*Gavia stellata* Pontopp, 1763	5	4	7	5
2.	*Gavia arctica* Linnaeus, 1788	25	15	20	23
3.	*Tachybaptus ruficollis* Pallas, 1764	35	20	15	23
4.	*Podiceps nigricollis* Brehm, 1831	10	18	25	18
5.	*Podiceps cristatus* Linnaeus, 1787	150	200	230	193
6.	*Phalacrocorax carbo* Linnaeus, 1766	50	100	200	116
7.	*Botaurus stellaris* Linnaeus, 1758	4	6	6	5
8.	*Ixobrychus minutes* Linnaeus, 1766	10	20	25	18
9.	*Nycticorax nycticorax* Linnaeus, 1758	25	30	40	32
10.	*Egretta garzetta* Linnaeus, 1766	35	15	20	23
11.	*Casmerodius albus* Linnaeus, 1758	100	120	120	113
12.	*Ardea cinerea* Linnaeus, 1758	300	200	300	267
13.	*Ardea purpurea* Linnaeus, 1766	10	10	25	15
14.	*Ciconia nigra* Linnaeus, 1758	20	30	40	30
15.	*Ciconia ciconia* Linnaeus, 1758	25	15	15	18
16.	*Anser albifrons* Scopoli, 1769	400	800	1500	900
17.	*Tadorna tadorna* Linnaeus, 1758	-	10	80	30
18.	*Anas penelope* Linnaeus, 1758	400	300	200	300
19.	*Anas strepera* Linnaeus, 1758	25	10	5	13
20.	*Anas crecca* Linnaeus, 1758	500	400	100	333
21.	*Anas platyrhynchos* Linnaeus, 1758	15000	18000	17000	16667
22.	*Anas acuta* Linnaeus, 1758	40	15	20	25
23.	*Anas querquedula* Linnaeus, 1758	500	450	300	417
24.	*Anas clypeata* Linnaeus, 1758	50	40	25	38
25.	*Aythya farina* Linnaeus, 1758	450	250	200	300
26.	*Anas nyroca* Guldenst, 1770	10	25	30	22
27.	*Anas fuligula* Linnaeus, 1758	25	30	15	23
28.	*Anas marila* Linnaeus, 1758	5	4	4	4
29.	*Bucephala clangula* Linnaeus, 1758	25	20	10	18
30.	*Mergus albellus* Linnaeus, 1758	20	45	30	32

No.	Species	The no. of individuals			The average number 2002 - 2003 - 2004
		2002	2003	2004	
31.	*Rallus aquaticus* Linnaeus, 1758	30	45	50	42
32.	*Porzana porzana* Linnaeus, 1758	30	40	50	40
33.	*Porzana parva* Scopoli, 1769	25	15	45	28
34.	*Crex crex* Linnaeus, 1758	10	15	40	22
35.	*Gallinula chloropus* Linnaeus, 1758	50	40	65	52
36.	*Fulica atra* Linnaeus, 1758	600	500	250	450
37.	*Charadrius dubius* Scopoli, 1761	20	15	35	23
38.	*Charadrius hiaticula* Linnaeus, 1758	5	5	10	7
39.	*Vanellus vanellus* Linnaeus, 1758	2000	2000	3000	2333
40.	*Calidris minuta* Leisl, 1770	50	20	25	32
41.	*Calidris alpine* Linnaeus, 1758	80	55	20	52
42.	*Philomachus pugnax* Linnaeus, 1758	250	300	300	283
43.	*Gallinago gallinago* Linnaeus, 1758	75	40	50	55
44.	*Limosa limosa* Linnaeus, 1758	55	20	10	28
45.	*Numenius arquata* Linnaeus, 1758	15	20	20	18
46.	*Tringa erythropus* Pallas, 1764	30	25	15	23
47.	*Tringa tetanus* Linnaeus, 1758	20	20	15	18
48.	*Tringa nebularia* Gunn, 1770	45	20	10	25
49.	*Tringa ochropus* Linnaeus, 1758	15	5	10	10
50.	*Tringa glareola* Linnaeus, 1758	60	40	25	42
51.	*Tringa hypoleucos* Linnaeus, 1758	20	20	10	17
52.	*Larus minutes* Pallas, 1776	20	20	20	20
53.	*Larus ridibundus* Linnaeus, 1778	3000	3000	5000	3667
54.	*Larus canus* Linnaeus, 1758	20	15	10	15
55.	*Larus cachinnans* Pallas, 1811	120	150	200	157
56.	*Sterna hirundo* Linnaeus, 1758	20	20	20	20
57.	*Chlidonias niger* Linnaeus, 1758	300	200	200	233
58.	*Chlidonias hybridus* Linnaeus, 1758	40	40	30	37
59.	*Chlidonias leucopterus* Temminck, 1700	10	10	15	12
	Total				> 27700

CONCLUSIONS

In accordance with RIS data three criteria are achieved for Dumbăviţa Complex but only an appropriate conservation management can maintain the bird "key" species in the area.

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NATURA 2000 SITES PROPOSAL FOR THE EUROPEAN COMMUNITY INTEREST COTTIDAE FISH SPECIES (ROMANIA)

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KEYWORDS: Romanian Carpathians, *Cottus gobio*, specific criteria, Natura 2000.

ABSTRACT

Present paper intends to bring arguments in favour of some Natura 2000 sites proposing (Upper Someşul Mare River, Vâlsan River, Upper Târnava Mare River, Upper Timiş River, Upper Buzău River, Upper Teleajen and Telejenel rivers, Nera River, Middle Crişul Repede River, Bistriţa River and Râul Mare Retezat River) for *Cottus gobio* species belonging to the Cottidae Family, Perciformes Order, in the Romanian Carpathians.

These arguments rely on the author's original no older then seven years data, about this species populations and communities, and specific criteria (well preserved fish populations; stable fish populations; healthy fish populations; typical natural habitats; low human impact; favorable geographical position).

RĖSUMĖ: Proposition de sites Natura 2000 pour les Cottidae d'intérêt communautaire (Roumanie).

Le présent travail apporte des arguments à la faveur de la désignation des sites Natura 2000 (le cours supérieur de la rivière Someşul Mare, la rivière Vâlsan, le cours supérieur de la rivière Târnava Mare, le cours supérieur de la rivière Timiş, le cours supérieur de la rivière Buzău, les rivières Teleajen et Telejenel, la rivière Nera, le cours moyen de la rivière Crişul Repede, la rivière Bistriţa et Râul Mare Retezat), dans les Carpates Roumains, pour l'espèce Cottus gobio appartenant à la famille des Cottidae, ordre des Perciformes. Ces arguments sont basés sur des données originelles datant depuis moins de sept ans, regardant les populations et les associations de cette espèce - des critères spécifiques (populations bien conservées de poissons; populations stables de poissons ; populations saines de poissons; habitats naturels typiques ; impact anthropique faible ; position géographique favorable).

REZUMAT: Propunere de situri Natura 2000 referitoare la Cottidae de interes comunitar (România).

Lucrarea aduce argumente în favoarea desemnării unor situri Natura 2000 (cursul superior al râului Someşul Mare, râul Vâlsan, cursul superior al râului Târnava Mare, cursul superior al râului Timiş, cursul superior al râului Buzău, râurile Teleajen şi Telejenel, râul Nera, cursul mijlociu al râului Crişul Repede, râul Bistriţa şi Râul Mare Retezat), în Carpaţii Româneşti, pentru specia *Cottus gobio* aparţinând familiei Cottidae, ordinului Perciformes

Aceste argumente se bazează pe date originale ale autorului nu mai vechi de şapte ani, referitoare la populaţiile şi comunităţile acestei specii - criterii specifice (populaţii de peşti bine conservate; populaţii de peşti stabile; populaţii de peşti sănătoase; habitate naturale tipice; impact antropic scăzut; poziţie geografică favorabilă).

INTRODUCTION

The main objectives of the European Community in the environmental field of interest are the conservation, the protection and the improvement of the environment quality, in the condition of the rationale use of the existing natural resources. The biodiversity conservation constituted an important task of the European Union in the last 25 years.

To elaborate its environmental policies the European Community takes in consideration the scientifically and technical available information, the environmental conditions characteristic for different regions of the Community and the need for an equilibrated development of all regions, the benefits involved and the costs involved.

The EC action frame, to preserve the biodiversity was established through the Council Directives (92/43/EEC) on the conservation of natural habitats and of wild fauna and flora. This European Directive have as objective to protect and sustain biodiversity in the EU through a network of protected areas (Nature 2000), in which to conserve habitats and species characteristic for the European biogeographic regions.

Romania contributes to the European Natural heritage with around: 47 % of the territory covered by natural and semi natural ecosystems; 780 types of habitats; 3700 superior plant, 33085 invertebrate and 717 vertebrates species. (Bănăduc, 2001)

Romania is the country with the highest biogeographic diversity of the European Union countries and the country which joined the European Union in 2007, with five biogeographic regions: continental, alpine, pannonic, pontic and stepic (Bănăduc, 2007a).

There are few ways through which the Natura 2000 initiative in Romania can improve the nature protection: extension of the natural areas; correct management plans; institutional capacity building; involvement of only proper educated and trained personel; raising awareness.

One important aspect of the implementation of the Directives is the establishment of a network of protected sites called Natura 2000 at the European level.

The author have done already some scientifical works regarding other fish species of European conservative interest for the potential Natura 2000 sites frame designation and management (Bănăduc, 2001; 2006; 2007a, b, c; 2008a, b). This work is about the *Cottus gobio* Linnaeus, 1758 species in Romania.

This type of data publication is necessary in the conditions in which the proposals for this species were considered as - insufficient minor - at the Biogeographical Seminar for Romania (Sibiu - 2007).

MATERIALS AND METHODS

This paper is based on original data, no older than seven years. Different samplings methods were used for fish capture: angling, diffent types of nets and electric fishing.

This species was under a constant human impact preasure in the last decades and was registered a sligthtly regres, that's why the sampled fish were released after their identificaton in the same place where they were captured due to conservative reasons.

Few site selection criteria were used: well preserved fish (of Community interest - oCi) populations; stable fish (oCi) populations; healthy fish (oCi) populations; typical natural habitats (oCi); low human impact; favorable geographical position for the species spreading in more than one hydrographic watershed; best option for species/habitat (oCi) in relation with the future Nature 2000 areas management.

RESULTS

General fact sheet

Scientific name: *Cottus gobio* Linnaeus, 1758; vernacular names: Bullhead (English), zglăvoc (Romanian); Order Scorpaeniformes, Family Cottidae.

General appearance: *Cottus gobio* is a small sized fish. The body is short, almost cylindrical and covered by a nude tegument. In some specimens a little pectoral prickled spot can be present under the pectoral fins. The head is relatively big, it represent a percent of 26.2 - 33 % from the total length. The cephalic lateral side is armed by a suborbitary spine, also the posterior merge of the preopercula and opercula bones are elongated and spine-merged. There exist membranes at the operculum openings. The eyes are located more dorsal on the head, which is reminded by the frog eyes. The mouth is large and rounded by horny lips. (Bănărescu, 1964)

The fish has two dorsal fins, the first of them being shorter and less high than the second dorsal fin. The anal fin has almost the same length and height as the second dorsal fin and is located in opposite side of the body. The pectoral fins are elongated and have inflexible sustaining rays. The ventral fins are less developed and each of them has four ossified rays. Caudal fin is round-ended. The lateral line of the body is complete; its course is fair from the head to the caudal fin. The pore openings as a rule are positioned to ventral side. An important exception on these sensory pores was seen in the populations from the Someşul Mare River System. The lateral line of this fish has double openings along it. (Bănărescu, 1964)

Terra typica: Europe.

Ecology: benthic; mountainous freshwater; the species is a typical inhabitant of mountainous rivers with stony bedrock and cold fast running water. Occasionally this fish can be encountered in some mountainous lakes or reservoirs there where the specimens are originated from the tributaries. This fish is not tolerating the water temperature exceeding 15^0C and the low oxygen content. It is a solitary fish and each individual manifest a territoriality that representing a group of riverbed stones. This fish has less mobility than the other that is accompanying it on the mountainous rivers. (Bănărescu, 1964)

This species feeds mainly on insects' larvae, nymphs and other invertebrates (amphipods - crustaceans and aquatic worms). In the *Cottus gobio* diet the preys like the juvenile fishes and eggs are very rare. (Bănăduc, 2003)

This fish ecological requirements make it to be very sensitive to the environmental changes. Consequently it can be considered a veritable stenobiontic and stenotope fish.

Short habitat description: *Cottus gobio* is a fresh-water fish that prefer the mountainous rivers and lakes, especially for their low temperature and oxygen richness. The main characteristic of this typical habitat comprises the fast running waters with narrow channel and the stony bedrock. On the river bottom under the boulders exists more hidden places that constitute a veritable refugees for this fishes. The main food resources in these habitats, the aquatic invertebrates, are fixed on the stony bottom.

Conservation status: in Romania had a relatively wide range but the range area is in a slightly regress. Its major threatenings are the mountainous deforestation, the soil erosion, the hydrotechnical works and the fluctuations in water level, temperature and oxygenation. Its position is considered as being with low vulnerability. Annex II species. *Cottus gobio* species is protected by the European Directive 92/43/EEC, through the Law no. 462/2001 (and the last amendments) regarding the protected natural areas and the habitats and wild flora and fauna conservation.

Regions of occurrence in Romania: *Cottus gobio* occurs in the Romanian rivers beginning on the north counties of Maramureş and Moldavia, till the central Transylvanian rivers and the extra - Carpathian Rivers from Muntenia and the southern Moldavian mountainous rivers. The species is also frequent in the Danube tributaries from the southern Banat area.

Habitats in Romania: The Romanian populations of *Cottus gobio* are encountered in the mountainous rivers and in some lakes or reservoirs in that are shedding the mountainous tributaries. This species live in the uppermost river stretches together the trout (*Salmo trutta*) and minnow (*Phoxinus phoxinus*) and exceptionally in the lover mountainous river stretches live together with the Mediterranean barbell (*Barbus petenyi*). The *Cottus gobio* location on the rivers channel is subsequent to the other congener fish *Cottus poecilopus* Heckel, 1837 that is most rheophilic and cryophilic species. Only in the Tisa River and its tributaries (that have their springs in the Gutâi Mountains and Maramureş Mountains) are living together both *Cottus* species that are mentioned above.

Proposed sites.

The relatively short lotic sectors with proper ecologic conditions for this noncomercial species, and the posibility to be wrongly identified (with *Cottus poecilopus*) make it a species characterised in general by old and sometimes triky information, reason for which new samppling campagnes were necessary. As a result of such field campaigns in the last seven years, in this paper some Natura 2000 sites or part of sites/sectors can be sustained with actualized or new data: Upper Someşul Mare River (upstream Năsăud to Ilva Mică in the Alpine biogeographic region), Vâlsan River (from its springs area to the middle of its course in the Alpine and Continental biogeographic regions), Upper Târnava Mare River (Târnava Mare River springs area to Upstream Zetea Lake - Alpine), Upper Timiş River (downstream the confluence with Teregova River to upstream of Slatina Timiş locality - Alpine and Continental), Upper Buzău River (Buzău Gorge - Alpine), Upper Teleajen and Telejenel rivers (Upstream the Teleajen Dam Lake - Alpine), Nera River (Nera River Gorge to the Romanian - Serbian national border - Continental), Middle Crişul Repede River (Downstream Huedin locality to Bratca locality - Alpine), Bistrița River (From the springs to the Teleşti locality proximity - Continental), Râul Mare Retezat River (From the Gura Apei Dam Lake to upstream Ostrov Dam Lake - Alpine).

Upper Someşul Mare River

Arguments for the proposal/sustaining of this (Upper Someşul Mare River) site (including the Someşul Mare River tributaries at least in their confluence sectors): relatively high number of *Cottus gobio* individuals; healthy individuals; good habitats under quantitative and qualitative aspects; the anthropogenic impact presence is in the tolerance limits of this species; river sector with a favorable geographical position with possibility for this species spreading downstream in Someş River.

Cottus gobio is as an umbrella species for the local ichtyofauna diversity (over 15 fish species). Based on the present known data, there are here, around four more fish species under diverse status of protection: *Thymallus thymallus* - endangered species (Law 13/1993 through which Romania became a part of Bern Convention; European Directive 92/43/EEC, Nature 2000; Law 462/2001 regarding the protected Natural areas and the Natural habitats and wild flora and fauna conservation); *Gobio uranoscopus* - vulnerable species (Law 13/1993 through Romania became a part of Bern Convention; European Directive 92/43/EEC, Nature 2000; Law 462/2001 regarding the protected Natural areas and the Natural habitats and wild flora and fauna conservation); *Gobio kessleri* - vulnerable species (Law 13/1993 through Romania became a part of Bern Convention; European Directive 92/43/EEC, Nature 2000; Law 462/2001 regarding the protected Natural areas and the Natural habitats and wild flora and fauna conservation); *Zingel streber* - endangered species (Law 13/1993 through Romania became a part of Bern Convention; European Directive 92/43/EEC, Nature 2000).

Vâlsan River

Arguments for the proposal/sustaining of this (Vâlsan River) site: high number of *Cottus gobio* individuals; healthy fish individuals; typical natural habitats; the human impact presence is low.

Cottus gobio can act here as an umbrella species for the local ichtyofauna diversity (over ten fish species). Based on the present known data, there are here, around two more fish species under diverse status of protection: *Gobio uranoscopus* - vulnerable species (Law 13/1993 through Romania became a part of Bern Convention; European Directive 92/43/EEC, Nature 2000; Law 462/2001 regarding the protected Natural areas and the Natural habitats and wild flora and fauna conservation); *Romanichthys valsanicola* - critical endangered species endemic for this river.

Upper Târnava Mare River

Arguments for the proposal/sustaining of this (Upper Târnava Mare River) site (including the Târnava Mare River tributaries at least in their confluence sectors): relatively high number of *Cottus gobio* individuals; healthy fish individuals; typical natural habitats/good habitats under quantitative and qualitative aspects; the anthropogenic impact presence is actually in the tolerance limits of this species.

Cottus gobio can act here as an umbrella species for the local ichtyofauna diversity (over five fish species). Based on the present known data, there is here, one more fish species under a status of protection: *Thymallus thymallus* - endangered species (Law 13/1993 through which Romania became a part of the Bern Convention; European Directive 92/43/EEC, Nature 2000; Law 462/2001 regarding the protected Natural areas and the Natural habitats and wild flora and fauna conservation).

Upper Timiş River

Arguments for the proposal/sustaining of this (Upper Timiş River) site (including the Timiş River tributaries at least in their confluence sectors): high number of *Cottus gobio* individuals; historic records continuity of this species in the last 100 years; healthy fish *Cottus gobio* individuals; typical natural habitats/good habitats under quantitative and qualitative aspects - enough space and diverse microhabitats in mosaic (longitudinal and transversal) shape; the anthropogenic impact presence is actually low in this area; river sector with a favorable geographical position with possibility for this species spreading downstream in Timiş River Watershed (27830 km^2 on the Romanian territory).

Cottus gobio can act here as an umbrella species for the local ichtyofauna diversity (over 15 fish species). Based on the present known data, there are here, around four more fish species under diverse status of protection: *Eudontomyzon vladykovi* - European Directive 92/43/EEC, Nature 2000; Law 462/2001 regarding the protected Natural areas and the Natural habitats and wild flora and fauna conservation); *Eudontomyzon danfordi* - endangered species (Law 13/1993 through Romania became a part of Bern Convention; European Directive 92/43/EEC, Nature 2000; Law 462/2001 regarding the protected Natural areas and the Natural habitats and wild flora and fauna conservation); *Thymallus thymallus* (Law 13/1993 through

Romania became a part of Bern Convention; European Directive 92/43/EEC, Nature 2000; Law 462/2001 regarding the protected Natural areas and the Natural habitats and wild flora and fauna conservation); *Gobio kessleri* - vulnerable species (Law 13/1993 through Romania became a part of Bern Convention; European Directive 92/43/EEC, Nature 2000; Law 462/2001 regarding the protected Natural areas and the Natural habitats and wild flora and fauna conservation); *Gobio uranoscopus* - vulnerable species (Law 13/1993 through Romania became a part of Bern Convention; European Directive 92/43/EEC, Nature 2000; Law 462/2001 regarding the protected Natural areas and the Natural habitats and wild flora and fauna conservation).

Upper Buzău River

Arguments for the proposal/sustaining of this (Upper Buzău River) site: high number of *Cotus gobio* individuals; healthy fish individuals; typical natural habitats/good habitats under quantitative and qualitative aspects; the anthropogenic impact presence is low.

Cotus gobio can act here as an umbrella species for the local ichtyofauna diversity (over 13 fish species).

Upper Teleajen and Telejenel rivers

Arguments for the proposal/sustaining of this (Teleajen and Telejenel rivers) site: high number of *Cotus gobio* individuals; healthy fish individuals; typical natural habitats/good habitats under quantitative and qualitative aspects; the anthropogenic impact presence is low.

Cotus gobio can act here as an umbrella species for the local ichtyofauna diversity (over five fish species).

Nera River

Arguments for the proposal/sustaining of this (Lower Nera River) site (including the Nera River tributaries at least in their confluence sectors): high number of *Cottus gobio* individuals; historic records continuity in the last 60 years; healthy fish individuals; typical natural habitats/good habitats under quantitative and qualitative aspects; the anthropogenic impact presence is low.

Cottus gobio can act here as an umbrella species for the local ichtyofauna diversity (over 30 fish species).

Based on the present known data, there are here, around four more fish species under diverse status of protection: *Gobio uranoscopus* - vulnerable species (Law 13/1993 through Romania became a part of Bern Convention; European Directive 92/43/EEC, Nature 2000; Law 462/2001 regarding the protected Natural areas and the Natural habitats and wild flora and fauna conservation); *Gobio kessleri* - vulnerable species (Law 13/1993 through Romania became a part of Bern Convention; European Directive 92/43/EEC, Nature 2000; Law 462/2001 regarding the protected Natural areas and the Natural habitats and wild flora and fauna conservation); *Cobitis elongata* - vulnerable species (Law 13/1993 through Romania became a part of Bern Convention; European Directive, Nature 2000; Law 462/2001 regarding the protected Natural areas and the Natural habitats and wild flora and fauna conservation); *Zingel streber* - endangered species (Law 13/1993 through which Romania became a part of Bern Convention; European Directive 92/43/EEC, Nature 2000).

Middle Crişul Repede River

Arguments for the proposal/sustaining of this (Middle Crişul Repede River) site (including Crişul Repede River tributaries at least in their confluence sectors): high number of *Cottus gobio* individuals; healthy fish individuals; typical natural habitats/good habitats under quantitative and qualitative aspects; the anthropogenic impact presence is low.

Cottus gobio can act here as an umbrella species for the local ichtyofauna diversity (over 13 fish species).

Bistriţa River

Arguments for the proposal/sustaining of this (Bistriţa River) site (including the Bistriţa River at least in their confluence sectors): relatively high number of *Cottus gobio* individuals; healthy fish individuals; typical natural habitats/good habitats under quantitative and qualitative aspects; the anthropogenic impact presence is actually in the tolerance limits of this species; river sector with a favorable geographical position with possibility for this species spreading downstream in Someş River basin.

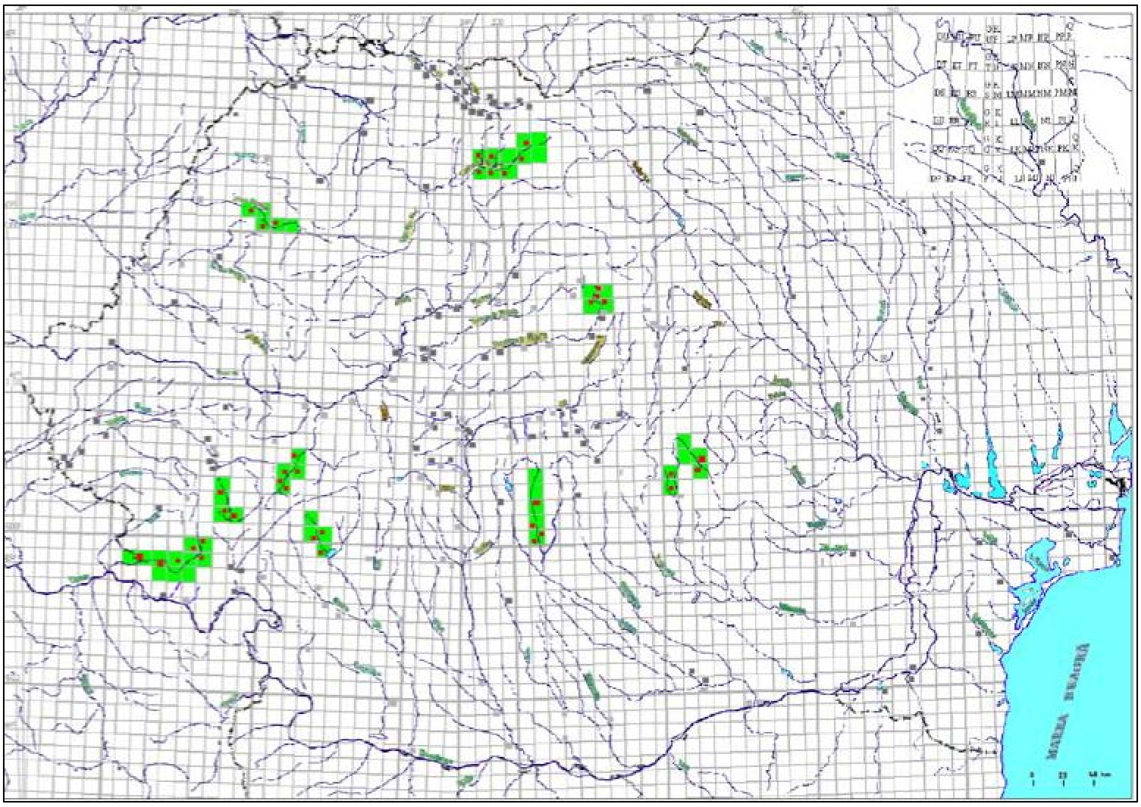

Figure 1: The proposed Community interest sites (■) localisation.

Râul Mare Retezat

Arguments for the proposal/sustaining of this (Râul Mare Retezat) site (including the Râul Mare Retezat tributaries at least in their confluence sectors): relatively high number of *Cottus gobio* individuals; healthy fish individuals; typical natural habitats/good habitats under quantitative and qualitative aspects; the anthropogenic impact presence is low. *Cottus gobio* can act here as an umbrella species for the local ichtyofauna diversity (over 10 fish species).

Based on the present known data, there are here, two more fish species under diverse status of protection: *Eudontomyzon danfordi* - endangered species (Law 13/1993 through Romania became a part of Bern Convention; European Directive 92/43/EEC, Nature 2000; Law 462/2001 regarding the protected Natural areas and the Natural habitats and wild flora and fauna conservation); *Thymallus thymallus* - endangered species (Law 13/1993 through Romania became a part of Bern Convention; European Directive 92/43/EEC, Nature 2000; Law 462/2001 regarding the protected Natural areas and the Natural habitats and wild flora and fauna conservation).

CONCLUSIONS

The presented data should be used due to their importance in terms of valuable populations, coverage and conectivity. This studied species start to have some problems in terms of its conservation in the last decades and protection actions should be proceed in the field by proper specialists, at the national level.

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DIVERSITY IN AQUATIC ENVIRONMENT - NEW CLASSIFICATION PROPOSAL

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KEYWORDS: biodiversity, diversity, sistemic theory, ecological diversity, autecology, synecology, ecosistem, landscape, ecosphere.

ABSTRACT

In the present acception there are three types of biodiversity: genetic, systematic and ecosystemic. If the question of biodiversity is analysed more carefully, starting from the basis of system theory, we notice that this approach needs some corrections, some of them substantial ones. We consider that ecological diversity could be divided into autecological, synecological, ecosystemic, landscape, ecozone and global/ planetary diversity. This paper presents our point of view concerning the variety and the complexity of the different types of ecological diversity, using examples of the limnetic environments.

RĖSUMĖ: Diversité en milieu aquatique - une nouvelle classification.

Dans les concepts actuels trois types de biodiversité existent: génétique, systématique et écosystèmique. Mais, si on analyse plus prudemment le problème du point de vue de la théorie des systèmes, on constate que cette approche nécessite certaines corrections qui peuvent être substancielles. Nous considérons que la biodiversité n'est pas celle des écosystèmes, mais c'est une diversité écologique (qui diffère des diversités biologiques), qui peut être subdivisé en diversité autécologique, sinécologique et écosystèmique (diversité au niveau d'un territoire pariculier, au niveau de l'écozone/biome et au niveau global, l'ecosphère). Dans cette publication est presenté notre point de vue concernant la varieté des différents types de diversité écologique, que nous démontrons à l'aide des aspects de la diversité écologique dans les milieux aquatiques.

REZUMAT: Diversitatea în mediul acvatic - nouă propunere de clasificare.

În conceptul actual, sunt acceptate trei tipuri de biodiversitate: genetică, sistematică şi cea a ecosistemelor. Dacă se analizează mai profund problema biodiversităţii de pe poziţiile teoriei sistemice, se constată că această abordare necesită corecturi, unele substanţiale. Noi apreciem că diversitatea ecologică se poate subdiviza în biodiversitate autecologică, sinecologică, ecosistemică, la nivel de landşaft, de ecozonă şi la nivel planetar. În lucrare, este prezentat punctul nostru de vedere, privind varietatea şi complexitatea diferitelor tipuri de diversitate ecologică, exemplificând cu aspecte legate de mediile limnice.

Definitions of biodiversity

The question of biodiversity is currently very topical. Consequently, it is approached by many specialists, non-specialists and even by uninformed persons. This has led to many confusions which persist, and there are some very different interpretations. To illustrate this, we present below some of the definitions drawn up during the last two decades (Bavaru et al., 2007): Biodiversity is the diversity which includes all the species of plants, animals and microorganisms, as well as the ecosystems and the ecological processes which imply these species. It is a term-umbrella for the level of nature variety, including the number and the frequency of the ecosystems, the species and the genes within a certain group (Reid and Miller, 1989, according to Cogălniceanu, 1999); Diversity and the whole variability of living organisms and of the systems to which they belongs (Heywood and Baste, 1995); Biological diversity means the variability which exists between all the sources of living organisms, inter alia, terrestrial, marine and from other aquatic ecosystems, as well as the ecological complexes to which they belong; this includes the diversity within the species, between species, as well as that of the ecosystems (this is the most widely accepted definition, drawn up in the Convention on the Biodiversity, signed by the states participating in the 1992 Rio de Janeiro Conference).

As believers in the theory of systems, we consider that at the basis of the setting in order of different types of biodiversity the definition proposed by Botnariuc (2005) should be mentioned: „Biodiversity refers to the totality of the forms through which life is diversified at different levels of organisation of the living matter, hence at the individual, populational, biocoenotic/ecosystemic levels”. Based on this, we consider that biodiversity has a hierarchical structure. It is the result of certain evolutive processes which allowed life to diversify in order to occupy a larger number of niches, which fill the environment in all its variety of forms, the living organisms being in close interrelationships with them (Bavaru et al., 2007).

„Official” components of biodiversity

From these definitions, one may notice that, at the beginning, most of the specialists distinguished a biodiversity of the species and one of the ecosystems. Later on, related to the development of genetics, genetic biodiversity was considered and, because the human beings are a major preoccupation, an antropic biodiversity was defined (considered mainly from a genetic starting point). So, „officially” four kinds of biodiversity are recognized (Heywood, 1995).

A personal point of view concerning diversity and biodiversity

As mentioned above, we approached the understanding of biodiversity starting from the concepts of the system theory. That is why we consider that at the level of the living matter there is a biodiversity that may be analysed at the individual, populational and taxonomic levels.

Ecological diversity is not the same as the biodiversity of the ecosystems. In our acception, ecology investigates the interactions between the living and the non-living, which are inseparable; as a result, we can speak of a biodiversity of the living and, separately, of an ecological diversity. In our opinion, ecology is not a branch of biology, but an independent science, situated at the border between the living and the non-living, the leading role being assigned to the living organisms.

Because in all the definitions of biodiversity there is no distinction between diversity and variability, we consider that at the individual level of organization of the living matter diversity may be approached from the following points of view: molecular, genetic, anatomic (cytological and hystological), physiological, ethologic. Likewise, we believe it is possible to consider a symbiotic diversity (Botnariuc, 2006), and another one, determined by the reaction of organisms to the influence of different anthropogenic factors.

Studying the literature published in this field, we noticed that individual diversity is at present investigated from the genetic point of view only, the other approaches not even being mentioned, in spite of the fact that everybody recognizes the variety of ways in which one organism differs from the others at the sub-individual level. Moreover, genetic diversity is investigated from two points of view: on the one hand at the individual level as the diversity of the individuals belonging to the same species and, on the other hand, at the populational level as the genetic diversity between the populations of a single species; hence, it is approached from two different organizational levels of the living matter.

The taxonomy considers living matter at the populational level of organization. It studies the classification of species and the arrangement of higher taxa, starting from the characteristics of one population or of a group of populations (metapopulations) of the same species, then rising to the kingdoms (Bavaru et al., 2007).

At the populational level, referring to man, it may be considered an anthropic biodiversity (genetic, anatomo-physiologic, linguistic and cultural).

The diversity of plants and domestic animals shows their high variety expressed by varieties and races. This biodiversity also occurs at the populational level. The study of this biodiversity involves the investigation of parental species, primary and secondary genetic centres, the analysis of the local races, of the necessity and of the role of genetic banks, etc.

Here biodiversity ends, and subsequently we may speak about ecological diversity. Faithful to the system theory, we consider that we can distinguish a diversity at the individual level (autecological), a diversity at the biocoenotic level (synecological), a diversity of landscapes, a diversity of the ecozones (or of the biomes) and one of the ecosphere (Fig. 1).

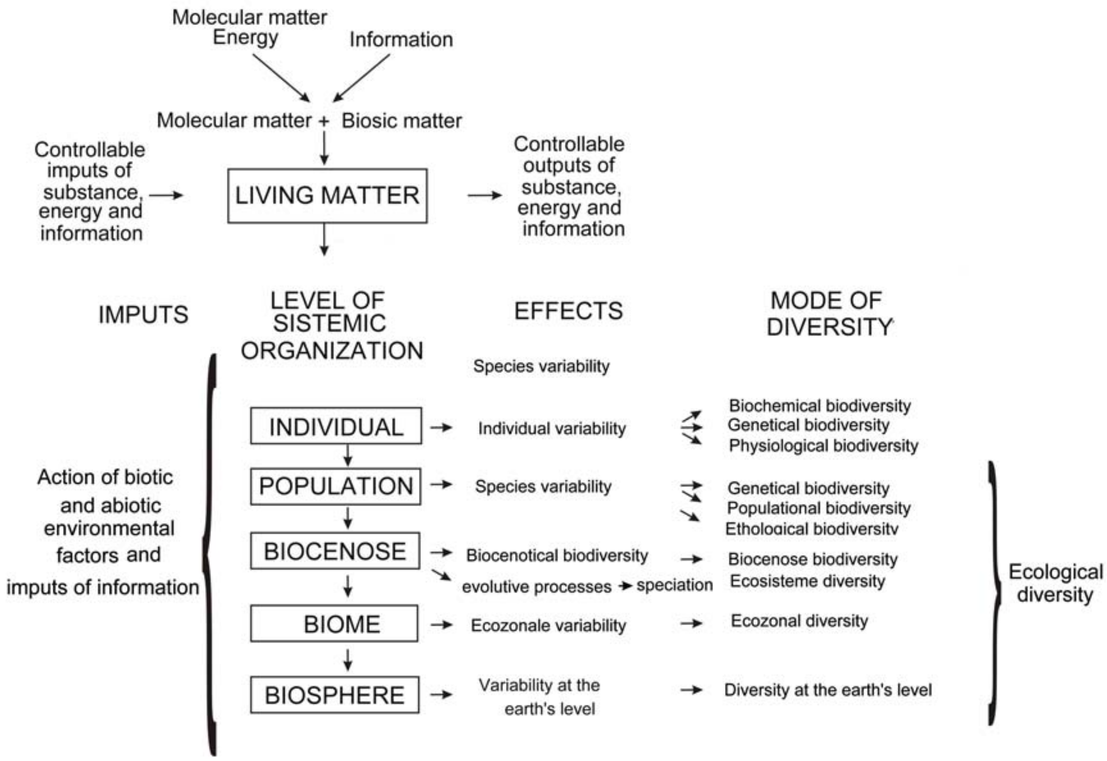

Figure 1: Sources of living matter, levels of systemic organization, types of variability, and modes of diversity and biodiversity.

Ecological diversity

The difference between biodiversity and ecological diversity consists in the way of the living organisms approaching (Mooney et al., 1995a, b). In ecological diversity, the list of species has a secondary role, the main attention focusing on intra- and interspecies relations, on the means of matter, energy, information circulation (stockage, consumption, transfer) - in space and time. At the ecological level diversity a functional feature is considered: how many trophic levels are, how many species belong to each one, the way occurring species achieve their ecological niches, the relationships between the living organisms and between them and the physical environment, etc. In the ecological systems, the species redundancy and resilience in each system is also considered, the problem of key species, dominant or recessive species, of invasive species, etc., is also investigated. Ecological diversity may take into consideration some specific aspects, such as the diversity of distribution of different species, territoriality, abundance, functional diversity, migrations between different ecological systems, the degree of complexity of ecological systems, etc. That is why, because of the variety of circumstances, ecology faces huge difficulties in ordering the data, in devising coherent, reliable classification systems or capable to facilitate the understanding and ordering of the information accumulated by scientific research. At present it is assumed that the variety of ecological systems is so high, that on our planet there are not two identical ecologic systems (Mooney et al., 1995a).

In ecology it is not possible to speak about one classification considered as „natural". Cogălniceanu (1999) tried to review different types of ecological systems classifications, although none of these types takes into account the concepts of the system theory: the function of the major characteristics of the biotope (aquatic, terrestrial, underground); the function of their functional characteristics (to fix energy, stock it, intake nutrients, accumulate water); the function of the structural characteristics (species abundance and distribution, their life span); the function of time successions of structural parameters; the function of functional roles (nitrogen fixation, denitrification process, the intensity of the cycling of the main chemical elements, the share of the decomposers, pollinators and top predators); the function of their successional stages (young, adult, senescent, in climax, etc); the function of the level of trophicity (oligotrophic, mesotrophic, eutrophic); the function of ecological systems resilience; the function of the type of anthropogenic impact (genuine systems, half-genuine, artificial); the function of the importance of the goods and services supplied to the social-human systems.

In the following pages we shall present the ecological diversity from the point of view of the system theory, with particular application to the limnetic aquatic environment.

Diversity at the populational level (autecological diversity)

The variability of the individuals within a population is indicated by their answer to abiotic and biotic stimulating features, and it is fixed in time at the level of genetic information. Phenotypical changes always have little amplitude, but they ensure the individual variability and allow the achievement of the heterozygotship within the respective population.

If a species appears as „n" populations (common situation in microorganisms, plants and animals), the environmental features specific to each population may increase or decrease individual variability, that can result in a divergent evolution or in a stabilizing evolution in these species. Thus, first a metapopulation is formed (aggregate populations belonging to the same interconnected species which, in spite of the fact that they occur in different but adjacent ecosystems, are connected through a high migration rate of component individuals between different populations (Bavaru, 2007), then higher units are formed, such as superpopulation, and, finally, their evolution leads to the appearance of new species.

Intrapopulational diversification depends on: the history of the species; the abiotic and biotic features of the environment, their variation amplitude, which is characteristic to each species; the level of stenoicity and eurioicity; the food spectra; the reproductive capacity and connected ethological relations; the prolificity and the number of viable descendants; the development cycle and juvenile mortality; mobility; the forms of resistance to unfavorable environmental features; the age ratio structure; space distribution; activity/functionality of the respective species; predators and parasites; the role within the biocenose to which belongs, etc.

Autecological diversity synthesizes the values of the ecological niche.

At the populational level we can speak about a diversity of the habitats of different species, but this diversity has not yet been accurately classified.

An example of autecological diversity is the grouping of aquatic organisms in function of the organic loading of water bodies (species belonging to different levels of saprobity). A saprobic system is based on the answer of the organisms to the organic matter, present in water as particulated organic matter, dissolved organic matter or in colloidal form, especially that easily degradable, but also on the resistance of some species to the presence of hydrogen sulphide, methane, detergents, heavy metals, or to the oxygen deficit. Autecological diversity refers also to organisms inhabiting mineral waters containing high concentrations of different substances: iron, carbonates, bicarbonates, sulphides, iodine, bromine, natrium chloride.

Diversity at the biocoenose level (synecological diversity)

Populations of different species may coexist in different environments constituting certain biocoenoses characteristic to those biotopes. In these biocoenoses existing species create numerous intrabiocoenotic/interspecific relations, using them to utilize the energy and material resources available in that biotope at the maximum level. At the biocoenose level food chains and trophic nets are established, energy flows and substance cycling becomes more efficient. As a result, it is here at the biocoenose level that the natural selection occurs, hence the evolution of the species. At the biocoenose level: - each species reaches its own abundance; a characteristic ecological niche for each species is developed; different types of relationships are formed: trophic, mutualistic, symbiotic, competitive, predatoristic, etc.; the populations of various species can be associated, forming characteristic functional groups: producers, consumers and decomposers.

The specialists have tried to devise different classification systems of the synecological diversity. Such systems have been better achieved for plants. Plant biocenology is called phytocenology. It is based on biological, soil, biogeographic, climatologic and hydrologic studies. This is why phytocenology is a true synecological science. The phytocenological classification proposed by Zurich-Montpellier school, adopted and used by the Romanian specialists uses the terminology presented here in the table 1 (Borza and Boşcaiu, 1965).

Table 1: The denomination of vegetation classification units (Borza and Boşcaiu, 1965).

Vegetation unit	Characterised by	Suffix	Examples
Class	Characteristic species	- etea	*Molinio-Arrhenatheretea*
Order	Characteristic species	- etalia	*Arrhenatheretalia*
Alliance		- ion	*Cynosurion cristati*
Group of associations	Characteristic species	-	
Association	Characteristic species	- etum	*Lolieto-Cynosuretum*
Group of subassociations	Characteristic species		
Subassociation	Different species	-etosum	*Lotetosum ulginosi*
Variant	Different species	-	var. with *Luzula campestris*
Facies	Dominant species	-	facies with *Hieracium pilosella*

This classification recognizes the existence in Europe of 42 classes of phytocenoses, eight of them referring to the aquatic environment (Tab. 2).

Table 2: Clasification of European phytocenoses - at the level of classes - used by Zürich-Montpellier school (Braun-Blanquet, 1964, in Doniță et al., 2005).

1. Class Lemnetea - floating communities of duckweed
2. Class Asplenietea rupestris - communities of roc fisures
3. Class Adiantetea - communities on tuff deposits
4. ClassThlaspietea rotundifolii - communities on stone debris
5. Class Crithmo-Limonetea - communities on littoral rocks
6. Class Ammophiletea - communities on littoral rocks
7. Class Cakiletea maritime - salt communities on beaches
8. Class Secalinetea - weed communities in cereal cultures
9. Class Chenopodietea - weed communities in hoeing cultures
10. Class Onopodietea - communities on fallow grounds
11. Class Epilobietea angustifolii - communities on cut forests
12. Class Bidentea tripartiti - communities on flooded lands
13. Class Zoosteretetea marinae - halophilous floating communities
14. Class Ruppietea maritimae - brackish weater communities
15. Class Potametea - floating fixed communities
16. Class Litorelletea - submerged communities at pond borders
17. Class Plantaginetea majoris - ruderal communities
18. Class Isoeto-Nanojuncetea - dwarfish sedge communities
19. Class Montio-Cardaminetea - old field communities
20. Class Corynephoretea - annual sand communities
21. Class Asteretea tripolium - communities of halophilic lawns
22. Class Salicornetea - communities of salt plants
23. Class Juncetea maritimi - communities of salt lawns
24. Class Phragmitetea - communities of reed and sedges
25. Class Spartinetea - communities of plants growing on marine sands
26. Class Sedo-Scleranthetea - communities of succulent plants
27. Class Salicacetea herbaceae - communities of snow rests
28. Class Arrhenatheretea - communities of improved lawns
29. Class Molinio-Juncetea - communities of wet lawns
30. Class Scheuzerio-Caricetea fuscae - arcto-alpine communities of acid swamps
31. Class Festuco-Brometea - communities of xerophytic hemicryptophytes
32. Class Elyno-Seslerietea - primary arcto-alpine neutrophilic-baziphilic communities
33. Class Caricetea curvulae - primary arcto-alpine acidophilic communities
34. Class Calluno-Ulicetea - communities with Ericaceae - *Ulex*
35. Class Oxycocco-Sphagnetea - bog communities
36. Class Salicetea purpureae - communities of littoral osier willows
37. Class Betulo-Adenostyletea - communities of mountain weeds
38. Class Alnetea glutinosae - lawn forest communities of alder
39. Class Erico-Pinetea - pine forest communities with *Erica*
40. Class Vaccino-Picetea - resinuous forest communities and acidophilic bushes
41. Class Quercetea robori-petrae - acidophilic deciduous forest communities
42. Class Querco-Fagetea - baziphilic deciduous forest communities

Zoologists and microbiologists did not achieved up-to-day any coherent classification systems, similar to that made by botanists and it seems such trials are not even ongoing now.

In the aquatic environment various coenoses were defined: in standing waters, function of water depth (area of mediolitoral swampy vegetation, reed and cattail area, floating leaves plants area, submersed plants area, mud bottom plants area, areas with Characeae), and in running waters according to the characteristics of the bottom (rock biocoenose, sand biocoenose, mud biocoenose and swamp and floating vegetation).

Diversity at the ecosystem level

We speak about ecosystemic diversity, but we have noticed that it is not well known, and defined. Ecosystemic diversity may be ascertained according to diversity determined by: the major type of the biotope, so the ecosystems may be classified as: marine, freshwater, terrestrial and underground; the structural characteristics of the ecosystems. Here ecosystems with one or more biocoenoses may be differentiated. At the ecosystem level subecosystemic structures (sinuzia, consortiums, merocoenoses) may be distinguished. At the same level there are distinguished several trophic levels (primary producers, consumers - of different degrees - and decomposers) characterized by various capacities in using the energy accumulated in the biomass. From a functional point of view, there are in biocoenoses dominant species and not dominant species (subdominant, rare, occassional ones). The number of niches occupied by occurring species differs from one biocoenose to the other within the same ecosystem. In ecosystem biocoenoses there are sedentary species, migratory species and species which are active only for specific periods of the year. All the biocoenoses are characterized by a continuous dynamics: circadian, seasonal, annual and multi-annual.

Due to this complexity, which depends on the variety, the number and the efficiency of living matter production by primary producers, as well as on the role (not yet well known) of the decomposers, the classification of the ecosystems is difficult to make if we consider only 2 - 3 criteria (such as the biotope, the climatic type or the dominant phytocoenoses).

The most realistic classification seems to be that made by Ellenberg (1973), which is almost unknown to modern ecologists. Ellenberg combined many characteristics used during different stages of his classification.

The characteristics used by Ellenberg are: a - the characteristics of the environmental features (air, water, soil); b - the biomass and the productivity of primary producers, especially of higher plants; c - the limiting factors of this primary productivity; d - the input and output of material resources; e - the role of the secondary producers; f - the role of the decomposers; g - the influence of man (direct or indirect).

Ellenberg established the following hierarchies in the classification of the ecosystems: - Megaecosystems - established on „a” criterium (M = marine, L = limnetic, S = semiterrestrial, T = terrestrial, U = urban-industrial); - Macroecosystems - established on criteria „b”, „c” and „d”; - Mesoecosystems - i. e. the common ecosystems, established on criteria „e”, „f” and „g”; - Microecosystems - larger subunits of the ecosystems - e. g. the sinuzia; - Nannoecosystems - smaller subunits of the ecosystems, the equivalent of the consortiums and merocoenoses (bioskenes).

Ellenberg also created some other subdivisions in order to underline the degree of influence of man on the ecosystems and the type of influence (for instance, for strong influences he noted g 1 - g 9, for slight influences g 001 - g 009), as well as classifications of biocoenoses (b), plant associations (p), classifications of vegetation on a floristic-sociologic basis (s) or considering the occurring animals (a).

In the table 3 we present the classification proposed by Ellenberg, based on the functionality of the ecosystems, but only at the level of the megaecosystems and mezoecosystems, completed by us to include subterraneous and anthropogenic ecosystems.

Table 3: Ecosystem classification (Ellenberg, 1973; modified by Bavaru et al., 2007)

Subgroup 1 - Aquatic ecosystems (M + L)
M = Marine ecosystems M1 - Oceanic ecosystems M1.1 - Oligotrophic oceans M1.2 - Moderate oligotrophic oceans M1.3 - Moderate eutrophic oceans M1.4 - Eutrophic oceans M2 - Neritic ecosystems M3 - Marine litoral ecosystems M3.1 - Coral reefs M3.2 - Rocky shores M3.3 - Stone shores M3.4 - Sandy shores M3.5 - Shallow waters with sandy muddy deposits M3.6 - Shallow waters with muddy sandy deposits M4 - Inland salt lakes M4.1 - Inland salt lakes with predominant salt content M4.2 - Inland salt lakes with moderate salt content M4.3 - Inland salt lakes with high salt content M4.4 - Inland salt lakes with very high salt content M4.5 - Inland salt lakes, temporarily dried M5 - Estuaries L = Limnetic ecosystems L1 - Deep freshwater lakes L1.1 - Oligotrophic lakes L1.2 - Moderate oligotrophic lakes L1.3 - Moderate eutrophic lakes L1.4 - Eutrophic lakes L1.5 - Highly eutrophic lakes L1.6 - Distrophic lakes L2 - Shallow lakes and pools L3 - Freshwater puddles L4 - Permanent running waters L4.1 - Eucrenon L4.2 - Hypocrenon L4.3 - Epirhythron L4.4 - Metarhythron L4.5 - Hyporhythron L4.6 - Epipotamon L4.7 - Metapotamon L4.8 - Hypopotamon L5 - Temporary running waters L6 - Thermal springs

Subgroup 2 - Terrestrial ecosystems (S + T)
S – Semiterrestrial ecosystems S1 - Spagnum bogs S1.1 - Very oligotrophic Shagnum bogs S1.2 - Oligotrophic Sphagnum bogs S1.3 - Moderate oligotrophic Sphagnum bogs S2 - Leavy mosses bogs S2.1 - Oligotrophic leavy mosses bogs S2.2 - Moderate oligotrophic leavy mosses bogs S2.3 - Moderate oligotrophic leavy mosses bogs with sedges S3 - Swamps with sedges S3.1 - Swamps with tall sedge S3.2 - Swamps with dwarf sedge S3.3 - Swamps with hard plants groupings (as cushions) S4 - Swamps with dwarf trees and bushes S4.1 - Oligotrophic swamps with small bushes S4.2 - Mesotrophic swamps with bushes S4.3 - Eutrophic swamps with bushes S5 - Forest swamps S5.1 - Warm forest swamps S5.2 - Forest swamps with variable temperatures S5.3 - Swamps with cold bushes T - Terrestrial ecosystems T1 - Closed forests T1.1 - Evergreen deciduous forests, of warm and moist climate T1.2 – Evergreen deciduous forests, of cold-moist climate, without frosts T1.3 - Evergreen deciduous forests, with hard leaves, of semi-moist climate, with variable heat T1.4 - Evergreen coniferous forests, of moist climate, with cold winters T1.5 - Deciduous forests of dry climate T1.6 - Deciduous forests of cold climate T1.7 - Extremely xeromorphic forests T2 - Open forests T3 - Bushes T3.1 - Deciduous bushes, of warm-moist climate T3.2 - Evergreen deciduous bushes, of cold-moist climate T3.3 - Evergreen deciduous bushes, of cold climate in winter T3.4 - Bushes of plants with needle-shaped leaves of cold climate in winter T3.5 - Bushes of plants with hard leaves of rainy winter leaves T3.6 - Deciduous barren bushes of dry climate T3.7 - Deciduous barren bushes of cold climate T3.8 - Closed bushes, very xeromorphic T3.9 - Open bushes, very xeromorphic T4 - Dwarfish bushes T5 - Herbaceous fields able for forest growing T5.1 - Savannas T5.2 - Herbaceous heath T5.3 - Oligotrophic lawns T5.4 - Fertilized lawns T6 - Herbaceous fields unable for forest growing

T6.1 - Steppe on plains with cold climate in winter T6.2 - Mountain steppe T6.3 - Cold steppe in moist zones T6.4 - Alpine dwarfish lawns T6.5 - Tundras T6.6 - Snowy unfinished lawns T7 - Desert or dry semidesert T7.1 - Dry semidesert T7.2 - Dry desert T8 - Anthropogenic desertified ecosystems T8.1 - Dunes with unfinished vegetation T8.2 - Erosion deserts T8.3 - Unfinished lawns on stony surfaces
Subgroup 3 - Subterranean ecosystems *U
U1 - Fissures net on basic rock U2 - Subterranean cavitites (caves) U3 - Standing subterranean waters U3.1 - Salt waters U3.2 - Fresh waters U4 - Running subterranean waters U5 - Human constructions U5.1 - Cavities, tunnels U5.2 - Fountains U5.3 - Water supplying installations (reservoirs, pipelines)
Subgroup 4 - Socio-economic ecosystems (SU + A)
SU - Socio-human ecosystems SU 1 - small village SU 2 - village SU 3 - commune SU 4 - town SU 5 - megalopolis A - agroecosystems A1 - Plantations of trees and bushes A1.1 - Plantations of trees A1.2 - Plantations of fruit trees A1.3 – Plantations of bushes A1.4 - Vineyard plantations A2 - Cultures of grassy plants A2.1 - Cultures of pharmaceutical plants A2.2 - Cultures of high grassy plants A2.3 - Cultures of fodder plants A2.4 - Cultures of cereals A2.5 - Cultures of technical plants A2.6 - Cultures of leguminous plants A2.7 - Gardens

In this classification the limnetic environment (L) is very well defined, but part of the wet terrestrial/semiterrestrial ecosystems (S) and of the subterranean ones (U3, U4, U5.2 and U5.3) should be added.

Table 4: Classification of european habitats after Habitats Directive 92/43/EEC (Doniță et al., 2005).

1. Coastal and halopytic habitats
1.1. Open sea and tidal areas
1.2. Sea cliffs and shingle or stony beaches
1.3. Atlantic and continental salt marshes and salt meadows
1.4. Mediterranean and thermo-Atlantic salt marshes and salt meadows
1.5. Salt and gypsum inland steppes
Boreal Baltic archipelago, coastal and landupheaval areas
2. Coastal sand dunes and inland dunes
Sea dunes of the Atlantic, North Sea and Baltic coasts
Sea dunes of the Mediterranean coast
Inland dunes old and decalcified
3. Freshwater habitats
Standing water
Running water
4. Heath and scrub
5. Sclerophyllous scrub (matorral)
Sub-mediterranean and temperate scrub
Mediterranean arborescent matorral
Thermo-Mediterranean and pre-steppe brush
Phrygana
6. Natural and semi-natural grassland formations
Natural grasslands
Seminatural dry grasslands and scrubland facies
Sclerophyllous grazed forests (dehesas)
Semi-natural tall-herb humid meadows
Mesophyle grasslands
7. Raised bogs and mires and fens
Sphagnum acid bogs
Calcareous fens
Boreal mires
8. Rocky habitats and caves
Scree
Rocky slopes with chasmophytic vegetation
Other rocky habitats
9. Forests
Forests of boreal Europe
Forests of temperate Europe
Mediterranean decidous forests
Mediterranean sclerophyllous forests
Temperate mountain coniferous forests
Mediterranean and Macronesian mountainous coniferous forests

Last years the term of „habitat” as an equivalent (or substituting) type of ecosystem was introduced, mistakenly, in our opinion. In our opinion, in the ecological sense, habitat sensu stricto means the living place (area) of a population, i. e. the abiotic environment where an organism lives. Hence, the habitat is a geotope; it corresponds to an ecotope, which is transformed by the biocoenose into a biotope (Doniță et al., 2005). The term of habitat was extended with no arguments, so habitat is synonymous with ecosystem. Because this term is now officially recognized, we consider it is not possible to stand against the general trend, particularly since it was made official through the CORINE program (which was the first to accept in 1991 the term of habitate instead of the term of ecosystem), PALEARCTIC HABITATS (1996 and 1999), EUNIS (1997-2005), EMERALD (2000) and NATURA 2000, at the European level by Habitats Directive (92/43/ECC) since 1992 (amended in 1999, 2002 and 2006) (Donita, 2005), and in Romania through Ministerial Decision no. 1198/25.11.2005. In the table 4 we present the current classification of European habitats.

Diversity at the landscape level

Landscape diversity is a category of ecological diversity which is on the way of being constituted and recognized as such. In Romania geographers call it „peisaj” (i. e. landscape as natural scenery), but this term seems inadequate, unrevealing. So we, as ecologist use the term of „landşaft”, which has been frequently used before; it was taken from German (*landschaft*) and has been assimilated into Romanian for decades. English speakers use the term of *landscape* to refer to „landsaft”.

The landscape is a complex of natural and anthropogenic ecosystems determined by a common history and evolution of certain geographically well defined units climatologically. The landscape is a category of various supraecosystems, disposed randomly in the territory, forming a mosaic and interacting with one another. In this category of landscapes we include in Romania the Danube Delta, Țara Bârsei, Țara Făgăraşului, Dornelor Depression, etc.

At the landscape level there is a huge variety of species; here we can speak about the existence of metapopulations, here the most intense movement of species between ecosystems takes place, here it is possible to investigate the characteristics of the microclimate, the details of air and water circulation/dynamics, the human influences upon natural ecosystems and upon those already modified, as well as their present coexistence. At the landscape level we can speak about the „key” dominant ecosystem and subordinate ecosystems.

Because the diversity of landscapes is very high, an acceptable classification has not yet been achieved.

Landscapes where water is the „key” element are the deltas of the great rivers (the Danube, the Volga, the Nile), the swampy areas (as Canaveral in the USA, Pantanal on the Paraguay River, between Brazil, Bolivia, Uruguay and Argentine), the upper basin of the Amazon River, the lower basin of the Mekong River, etc.

Diversity at the ecozones level

Ecozones represent communities of living beings (assambling various ecosystems) which have a common geographic origin and which occupy environments of wide geographical extension. The organisms from these ecological formations have many common characteristics, such as the preference for a specific type of regional climate (monsoonic, tropical, desertic, arctic, etc.), a certain chemical composition of the water or the soil, certain soil characteristics. Here speciation centres or refuges (in case of catastrophes) may appear.

Classifications of this type of ecologic systems, called improperly „ecosystemic”, were proposed by specialists from different fields: biogeographers identified certain biogeographical areas (palearctic, australian, african), climatologists distinguished the equatorial, tropical, temperate, boreal and arctic areas (on this basis Bailey proposed the delimitation of the ecoregions - Bailey, 1995; Vadineanu et al., 1992), geobotanists made a zonation of the planetary vegetation on floristic criteria (Walter, 1974), etc. Ecologists showed the ecological diversity by introducing different terms: bioms, ecobioms, macroecosystems, ecozones, ecoregions (Bavaru et al,, 2007). In the table five we present the criteria used by different authors to establish the possibilities to distinguish between them.

Based on this we present in the table seven the comparison of the different classification systems used to-day.

Considering the criteria used, we agree with the system proposed by Schultz (1995 in Cogalniceanu, 2003) which, although referring only to terrestrial ecozones, is based mainly on ecological criteria). Analysing the diversity at the ecozones level, we propose the following ecozones, which correspond more or less with the classification of the „bioms” established by Odum in 1971 (Tab. 6).

Table 5: Main criteria used for defining the supraecosystemic level of ecological systems (Bavaru et al., 2008).

Biome (UNEP, 1995)	Biomes (Mooneyetal.,1995	Ecoregions (Dienenstein, 1995)	Ecozones (Schultz, 1995)
* geographic characteristics * climatic characteristics * hydrologic characteristics * soil type * soil structure - nutrient level - decomposing process dynamics * productive capacity * biomass accumulation * biotic interactions * microbial activity * atmospheric actions and feedbacks * effects of biodiversity upon the distribution and quality of waters * influence of biodiversity upon the structure of component ecosystems	* productive capacity and biomass * soil structure, nutrients and degradation * distribution, balance and quality of water * characteristics of the atmosphere and its feedbacks * territory structure and structure of water bodies * biotic interactions or their separation and that of component species * microbial activity	* geomorphological structure * geologic structure * pedologic structure * climatic features * annual rainfall * altitude * major ecological characteristics * identification of regional borders for bioregions, habitats and ecosystems * physiography * past, recent and potential vegetation * kind of territory use by man * main vegetal crops * livestock	* geographic features * geologic features * climatic features * pedologic features * biomes * plant cover * level of territory use by man * primary production * biomass * carbon content * detritus * nutrients * turnover rate

Ecological diversity at the planetary level (ecosphere eiversity)

This diversity can be known and understood only by the specialists who have a holistic vision of our planet. In the ecosphere diversity we may examine the diversity determined by the variations of the size of the orbit of the Earth around the Sun, by the angle of the axis of the planet aginst the orbit plane, by the influence of the rotation of the Earth around the Sun, by the influence of light, of cosmic radiation, of the influence of the Moon and of the other planets upon the life of Earth, of the movements of the tectonic shields and their consequences, of the volcanic phenomena, on the characteristics of the life cycles of many living organisms, of the influence of the annual or multiannual variations of atmospheric and hydrological features, of the circulation of warm and cold oceanic streams, of the specificity of various biogeochemical cycles, of the dynamics of the primary production at the planetary level, of the complexity of the pathways of organic substances by living organisms, of the characteristics of the movement of energy flows at the planetary level. Ecosphere diversity does not have yet a classification system.

Table 6: The ecozones of the Earth (according Bavaru et al., 2007).

Environment	Ecozone
Aquatic environment	Open ocean Oceanic littoral zone Abyssal oceanic zone Freshwater running waters Standing fresh waters Wet zones
Terrestrial environment	Snow-glaciar deserts and the top of high mountains Deserts Semidry fields Tundra Temperate grassy fields Tropical savannas Coniferous temperate forests (boreal forests) Decidous temperate forests Mediterranean forests and bushes Dry tropical forests Moist tropical forests
Subterranean environment	
Anthropogenic environment	

Table 7: The main systems of superecosistemic classification (Bavaru et all., 2007).

	Terestrial envionment	Limnic envionment	Marine environment	Antropic environment
Bioms (Whittaker, 1975)	* Tundra and alpine region * Boreal forest * Temperate forest * Tropical forest * Woodland and schrubland * Savanna * Temperate grassland * Desert scrub * Extreme desert, rock and ice	* Lake and stream * Swamp and marsh	* Open ocean * Continental shelf * Attached algae and estuaries * Mangrove systems	Agricultural land
Bioms (Odum, 1993)	* Tundras * Grasslands * Forests * Deserts	* Streams and rivers * Lakes and ponds * Fresh-water marshes	* Sea * Estuaries and seashores	-
Ecozones (Schultz, 1995)	* Polar and subpolar * Boreal (Taiga) * Wet temperate * Dry temperate * Wet tropical * Subtropical mediteranean * Subtropical wet * Dry tropical and subtropical zone * Steppes and preeria * Savannas * Deserts and semideserts	-	-	-
Ecoregions (Bailey, 1995)	100 Polar Domain 200 Humid Temperate Domain 300 Dry Domain 400 Humid Tropical Domain		500 Polar Domain 600 Temperate Domanin 700 Tropical Domain	

Bioms (Mooney et al., 1995)	Terestrial envionment	* Arctic and alpine systems * Tropical forests * Temperate forests systems * Arid and semiarid lands * Tropical savannas * Boreal forests * Temperate grasslands * Mediterranean-type ecosystems	Limnic envionment	* Lakes and rivers	Marine environment	* Coastal systems * Coral reefs * Mangrove systems * Open ocean	Antropic environment	
Major ecosistems (Groombridge et al., 2000)		* Tundra * Temperate coniferous forest * Temperate * Savanna and herbs * Temperate woodland and schrubland * Bushses * Tropical wet forest * Tropical dry forest * Desert and semidesert		* Lotic systems: rivers and accumulations basins * Lentic systems: lakes and marshes * Wet regions		Pelagic zone Continental shelf Abisal zone		
Ecobioms (Pârvu, 2000)		* Arctic tundra * Antarctic tundra * Boreal temperate forests and schrublands * Tropical wet sempervirescent and semisempervirescent forests * Tropical xerophylous forests * Savanas * Steppes * Mountains * Deserts		* Lotic systems: rivers and accumulations basins *Lentic systems: lakes and marshes * Wet regions				Agricultural land

Conclusions

From this brief analysis of ecological diversity, we conclude that it cannot be subordinated only to the biological point of view, although we would like to emphasize that the biological aspects are the leading features for the ecological processes.

Ecological classification is still at the beginning of the road and, normally, it generates numerous discussions. To understand it, a unitary point of view is necessary, which can be the perseverent application of the systemic theory. This is the only way to clarify and order this issue.

In this context limnology is a branch of ecology which approaches, at different levels, life from the inland aquatic environment (running waters, standing or subterranean waters), either from natural environments or from those altered by human beings. As a consequence, in limnology we can study aquatic organisms from the autecological, synecological, ecosystemic points of views, at the landscape level or in the ecozones, at every level existing different systems, parameters and ways of classification. At the levels of the landscape, ecozone and ecosphere it is no longer possible to make a clear cut distinction between aquatic and terrestrial organisms, the problems extending beyond pure limnological topics.

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